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FOREWORD

I am honoured to introduce this latest issue to the International Journal of Environment, Agriculture and Biotechnology (IJEAB). Our journal is dedicated to disseminating high-quality research and innovative findings that contribute to advancing knowledge in these critical fields.

In this issue, we present a collection of papers that exemplify the diversity and depth of contemporary environmental, agriculture, and biotechnology research. The articles include various topics, from sustainable agricultural practices and environmental conservation strategies to cutting-edge biotechnological innovations. Each contribution has undergone a rigorous peer-review process, ensuring the publication of only the most significant and original research.

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We are grateful to our dedicated authors, whose hard work and intellectual rigour are the backbone of our journal. We also extend our appreciation to our reviewers and editorial board members, whose expertise and diligence ensure the high standards of our publication. Finally, we thank our readers for their continued support and engagement.

We hope you find the articles insightful and inspiring as you explore this issue. We encourage you to contribute your research to future issues and join us in our mission to advance knowledge and drive positive change in the environment, agriculture, and biotechnology fields.

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Effect of three insecticides on Post Embryonic development, egg production and body weight of *Rhynocoris longifrons* (Stal) (Insecta: Hemiptera: Reduviidae)

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***Abstract*— *Post embroyonic development time egg production rate and body weight of Rhynocoris longifrons (Stal°) were studied for three commonly used insecticides in the agro ecosystem namely monocrotophos, dimethoate and quinalphos. All of the instecticides increased and stadial period and decreased the body weight, egg production and longevity. Maximum effect of the insecticides was observed in monocrotophos treated insects which was followed by dimethoate and quinalphos applied insects. This study paves an idea that while applying the insecticides in the agro ecosystem to control insect pests, care should be taken in the selection of insecticides which will be safe to the non-target insects which is already available in the ecosystem.*

Keywords*— *Rhynocoris longifrons, monocrotophos, dimethoate, quinalphos, post embryonic development

I. INTRODUCTION

Reduviids (Hemiptera : Reduviidae) are one of the highly successful predators, and they play a key role in the biological control of insect pests. The reduviid biocontrol agents inhabit scrub jungles, semi-arid zones and agro ecosystems and they on a wide range of insect pests of various sizes holding promise as useful agents in Integrated Pest Management (Ambrose, 1988,1995,1996). Modern agriculture has come to rely extensively on synthetic chemical pesticides for pest control. Although these toxins are targeted at plant pests , many of them are broad spectrum biocides that have profound effects on the non-target species in agro ecosystems (George and Ambrose, 1999a,b). Non target reduviid predators (Assassin bugs) living in agro ecosystems are being exposed to insecticides frequently which are indiscriminately used to control insect pest population (George and Ambrose, 2004). Even though insecticides are widely studied for their control potential against particular insect pests, they are very less studied or even neglected on their control potential against particular insect pests, they are very less studied or even neglected on their impact on non-target insects. Much less is known about effects of chemical insecticides on non-target predators than on herbivorous insects (Croft and Brown,1975; Sahayaraj and Amalraj, 2005). This prompted the author to study the impact of sub lethal concentrations of the three commonly used insecticides in the cotton ecosystem namely monocrotophos, dimethoate and quinalphos which are both contact and stomach poison on the post embryonic development, egg production and body weight of the reduviid predator *Rhynocoris longiforns* (Stal). *R.longifrons* was reported to be living in cotton agro ecosystem and predating upon various insects pests like *Aphis gossyphii, Dysdercus cingulatus*, *P. solenopsis* , *Clavigralla gibbosa* Spinola and *Nesara viridula* Linnaeus, *H. armigera* and *Spodoptera litura* Fab.(Sahayaraj *et.al.,*, 2020). Information from such study will enable researchers and farmers to select the most suitable insecticides with least damage to *R. longifrons* which are existing in the agroecosystem.

II. MATERIALS AND METHODS

The predator, *R. longifrons* was collected from the Sunkankadi scrub jungle (77. 26'E and 8. 16'N) and Muppanthal (77. 31' E and 8 22' N) scrub jungle, in Kanyakumari district of Tamil Nadu, South India . They were maintained in round plastic troughs with netted lids (16cm diameter x 7 cm height) in the Kalasalingam Biocontrol Laboratory at 28-34° C temperature, 12-13h photoperiod and 75-80% relative humidity. *R.longifrons* was found to inhabit concealed microhabitats such as beneath the boulders and in small crevices in pairs. The nymphs were also found along with the adults. The adults were alate, crepuscular, entomosuccivorous and polyphagous. They laid eggs in clusters. The reduviids mass reared in the laboratory on *Corcyra cephalonica* Stainton were used for the experimental studies. The nymphs were reared separately as the III instar nymphs are used for present study.

Preliminary studies were conducted with each insecticide to find out the LC_{50} concentration of III nymphal instar for 48 h duration and 1/10 values of the 48h LC_{50} concentration of each insecticide were considered as the sub lethal concentrations. They were 0.0011, 0.0018 and 0.0032% for monocrotophos, dimethoate and quinalphos, respectively. 75 ml plastic containers covered with netted lids were used for the present experiment. Cotton leaves were cut based on the size of the container and sub lethal concentration of each of insecticide was sprayed over the leaves separately with help of the hand sprayer. Sprayed leaves were dried for about 15 minutes under normal ceiling fan and then they are placed over moist tissue paper to keep them turgid inside the container for longtime. Three to four leaves were placed inside each container with the ventral surface of the leaves facing upwards (George and Ambrose, 1999).

Fifteen III instar nymphs were taken from the culture and exposed to the sub lethal concentration of each insecticide, separately. Fifteen III instar nymphs were taken and they are exposed to cotton leaves sprayed with water and maintained as a control group. The experimental as well as control group were maintained at room temperature (29 ± 1°C) The insect concentration was maintained continuously for 20 days: ie, the insecticide sprayed leaves were changed with fresh leaves sprayed with insecticide, the insecticide exposed III instar nymphs were reared up to adult. The stadial period and body weight of the IV and V instar nymphs and adults were recorded. The egg production of the adult and longevity of both male and female were also recorded. All the variations caused by the three insecticides, stadial period and weight were initially analyzed by oneway ANOVA (SAS Institute, 1988) to determine if there is any differences existed among and treatment means. If significant differences are there, then the individual treatment means were tested by post ANOVA (Tukey, 1953). Statistical significance was determined by setting the aggregate type 1 error at 5% ($P<0.05$) for each set of comparisons.

Regarding the effect of insecticides on the longevity and fecundity, as 1/10 of 48h LC_{50} will cause mortality in the prolonged exposure, 96h LC_{50} concentration was considered as one toxic unit and 1/3, 1/6, 1/9 and 1/12 of the adult 96h LC_{50} concentrations were selected as sub lethal concentration for all three insecticides. Adult males and females aged less than 10 days were used from the existing laboratory culture. Totally 60 adult insects (30 male insects and 30 female insects) were used for each insecticide, 15 insects per concentration of insecticides (4 x 15 = 60). Fifteen adults were also maintained as control and the insecticide exposure was carried out for 20 days. The number of eggs laid in each experimental and control category were recorded separately. The longevity of male and female in experimental and control were also recorded and all the experimental data were compared with control categories and subjected to students t-test to find out the impact insecticides.

III. RESULTS AND DISCUSSION

The insecticides heavily altered the stadial period, body weight, number of eggs laid and also the longevity. Table 1 shows the impact of the sub lethal concentration of three insecticides monocrotphos, dimethoate and quinalphos on the stadial period of *R.longifrons*. The insecticides showed an extension of III stadial period from 9.13 ± 2.48 (control) to 13.68 ± 3.36, 10.13 ± 3.43 and 11.67 ± 3.13 by the sub lethal concentrations of the insecticides monocrotophos, dimethoate and quinalphos, respectively. Similar observation was also noticed for the IV and V stadial period. It is also observed that the females took more time for the development than males. Among the three insecticides monocrotophos showed maximum extension in the stadial period which is followed by quinalphos and dimethoate. The extension of the stadial might be due to the insecticidal blocking of the hydroxylation process which might have reduced the hormone level necessary for moulting (Conney *et.al.*,1966). George and Ambrose (1999 a, b) also reported similar increase in the stadial period due to the exposure of the sub lethal concentration of 5 insecticides on the on the reduviid *Rhynocoris kumarii* Ambrose and Livingstone.

Table 1. Impact of sub lethal concentration (1/10 0f 48h LC_{50}) of three insecticides on the stadial period (days) of R.longifrons.

Insecticides	III – IV instar	IV – V instar	V – Adult male	V – Adult female
Control	9.13 ± 2.48^{a}	13.67 ± 3.84^{a}	16.85 ± 3.59^{a}	17.41 ± 3.81^{a}
Monocrotophos	13.68 ± 3.36^{b}	18.33 ± 4.12^{c}	21.21 ± 4.19^{c}	23.11 ± 2.89^{c}
Dimethoate	10.13 ± 3.43^{a}	14.11 ± 3.52^{ab}	17.87 ± 3.12^{ab}	18.23 ± 3.11^{ab}
Quinalphos	11.67 ± 3.13^{ac}	15.54 ± 3.28^{b}	18.56 ± 3.87^{b}	19.25 ± 3.55^{b}

Means followed by the same alphabetic letter in a column are not statistically significant at 5% ($P > 0.05$) by Tukey test

The body weight also shows drastic reduction by the sub lethal concentration of insecticides. The impact of insecticides on the body weight is shown in the table 2. All the three insecticides reduced the body weight of the IV, V instar insects and adults of *R.longifrons*. It is observed that the weight of insects in the IV instar 34.16 ± 2.21mg is reduced to 27.33 ± 3.41, 30.18 ± 2.22 and 29.77 ± 2.36mg by the sub lethal concentration of the insecticides monocrotophos, dimethoate and quinalphos, respectively. Maximum reduction in the body weight is observed in the monocrotophos treated category which is followed by quinalphos and dimethoate. The reduction in body weight might be due to the blocking of lactate and succinate dehydrogenases (Dimov and Kalyanova (1967). George and Ambrose (1999a, b) reported such reduction in the body weight in the reduviid predator *R.kumarii*. O'Brien (1957) reported some degree of inhibition of glycolytic tricarboxylic metabolic pathways for the reduction of body weight in cockroaches.

Table 2. Impact of sub lethal concentration (1/10 0f 48h LC_{50}) of three insecticides on the body weight (mg) of R.longifrons.

Insecticides	IV instar	V instar	Adult
Control	34.16 ± 2.21^{c}	82.45 ± 4.11^{c}	136.34 ± 8.53^{c}
Monocrotophos	27.33 ± 3.41^{a}	67.54 ± 5.23^{a}	118.45 ± 6.77^{b}
Dimethoate	30.18 ± 2.22^{b}	75.23 ± 3.46^{a}	127.49 ± 4.67^{a}
Quinalphos	29.77 ± 2.36^{ab}	71.92 ± 4.64^{a}	123.65 ± 5.34^{ab}

Means followed by the same alphabetic letter in a column are not statistically significant at 5% ($P > 0.05$) by Tukey test

The variations caused by the sub lethal concentration of the insecticides on the fecundity and longevity is shown in the table 3. All of the four sub lethal concentrations of all three insecticides reduced the fecundity of *R. longifrons* than the control. The total number of eggs laid in the control insects (143.08 ± 17.07) is drastically reduced to 83.23 ± 6.49, 87.11 ± 5.41, 90.68 ± 5.39 and 95.19 ± 4.86 in the 1/3, 1/6, 1/9 and 1/12 of 96h LC_{50} sub lethal concentrations treated insects. Similar reduction in fecundity is noticed in the sub lethal concentration treated insects of dimethoate and quinalphos. Here again, maximum reduction in the fecundity is noticed in the monocrotophos treated insects which explicit the highest toxicity. The reduced fecundity might be due to the the inhibition of food intake. Khowaja *et.al.,* (1992, 1994) reported similar reduced egg out put in *Dysdercus cingulatus* Fabricius by monocrotophos. George and Ambrose (1999 a, b) also reported similar reduction in the fecundity in *R. kumari* treated with five insecticides.

Similarly, the insecticides reduced the longevity of the reduviid predator *R.longifrons* which is also shown in the Table 3. All of the three insecticides reduced the life span of both the males and females of *R. lonfifrons*. Monocrotophos caused the maximum reduction in the longevity of males and females of *R. longifrons* from 117.23 ± 12.36 and 114.43 ± 11.45 to 85.23 ± 9.77 and 83.41 ± 9.34, 88.56 ± 8.67 and 85.19 ± 7.24, 90.33 ± 7.43 and 87.19 ± 6.91 and 92.54 ± 6.45 and 89.26 ± 6.11 respectively, for the 1/3, 1/6, 1/9 and 1/12 of 96h LC_{50} sub lethal concentrations treated insects. Increased respiration and the release of a paralysis inducing stress factor by the insecticides may account for the decrease in longevity and Lucky (1968) explained this through hormologosis hypothesis. Similar results were also obtained by Hamilton and Schal (1990) and Abd Elghafar and Appel (1992) on German cockroaches and George and Ambrose (1999 a, b) in *R. kumarii*. This research clearly gives an idea to the agriculturists who are engaged in IPM that the insecticides monocrotophos and quinalphos are not safe and should not be applied when *R. longifrons* is incorporated in biological control of insects pests and dimethoate is considered as safe pesticide which cause very less impact on *R. longifrons*.

Table 3. Impact of sub lethal concentration (1/3, 1/6, 1/9 and 1/12 of 96 LC_{50}) of three insecticides on the fecundity (nos.) and longevity (days) of R. longifrons.

Insecticides	Concentration	Total number of eggs laid	Longevity (days)	
			Male	Female
Control		143.08 ± 17.07	117.23 ± 12.36	114.43 ± 11.45
Monocrotophos	1/3 of 96h LC_{50}	80.23 ± 6.49***	85.23 ± 9.77***	83.41 ± 9.34***
	1/6 of 96h LC_{50}	87.11 ± 5.41***	88.56 ± 8.67***	85.19 ± 7.24***
	1/9 of 96h LC_{50}	90.68 ± 5.39**	90.33 ± 7.43**	87.19 ± 6.91***
	1/12 of 96h LC_{50}	95.19 ± 4.86**	92.54 ± 6.45**	89.26 ± 6.11**
Dimethoate	1/3 of 96h LC_{50}	121.10 ± 4.54*	97.26 ± 6.83*	93.25 ± 6.55**
	1/6 of 96h LC_{50}	126.33 ± 5.11*	99.39 ± 7.49*	96.25 ± 6.55*
	1/9 of 96h LC_{50}	129.70 ± 4.29NS	102.45 ± 6.43^{NS}	98.26 ± 5.87*
	1/12 of 96h LC_{50}	131.19 ± 4.71NS	105.27 ± 5.71^{NS}	101.46 ± 6.28*
Quinalphos	1/3 of 96h LC_{50}	100.21 ± 6.21**	91.35 ± 7.58**	90.28 ± 5.98**
	1/6 of 96h LC_{50}	106.41 ± 4.68**	93.56 ± 8.13*	92.43 ± 6.38**
	1/9 of 96h LC_{50}	110.13 ± 5.11*	96.43 ± 6.26*	96.11 ± 5.49*
	1/12 of 96h LC_{50}	115.40 ± 5.44*	97.18 ± 8.41*	95.28 ± 4.67*

Significance is shown at 0.1% (***), 1% (**) and 5% (*) levels of probability. NS indicates not significant.

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Co-application of bio-organic and fly ash: strategies for managing root-knot nematode, *Meloidogyne incognita* in papaya (*Carica papaya*) crop

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***Abstract*— *This study investigates the effects of various bio-organic amendments on the growth, physiological parameters, and nematode infestation in papaya crop. Treatments included fly ash (FA) at different concentrations (10%, 20% and 30%) inoculated with 2000 juveniles of Meloidogyne incognita (MI), neem cake (NC) at 50g and 100g inoculated with MI, and Trichoderma viride (Tv) at 1g and 2g inoculated with MI juveniles. Results showed significant improvements in shoot length, root length, fresh and dry weights, and chlorophyll content in plants treated with bio-organic and FA amendments compared to the untreated inoculated control (UIC). The highest shoot length was observed in the untreated un-inoculated control (UUC) at 55 cm, while UIC had the lowest at 32 cm. Treatments with 100g NC + MI and 2g Tv + MI resulted in shoot lengths of 52 cm and 54 cm, respectively, and increases of 62.5% and 68.8% compared to UIC. Root length was significantly improved with 100g NC + MI and 2g Tv + MI, reaching 43 cm and 47 cm, respectively, representing increases of 230.8% and 261.5% compared to UIC. Chlorophyll-a content increased to 2.04 mg/g and 2.113 mg/g, while chlorophyll-b content reached 1.06 mg/g and 1.15 mg/g in treatments with 100g NC + MI and 2g Tv + MI, respectively. Total chlorophyll content was highest at 3.1 mg/g with 100g NC + MI. Nematode infestation was markedly reduced, with 100g NC + MI and 2g Tv + MI showed no egg masses and root-knot indices (GI) of 2 and 2, respectively. Overall, bio-organic amendments, particularly higher concentrations of neem cake and T. viride, significantly enhance plant growth and reduce nematode infestation, suggesting their potential as sustainable agricultural practices for managing plant parasitic nematodes.*

***Keywords*— Bio-organic amendments, Fly ash, Neem cake, Nematode suppression, Plant growth and yield enhancement, Trichoderma viide**

I. INTRODUCTION

Nematodes, particularly plant parasite nematodes (PPNs) like root-knot nematodes (RKNs), pose a severe economic ($157 billion) threat to global agriculture [1]. Every year, plant parasitic nematodes (PPNs) result in agricultural loss (21.3%), which amounts to Rs. 102,039.79 million. Anticipated losses in 19 horticultural crops were estimated to be Rs. 50,224.98 million, while anticipated losses in 11 field crops were estimated to be Rs. 51,814.81 [2]. RKNs, including *M. incognita, M. javanica, M. arenaria*, and *M. hapla*, are predominant in agriculture, inflicting damage by establishing feeding sites on plant roots, causing galling, stunted growth, and reduced yields [3]. Their ability to attack underground plant parts, combined with a broad host range and rapid reproduction, complicates effective control measures [4,5]. RKN's are sedentary endo-parasites infesting over 3,000 plant species, including major crops like cotton, bananas, and tomatoes [6], and chemical nematicides pose health risks [7]. Eco-friendly alternatives like bio-control agents (*Trichoderma* spp.) and organic amendments (oil cakes and fly ash) have proven effective against nematode infestations [8,9,10,11,12]. With approximately 10,000 species, *Trichoderma* strains exhibit diverse morphologies from white to green compact tufts, crucial for bio-control against plant [13,14,15,16]. Azadirachtin, a key insecticidal compound found in neem, offers biopesticidal properties [17,18].

Fly ash (FA), applications have proven effective in acid lateritic soils, benefiting field crops [19,20,21]. Recent studies underscore FA potential in remedying degraded soils and exploring sustainable nematode management practices [22].

Papaya (*Carica papaya* L.) is a versatile tropical crop known globally for its culinary uses and medicinal benefits. Its fast-growing, semi-woody trees yield latex containing papain, used for meat tenderization and rich in nutrients, papaya's edible portion includes 88.83% water, carbohydrates, and essential vitamins (A, B1, and B2) [23]. India ranks papaya as its fourth highest fruit crop by yield, with 138.4 thousand hectares cultivated producing 5988.8 thousand metric tons annually [24]. Papaya is crucial for its immune-boosting properties and anticancer effects, particularly against hormone-related cancers [25]. It's significance in India underscores its economic and health benefits. Our study aims to investigate the synergistic effects of fly ash, *Trichoderma*, and neem cake on papaya plants infected with *Meloidogyne incognita.*

We hypothesize that the application of different concentrations of these bio-organic amendments will positively influence papaya growth, photosynthetic pigment content, and mitigate disease intensity compared to untreated plants. Specifically, our hypothesis suggests that FA will enhance growth parameters, *Trichoderma* will increase photosynthetic pigments such as chlorophylls and carotenoids, and NC will reduce nematode-induced disease symptoms and root damage. Our objectives include evaluating root, shoot growth, measuring chlorophyll, and carotenoid levels.

II. MATERIALS AND METHODS

2.1 Experimental site

The experiment was conducted at the Department of Botany (27°52' N and 78°05' E) Aligarh Muslim University, Uttar Pradesh, India. The area features diverse soil types, including loamy, sandy, clay loam, and sandy loam, suitable for various agricultural experiments. Aligarh experiences a tropical semi-arid climate, with temperatures ranging from 4.0°C in winter to 45°C in summer. The district receives an average annual rainfall of 800 mm, with a relative humidity of 70%, mainly during July to September.

2.2 Soil sterilization

Soil was placed in gunny bags, steam sterilized and autoclaved at 15 psi and 121°C for 15 minutes. The autoclaved soil was then dried and mixed with various concentrations of chopped fly ash, neem oil cake, and *T. viride* to create different ratios.

2.3 Experimental materials

The fungal bio-agent, *T. viride*, was cultured on Potato Dextrose Agar (PDA) medium. Petri dishes with *T. viride* were incubated at 25°C for 15 days. For mass culturing, *T. viride* was inoculated into PDA flasks and incubated at s25±1°C for 15 days. After sufficient growth, the fungal mycelia were filtered, dried, and ground with distilled water to prepare inoculum suspensions containing 1g/10 mL and 2g/10 mL of distilled water. Neem cake was purchased from a seed shop in Aligarh. It was weighed to 50g and 100g as needed and applied to the soil in pots. Water was added, and the soil was left to decompose for 10-14 days. Fly ash was collected from the thermal power plant in Kasimpur. It was weighed to create 10%, 20%, and 30% mixtures. For a 10% mixture, 400g of fly ash was combined with 3600g of soil in a 4 kg pot. The same procedure was followed for other percentages (Fig. 1).

2.4 Collection and preparation of nematode inoculum

J2s of *M. incognita* were cultured on egg plants and housed in a greenhouse at university. Egg plants were carefully uprooted to prevent detachment of egg masses from the roots, followed by thorough washing in distilled water to remove all soil debris. Egg masses were carefully removed from infected roots using sterilized forceps, washed with distilled water and transferred to 25 µm pore-size mesh sieves lined with tissue layers. The sieves were placed in petri dishes with water just enough to cover the egg masses, facilitating the hatching of J2s of *M. incognita*. The petri dishes were then incubated at 25°C for 24 hours. The mesh sieves retained the egg masses while the hatched J2s passed through and settled at the bottom of the dishes. The suspension containing hatched J2s was collected, and the concentration of juveniles per ml was standardized by counting them in a 10ml suspension (Fig. 2).

Fig. 1: Figures show the bio-organic materials and fly ash used for the treatments against M. incognita, (A) Trichoderma viride, (B) Neem cake, (C) Fly ash

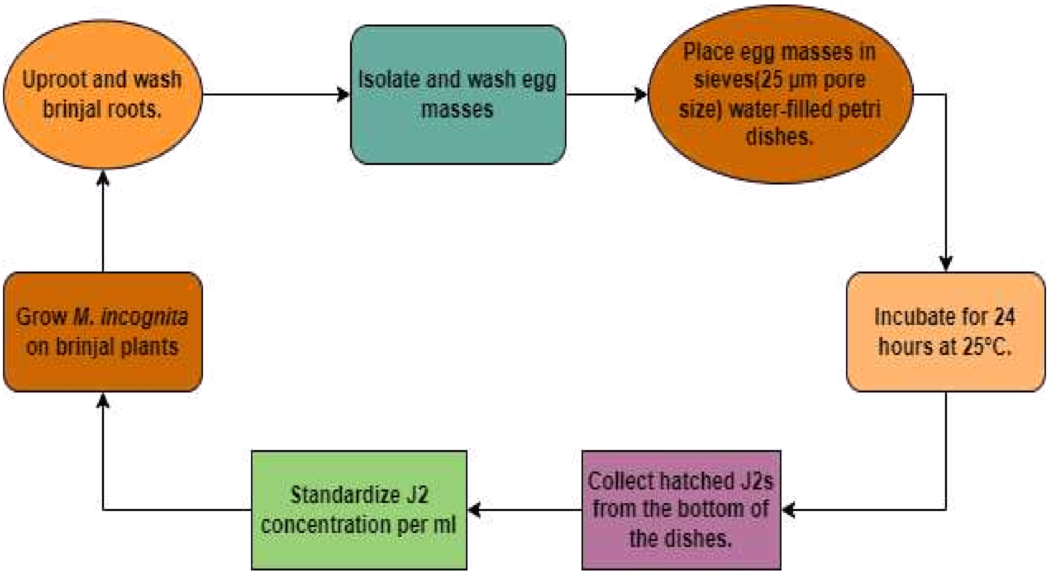

Fig. 2: Steps of collection and preparation of nematode inoculum

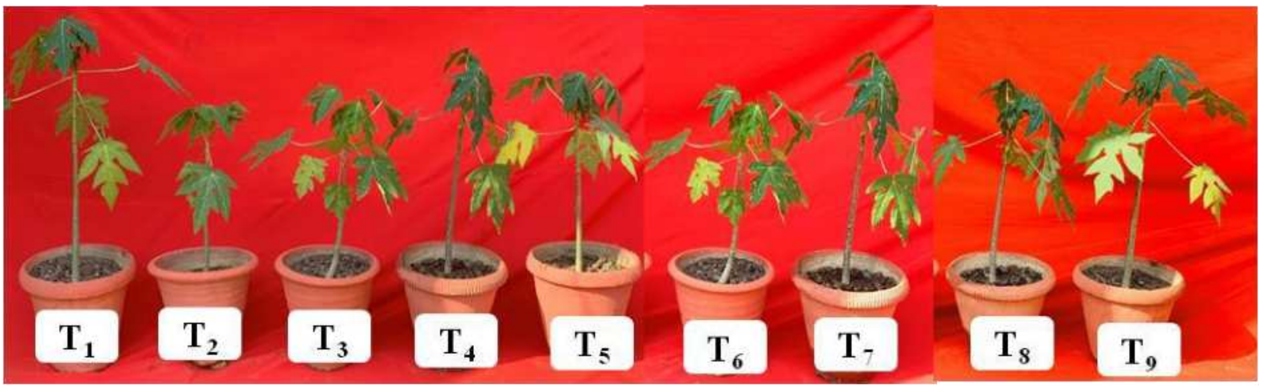

Fig. 3: Effect different treatments on M. incognita and growth of papaya plants (for treatment details Table 1)

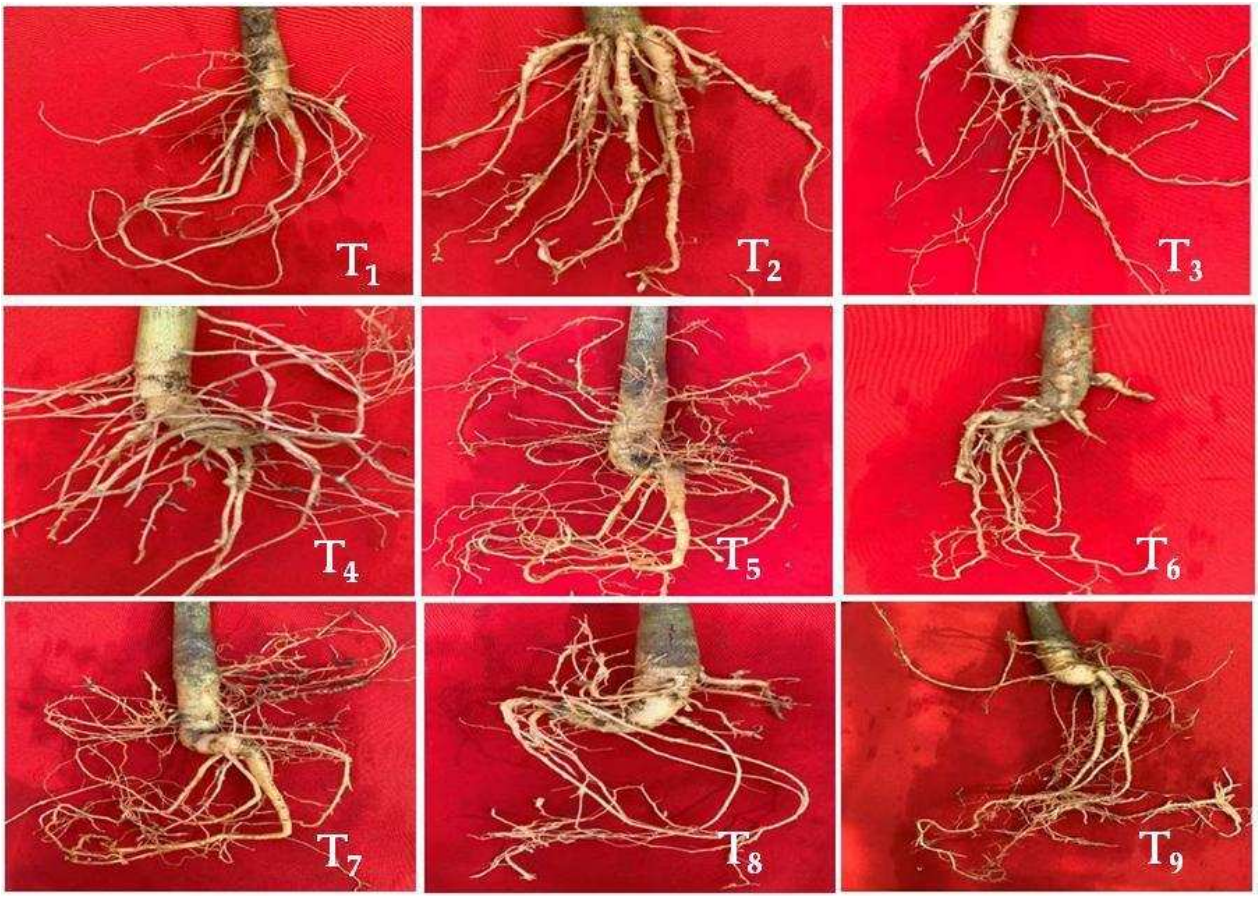

Fig. 4: Effect of different treatments on root-knot disease development caused by M. incognita on papaya roots (for treatment details Table 1)

2.5 Pot experiment and data collection

A pot experiment was carried out in the September, 2023, winter season with papaya and *M. incognita* (Table 1). At maturity plants were uprooted and root and shoot lengths were measured using a meter scale, and fresh weights were recorded with a weighing machine. Subsequently, root and shoot samples were dried in an incubator at 72°C to determine dry weights.

2.6 Estimation of photosynthetic pigments

Fresh leaves (1g) were ground in 100 ml acetone (80%) to extract chlorophyll a, chlorophyll b, and carotenoids. The filtrate was analyzed for percent transmittance at specific wavelengths using a spectrophotometer: 645 nm and 663 nm for chlorophyll [26], and 480 nm and 510 nm for carotenoids [27].

$$\text{Chlorophyll} - \text{a}\ (\text{mg g}^{-1}) = \frac{12.7\ (A663) -\ 2.69\ (A645) \times V}{1000\ \times W} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(\text{i})$$

$$\text{Chlorophyll} - b\ (\text{mg g}^{-1}) = \frac{22.9\ (A645) - 4.68\ (A663) \times V}{1000\ \times W} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(\text{ii})$$

$$\text{Chlorophyll} - a + b\ (\text{mg g}^{-1}) = \frac{20.2\ (A645) + 8.02\ (A663) \times V}{1000\ \times W} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(\text{iii})$$

$$\text{Carotenoid}\ (\text{mg g}^{-1}) = \frac{7.62\ (A480) - 1.49\ (A510) \times V}{1000\ \times W} \ldots\ldots\ldots\ldots\ldots\ldots..(\text{iv})$$

Where, A = absorbance of all specific wavelength; V= final volume of chl. extract in 80% acetone(ml), W = weight of the fresh tissues extracted (g)

2.7 Pathological parameters

The number of galls per plant was determined by measuring their dimensions with a micrometer and visually counting them. Egg masses on infected roots were stained with phloxine-B, washed, and counted. The root-knot index, based on [28], assessed gall and egg mass severity on a scale from 0 to 5, ranging from no galls/egg masses to over 100 per root system.

2.8 Data analysis

Three replicates were considered for each treatments. Analysis of variance (ANOVA) was used to assess differences among treatments ($p < 0.05$).

Table 1: Treatment details used during experiment

Treatment[1]	Treatment Description	Fly Ash (%)	*Trichoderma viride* (g)	Neem Cake (g)	J2s (per pot)
T_1	Untreated uninoculated control	-	-	-	-
T_2	Untreated inoculated control	-	-	-	2000
T_3	10% Fly ash + 2000 J2s	10	-	-	2000
T_4	20% Fly ash + 2000 J2s	20	-	-	2000
T_5	30% Fly ash + 2000 J2s	30	-	-	2000
T_6	50 g Neem cake + 2000 J2s	-	-	50	2000
T_7	100 g Neem cake + 2000 J2s	-	-	100	2000
T_8	1 g *Trichoderma viride* + 2000 J2s	-	1	-	2000
T_9	2 g *Trichoderma viride* + 2000 J2s	-	2	-	2000

Table 2 : Effect of different treatments on growth performance of papaya (treatment details in table 1)

Treatments	Length (cm)		Fresh weight (g)		Dry weight(g)	
	Shoot	Root	Shoot	Root	Shoot	Root
T1	55	48	62.2	27.2	12.01	4.39
T2	32	13	27.12	9.3	4.31	1.91
T3	37	21	39.7	12.91	7.13	2.35
T4	47	36	53.69	20.01	9.83	3.36
T5	35	19	31.61	11.1	5.91	2.01
T6	41	24	46.3	15.01	7.49	2.61
T7	52	43	59.71	25.9	11.01	3.99
T8	45	29	49.21	18.01	8.91	2.98
T9	54	47	61.01	26.13	11.93	4.21

[1]Fly Ash (%) - percentage of fly ash used in the treatment; *Trichoderma viride* (g) – amount of *Trichoderma viride* applied in grams. Neem Cake (g) - amount of neem cake applied in grams. J2s (per pot) - number of *M. incognita* juveniles inoculated per pot

Table 3: Effect of different treatments on number of leaves and root circumference of papaya (treatment details in table 1)

Treatments	Number of leaves	Root circumference (cm)
T1	19	6.98
T2	8	3.26
T3	11	3.99
T4	15	5.96
T5	10	3.48
T6	13	4.81
T7	16	6.41
T8	14	5.21
T9	18	6.81

Table 4: Effect of different treatments on photosynthetic pigments of papaya (treatment details in table 1)

Treatments	Photosynthetic pigments (mg/g leaf tissue)			
	Chl.'a'	Chl.'b'	Total Chl. (a+b)	Carotenoids
T1	2.158	1.213	3.371	0.705
T2	1.263	0.313	1.576	0.17
T3	1.595	0.695	2.29	0.31
T4	1.913	0.96	2.873	0.52
T5	1.363	0.516	1.879	0.27
T6	1.7	0.74	2.44	0.39
T7	2.04	1.06	3.1	0.63
T8	1.809	0.896	2.705	0.46
T9	2.113	1.15	3.263	0.69

Table 5: Effect of different treatments on pathological attributes of papaya (treatment details in table 1)

Treatments	Disease	Number of galls	Number of egg masses	GI/EMI
T1	**Nil**	0	0	**0/0**
T2	**Severe**	67	31	4/4
T3	**Moderately severe**	29	19	3/3
T4	**Mild**	17	10	3/2
T5	**Very mild**	10	2	2/1
T6	**Mild**	19	13	3/3
T7	**Nil**	5	0	2/0
T8	**Very mild**	7	1	2/1
T9	**Nil**	3	0	2/0

III. RESULTS

3.1 Shoot length

Pot with UUC showed maximum (55 cm) shoot length, while UIC showed reduced (32 cm) growth. Treatments with 10% FA+MI increased (+15.6%, 37 cm), 20% FA+MI resulted significant improvement (46.9%, 47 cm), 30% FA+MI showed a moderate increase to 35 cm. Notably, treatments with 50g NC+MI and 100g NC+MI increased shoot length to 41 cm and 52 cm, respectively, with increases of 28.1% and 62.5% compared to UIC. Moreover, treatments with 1g Tv + MI and 2g Tv + MI, demonstrated substantial growth, reaching 45 cm and 54 cm, respectively, representing increases of 40.6% and 68.8% compared to UIC.

3.2 Root length

Data showed that UUC treatment exhibited root length (48 cm), while UIC showed decreased root length (13 cm). 10% FA + MI noticed 21 cm root length, representing a 61.5% increase compared to UIC. Treatments with 20% FA+MI led to a significant improvement to 36 cm, marking a 176.9% increased. The treatment with 30% FA+MI showed a moderate increase (19 cm). 50g NC+ MI and 100g NC+ MI increased root length to 24 cm and 43 cm, respectively, with increases of 84.6% and 230.8% compared to UIC. Moreover, treatments with 1g Tv + MI and 2g Tv + MI, demonstrated substantial growth, reaching 29 cm and 47 cm, respectively, representing increases of 123.1% and 261.5% compared to UIC.

3.3 Shoot fresh weight

Results showed that pot with UUC had a fresh weight of shoot of 62.2 g, while UIC showed reduced growth with a fresh weight of shoot of 27.12 g. At 10% FA+MI increased fresh weight of shoot to 39.7 g, representing a 46.5% increase compared to UIC. Treatments with 20% FA+MI resulted in a significant improvement to 53.69 g, marking a 98.1% increase. 30% FA+MI showed a moderate increase to 31.61 g. Treatments with 50g NC+MI and 100g NC+MI increased fresh weight of shoot to 46.3 g and 59.71 g, respectively, with increases of 70.7% and 120.3% compared to UIC. Moreover, treatments with 1g Tv + MI and 2g Tv + MI demonstrated substantial growth, reaching 49.21 g and 61.01 g, respectively, representing increases of 81.3% and 125.6% compared to UIC.

3.4 Shoot dry weight

Data showed that pot with UUC had a dry weight of shoot of 12.01 g, while the UIC had a reduced dry weight of shoot of 4.31 g. Treatments with 10% FA + MI resulted in a dry weight of shoot of 7.13 g, representing a 65.9% increased compared to UIC. At 20% FA+MI showed a significant improvement to 9.83 g, marking a 128.5% increase. 30% FA+MI showed a moderate increase to 5.91 g. Treatments with 50g NC+ MI and 100g NC+ MI increased dry weight of shoot to 7.49 g and 11.01 g, respectively, with increases of 73.5% and 155.7% compared to UIC. Moreover, treatments with 1g Tv + MI and 2g Tv + MI demonstrated substantial growth, reaching 8.91 g and 11.93 g, respectively, representing increases of 106.7% and 177.4% compared to UIC.

3.5 Root fresh weight

Data showed that the pot with UUC had a fresh weight of root of 27.2 g, while the UIC showed reduced growth with a fresh weight of root of 9.3 g. Treatments with 10% FA+MI increased the fresh weight of root to 12.91 g, representing a 38.6% increase compared to UIC. Treatments with 20% FA+MI resulted in a significant improvement to 20.01 g, marking a 115.1% increase. 30% FA+MI showed a moderate increase to 11.1 g. Treatments with 50g NC+ MIand 100g NC+ MI increased fresh weight of root to 15.01 g and 25.9 g, respectively, with increases of 61.3% and 178.5% compared to UIC. Moreover, treatments with 1g Tv + MI and 2g Tv + MI demonstrated substantial growth, reaching 18.01 g and 26.13 g, respectively, representing increases of 93.5% and 181.3% compared to UIC.

3.6 Root dry weight

Results showed that pot with UUC had a dry weight of root of 4.39 g, while the UIC had a reduced dry weight of root of 1.91 g. 10% FA+MI resulted in a dry weight of root of 2.35 g, representing a 23.6% increase compared to UIC. 20% FA+MI showed a significant improvement to 3.36 g, marking a 75.4% increase. The treatment with 30% FA+MI showed a moderate increase to 2.01 g. Treatments with 50g NC+ MI and 100g NC+ MI increased dry weight of root to 2.61 g and 3.99 g, respectively, with increases of 36.6% and 109.4% compared to UIC. Moreover, treatments with 1g Tv + MI and 2g Tv + MI demonstrated substantial growth, reaching 2.98 g and 4.21 g, respectively, represented increases of 56.0% and 120.9% compared to UIC.

3.7 Root circumference

Data showed that UCC had a root circumference of 6.98 cm, while the UIC had a significantly lower circumference of 3.26 cm. Treatments with 10% FA+MI resulted in a root circumference of 3.99 cm, representing a 22.7% increase compared to UIC. At 20% FA+MI showed a substantial increase to 5.96 cm, marking an 82.2% increase. The treatment with 30% FA+MI resulted in a root circumference of 3.48 cm. Treatments with 50g NC + MI and 100g NC + MI increased the root circumference to 4.81 cm and 6.41 cm, respectively, with increases of 47.2% and 96.6% compared to UIC. Additionally, treatments with 1g Tv + MI and 2g Tv + MI demonstrated significant growth, reaching 5.21 cm and 6.81 cm, respectively, representing increases of 60.1% and 108.9% compared to UIC.

3.8 Chlorophyll a

Pot with UUC exhibited a chlorophyll a content of 2.158 mg/g. In contrast, UIC showed a significantly lower content of 1.263 mg/g. Treatments with 10% FA+MI resulted in a chlorophyll a content of 1.595 mg/g, representing a 26.3% increase compared to UIC. At 20% FA+MI showed a substantial increase to 1.913 mg/g, marked (+51.6%). Treatment with 30% FA+MI resulted in a chlorophyll a content of 1.363 mg/g. Treatments with 50g NC + MI and 100g NC + MI increased the chlorophyll a content to 1.7 mg/g and 2.04 mg/g, respectively, with increases of 34.5% and 61.5% compared to UIC. Additionally, treatments with 1g Tv + MI and 2g Tv + MI demonstrated significant increases, reaching 1.809 mg/g and 2.113 mg/g, respectively, representing increases of 43.3% and 67.4% compared to UIC.

3.9 Chlorophyll b

Pot with UUC exhibited a chlorophyll-b content of 1.213 mg/g. In contrast, the UIC showed a significantly lower content of 0.313 mg/g. Treatments with 10% FA+MI resulted in a chlorophyll b content of 0.695 mg/g, represented (+122.8%) compared to UIC. Treatment with 20% FA+MI showed a substantial increase to 0.96 mg/g, marking a 206.1% increase. 30% FA+MI resulted in a chlorophyll b content of 0.516 mg/g. Treatments with 50g NC + MI and 100g NC + MI increased the chlorophyll b content to 0.74 mg/g (+136.3%) and 1.06 mg/g (+238.7%) compared to UIC. Additionally, treatments with 1g Tv + MI and 2g Tv + MI demonstrated significant increases, reaching 0.896 mg/g and 1.15 mg/g, respectively, representing increases of 186.6% and 267.8% compared to UIC.

3.10 Total chlorophyll (a + b)

Pot with UUC exhibited a total chlorophyll content of 3.371 mg/g. In contrast, the UIC showed a significantly lower content of 1.576 mg/g. Treatments with 10% FA+MI resulted in total chlorophyll content of 2.29 mg/g, represented (+45.5%) compared to UIC. At 20% FA+MI showed a substantial increase (2.873 mg/g, +82.6%). At 30% FA+MI resulted in total chlorophyll content of 1.879 mg/g. Treatments with 50g NC + MI and 100g NC + MI increased the total chlorophyll content to 2.44 mg/g (+55.4%) and 3.1 mg/g (+97.5%), than UIC. Additionally, treatments with 1g Tv + MI and 2g Tv + MI demonstrated significant increased (2.705 mg/g and 3.263 mg/g) than UIC.

3.11 Carotenoid content

Pot with UUC showed a carotenoid content of 0.705 mg/g. In contrast, the UIC exhibited a significantly lower content of 0.17 mg/g. Treatments with 10% FA+MI resulted in a carotenoid content of 0.31 mg/g, represented (+82.4%) compared to UIC. Treatment with 20% FA+MI showed a substantial increase to 0.52 mg/g (+205.9%). At 30% FA+MI resulted in a carotenoid content of 0.27 mg/g. Treatments with 50g NC + MI and 100g NC + MI increased the carotenoid content to 0.39 mg/g and 0.63 mg/g, respectively, with increases of 129.4% and 270.6% compared to UIC. Additionally, treatments with 1g Tv + MI and 2g Tv + MI demonstrated significant increased (0.46 mg/g, +170.6% and 0.69 mg/g +305.9%) than UIC.

3.12 Disease ratings and plants infestation

Pot with UUC showed no disease symptoms. In contrast, UIC exhibited severe disease symptoms. Treatments with 10% FA+MI and 20% FA+MI resulted in moderately severe and mild disease symptoms, respectively. At 30% FA+MI resulted in very mild disease symptoms. Treatments with 50g NC + MI and 100g NC + MI showed mild and no disease symptoms, respectively. Additionally, treatments with 1g Tv + MI and 2g Tv + MI demonstrated very mild and no disease symptoms, respectively.

3.13 Number of galls

Pot with UUC showed no galls, indicated the absence of RKN infestation. In contrast, UIC exhibited a substantial infestation with 67 galls per plant. 10% FA+MI resulted in 29 galls (-56.7%) than UIC. Similarly, 20% FA+MI and 30% FA+MI showed further reductions with 17 galls (-74.6% reduction) and 10 galls (85.1% reduction), respectively. 50g NC + MI and 100g NC + MI resulted in 19 galls (71.6% reduction) and 5 galls (92.5% reduction), respectively.

3.14 Number of egg masses

Pot UUC exhibited no egg masses, confirming the absence of RKN infestation. In contrast, UIC showed 31 egg masses per plant, indicated a severe infestation with *M. incognita*. Treatments with bio-organic amendments demonstrated varying degrees of effectiveness in reduced egg mass formation. At 10% FA+MI resulted in 19 egg masses, represented (38.7%) reduction than UIC. Increased the concentration of 20% FA+MI further reduced the egg masses to 10 (67.7% reduction), and at 30% FA+MI, only 2 egg masses were observed (93.5% reduction). 50g NC + MI showed 13 egg masses (58.1% reduction), while at 100g NC + MI, there were no egg masses observed (100% reduction). Furthermore, treatments incorporating *T. viride* (1g Tv + MI and 2g Tv + MI) also showed significant reductions in egg masses compared to UIC, with 1 egg mass (96.8% reduction) for 1g Tv + MI and no egg masses observed (100% reduction) for 2g Tv + MI.

3.15 Root-knot index (GI) and egg mass index (EMI)

Pot with UUC showed a GI of 0 and an EMI of 0, indicated no infection by M. *incognita*. In contrast, UIC had a GI of 4 and an EMI of 4, indicated a severe infestation with significant gall formation and egg mass production. Treatment with 10% FA+MI resulted in a GI of 3 and an EMI of 3, represented a moderate reduction than UIC. Increased the concentration of 20% FA+MI resulted in a GI of 3 and an EMI of 2, indicated further improvement in nematode suppression. At 30% FA+MI, the GI reduced to 2 and the EMI to 1, showed even better control of nematode infestation. At 50g NC + MI showed a GI of 3 and an EMI of 3, demonstrated moderate effectiveness. Increased the neem cake (100g NC + MI) resulted in a GI of 2 and an EMI of 0, indicated significant suppression of nematode activity, with no observed egg masses. Treatments incorporating *T. viride* (T8 and T9) also showed promised results. 1g Tv + MI had a GI of 2 and an EMI of 1, while 2g Tv + MI showed a GI of 2 and an EMI of 0. These treatments effectively reduced both gall formation and egg mass production than UIC.

IV. DISCUSSION

4.1 Root length and shoot weight

All treatments except 30% FA+MI significantly increased shoot and root length and fresh and dry weight compared to the untreated inoculated control (UIC). The most improved effects were observed with 2g Tv + MI, which substantially increased shoot and root growth parameters compared to UIC. Significant improvements were observed in growth performance, photosynthetic pigments, protein, proline, antioxidant activity, and mineral levels when 10% FA-amended soil was used. On the other hand, all of the previously described metrics were adversely affected by the higher fly ash doses (25%) which caused oxidative stress by raising the levels of lipid peroxidation and electrolytic leakage [29]. Fungi, among tiny creatures, can colonize, trap, and diminish nematode populations. Some *Trichoderma* fungi have been demonstrated to control plant parasitic nematode populations while increased vegetable crop yields [30].

4.2 Root circumference

Similar to root length, all treatments except 30% FA+MI increased root circumference compared to UIC. The most substantial increase was observed with 2g Tv + MI. Several *Trichoderma* species, including *T. harzanium* and *T. viride*, have been previously identified as promising bio-control agents against RKNs [31,32,33]. This finding suggests that Tv+N amendments are particularly effective in promoting overall root development, potentially by increasing root branching and diameter.

4.3 Chlorophyll content

The application of all treatments except 30% FA+MI significantly increased chlorophyll a, chlorophyll b, and total chlorophyll content compared to UIC.*M. incognita* considerably lowered plant growth performance, photosynthetic pigments, and beetroot yield when compared to control plants; however, 15% FA greatly reduced the detrimental effects of *M. incognita*. When compared to a control, confocal laser microscopy demonstrated that 15% FA in soil decreased nematode-juvenile invasion in beetroot [34]. The highest increases were observed with 2g Tv + MI. Many secondary metabolites produced by *Trichoderma* spp., including flavonoids and phenols, provide resistance to biotic stress [35,36]. This indicated that these treatments, particularly Tv + MI, play a role in enhanced chlorophyll biosynthesis, potentially leading to improved photosynthetic activity and plant growth.

4.4 Carotenoid content

All treatments except 30% FA+MI increased carotenoid content compared to UIC. The most significant increase was again observed with 2g Tv + MI. In comparison to the control, the photosynthetic pigments (carotenoid and chlorophyll) were considerably elevated at fly ash concentrations of 10%, 20%, and 30%. But both pigments gradually decreased at 40% and 50% fly ash levels [37]. Many of *Trichoderma* spp. effects are now established as BCA, including competition, antibiosis, resistance, plant tolerance to biotic and abiotic stressors, and activation of pathogen defenses [38]. Results suggested that these treatments may stimulate carotenoid production, which can play a role in photosynthesis and defense against stress.

4.5 Disease ratings and plants infestation

Disease symptoms were less severe in plants treated with amendments compared to UIC. Notably, both concentrations of Tv + MI completely suppressed disease symptoms. *Trichoderma* chemicals, including B-1,3-glucanase, protease, chitinase, lipase, and other metabolites, may contribute to nematode parasitism [39,30,40]. This suggests that these treatments, particularly Tv + MI, may enhance plant defense mechanisms against pathogens.

4.6 Number of galls

All treatments significantly reduced the number of galls compared to UIC, indicating their effectiveness in suppressing RKN infestation. The most significant reduction was observed with 100g NC+MI and 2g Tv + MI. NC reduced root galls (96%) and gall index (62%), outperforming artificial nematicides. The maximum yield was found with the NC treatment. As a result, neem-based solutions, particularly NC, can be recommended for the environmentally friendly management of *M. javanica* in field peas [41]. Applying organic materials to the soil, such as oil cakes, plant extracts, and agricultural wastes, both *in vitro* and *in vivo*, is beneficial. Oil cakes made from botanical extracts destroy nematodes by preventing their juveniles from moving about in the soil and releasing secondary metabolites [42]. These findings suggest that both neem cake (NC) and *T. viride* amendments have nematicidal properties and can be used as control strategies against RKN.

4.7 Number of egg masses

Similar to gall formation, all treatments except 10% FA+MI significantly reduced the number of egg masses compared to UIC. The most effective treatments were 100g NC+MI and 2g Tv + MI, which completely suppressed egg mass production. The number of egg masses and eggs per egg mass on tomato roots were dramatically reduced after applying the neem cake to the soil for protection and cure [43]. Bio-carbon compounds generated from oil cakes have been investigated and used to control nematodes. Oilseed cakes regulate nematodes in vegetables, cereals, and fruit crops [44]. This indicates that these amendments can effectively disrupt the RKN life cycle by reducing egg-laying by females.

4.8 Root-knot index (GI) and egg mass index (EMI)

The root-knot index (GI) and egg mass index (EMI) reflected the overall severity of RKN infestation. All treatments except 10% FA+MI significantly reduced both GI and EMI compared to UIC. The most effective treatments were 100g NC+MI and 2g Tv + MI, achieving the lowest GI and EMI values for RKN infestation. Botanical extracts and oil cakes can kill nematodes by producing secondary metabolites and limiting juvenile mobility in the [42]. Soil application of *T. viride* in conjunction with neem cake at varying doses was found to be more effective against *M. incognita*, with increased plant growth parameters and a decrease in root-knot nematode population in soil than other treatments [45]. Fly ash concentrations significantly and dose-dependently decreased the gal index, egg mass index, and reproduction factor of *M. incognita*. Therefore, at the right dosages, fly ash suppresses root-knot nematodes while simultaneously promoting plant development and yield [46]. These findings show us the effectiveness of these treatments in controlling RKN.

V. CONCLUSION

This study explored the efficacy of various bio-organic amendments in enhancing plant growth and suppressing nematode infestation. Results demonstrated significant improvements in multiple growth parameters and physiological traits of papaya plant treated with fly ash (FA), neem cake (NC), and *Trichoderma viride* (Tv) inoculated with 2000 juveniles of *Meloidogyne incognita* (MI). Shoot and root lengths, fresh and dry weights, and chlorophyll content were notably enhanced compared to untreated inoculated controls (UIC). The highest shoot length of 55 cm and root length of 48 cm were observed in the untreated uninoculated control (UUC), indicated the potential growth under optimal conditions. Treatments with 100g NC + MI and 2g Tv + MI showed substantial increases in shoot and root lengths, with improvements of up to 68.8% and 261.5%, respectively, compared to UIC.

Chlorophyll-a and chlorophyll-b contents also increased significantly in treated plants, with concentrations peaked at 2.113 mg/g and 1.15 mg/g, respectively, in the 2g Tv + MI treatment. Total chlorophyll content reached 3.1 mg/g in plants treated with 100g NC + MI, indicated robust physiological activity and photosynthetic efficiency. These enhancements highlight the role of bio-organic amendments in promoting plant health and vigor. Importantly, bio-organic treatments exhibited strong nematode suppression effects. Plants treated with 100g NC + MI and 2g Tv + MI showed no egg masses and reduced root-knot indices (GI), demonstrating effective control of nematode infestation. This suggests that bio-organic amendments not only support plant growth but also contribute to sustainable pest management strategies in agriculture. Overall, utilize bio-organic amendments, particularly neem cake and *T. viride*, to enhance plant growth and suppress nematode infestation effectively. Optimize application rates and assess long-term impacts on soil health and crop productivity for sustainable agricultural practices.

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Using wood for fuel in the North-Eastern Part of India - A review of the current situation

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***Abstract*— The domestic usage of fuelwood as the primary energy source has created considerable deforestation in North East India. The extraction of most fuel wood from wood is one of the principal causes of disturbance to the native forest flora of north east India. In this study, scientific journals, edited books, and other scientific databases were studied to examine fuelwood consumption trends in the North East India. A total of 162 plant species from 53 families were utilized as fuel by the natives of the region of seven sister states, along with Sikkim, according to a review of the relevant literature. Depending on their local availability, different plant species have been used as fuels in diverse locations. Schima wallichi, A. procera, and Toona ciliata were the most profound species reported in scientific literature. The FVI ranges from 22678 to 2.43 in the listed species. The accumulated data on fuelwood consumption patterns and fuelwood species utilized in the NEH could serve as a baseline for future studies and policy formulation, thus aiding in conserving the region's forest resources.*

***Keywords*— Calorific value, fuelwood, Fuel-Value Index, socio-economic, sustainable energy.**

I. INTRODUCTION

One of the main factors contributing to the degradation of forests in many developing nations is fuelwood. In India, fuelwood is the cheapest and most accessible source for most of the population, especially those living in rural areas (Dayanand & Olivia E. Atherton1, Jennifer L. Tackett2, Emilio Ferrer1, 2018; Hussain et al., 2017; Sharma & Dash, 2022). The primary energy source in all Indian hilly settlements is fuelwood. In India, 49% of households use fuelwood as their primary fuel for cooking (Khanwilkar et al. 2021). In developing countries, including India, fuelwood is the primary and most important source of traditional domestic energy used for cooking, heating, and other purposes (Akpalu et al., 2011; Foundation, 2010; Singh et al., 2021). The demand for fuelwood has grown much faster than its supply. The North Eastern Himalayan (NEH) tribal regions experience a similar situation, clearly related to the loss of forest cover. In the North Eastern Himalayan (NEH) region, biomass is a major energy source used by almost 90% of the tribal population. However, the region's ecosystem has deteriorated significantly due to changing agriculture combined with excessive deforestation or the harvest of timber and fuel. In the north eastern zone of India, a huge amount, almost 3-4 fold higher fuelwood consumption rate, is used compared to other parts of the country. In the North Eastern Himalayan region, the demand for fuelwood is more than 228 million tons, with a substantial supply of 128 million tons (Iiyama et al., 2014; Saxena et al., 2016). There is a huge gap between the demand and supply of fuelwood, which leads to pressure on existing forests to overcome the scarcity of this huge demand. Based on satellite images and official estimates, the north eastern region has 163,799 sq km of forest, constituting approximately 64% of the total area (Ghilardi et al., 2009). Most (approximately 80%) of the North Eastern Himalayan (NEH) population lives in rural areas. The tribal of the NEH region relies heavily on forest resources for subsistence, and 90% of the region's population uses biomass as an important energy source (Khuman et al., 2011). Mass afforestation using suitable firewood tree species is required to meet the rising demand for fuelwood. Extensive farming of firewood could be the only alternative to bridge the gap between demand and supply (Campos et al., 2019; Tewari et al., 2003).

Farming farmers should prefer species with good calorific value, Fuelwood Value Index (FVI), and native species (Deka et al., 2007; Ojelel et al., 2015). Thus, the place's ecosystem remains balanced, and demand can be fulfilled. For this purpose, we need to compile existing information (availability, Fuel Value Index, species) on fuelwood resources utilized in India's north eastern region for policymaking to achieve sustainable development (Bhatt & Sachan, 2004; Negi et al., 2018). The present study was undertaken to review studies conducted on fuelwood consumption in different NEH region villages and to compile a comprehensive list of plant species used as fuel by the region's local people.

Study area

The North Eastern Himalayan region comprises the states of Manipur, Meghalaya, Nagaland, Sikkim, Tripura, Arunachal Pradesh, and Mizoram (Seven Sisters) (between 21.50 °N and 29.50 °N latitude and 85.5º-97.5ºE longitude). It represents a distinct agro-climatic area in India. The hilly states of the region have a total geographical area of 183,741 km^2 (5.589% of India) and are populated by 12.41m people (1.13% of the country). An undulating topography and wide variations in altitude, rainfall, temperature, and soil conditions characterize the NEH region. The climate is typically monsoonal, with approximately 85% of the annual precipitation occurring during the rainy season. The average maximum temperature during the rainy season is 30 °C, and the average minimum temperature is 14 °C, with a maximum and minimum of 20 °C and 8 °C, respectively, during winter.

II. MATERIALS AND METHODS

The literature on fuelwood consumption in various villages of the NEH available in scientific journals, edited books, and other scientific databases was searched. Only field-based surveys carried out in the NEH region that reported first-hand information on fuelwood consumption in different villages were included in this study. Confusing or erroneous data, where information on fuelwood consumption was unclear, were omitted from the analysis. An exhaustive list of plants used as fuel was compiled.

III. RESULTS

A detailed list of plant species reported to be used as fuelwood in NEH, India, along with their botanical name and calorific value of the respective species (KJg^{-1} dry weight), is given in (Table 1). A total of 162 plant species belonging to 53 families were used as fuelwood in NEH villages. Based on scientific literature citations, the most preferred fuelwood species used in the NEH were *Schima wallichi* and *Albizia procera,* cited in five studies. This was followed by *Toona ciliata,* which were mentioned in three studies. As reported in two studies, other preferred species were Cassia siamea, Terminalia myriocarpa, and Pinus kesiya. Fabaceae family species dominate 16.67%, followed by Theaceae and Meliaceae at 4.84% in this study. Different authors calculated the Fuel Value Index (FVI), obtained the highest value of 22,678 in Rhododendron arboretum and the lowest value of 2.43 in *Bombax ceiba.*

IV. DISCUSSION

The sustainable use of forests and associated resources is a complicated topic that encompasses social needs, ethical and cultural values, and the socio-economic situations of forest-dependent people (Plieninger et al., 2023; Purvis et al., 2019). The dependence on forests for fuelwood results in catastrophic deforestation throughout the Indian continent (Chakraborty et al., 2018; Ghanbari & Kern, 2021). In the developing world, biomass is the predominant energy source for residential consumption (Benti et al., 2021). Utilization of fuelwood is widespread in rural areas of the developing world, particularly in areas where these fuels are locally accessible (Ghazoul & Evans, 2004). Communities use fuelwood for numerous uses, mostly firewood and house construction, resulting in overuse and increased deforestation. In India, 49% of households use fuelwood as the primary fuel for cooking (Nagothu, 2001). Sudha et al. (2003) estimated that 11.28 million individuals collect firewood in India.

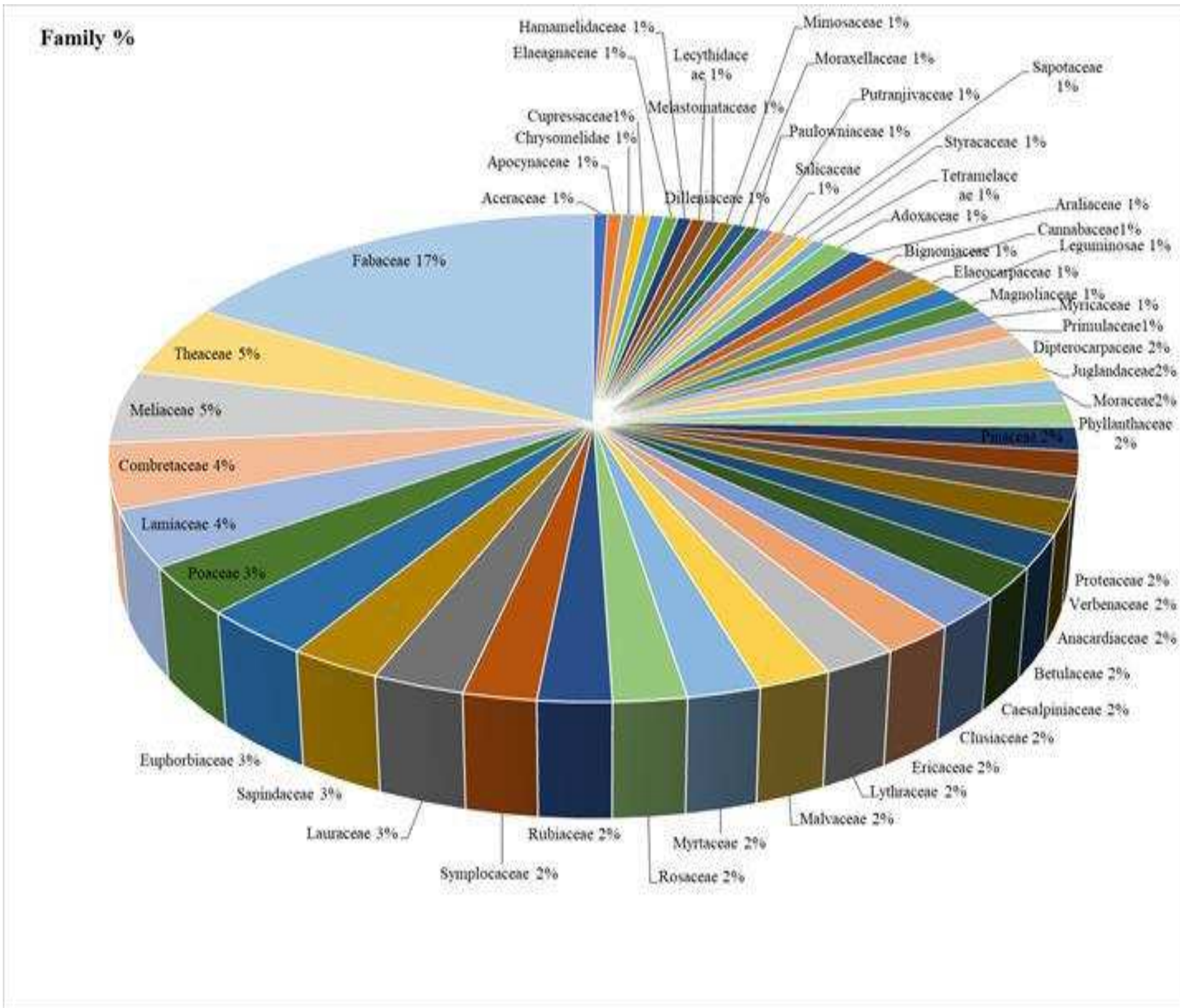

Fig 1: Graphical representation of Species Percentage

The International Energy Agency observed in its 2006 World Energy Outlook Report that Indian households favored using wood burners to bake traditional bread. (Kumar et al., 2020). Due to the reduction in forest cover, unsustainable firewood harvesting has considerably contributed to biodiversity loss and soil erosion (Damette & Delacote, 2011).

Several factors, including household size, education, lifestyle, ethnicity, geographic location, climatic condition, subsidies, energy supply factors, price, availability, and accessibility, influence fuel selection in the villages of the North Eastern Himalayan region (Narasimha Rao & Reddy, 2007; Zou & Luo, 2019).

Table 1: Plant species used as fuelwood in the Northeastern Himalayan Region, India.

S.No	Name of the Species	Family	FVI	References
1	*Acacia auriculiformis*	Fabaceae.	1851	Kataki and Konwer(2002)
2	*Acacia nilotica*	Fabaceae	2089	Kataki and Konwer(2002)
3	*Acer oblongum*	Sapindaceae	5403, n.a	Chettri and Sharma(2008), Bhatt and Sachan(2004)
4	*Acrocarpus fraxinifolius*	Fabaceae	306	Sahoo et.al(2014)
5	*Actephila excelsa*	Phyllanthaceae	370	Kataki and Konwer(2002)
6	*Adina cordifolia*	Rubiaceae	529	Sahoo et.al(2014)

7	*Adina polycephala*	Rubiaceae	554	Kataki and Konwer(2002)
8	*Aesculus assamicus*	Sapindaceae	1008, n.a	Kataki and Konwer(2002), Bhatt and Sachan(2004)
9	*Albizia chinensis*	Fabaceae	242	Sahoo et.al(2014)
10	*Albizia lebbeck*	Fabaceae	1329	Kataki and Konwer(2002)
11	*Albizia odoratissima*	Verbenacece	475.99	Sedai et.al(2016)
12	*Albizia procera*	Fabaceae	532, 16.588, 1793,291.6	Sahoo et.al(2014), Taran et.al(2016), Sahoo et.al(2014), Taran et.al(2016), Kataki and Konwer(2002), Rai et.al(2002)
13	*Albizia thomsoni*	Leguminosae	867	Sahoo et.al(2014)
14	*Albizzia chinensis*	Fabaceae.	477	Kataki and Konwer(2002)
15	*Alnus nepalensis*	Betulaceae	692, 780	Chettri and Sharma(2008), Kataki and Konwer(2002)
16	*Andromeda elliptica*	Ericaceae	3933.8	Rai et.al(2002)
17	*Anogeissus acuminata*	Combretaceae	1370,7.41	Sahoo et.al(2014), Taran et.al(2016)
18	*Aralia aramata*	Araliaceae	n.a	Lynser et.al(2020)
19	*Artocarpus integrifolia*	Moraceae	n.a	Bhatt and Sachan(2004)
20	*Bahunia Variegata*	Caesalpiniaceae	9.882	Taran et.al(2016)
21	*Bambusa balcooa*	Poaceae	n.a	Bhatt and Sachan(2004)
22	*Bambusa cacharensis*	Poaceae	n.a	Bhatt and Sachan(2004)
23	*Bambusa nutans*	Proteaceae	n.a	Bhatt and Sachan(2004)
24	*Bambusa pallida*	Poaceae	n.a	Bhatt and Sachan(2004)
25	*Bauhinia variegate*	Theaceae	2074.62	Sedai et.al(2016)
26	*Beilschmiedia sikkimensis*	Lauraceae	8935	Chettri and Sharma(2008)
27	*Betula alnoides*	Betulaceae	48,14	Chettri and Sharma(2008)
28	*Betula spp*	Betulaceae	n.a	Bhatt and Sachan(2004)
29	*Bischofia javanica*	Phyllanthaceae	272	Sahoo et.al(2014)
30	*Bombax ceiba*	Malvaceae	2.436	Taran et.al(2016)
31	*Bridelia retusa*	Sapotaceae	2162.7	Sedai et.al(2016)
32	*Callicarpa arborea*	Verbenaceae	580	Sahoo et.al(2014)
33	*Camellia sp.*	Theaceae	n.a	Lynser et.al(2020)
34	*Careya arborea*	Lecythidaceae	7.24	Taran et.al(2016)
35	*Cassia fistula*	Caesalpiniaceae	8.347	Taran et.al(2016)
36	*Cassia siamea*	Caesalpiniaceae	1062, 10.03	Kataki and Konwer(2002), Taran et.al(2016)
37	*Castanopsis hystrix*	Fagaceae	9080	Chettri and Sharma(2008)
38	*Castanopsis indica*	Primulaceae	1705.64	Sedai et.al(2016)
39	*Castanopsis tribuloides*	Fagaceae	726, 1469.1	Sahoo et.al(2014), Rai et.al(2002)
40	*Catanopsis sp.*	Fagaceae	n.a	Lynser et.al(2020)
41	*Cedrela serrata Royle.*	Meliaceae	1050	Kataki and Konwer(2002)

42	*Celtis australis*	Phyllanthaceae	1241.58	Sedai et.al(2016)
43	*Chuckrasia tabularis*	Meliaceae	n.a	Bhatt and Sachan(2004)
44	*Cinnamomum impressinerium*	Lauraceae	982.8	Rai et.al(2002)
45	*Cryptomeria japonica*	Cupressaceae	n.a	Bhatt and Sachan(2004)
46	*Dendrocalamus hamiltonii*	Poaceae	n.a	Bhatt and Sachan(2004)
47	*Dendrocalamus sp.*	Poaceae	_	Rai et.al(2002)
48	*Derris robusta*	Fabaceae	691	Sahoo et.al(2014)
49	*Dillenia pentagyna*	Dilleniaceae	4.576	Taran et.al(2016)
50	*Dipterocarpus macrocarpus*	Dipterocarpaceae	n.a	Bhatt and Sachan(2004)
51	*Drypetes lancifolia*	Putranjivaceae	_	Rai et.al(2002)
52	*Duabanga indica*	Lythraceae	n.a	Bhatt and Sachan(2004)
53	*Dysoxylum binectariferum*	Myrtaceae	1331.21	Sedai et.al(2016)
54	*Dysoxylum procerum*	Meliaceae	10.952, 2493.49	Taran et.al(2016), Sedai et.al(2016)
55	*Elaeagnus umbellata*	Elaeagnaceae	1082	Kataki and Konwer(2002)
56	*Elaeocarpus lanceifolius*	Elaeocarpaceae	390	Sahoo et.al(2014)
57	*Elaeocarpus sp.*	Elaeocarpaceae	n.a	Lynser et.al(2020)
58	*Engelhardtia sp.*	Juglandaceae	_	Rai et.al(2002)
59	*Engelhertia spicata*	Juglandaceae	n.a	Lynser et.al(2020)
60	*Eurya acuminata*	Theaceae	3600,n.a	Chettri and Sharma(2008), Lynser et.al(2020)
61	*Exbucklandia populnea*	Hamamelidaceae	n.a	Lynser et.al(2020)
62	*Ficus hispida*	Moraceae	3.203	Taran et.al(2016)
63	*Ficus semicordata*	Moraceae	291	Sahoo et.al(2014)
64	*Garcinia paniculata*	Clusiaceae	n.a	Bhatt and Sachan(2004)
65	*Garcinia pedunculata*	Clusiaceae	n.a	Bhatt and Sachan(2004)
66	*Garcinia sp.*	Clusiaceae	n.a	Lynser et.al(2020)
67	*Gmelina arborea*	Lamiaceae	10.868	Taran et.al(2016)
68	*Grevillea robusta*	Proteaceae	742	Kataki and Konwer(2002)
69	*Helicia nilagirica*	Proteaceae	n.a	Lynser et.al(2020)
70	*Holarrhena antidysenterica*	Apocynaceae	3.962	Taran et.al(2016)
71	*Jambosa sp.*	Myrtaceae	_	Rai et.al(2002)
72	*Juglandaceae*	Juglandaceae	1358.6	Rai et.al(2002)
73	*Kydia calcyna*	Meliaceae	4091.38	Sedai et.al(2016)
74	*Lagerstroemia citrata*	Lythraceae	n.a	Bhatt and Sachan(2004)
75	*Lagerstroemia parviflora*	Lythraceae	448	Kataki and Konwer(2002)
76	*Lagerstroemia speciosa*	Lythraceae	n.a	Bhatt and Sachan(2004)
77	*Lantana camara*	Verbenaceae	516	Kataki and Konwer(2002)
78	*Leucosceptrum canum*	Lamiaceae	1027.8	Rai et.al(2002)
79	*Lithocarpus sp.*	Fagaceae	n.a	Lynser et.al(2020)
80	*Litsea elongata*	Lauraceae	448	Chettri and Sharma(2008)

81	*Litsea polyantha*	Lauraceae	369, 926.03	Kataki and Konwer(2002), Sedai et.al(2016)
83	*Macaranga denticulata*	Euphorbiaceae	n.a	Bhatt and Sachan(2004)
84	*Macaranga indica*	Euphorbiaceae	515	Sahoo et.al(2014)
85	*Macaranga pustulata*	Euphorbiaceae	672.6, 802.7	Rai et.al(2002), Sedai et.al(2016)
86	*Macropanax dispermus*	Araliaceae	220	Sahoo et.al(2014)
87	*Maesa chisia*	Primulaceae	429.9	Rai et.al(2002)
88	*Magnoli hodgsonii*	Magnoliaceae	1803.23	Sedai et.al(2016)
89	*Mallotus phillipensis*	Lamiaceae	1931.09	Sedai et.al(2016)
90	*Melastoma malabathricum*	Melastomataceae	6.498	Taran et.al(2016)
91	*Melia azedarach*	Meliaceae	968	Kataki and Konwer(2002)
92	*Melocanna baccifera*	Poaceae	n.a	Bhatt and Sachan(2004)
93	*Mesua ferrea*	Clusiaceae	1244	Sahoo et.al(2014)
94	*Michelia champaca*	Magnoliaceae	n.a	Bhatt and Sachan(2004)
95	*Momosops elengi*	Fagaceae	819.56	Sedai et.al(2016)
96	*Moraxella oblonga*	Moraxellaceae	n.a	Bhatt and Sachan(2004)
97	*Myrica esculenta*	Myricaceae	801	Sahoo et.al(2014)
98	*Myrica sp.*	Myricaceae	n.a	Lynser et.al(2020)
99	*Myrsine semiserrata*	Fabaceae	1723.68	Sedai et.al(2016)
100	*Oroxylum indicum*	Bignoniaceae	4.392	Taran et.al(2016)
101	*Persea sp.*	Lauraceae	n.a	Lynser et.al(2020)
102	*Photinia sp.*	Rosaceae	n.a	Lynser et.al(2020)
103	*Phyllocharis undulata*	Chrysomelidae	n.a	Bhatt and Sachan(2004)
104	*Pinus kesiya*	Pinaceae	n.a, 1308	Lynser et.al(2020), Kataki and Konwer(2002)
105	*Pinus wallichiana*	Pinaceae	560	Kataki and Konwer(2002)
106	*Premna integrifolia*	Fabaceae	274.01	Sedai et.al(2016)
107	*Prunus cerasoides*	Rosaceae		
108	*Prunus nepalensis*	Rosaceae	9046	Chettri and Sharma(2008)
109	*Pterospermum acerifolium*	Euphorbiaceae	2347.87	Sedai et.al(2016)
110	*Quercus delbata*	Fagaceae	661	Kataki and Konwer(2002)
111	*Quercus floribunda*	Fagaceae	895	Sahoo et.al(2014)
112	*Quercus glauca*	Fagaceae	725	Kataki and Konwer(2002)
113	*Quercus helferiana*	Fagaceae	1110	Sahoo et.al(2014)
114	Quercus lamellosa	Fagaceae	16431, 3860.7	Chettri and Sharma(2008), Rai et.al(2002)
115	*Quercus lineata*	Fagaceae	10,59,63,539.60	Chettri and Sharma(2008),Rai et.al(2002)
116	*Quercus pachyphylla*	Fagaceae	1361, 1210	Sahoo et.al(2014), Sahoo et.al(2014)
117	*Quercus semicaprifolia*	Fagaceae	748	Kataki and Konwer(2002)
118	*Quercus serrate*	Fagaceae	1077	Sahoo et.al(2014)

119	*Quercus sp.*	Fagaceae	n.a	Lynser et.al(2020)
120	*Quercus xylocarpa*	Fagaceae	1193	Sahoo et.al(2014)
121	*Rhododendron arboreum*	Ericaceae	22,678	Chettri and Sharma(2008)
122	*Rhododendron barbatum*	Ericaceae	9855	Chettri and Sharma(2008)
123	*Rhododendron falconeri*	Ericaceae	10,241	Chettri and Sharma(2008)
124	*Rhus javanica*	Anacardiaceae	n.a	Lynser et.al(2020)
125	*Rhus parviflora*	Anacardiaceae	370	Kataki and Konwer(2002)
126	*Rhus semialata*	Anacardiaceae	693.1	Rai et.al(2002)
127	*Rhus succedanea*	Anacardiaceae	594.8	Rai et.al(2002)
128	*Salix tetrasperma*	Salicaceae	687	Kataki and Konwer(2002)
129	*Sapindus laurifolius*	Sapindaceae	388	Kataki and Konwer(2002)
130	*Sapindus mukorossi*	Sapindaceae	801	Kataki and Konwer(2002)
131	*Schima khasiana*	Theaceae	n.a	Bhatt and Sachan(2004)
132	*Schima wallichi*	Theaceae	889.6, 694.81, 928,n.a,11365	Rai et.al(2002), Sedai et.al(2016), Sahoo et.al(2014),Lynser et.al(2020),Chettri and Sharma(2008)
133	*Shorea assamica*	Dipterocarpaceae	n.a	Bhatt and Sachan(2004)
134	*Shorea robusta*	Dipterocarpaceae	1027	Kataki and Konwer(2002)
135	*Simingtonia populnea*	Hamamelidaceae	n.a	Bhatt and Sachan(2004)
136	*Sterculia villosa*	Malvaceae	2.75	Taran et.al(2016)
137	*Stereospermum personatum*	Bignoniaceae	769	Sahoo et.al(2014)
138	*Styrax serrulatum*	Styracaceae	497	Sahoo et.al(2014)
139	*Symplocos crataegioides*	Symplocaceae	473	Kataki and Konwer(2002)
140	*Symplocos ramosissima*	Symplocaceae	1033	Chettri and Sharma(2008)
141	*Symplocos sp.*	Symplocaceae	n.a	Lynser et.al(2020)
142	*Symplocos theifolia*	Symplocaceae	713.4	Rai et.al(2002)
143	*Syzygium cerasoids*	Combretaceae	851.42	Sedai et.al(2016)
144	*Syzygium cumini*	Myrtaceae	9.083	Taran et.al(2016)
145	*Syzygium tetragonum*	Myrtaceae	n.a	Lynser et.al(2020)
146	*Tectona grandis*	Lamiaceae	12.353	Taran et.al(2016)
147	*Terminalia arjuna*	Combretaceae	714	Kataki and Konwer(2002)
148	*Terminalia bellerica*	Combretaceae	460	Kataki and Konwer(2002)
149	*Terminalia chebula*	Combretaceae	602	Kataki and Konwer(2002)
150	*Terminalia myriocarpa*	Combretaceae	n.a, 1801.73	Bhatt and Sachan(2004),Sedai et.al(2016)
151	*Terminalia tomentosa*	Combretaceae	433	Kataki and Konwer(2002)
152	*Tetrameles nudiflora*	Tetramelaceae	218	Sahoo et.al(2014)
153	*Toona ciliata*	Meliaceae	445, 8.158,343	Kataki and Konwer(2002), Taran et.al(2016),Sahoo et.al(2014)
154	*Trema orientalis*	Cannabaceae	2.729	Taran et.al(2016)

155	*Trewia nudiflora*	Euphorbiaceae	12.456	Taran et.al(2016)
156	*Viburnum contifolium*	Adoxaceae	991	Kataki and Konwer(2002)
157	*Viburnum sp.*	Adoxaceae	_	Rai et.al(2002)
158	*Vitex altissima*	Lamiaceae	2270.83	Sedai et.al(2016)
159	*Vitex peduncularis*	Lamiaceae	1276, 10.666	Sahoo et.al(2014),Taran et.al(2016)
160	*Wendlandia grandis*	Rubiaceae	877	Sahoo et.al(2014)
161	*Wendlandia wallichii*	Rubiaceae	n.a	Lynser et.al(2020)
162	*Wightia speciosissima*	Paulowniaceae	358	Sahoo et.al(2014)

Tribal reliance on wood for fuelwood as a key source of energy is generating severe deforestation in North Eastern Himalayan (Bhatt & Sachan, 2004; Bhatt & Tomar, 2002), which subsequently creates desertification in many parts of Meghalaya. Many people in north eastern India utilize fuelwood despite having access to alternative energy sources (Mottaleb & Rahut, 2021; Tofu et al., 2022). The average fuelwood consumption in NEH is 4.90 to 8.41 kg/capita/day, which is higher than previously reported values for other parts of Asia, such as 1.9–2.2 kg/capita/day for Southern India, 1.7–2.5 kg/capita/day for South and South-East Asian countries, 1.23 kg/capita/day for the Himalayan range of Nepal (Fox, 1984; Ives, 2004; Maikhuri, 1991).

Based on these tribal societies' fuelwood use patterns, deforestation must be carefully considered. It is vital to emphasize that if the current trends in fuelwood use in this region continue, there will be a shortage. Therefore, an urgent need is to educate indigenous tribes about preserving existing woods. Numerous studies have established a strong positive link between income and the amount of energy used (Angelsen et al., 2014; Chu & Karr, 2017; Coman et al., 2020). Many middle-income families in the region have access to LPG, but traditional chulha (wood burners) using fuelwood are still widely used for cooking. In addition, the remote areas of north eastern India have prevented many families from converting to modern fuels because of the distribution infrastructure. A literature review found that only a few studies have been undertaken on patterns of fuelwood consumption in North eastern India, and the majority were limited to small regions. Different approaches were utilized in further research to determine the pattern of per capita fuelwood usage. There is a need to record many aspects of fuelwood usage patterns in North Eastern India to formulate applicable laws. The data from the present study on fuelwood consumption patterns in North eastern India could be used to design and implement relevant technologies and management policies for the sustainable use of forest resources in this region.

V. CONCLUSION

People in the NEH have long relied on fuelwood as their primary energy source, which has resulted in significant deforestation across the state. On underutilized, deteriorated, and forested lands, it is imperative to construct large-scale energy plantations to avoid this catastrophe. However, when selecting tree species for energy plantations, special consideration should be given to Indigenous tree species traditionally favored for fuel by rural residents in the region. The fuel value index (FVI) is an essential screening criterion for acceptable fuelwood species. There is an urgent need for activities encouraging the conservation and sustainable use of imperiled forests in Northeast India. This paper outlines the tangible steps communities may take to better protect and manage impervious ecosystems. The woodlands in this region are renowned worldwide because of their rich biodiversity. The area is home to various cultural groups and has a staggering geographical variety.

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DECLARATION OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Innovative nano-solution: Biosynthesized nickel oxide nano-particles (NPs) protect carrot roots from root knot nematode, *Meloidogyne incognita* infestation

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***Abstract*— *Carrot (Daucus carota L.) is a crucial horticultural crop globally, valued for its nutritional benefits and economic significance. However, it faces substantial challenges from plant-parasitic nematodes, particularly Meloidogyne incognita, which significantly impact yield and quality. In this study, we examined the effect of Meloidogyne incognita (MI) infected carrot plants, that were treated separately with Ocimum santum leaves extract, Nickel sulphate salts and Nickel oxide nanoparticles (NiO-NPs) at different concentration (10, 50, 250, 500, 750 & 1000 ppm) as a pot set experiment. The result focused on the plant physiological, growth and nematode related parameters of MI inoculated plants that were treated with 1000 ppm verses the controlled untreated one. It shows significant plant growth in shoot length increased by 35.47%, root length by 266.4%, shoot fresh weight by 724%, root fresh weight by 631.2%, shoot dry weight by 819%, and root dry weight by 560.1% and the Physiological parameters shows improvement in total chlorophyll content 115% and carotenoid content decreased by 61.26% compared to the untreated control. Substantial reduction in the activity of nematode population per soil, gall formation and eggs per egg mass indicates promising applications of green-synthesized NiO NPs at 1000 ppm as sustainable agents for managing nematode infestations in carrot cultivation, there by contributing to enhanced crop productivity and sustainability in agriculture.*

***Keywords*— Biosynthesized nanoparticles, Meloidogyne incognita, Plant Parasitic Nematodes, Scanning Electron Microscopy**

I. INTRODUCTION

Carrot (*Daucus carota* L.), a member of the Apiaceae family, is known for its aromatic qualities, ornamental uses, and applications in herbal medicine. Approximately 20 species in the *Daucus* genus are distributed globally, the majority of subspecies are found in the western Mediterranean region. Accoding to Food and Agricultural Organization (FAO) Turnips and carrots global output reached 40.24 Mt from 1082967 ha in 2020 and approximately 41.67 Mt from 1096007 ha in 2021 (FAO STAT, hhps://www.fao.org/faostat/en/#data/QCL). China presently holds top position in the world for both carrot production and consumption, which represents about 45% of the worldwide market. The US, Ukraine, Uzbekistan, and Russia are the next in order. Carrots are grown on 97,000 hectares of land in India, producing 1648,000 million tonnes year [1] (Figure 1). Carrot requires cool to moderate temperature and typically have flowers with flattened umbels and compound leaves. [2]. As a tap root vegetable it has good storage ability possess various health benefits because of their rich in minerals, dietary fiber, vitamins, carotenoids, carbohydrates and antioxidant. Due to β-carotene carrot gets the characteristic orange colour which act as the precursor of Vitamin A. It has the potential to resist the cardiovascular diseases and cancers [3, 4]. Carrots get affected by microorganisms like bacteria, fungi and nematodes and cause major diseases like Alternaria leaf blight by *Alternaria dauci, Cercospora carotae*, and *X. hortorum* pv. *carotae* [5,6,7]. Plant parasitic nematode (PPN) cause losses in 40 key crops of 12.3% every year on average; the losses are higher in developing countries (14.6%) than in developed countries (8.8%). The yearly economic crop output losses resulting from plant-parasitic nematodes in main crops have been estimated to be USD 173 billion based on this survey conducted globally [8, 9]. Many nematode species cause significant yield losses annually in agricultural crops, particularly genera such as *Meloidogyne* and *Heterodera*, which are economically impactful due to their sedentary endoparasitic nature. Carrots are severely affected by *Meloidogyne incognita*, and managing this nematode with pesticides or nematicides is challenging due to their environmental damage.

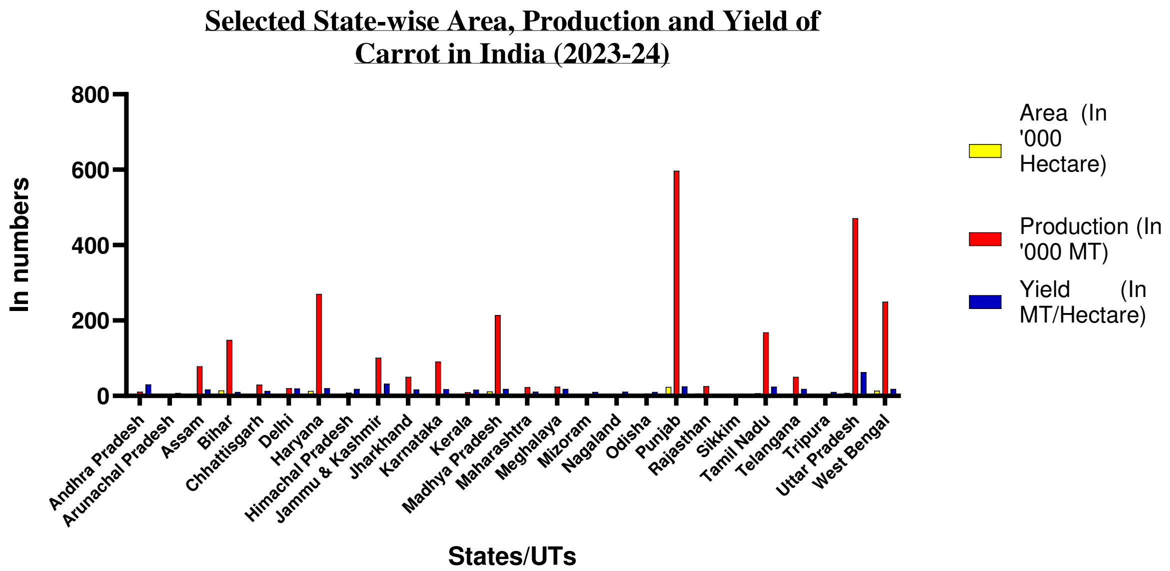


Fig.1: Carrot production states in India 2023-24, based on area (in hectare), production volume (in million metric tons) and yield (Source: https://www.indiastat.com/table/template/agriculture/selected-state-wise-area-production-yield-carrot-i/1455678)

Over the decades the use of biosynthesized nanoparticles in sustainable farming has garnered significant attention [10]. These nanoparticles are typically spherical and polymeric, with sizes ranging from 10 to 100 nm and their properties are determined by their shape, dimensions, structure, and crystallinity [11]. NPs have been used to control nematodes because of large surface areas, which enhance their affinity for the target organism, such as *M. incognita* the RKN nematode [12]. Biological methods for synthesizing nanoparticles, such as those using plants, fungi, and bacteria, are gaining interest due to their eco-friendly nature and avoidance of toxic by-products. Among these, plant-based approaches are particularly advantageous for nanoparticle synthesis as they involve protocols free from harmful chemicals [13]. Tauseef et al., 2021 [14] reported that the use of magnesium oxide nanoparticles on *Meloidogyne* infected cowpea reduced nematode fecundity and the number of galls formed. When tomato plants were treated with biosynthesized silver NPs enhanced the growth parameters with notably reduction in gall formations, Number of eggs per egg mass and egg mass on the roots.

A study by Fabiyi et al., (2024) [15] demonstrates that biosynthesized nanoparticles show promising efficacy in controlling root-knot nematodes, specifically in reducing egg masses, gall index, and population of *Meloidogyne incognita* in cabbage fields, against the standard nematicide carbofuran. This all approach is advantageous due to the nanoparticles are available easily, capability for bulk preparation and handling, as well as their wide range of metabolites that contribute to their effectiveness [16]. However, there is a lack of study in research focusing on the biosynthesis and application of Nickel Oxide nanoparticles (NiONPs) for controlling root-knot nematodes in carrot cultivation.

This study aims to address this research gap by biosynthesizing NiONPs from *Ocimum sanctum* leaves extract and characterizing the green-synthesized NiONPs. Furthermore, the study investigates the nematicidal activity of these NiONPs against *M. incognita* affecting *Daucus carota* L., with the primary objectives being: (a) biosynthesis of Nickel Oxide nanoparticles, (b) characterization of biosynthesized Nickel Oxide nanoparticles, and (c) evaluation of the nematicidal activity of NiONPs against M. incognita infecting carrots.

II. MATERIALS AND METHODS

2.1 Preparing and sterilising the mixture of soil

Sandy loam soil was collected from the Department of Botany at Aligarh Muslim University (27°52' N and 78°05' E), UP, India and passed through a 20-mesh size sieve. The soil was mixed with organic manure and river sand in 3:1:1 (v/v) ratio, and 9-inch diameter clay pots were filled with 2 kg of this mixture. The soil was pre-wet with 250 ml of water and then sterilized in an autoclave at 121°C under 20 lb pressure for 20 minutes [17]. After sterilization, the pots were cooled to room temperature before being used in the experimental study.

2.2 Raising of experiment plant

Carrot seeds from a certified seed bank in Aligarh were surface-sterilized in 0.01% mercuric chloride ($HgCl_2$) after rinsed with sterile water, and then sown in sterilized soil in 9-inch diameter clay pots. After germination, seedlings were thinned to retain a single seedling per pot [18]. The experiment followed a fully randomized block design with three replications per treatment, and untreated plants were used as control. The study was terminated 90 days after pathogen inoculation.

2.3 Preparation and maintenance of nematode inoculum

Nematode-infected eggplants were collected from fields near Vivekanand College of Technology and Management, Aligarh, and identified as *Meloidogyne incognita* based on perineal patterns [19]. Egg masses were handpicked, washed, and placed in mesh sieves mounted with cross double layered tissue paper over water in Petri dishes, where they were incubated at 25°C until hatching. After 48 hours, second-stage juveniles (J2) were emerged and their density was measured using a stereomicroscope. J2 concentration in water suspension was adjusted such that 200 ± 5 nematodes could be found in each ml.

2.4 Applying nematode inoculum to the test plant

The soil around the root of carrot seedlings was carefully removed and 10 ml of nematode suspension containing 2000 second-stage juveniles (*M. incognita*) was evenly applied. The roots were then immediately covered with the soil.

2.5 Nickel oxide nanoparticles (NiO NPs) synthesis

2.5.1 Preparation of the leaf extract

20 g fresh leaves of *Ocimum sanctum* from the Department of Botany, A.M.U., Aligarh, were washed with tap and distilled water (DW), then boiled in 100 ml of distilled water for ten minutes. The extract was filtered through Whatmann No. 1 filter paper, collected in an Erlenmeyer flask, and refrigerated at 4°C.

2.5.2 Preparation of nickel sulphate ($NiSO_4$) solution

NiO NPs were synthesized using Nickel sulphate ($NiSO_4$), which was purchased from the Thermo fisher Scientific Pvt. Ltd. Aqueous solution of $NiSO_4$ was prepared by adding 6.4 g of $NiSO_4$ in 1 litre

of double distilled water (DDW).

2.5.3 Concoction of $NiSO_4$ biosolution and biosynthesis of NiO NPs

The leaf extract (40 ml) was added to 160 ml of $NiSO_4$ solution to reduce the nickel ions (Ni^{+2}) to nickel nanoparticles (NiO). The contents were boiled for 20 minutes to complete the reaction. The composite mixture was almost transparent having NiO NPs in liquid form (Figure 2). This mixture was centrifuged at 4000 rpm for 10 min, and obtained nanoparticles were dried at 60 ºC for 24 h (Figure. 3; Liquid form of NiO NPs) [20].

2.6 Characterization and analysis of Biosynthesized NiO NPs

2.6.1 Ultraviolet- visible (UV-VIS) Spectroscopy analysis

The qualitative optical properties of biosynthesized NiO nanoparticles (NPs) were analyzed using UV-Vis spectroscopy, a non-destructive technique that measures absorbance across a wavelength range of 200 to 700 nm. A 1 ml sample of the nanoparticle suspension was compared to a 1 ml distilled water reference. The intensity of the reflected light was measured with a UV-Vis spectrophotometer (Schimadzer, Kyoto, Japan, UV-visible spectrophotometer, Model 1800) at a right angle to the light source.

2.6.2 Fourier Transform Infrared Spectroscopy (FTIR) analysis

The Fourier transformed infrared (FTIR) spectrophotometer analyzes NiO nanoparticles by passing 100 to 10000 cm^{-1} infrared radiation through the sample, where absorbed radiation provides information on molecular bonding through vibrational and rotational energy. The resulting spectrum, typically ranging from 400 cm^{-1} to 4000 cm^{-1}, serves as a molecular fingerprint for chemical identification. Peaks in the spectrum, compared with the Merck Infrared chart, indicate interactions and bond characteristics.

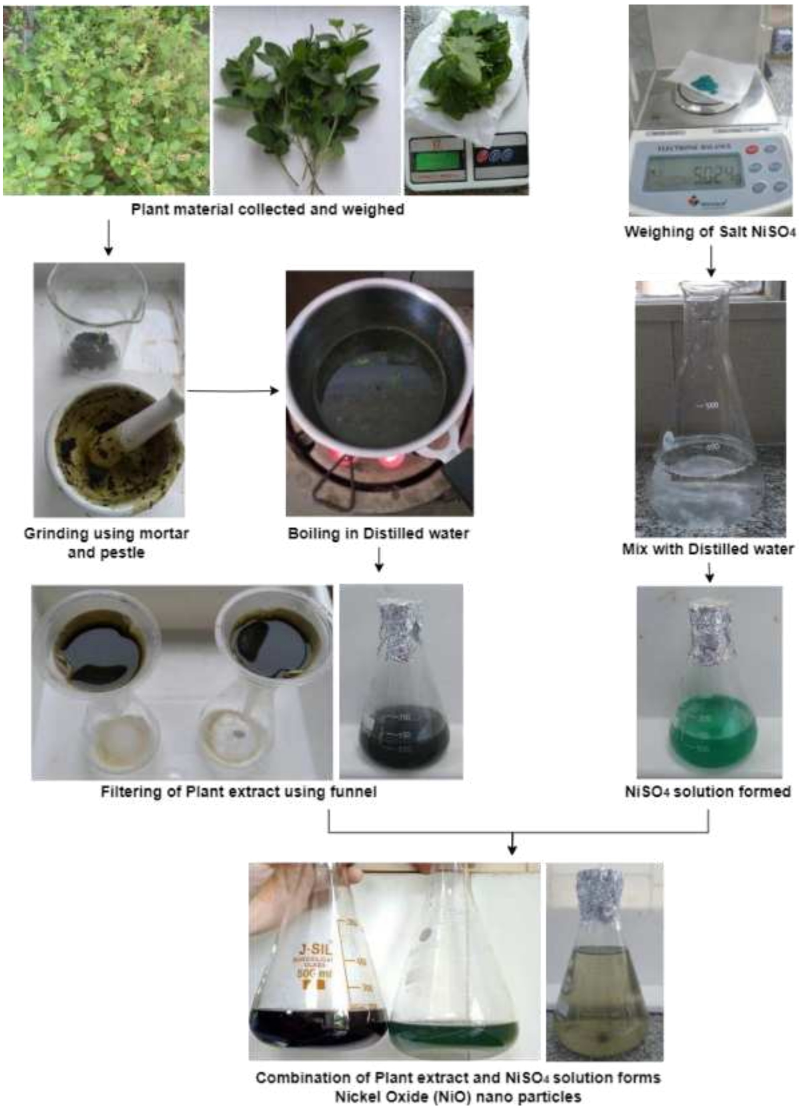


Fig.2: Preparation of Nickel oxide nanoparticles

2.6.3 Scanning Electron Microscopy (SEM) analysis

Scanning electron microscopy (SEM) was employed to examine the surface morphology of NiO nanoparticles. A small amount of the sample was applied to a carbon-coated copper grid to create thin film and excess solution was blotted off. Let the grid to dry under a mercury lamp. The dried grid was then analyzed using a scanning electron microscope (JSM6510 , JEOL, Japan).

2.7 NiO NPs inoculation to the test plant

Biosynthesized NiO nanoparticles (NPs) were applied to plants at concentrations of 10 ppm, 50 ppm, 250 ppm, 500 ppm, 750 ppm, and 1000 ppm. Soil around the roots was gently removed, and the NPs were introduced using a micropipette. The roots were then covered with soil, and the plants were regularly watered until the end of the experiment.

2.8 Experimental setup

The experiments were conducted during the winter season (November to January) using a completely randomized block design, with three variable treatments for each NiO NPs concentration and three replicates per treatment (Table 1). Pots were watered as needed and placed on glasshouse benches with temperatures ranging from 25-30 ºC.

2.9 Plant growth parameters

After 90 days of nematode inoculation, plants were harvested and roots were carefully washed. Plants were cut above the root base for height and weight measurements, while shoot and root lengths were recorded from the cut end to the top leaf and longest root, respectively. Fresh weights were recorded after blotting excess water, and dry weights were determined after drying in an oven at 60ºC for 72 hours.

Table 1: Treatments given to the testing plant at different concentration

Designation	Treatment
C	Control plant (untreated)
T1	$NiSO_4$ salt only
T2	*Meloidogyne incognita* (MI)
T3	MI + $NiSO_4$ salt
T4	MI + Plant extract
T5	MI + NiO NPs (10 ppm)
T6	MI + NiO NPs (50 ppm)
T7	MI + NiO NPs (250 ppm)
T8	MI + NiO NPs (500 ppm)
T9	MI + NiO NPs (750 ppm)
T10	MI + NiO NPs (1000 ppm)

2.9.1 Estimation of Chlorophyll content

Chlorophyll content in fresh leaves was estimated using Mackinney (1941) and Lichtenthaler and Welburn (1983) methods. Leaves were ground with 80% acetone, centrifuged, and the supernatant's absorbance measured at 645 nm and 663 nm. Chlorophyll content was calculated using Arnon's (1949) formula: Total chlorophyll (mg g-1 FW) = 20.2 (A645) + 8.02 (A663) x V/100 x W.

2.9.2 Estimation of Carotenoid content

Carotenoid content in fresh leaves was estimated using Mac Lachlan and Zalik's (1963) method, similar to chlorophyll extraction. Absorbance was measured at 480 nm and 510 nm using a spectrophotometer (EI 3305) with 80% acetone as a blank. Carotenoid content (mg g-1 FW) was calculated using the formula: 7.6 (OD 480) – 1.49 (OD 510) x V/D x W x 1000.

2.9.3 Estimation of Phenolic content

100 mg (0.1 g) of fresh leaves were homogenized in 2 ml of 80% methanol and agitated at 70 ºC for 15 mins (Zieslin and Zaken, 1993). Homogenate was collected in a test tube and 2.5 ml of 10% Folin–Ciocalteu reagent (FCR) and 2.5 ml of 7.5 % sodium bicarbonate ($NaHCO_3$) solution were added to it. This mixture was thoroughly mixed before incubating at 45 ºC for 45 minutes. An absorbance was recorded at 765 nm in a spectrophotometer (Model: EI 3305) against blank (all the mixture content without leaf material). Total phenolic content subsequently calculated and expressed as mg gallic acid equivalent (GAE) per gram of dry extract (mg GAE/g dw) (Patel et al., 2010; Ashraf et al., 2021).

2.9.4 Estimation of Proline content

50 mg of leaf tissue were homogenised in 7.5 ml of sulphosalicylic acid (3% aqueous) (SSA). The homogenate was placed in a centrifuge tube and spun for five minutes at 5,000 rpm. The pellet was disposed of and the supernatant was collected. A test tube was filled with one ml of leaf extract, one ml of glacial acetic acid (GAA), and one ml of acid ninhydrin were added to it. This mixture was heated in boiling water bath for 1 h and the reaction was terminated by placing the test tube in an ice bath. After cooling, 2 ml of toluene was added to it. After shaking it for 30 sec, two heterogenous layers were formed. The upper layer was pipetted out carefully and absorbance was recorded at 520 nm. Toluene was used as blank [21].

2.10 Nematode Related Parameters

2.10.1 Nematode population per 250g soil

Soil in each pot was well mixed before the juveniles were extracted using the Cobb's sieving, and decanting method followed by Baermann funnel technique. The nematode suspension was homogenized and 5 ml was transferred to a counting dish. Nematode populations per 250 g of soil were calculated by counting under a stereoscopic microscope [22].

2.10.2 Number of galls and egg masses per root system

At the end of the experiment, harvested plant roots were washed with tap water, and gall counts were recorded visually. For egg mass assessment, roots were immersed in 20 ml of 2% NaOCl solution and agitated for 1 minute. After dyeing with acid Fuchsin, egg masses were counted under a stereoscopic microscope [23].

2.10.3 Fecundity

Fecundity, the number of eggs per egg mass, was assessed using the Chlorax method by shaking 1g 1-2cm cut pieces of root in a 1.0% NaOCl solution for 5 minutes and filtering through 200- and 500-mesh sieves. Then eggs were rinsed with cold water to remove NaOCl and counted under a stereoscopic microscope. The total number of eggs was determined by multiplying the count by the fresh weight of the root in each treatment [24].

2.10.4 Reproduction factor

Soil in each pot was thoroughly mixed and juveniles were collected by Cobb's sieving and decanting method followed by Baermann funnel technique.

$$Rf = \frac{P_f}{P_i}$$

Where,

R_f = reproduction factor

P_f = final nematode population

P_i = initial nematode population

2.10.5 Root-knot gall index

The root-knot gall indices were determined on 0 to 5 scale, where 0 = no gall, 1 = 1 to 2 galls, 2 = 3 to 10 galls, 3 = 11 to 30 galls, 4 = 31 to 100 galls and 5 = >100 galls per root system [25, 26].

2.11 Statistical analysis

The whole data collected during the experiment was subjected to analysis of variance statistically. Least significant difference (LSD) was calculated at $p \leq 0.05$. Duncan's multiple range test (DMRT) was employed to indicate the level of significance between the treatments [27].

III. RESULTS

3.1 Biosynthesized NiO NPs: Characterization

3.1.1 Ultraviolet-visible (UV-Vis) Spectroscopy analysis

Ultraviolet-visible spectroscopy was utilized to analyze the optical characteristics of biogenically synthesized NiO nanoparticles using a Perkin-Elmer-Lambda 365 UV-vis spectrophotometer. The spectra of bio-synthesized NiO NPs have been examined in the 200 – 750 nm range, and outcomes are displayed in (figure 4). The presence of an excitonic peak in the ultraviolet range, coupled with absorption in the visible spectrum, clearly demonstrates the UV and visible light responsiveness of NiO nanoparticles. It is a useful material for photovoltaic applications because of its high transparency in the visible area and low transparency in the UV region. The good optical properties of the synthesised NiO NPs are indicated by the absence of other peaks in the spectrum.

3.1.2 Fourier Transform Infrared Spectroscopy (FTIR) analysis

FTIR analysis provides information about the vibrational characteristics of NiO nanoparticles. FTIR analysis provides information about the vibrational signatures of NiO nanoparticles. The peak observed at 702.84 cm^{-1} indicates the presence of Ni-O stretching vibrations. Other peaks within the range of 500–4000 cm^{-1} correspond to vibrations from molecules affixed to the surface of the NiO nanoparticles. The stretching vibration of the C=C bond in alkane groups is detected at 1633.80 cm^{-1}. Additionally, a peak at 3436.32 cm^{-1} signifies OH stretching vibrations, indicating the presence of absorbed CO_2 and molecular water on the nanoparticle surface (Figure 5).

3.1.3 Scanning Electron Microscopy (SEM) analysis

The morphology of the synthesized NiO nanostructure was analyzed using SEM images (figure 6). SEM micrographs at different magnifications, specifically (a and b) 10 µm, (c) 5 µm, and (d) 1 µm, clearly depict the formation of NiO nanosheets that are randomly distributed and have well-defined particle boundaries. These NiO nanosheets are uniformly shaped and have a thickness ranging from 15 to 40 nm.

Fig.3: NiONPs in liquid form

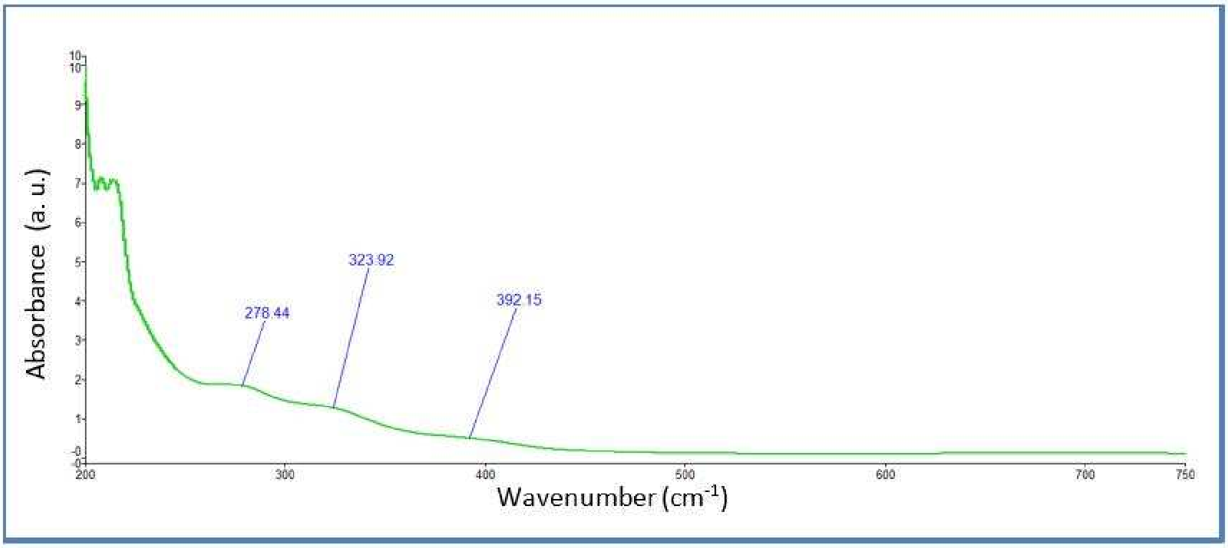


Fig.4: UV–Vis spectrum analysis of biosynthesized NiONPs

3.2 Plant growth Parameters

M. incognita led to a considerable reduction in all growth parameters of carrot plants. Inoculation with *M. incognita* resulted in a decrease of 30.26% in shoot length, 75.9% in root length, 83.42% in shoot fresh weight, 90.43% in root fresh weight, 89.8% in shoot dry weight, and 89.17% in root dry weight. The application of NiO nanoparticles at various concentrations significantly enhanced all plant growth parameters compared to inoculated plants. Among the treatments, plants treated with a 1000 ppm solution of NiO nanoparticles showed the greatest improvements: shoot length increased by 35.47%, root length by 266.4%, shoot fresh weight by 724%, root fresh weight by 631.2%, shoot dry weight by 819%, and root dry weight by 560.1% compared to inoculated plants.

Plants treated with a 10 ppm solution of NiO nanoparticles exhibited substantial enhancements in shoot length, root length, shoot fresh weight, root fresh weight, shoot dry weight, and root dry weight, increasing by 18.49%, 190.5%, 101.3%, 216.9%, 71.

4%, and 163.8%, respectively as compared to plants that were only inoculated. (Table-3) (Figure 7.).

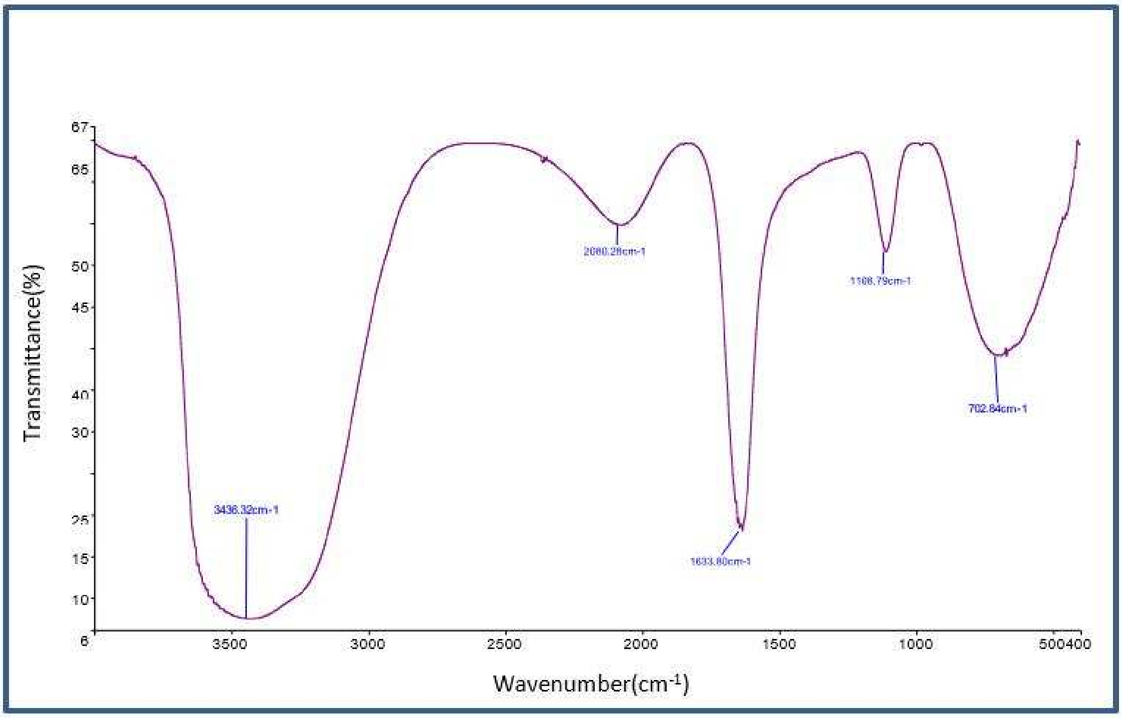
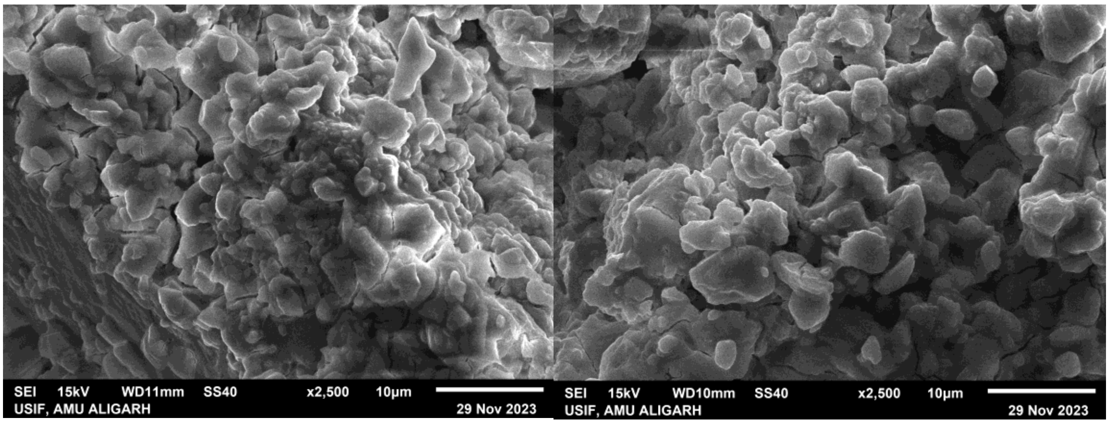
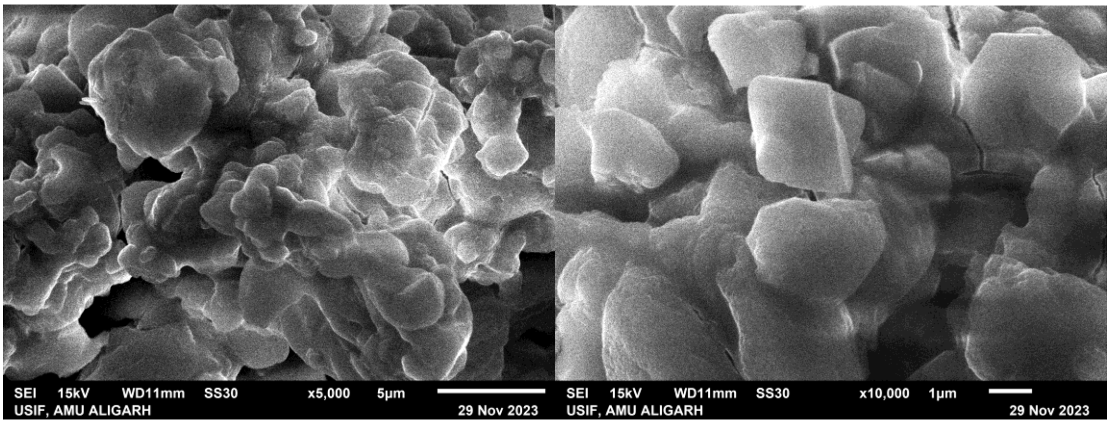


Fig.5: FTIR spectrum of Biosynthesized NiONPs



(a) *(b)*



(c) *(d)*

Fig.6 (a-d): SEM images of biosynthesized NiONPs

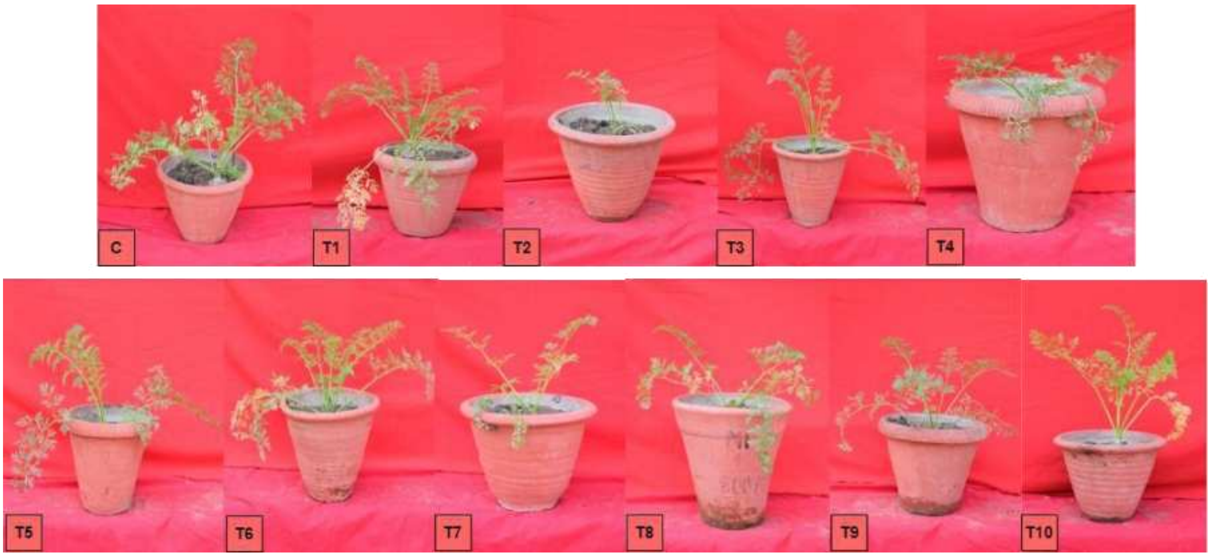


Fig.7: C = Control (untreated); T1 = $NiSO_4$ salt; T2 = Meloidogyne incognita (MI); T3 = MI + $NiSO_4$; T4 = MI + Plant extract; T5 = MI + 10 Ppm (NiO NPs solution); T6 = MI + 50 Ppm (NiO NPs solution); T7 = MI + 250 Ppm (NiO NPs solution); T8 = MI + 500 Ppm (NiO NPs solution); T9 = MI + 750 Ppm (NiO NPs solution); T10 = MI + 1000 Ppm (NiO NPs solution)

3.3 Physiological Parameters

3.3.1 Chlorophyll and carotenoid content

M. incognita caused substantial decrease in chlorophyll content by 53.55% as compared to untreated control. Application of NiO NPs solution caused considerable enhancement in chlorophyll content as compared to inoculated control. NiO NPs, at 1000 ppm, shows maximum improvement in total chlorophyll content by 115% as evaluating with inoculated control (Table-2). *M. incognita* caused pronounced decrease in carotenoid content by 61.26% as compared to untreated control.

Application of NiO NPs caused considerable enhancement in carotenoid content as compared to inoculated control. NiO NPs, at 1000 Ppm, shows maximum improvement in carotenoid content by 158% as compared to inoculated control. As compared to only inoculated plants, plants treated with 10 ppm solution of NiO NPs also showed significant improvement in chlorophyll by 10.8% and carotenoid content by 14.5%.(Table-2).

Table 2: Effect of different concentration of nickel nanoparticle treatments on plant growth parameters of carrot infected M.incognita.

Treatments	Length (cm)		Fresh weight (g)		Dry weight(g)		Total Chlorophyll (mg/g leaf tissue)	Total Carotenoids (mg/g)	Phenolic content (765nm) (mg/g)	Proline content (520nm) (mg/g)
	Shoot	Root	Shoot	Root	Shoot	Root	3.38±0.011^{a}	1.42±0.011^{a}	0.452±0.001^{d}	0.028±0.001^{i}
C	38±1.15^{a}	22±1.15^{a}	22.02±1.12^{b}	106.77±1.38^{a}	4.12±0.01^{a}	9.98±0.005^{a}	1.41±0.17^{f}	0.56±0.011^{d}	0.502±0.021^{c}	0.089±0.001^{g}
T1	27±1.15^{f}	10±1.15^{f}	6.38±0.02^{e}	25.36±0.023^{g}	0.45±0.02^{hi}	2.26±0.011^{i}	0.88±0.005^{g}	0.07±0.011^{c}	0.702±0.001^{a}	0.565±0.001^{a}
T2	26.5±0.23^{f}	5.3±1.52^{g}	3.65±0.03^{f}	10.21±0.017^{h}	0.42±0.01^{i}	1.08±0.023^{j}	1.57±0.011^{ef}	0.55±0.015^{d}	0.569±0.003^{b}	0.091±0.001^{g}
T3	30±1.73^{de}	13.5±1.53^{de}	7.06±0.01^{e}	26.68±0.02^{g}	0.55±0.01^{g}	2.55±0.023^{h}	0.92±0.011^{g}	0.54±0.011^{d}	0.577±0.001^{b}	0.468±0.001^{b}
T4	27.3±0.55^{ef}	12±1.3^{ef}	6.84±0.02^{e}	25.52±0.026^{g}	0.50±0.02^{gh}	2.28±0.011^{i}	1.67±0.011^{e}	0.59±0.017^{cd}	0.562±0.001^{b}	0.162±0.001^{c}
T5	31.4±0.7^{cd}	15.4±0.26^{cd}	7.35±0.02^{e}	32.36±0.017^{f}	0.72±0.02^{f}	2.85±0.023^{g}	1.74±0.011^{de}	0.63±0.115^{cd}	0.549±0.023^{b}	0.142±0.001^{d}
T6	31.7±0.78^{cd}	16±1.52^{cd}	12.74±0.02^{d}	37.04±0.011^{e}	1.74±0.01^{e}	3.40±0.115^{f}	1.92±0.015^{d}	0.70±0.017^{c}	0.509±0.001^{c}	0.120±0.001^{e}
T7	32.6±0.11^{cd}	16.8±0.32^{bc}	13.06±0.09^{d}	41.84±0.011^{d}	2.02±0.2^{d}	4.04±0.011^{e}	2.36±0.011^{c}	0.93±0.115^{b}	0.498±0.027^{c}	0.107±0.011^{ef}
T8	33.3±0.11^{bc}	17.1±0.35^{bc}	13.32±0.18^{d}	43.13±0.017^{d}	2.03±0.01^{d}	4.70±0.115^{d}	2.80±0.011^{b}	1.01±0.011^{b}	0.485±0.002^{cd}	0.102±0.001^{fg}
T9	33.5±1.72^{bc}	17.6±0.17^{bc}	16.43±1.24^{c}	68.15±0.476^{c}	2.58±0.02^{c}	6.55±0.015^{c}	3.33±0.115^{a}	1.04±0.015^{b}	0.458±0.001^{d}	0.060±0.001^{h}
T10	35.9±0.25^{ab}	19.4±0.23^{ab}	30.10±1.80^{a}	74.69±0.023^{b}	3.86±0.01^{b}	7.13±0.011^{b}	3.38±0.017^{a}	1.42±0.011^{a}	0.452±0.001^{d}	0.028±0.011^{i}
LSD	2.82	0.64	2.18	1.29	0.05	0.15	0.18	0.109	0.037	0.014

*Means with same letter are not significantly different according to Duncan Multiple Range Test (p0.05). Each value is a mean of three replicates.

**C= Untreated control; T1= $NiSO_4$ (1000 ppm); T2 =MI; T3= MI + $NISO_4$; T4 =MI+ Plant Extract (20 ml); T5 =MI +NiO NPs (10 ppm); T6 =MI +NiO NPs (50 ppm); T7 =MI +NiO NPs (250 ppm); T8 =MI +NiO NPs (500ppm); T9 =MI +NiO NPs (750 ppm); T10 =MI +NiO NPs (1000 ppm); LSD =Least Standard Deviation.

Table 3: Effect of different concentration of nickel nanoparticle on nematode related parameter of root-knot nematode, M. incognita infecting carrot plant.

Treatment	Total soil nematode population (250g)	Number of galls	Number of egg masses	Fecundity	Reproduction factor	RKI
C	0	0	0	0	0	0
T1	0	0	0	0	0	0
T2	900±7.63^{a}	108±1.15^{a}	85.8±1.94^{a}	311±1.15^{a}	2.53±0.03^{a}	5±2.3^{a}
T3	765±2.08^{b}	84±1.15^{bc}	74±1.15^{b}	241±1.52^{b}	1.87±0.02^{b}	4±1.15^{a}
T4	630±1.52^{c}	87±1.73^{b}	69.9±1.46^{c}	206±1.15^{c}	1.72±0.01^{c}	4±0.57^{a}
T5	585±2.51^{d}	81±1.73^{c}	60.3±1.19^{d}	194±2^{d}	1.64±0.01^{d}	4±1.15^{a}
T6	550±2.3^{e}	73±1.73^{d}	54±1.15^{e}	183±1.73^{e}	1.35±0.01^{e}	4±1.73^{a}
T7	471±3^{f}	65±2.88^{e}	51.8±1.15^{e}	177±2.08^{f}	1.12±0.01^{f}	4±2.51^{a}
T8	419±3.51^{g}	57±1.15^{f}	45.7±1.28^{f}	173±1.52^{f}	0.99±0.01^{g}	4±1.52^{a}
T9	390±1.52^{h}	48±1.15^{g}	43±1^{g}	165±1.52^{g}	0.94±0.01^{h}	4±1.52^{a}
T10	362±2.3^{i}	28±2.3^{h}	41±1.52^{g}	143±1.52^{h}	0.84±0.01^{i}	3±1.52^{a}
LSD	9.08	4.67	3.57	4.27	0.04	4.32

*Means with same letter are not significantly different according to Duncan Multiple Range Test (p0.05). Each value is a mean of three replicates.

**C= Untreated control; T1= $NiSO_4$ (1000 ppm); T2 =MI; T3= MI + $NISO_4$; T4 =MI+ Plant Extract (20 ml); T5 =MI +NiO NPs (10 ppm); T6 =MI +NiO NPs (50 ppm); T7 =MI +NiO NPs (2 50 ppm); T8 =MI +NiO NPs (500ppm); T9 =MI +NiO NPs (750 ppm); T10 =MI +NiO NPs (1000 ppm); LSD =Least Standard Deviation.

Fig.8: C = Control (untreated); T1 = $NiSO_4$ salt; T2 = Meloidogyne incognita (MI); T3 = MI + $NiSO_4$; T4 = MI + Plant extract; T5 = MI + 10 Ppm (NiO NPs solution); T6 = MI + 50 Ppm (NiO NPs solution); T7 = MI + 250 Ppm (NiO NPs solution); T8 = MI + 500 Ppm (NiO NPs solution); T9 = MI + 750 Ppm (NiO NPs solution); T10 = MI + 1000 Ppm (NiO NPs solution)

3.3.2 Phenolic content

Compared to the untreated plants (control), the treated plants had noticeably higher phenol content. *M. incognita* caused the significant increase in phenol content by 25.8% as compared to untreated control. NiO NPs (1000 ppm) shown maximum increase in phenol content by 20.7% as compared to untreated control.

As compared to only inoculated plants, plants treated with 10 ppm solutions of NiO NPs also showed significant increase in phenolic content by 3.51 % (Table-2).

3.4 Nematode Related Parameters

Application of NiO NPs at 1000 ppm caused significant decrease in nematode population per 250 g of soil by 59.77%. When *M. incognita* was used alone, there were a lot of galls per root system and nematode proliferation (Table-3).

NiO NPs caused the significant decrease number of galls, the highest reduction being in case of 1000 ppm solution of NiO NPs in T10, by 74.07 %. Number of eggs per egg mass was found significantly decreased in plants treated with 1000 ppm solution of NiO NPs in T10; the highest reduction is by 54.65% (Figure 8). There was a decrease in fecundity by 54.01% and reproduction factor by 66.79%.

IV. DISCUSSION

Root knot nematodes, which are polyphagous sedentary endoparasites, pose a significant threat to global agricultural production, particularly in vegetable fields such as those growing carrots [28]. Nematicides are highly toxic and adversely affect the environment and may restrict their usage against plant parasitic nematodes. The interest in creating biological control strategies has increased due to the necessity for ecologically friendly control methods. Traditional methods of synthesizing nanomaterials involve the use of chemicals and solvents that pose hazards to the nature, human and animal health. In contrast, green synthesis utilizes organic compounds like plant extracts and solvents with minimal or no toxicity, promoting an environmentally sustainable approach. The synthesis of nanoparticles can use as an alternative due to their cytotoxicity, physicochemical traits, and biological properties [29, 30]. NiO nanoparticles fabricated using extracts from *Ananas comosus, Hordeum vulgare, Calotropis gigantea, Ocimum sanctum* and *Brassica rapa* leaf have shown consistent and trustworthy biochemical properties in vitro. The results demonstrate the usefulness of biogenic NiO NPs in agricultural and biomedical domains because of their intrinsic anti-pathogenic characteristics, controlled size, oxidative stress-generating capacity, and conducting nature [31, 32].

In this research, we have presented a sustainable method for synthesizing NiO nanoparticles using extracts from the *Ocimum sanctum* plant. NiO nanoparticles, appearing as an olive-green precipitate, were obtained after drying for 24 hours at 60°C. Nickel oxide is the second largest prevalent metal oxide, known for its affordability, safety, and straightforward preparation process.

Characterization involved UV-Vis spectrophotometry, FTIR analysis, and SEM analysis. According to Medda et al. (2015), nanoparticles typically exhibit absorbance spectra between 400-700 nm when synthesized from their respective salt precursors, showing a distinct and can perceive a prominent peak in the spectrum of visible light. This characteristic is often attributed to the close proximity of nickel nanoparticles' conduction and valence bands, facilitating electron movement and resulting in a pronounced surface plasmon resonance peak [33].This peak likely arises from nickel oxide band gap absorption, where electrons transition from the valence to the conduction band. UV-Vis spectrum analysis examined the spectra of biogenically synthesized NiO nanoparticles within the 200 – 750 nm range. FTIR analysis revealed a peak at 702.84 cm^{-1}, and SEM analysis indicated that the average thickness of NiO particles ranged from 15-40 nm, exhibiting a hexagonal shape.

V. CONCLUSION

The study utilized *Ocimum sanctum* leaf extract to biosynthesize NiO nanoparticles, characterized by FTIR, SEM, and UV-Vis techniques for revealing their shape, size, surface appearance, structural organization and purity of NPs and the presence of secondary metabolites in leaf extract, which served capping agents for the production of NPs. These nanoparticles contain specific phytochemicals and secondary metabolites that can provide resistance to pests and pathogens, making them a safer alternative to various pesticides. The green-synthesized NiO NPs effectively controlled *Meloidogyne incognita* in *Daucus carota*, enhancing plant growth and showing significant reduction in nematodal activity at various concentrations, particularly at 1000 ppm.

The nanoparticles, rich in phytochemicals, offer a safer and more eco-friendly alternative to conventional pesticides. Overall, this plant-based synthesis method is a promising, cost-effective and sustainable approach for managing plant pathogens and advancing agricultural research.

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Ecological Sensitivity Analysis of Maoming City based on GIS and Analytic Hierarchy Process (AHP)

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Abstract— *Urban ecological environment is the material basis for the survival and development of residents, and ecological sensitivity research is of great significance for understanding and protecting the ecosystem, promoting sustainable development, preventing and controlling environmental problems. With the progress of science and technology and the increasingly prominent environmental problems, the importance of ecological sensitivity research is increasing, and it has become one of the hot spots in environmental science research. In this paper, geographic information system (GIS) and analytic Hierarchy Process (AHP) are used to evaluate the ecological sensitivity of Maoming City. Firstly, the spatial database of ecological sensitivity assessment is constructed by integrating 9 factors such as elevation and slope with GIS technology. Secondly, AHP method was used to determine the weight of each ecological sensitivity factor, including elevation, slope, slope direction, land use type, vegetation coverage and water environment. Finally, combined with the above data and weights, the ecological sensitivity of Maoming City was quantitatively evaluated, and divided into four sensitive areas: insensitive, low sensitive, medium sensitive and high sensitive, and the spatial distribution map of ecological sensitivity was drawn. The results showed that the comprehensive ecological sensitivity of Maoming city was high, mainly characterized by insensitivity and low sensitivity, which accounted for 69.31%.*

***Keywords*— Ecological Sensitivity (ES); Geographic Information System (GIS); Analytic Hierarchy Process (AHP); Maoming City**

I. INTRODUCTION

Urban ecological environment refers to the system composed of all living organisms (including human beings) and the environment in an urban area. It is a highly complex social-economic-natural ecosystem, composed of social subsystems, economic subsystems, and natural subsystems. Urban ecosystems are not only influenced and controlled by natural factors but also influenced and controlled by social and economic factors. Human planning of urban structure and layout determines the basic spatial pattern of urban ecosystems [1]. As a result, the urban ecological environment evaluation is of great significance for promoting urban sustainable development, ensuring the health of residents, preserving ecological balance, dealing with climate change, and improving the city's image and competitiveness.

Ecological sensitivity refers to the degree of ecosystem sensitivity to disturbance by natural and human activities within the region. It reflects the degree of difficulty and possibility of the ecological environment problems when the regional ecosystem encounters interference and is used to characterize the possible consequences of external interference. That is, under the influence of various ecosystems under the action of interference intensity or external force. Assessment of ecological sensitivity is essential for understanding and protecting ecosystems. By assessing ecological sensitivity, we can identify areas that are particularly sensitive to human activities or vulnerable to natural disasters, which often require special conservation and management measures to prevent ecological degradation and environmental damage. In addition, ecological sensitivity assessment can also help decision-makers make more scientific and rational decisions in land planning, resource development, and environmental protection.

Scholars at home and abroad have made significant advances in the field of ecological sensitivity. Scholars have discussed the definition of ecological sensitivity and tried to build a theoretical model of ecological sensitivity assessment. For example, some studies have proposed a theoretical framework for ecological sensitivity assessment and conducted an empirical study taking Shaanxi Province as an example. The researchers have also created a variety of ecological sensitivity evaluation methods, including the Delphi method, the ecological factor scoring method, and the GIS technology [3]. These methods are used to analyze and evaluate the ecological sensitivity of specific regions in order to take corresponding protection and development measures. In the study of ecological sensitivity, scholars have carried out empirical studies of ecological sensitivity in different regions, such as sensitivity analysis of soil erosion, acid rain, desertification, and other issues, as well as sensitivity research of watershed ecology. These studies help to understand the spatial distribution of ecological sensitivity and provide a scientific basis for the prevention and governance of ecological environmental problems [2].

Simultaneously, several researches have combined ecological sensitivity evaluation with ecological red line demarcation to explore how to delimit strict protection boundaries in ecologically sensitive areas to ensure ecological security and sustainable development. The researchers also tried to combine the evaluation of ecological sensitivity with the evaluation of ecological service value so as to more comprehensively evaluate the function and value of the ecosystem and provide technical methods and ideas for ecological protection and ecological construction. These research results not only enhance our understanding of ecological sensitivity but also provide a scientific basis for ecological protection and environmental management. With the progress of science and technology and the continuous improvement of research methods, future research on ecological sensitivity will be more thorough and accurate.

In recent years, many researchers have conducted a lot of research on various aspects of ecological evaluation, with diversified research scales. Although there are urban scales, there are few studies on ecological sensitivity in fourth-tier cities[4]. Therefore, it is particularly important to carry out the ecological sensitivity research in Maoming. Maoming coastal zone is a region with high ecological sensitivity, which is greatly affected by natural factors and human activities, such as coastal erosion, soil erosion, storm surge, red tide, etc., which need to be evaluated and planned through ecological sensitivity research. And Maoming coastal areas from the perspective of the sea as a whole, we need to consider the interaction and influence of land and marine ecosystems. Ecological sensitivity research helps to identify and protect important ecological origins, corridors, and nodes; identify and protect important ecological spaces; promote the construction of ecological civilization; and achieve sustainable development[6]. At the same time, ecological sensitivity research can reveal the sensitivity of the ecosystem to natural and human activities, help Maoming City better understand the vulnerability and sensitivity of its coastal zone ecosystem, formulate corresponding protection and management measures, and ensure ecological balance and sustainable development[6]**Error! Reference source not found.**.

In terms of methodology, generally applying the digital elevation model (DEM) data to extract the slope and aspect and then using the data to calculate the normalized difference vegetation index (NDVI) and the normalized differential water index (NDWI) using the remote sensing image data. These indicators can help to assess ecological sensitivity and classify them into different sensitivity grades, such as insensitive, low sensitivity, medium sensitivity, and high sensitivity. Moreover, the analysis based on remote sensing images to calculate the NDVI index is helpful to evaluate the vegetation coverage and assess the health status of vegetation, which indirectly reflects the ecological sensitivity. Finally, the comprehensive evaluation method was used. The evaluation of ecological sensitivity requires the comprehensive consideration of various factors, such as terrain, vegetation, and water bodies. This involves the use of geographic information system (GIS) technology to synthesize the effects of different factors and generate a spatial distribution map of ecological sensitivity [7].The advantage of such a method is that it is able to provide a wide range of ecological sensitivity assessments, suitable for regional planning and environmental management, and the combination of DEM and remote sensing image data can accurately reflect the physical and biological characteristics of the ecosystem**Error! Reference source not found.**. It can also, through GIS technology, provide ecological sensitivity spatial distribution visualization to understand and communicate[10]. The disadvantage is that data acquisition and processing may be expensive, especially high-quality remote sensing image data, and the analysis process is complex, which requires professional knowledge and skills and sensitivity assessment for small-scale or special ecosystems. The existing methods may not be fine enough. In practical research, ecological sensitivity analysis methods can be applied to a variety of scenarios, such as urban planning, land use planning, environmental protection, etc. For example, the urban expansion and green space layout can be guided by analyzing the ecological sensitivity of the surrounding city to reduce the negative impact on the surrounding ecosystem.

In conclusion, the ecological sensitivity analysis method is an interdisciplinary field, involving many aspects of geography, ecology, remote sensing, and GIS technology. As technology evolves, these methods will become more precise and efficient, contributing to better protection and management of the environment [9].

II. STUDY AREA

Maoming, located in southwest Guangdong Province, is a prefecture-level city in Guangdong Province. It is adjacent to Yangjiang City in the east, the South China Sea in the south, Zhanjiang City in the west, and Yunfu City and Guangxi Zhuang Autonomous Region in the north. The administrative area of Maoming City has a total land area of 11,427.63 square kilometers and a coastline of 182.1 kilometers long. The city faces the sea behind the mountains, and the terrain is high in the north and low in the south, leaning from northeast to southwest. The highest point is 1704 meters, and the lowest point is 1.6 meters. In the north and northeast, there are three mountains of yunkai, leakage, and clouds, forming the northern barrier of the city, while the central and southwest are mainly hills, plains, and platforms.

The climate of Maoming belongs to the subtropical monsoon climate, with obvious monsoon, with north wind prevailing in winter and southeast wind prevailing in summer. The main climate features are no severe cold in winter, no extreme heat in summer, long in summer and short in winter, rich in heat, abundant rainfall, and an obvious dry and wet season.

Annual rainfall is between 1500 and 1800 mm, of which the rainfall from April to September accounts for more than 80% of the whole year. The annual average sunshine hours were between 1700 and 2000 hours, and the sunshine percentage was between 40% and 44%. The hydrological condition of Maoming is influenced by its geographical location and climatic characteristics. Because it is located in the south of the Tropic of Cancer, with abundant rainfall, plus the terrain is high in the north and low in the south, and mountainous in the north, so the water resources are relatively abundant. The main rivers of Maoming city are the Jianjiang River, Meihua River, Luojiang River, Huanghua River, and Xiaodong River. Except that the Huanghua River belongs to the Xijiang River basin, all the others belong to the Jianjiang River system. The average annual rainfall in Maoming is about 20.3 billion cubic meters, with a rainfall depth of 1791 mm, the runoff is about 11 billion cubic meters, and the average runoff depth is about 973 mm.

.By the end of 2022, the permanent resident population of Maoming was 6.2382 million, and the registered population was 8.2597 million. In 2022, the city's gross regional product (preliminary accounting number) was 390.463 billion yuan, an increase of 0.5% over the previous year. Maoming has jurisdiction over two municipal districts, three county-level cities, 26 street offices, 86 towns, 276 resident 'committees, and 1,628 villagers' committees.

Maoming is rich in marine resources and beautiful coastal scenery. Meanwhile, Maoming is also an important petrochemical base in China, with the nickname "Southern Oil City." In recent years, Maoming has actively promoted the adjustment, transformation, and upgrading of industrial structures and strives to build a modern economic system [4].

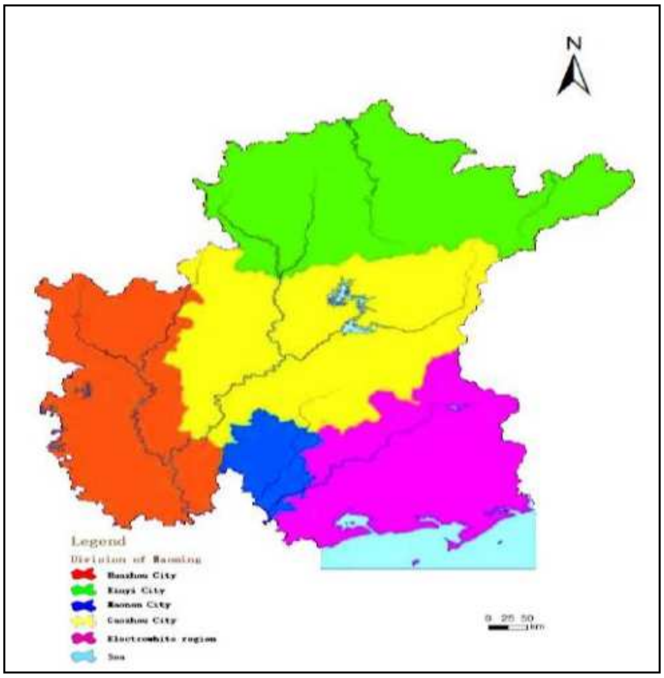

Fig.1 The administrative area of Maoming City

III. RESEARCH METHODS

3.1 Data Source

The data of this study are mainly divided into raster and vector data. Raster data include 2019 digital elevation model (DEM), image data (30 m× 30 m), 2021 annual vegetation cover (NDVI) image data (30 m× 30 m), 2021 land use data (30 m× 30 m), population density data in 2019 (1 km× 1 km), and GDP per capita data in 2020 (1 km× 1 km). Vector data includes water environment data and road data in 2021.

DEM data and NDVI data are from the geospatial data cloud; land use data, road data, and water environment data are from the National Center for Basic Geographic Information; and population density and per capita GDP data are from the Resource and Environmental Science and Data Center of the Chinese Academy of Sciences. DEM data are analyzed and processed by ArcGIS 10.8 software to obtain slope and aspect data; NDVI data is used in ENVI 5.3 software. The above data are unified in the coordinate system and the projection system in ArcGIS 10.8 [10].

3.2. Construction of the Evaluation System

In the process of constructing the evaluation index system, the selection of evaluation factors, the delineation of sensitive levels, and the weight determination are the most important, which have the greatest impact on the rationality of the evaluation results. First of all, the purpose of the evaluation and the geographical scope of the evaluation need to be clarified, which will determine the design direction and coverage content of the evaluation system. According to the evaluation objectives, select the indicators that can reflect the ecological sensitivity. These indicators usually include natural factors (such as climate, topography, hydrology, etc.) and human factors (such as land use, population density, economic activities, etc.). The selected indicators are organized according to certain logical relations to form a distinct hierarchical evaluation system.

This system usually includes the target layer, the criteria layer, and the index layer. Evaluation criteria were set for each indicator, and different weights were given according to its influence on ecological sensitivity. Data related to evaluation indicators are collected and performed the necessary processing to facilitate subsequent analysis and calculation. Select the AHP for evaluation. According to the results of the evaluation model, the ecological sensitivity level of each region is analyzed, and the results are interpreted and verified. The evaluation results are applied to the actual ecological protection, planning, and management to provide a scientific basis for decision-makers.

In the construction of an ecological sensitivity evaluation system, this paper considers that the evaluation system should consider natural and human factors and their interaction (comprehensive); the evaluation system should be an organic whole with clear connection and interaction (systematic); the ecological sensitivity changes with time and environment, and the evaluation system should be able to reflect such dynamic change (dynamic); the evaluation system should be strong and practical to facilitate practical operation and data processing (operational). Taking Maoming as the research object, 9 evaluation factors such as elevation and slopes were selected (Table 1). These factors are closely related to the topography and human activities of the region, and can reflect the ecological sensitivity of the region.

1. The effect of elevation on ecological sensitivity elevation is reduced precipitation; these changes will affect plant growth and animal habitat, making these areas more vulnerable to disturbance and destruction.
2. The effect of slope can affect the retention of water and the degree of soil erosion. A steep slope often means a faster flow rate and stronger soil erosion, which may lead to soil erosion and land degradation and increase ecological sensitivity.
3. The effect of aspect will affect the reception of solar radiation and the evaporation rate of water, and different slopes will lead to different microclimate conditions. For example, the south slope receives more sunlight and may have higher temperatures and less humidity, while the North Slope does the opposite, all affecting the stability and ecosystem sensitivity.
4. The impact of the water environment, including the quality and quantity of water bodies, is crucial to the ecosystem. Pollution or lack of water bodies will affect the survival of aquatic life, change the ecological function of wetlands and rivers, and thus affect the health and stability of the whole ecosystem.
5. The influence of vegetation coverage is an important indicator to measure the health state of ecosystems. High vegetation coverage usually means good soil maintenance and water conservation, while low vegetation coverage may indicate bare soil exposure and insufficient water content, which may increase ecological sensitivity; the impact of roads on ecological sensitivity.
6. Road construction will change the surface cover, increase soil erosion and pollutant discharge, and may also promote human activities in an otherwise relatively remote natural environment, increasing the risk of ecological disturbance.
7. The influence of land use will directly affect the structure and function of the ecosystem. Activities such as overexploitation, urbanization, and agricultural expansion may lead to habitat loss and decreased ecological services, increasing ecological sensitivity.
8. The effect of population density: high population density will affect the amount of resource consumption and waste production, and high population density may lead to greater resource pressure and environmental pollution, thus increasing ecological sensitivity.
9. The impact of per capita GDP is often used to measure the level of economic development in a region. Higher GDP per capita may mean higher energy consumption and industrial activities, which may lead to more environmental pollution and ecological destruction, thus affecting the ecological sensitivity of.

In conclusion, the above factors affecting the stability and resilience of the ecosystem need to consider the interaction and influence of these factors through different mechanisms [11].

.Table 1 Indicators and Weights of the Ecological Sensitivity of Guangzhou City

Index factors	Classification reference basis	Non sensitivity	Low sensitivity	Middle sensitivity	High sensitivity
Elevation	Ecological sensitivity evaluation of national ecological county based on GIS[11]	<200	[200, 300)	[300, 800)	≥800
Slope	Standard for vertical planning of urban and rural construction land[13]	<3	[3, 5)	[5, 15)	≥15

Aspect	Ecological sensitivity evaluation of national ecological county based on GIS[11]	Flat ground, just due south	Southeast, Southwest	northeast, northwest	due north
Main rivers	GIS based on Xingyun Lake basin State sensitivity evaluation[14]	>1 500	(1 000, 1 500]	(500, 1 000]	≤500
Fraction Vegetation Coverage	Red line demarcation technology for ecological protection[17] Guide Land Use Survey techniques regulation[18]	[0, 30)	[30, 50)	[50, 70)	[70, 100)
Main roads	Based on ecological sensitivity and ecosystem Unified service value of Changli County ecology Corridor construction[16]	>3 000	[2 000, 3 000]	[1 000, 2 00)	<1 000
Land use	Ecological sensitivity evaluation of Heyuan City[15]	bare area Artificial	Cultivated land, shrub land	Grassland, wetland, forest	Water body
Population density	Evaluation of land ecological sensitivity based on GIS in Taiyuan City [19]	>23 203	[10463,23203]	[3328, 10463)	[0, 3328)
GDP per capita	Correlation analysis of ecological sensitivity and social economy in Guizhou Province [20]	>16. 708 0	[7.7106,16.7080]	[2.4336,7.7106)	[0, 2. 4336)
Value		1	3	5	7

3.3 Determination of the AHP Index Weight

AHP is a structured decision analysis method proposed by American operations chip Thomas (T. L. Saaty) in the mid-1970s. It determines the relative importance of complex decisions by splitting their decision problems into multiple levels and factors and making pairwise comparisons of these factors. Hierarchical analysis is a combination of qualitative and quantitative methods that addresses multi-objective, multi-criterion decision-making problems, especially for situations that are difficult to quantify or need to synthesize multiple factors. First, a hierarchical structure model is established to decompose complex problems or decision objectives into multiple levels.

This usually includes a target layer, multiple criterion layers (or sub target layers), and possible sub criterion layers and indicator layers. Elements of the same layer affect the upper layer, and also dominate the elements of the next layer. Then, to establish the scale of mental judgment and quantification, when the two factors compare with each other, a quantitative scale is needed to show the relative importance between them. Common scales such as the 1-9 scale method, where 1 means that two factors are equally important and 9 means that one factor is more important than the other. Then, the judgment matrix is constructed. For the two adjacent layers, the elements of the above layer are the criterion. Then, the lower elements are compared in pairs, and certain values are given according to the relative importance to form a judgment matrix. These values are usually assigned according to the aforementioned 1-9 scaling method. Then, the weight vector is calculated, and the maximum eigenvalue of the judgment matrix and its corresponding eigenvector are calculated by mathematical methods (such as eigenvalue method, square root method, etc.).

This eigenvector is the weight vector of the lower element to the upper criterion. Then, the consistency test, after constructing the judgment matrix, in order to test the consistency of the matrix (i. e., judging whether there are logical errors), the consistency index (Consistency Index, CI) and the consistency ratio (Consistency Ratio, CR) need to be calculated. Finally, CI is calculated by a specific formula, and CR is the ratio of CI and random consistency index (Random Index, RI). RI is a known value that corresponds to different orders of the matrices with different RI values. If the CR is less than 0.1 (the usual threshold used), the judgment matrix consistency is considered acceptable; otherwise, the judgment matrix needs to be readjusted. The combined weight is calculated, from the highest level to the lowest layer, the combined weight of the elements of each layer for the total target is calculated in order, the final weight ranking is obtained, and the result of a 99 judgment matrix (Table 2) was obtained [11].

Table 2 the AHP Judgment Matrix

Index factors	**Elevation**	**Slope**	**Aspect**	**Water**	**Coverage**	**Road**	**Land use**	**Density of population**	**GDP**
Elevation	1. 000	0. 333	3. 000	0. 143	0. 143	3. 000	0. 143	3. 000	0. 200
Slope	3. 000	1. 000	3. 000	0. 143	0. 143	3. 000	0. 200	5. 000	0. 333
Aspect	0. 333	0. 333	1. 000	0. 111	0. 111	0. 333	0. 111	1. 000	0. 143
Water	7. 000	7. 000	9. 000	1. 000	1.000	9. 000	3. 000	9. 000	5. 000
Coverage	7. 000	7. 000	9. 000	1. 000	1.000	9. 000	3. 000	9. 000	5. 000
Road	0. 333	0. 333	3. 000	0. 111	0. 111	1. 000	0. 143	3. 000	0. 200
Land use	7. 000	5. 000	9. 000	0. 333	0. 333	7. 000	1. 000	9. 000	3. 000
Density of population	0. 333	0. 200	1. 000	0. 111	0. 111	0. 333	0. 111	1. 000	0. 200
GDP	5. 000	3. 000	7. 000	0. 200	0. 200	5. 000	0. 333	5. 000	1. 000

3.4 GIS Weighted Superposition Method

The GIS weighted superposition method is a commonly used spatial analysis technique that allows users to perform a comprehensive evaluation of multiple layers for the importance of different factors. This approach usually involves the following steps:

1. Determine the analysis objectives: clarify the problems to be solved and the objectives of the analysis.

2. Select the influencing factors: select various factors related to the analysis goal, such as slope, land class, distance, etc.

3. Weight assignment: according to the influence of each factor on the analysis target. The weights can be the values of expert opinion, statistics, or other methods.

4. Reclassification and standardization: The original data of each factor is reclassified and standardized to make them comparable.

5. Weighted superposition calculation: the reclassified and standardized data are weighted and superimposed according to the weight to obtain the comprehensive evaluation results.

6. Results analysis: analyze the weighted superposition results to identify the regions or characteristics that meet the analysis objectives.

The formula for the comprehensive sensitivity calculation is shown as follows:

$$P = \sum_{i=1}^{n} W_i C_i \quad (1)$$

Where, P represents the comprehensive ecological sensitivity value, Wi, the weight value of the ith evaluation factor obtained by hierarchical analysis, Ci, the evaluation value of the ecological sensitivity level of the ith evaluation factor, and n, the number of evaluation factors.

IV. RESULTS AND ANALYSIS

4.1 Single Factor Sensitivity Analysis and Evaluation

4.1.1 Elevation Sensitivity Analysis

According to Figure 2,3, Table 3, the high sensitive area is 392.62 km^2, accounting for 30% of the total area, mainly distributed in the northeast Maoming; the medium sensitive area is 2465.33 km^2, accounting for 20% of the total area, distributed in the northeast Maoming; the low sensitivity area is 1034.03 km^2, accounting for 8% of the total area, mainly distributed in the northeast Maoming; the insensitive area is 8508.05 km^2, accounting for 69% of the total area, mainly distributed in the southern plain. As can also be seen from Figure 1, the elevation sensitivity of Maoming decreases from the mountains (highly sensitive) in the northeast to the plain (insensitive) in the south. Therefore, in urban construction, expansion should be considered in the insensitive areas in the south and protecting the highly sensitive areas in the north [22].

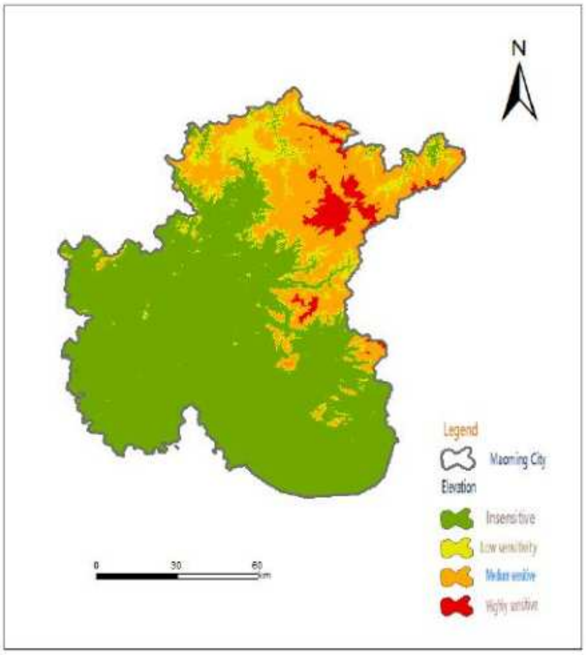

Fig.2 Elevation Sensitivity Analyses

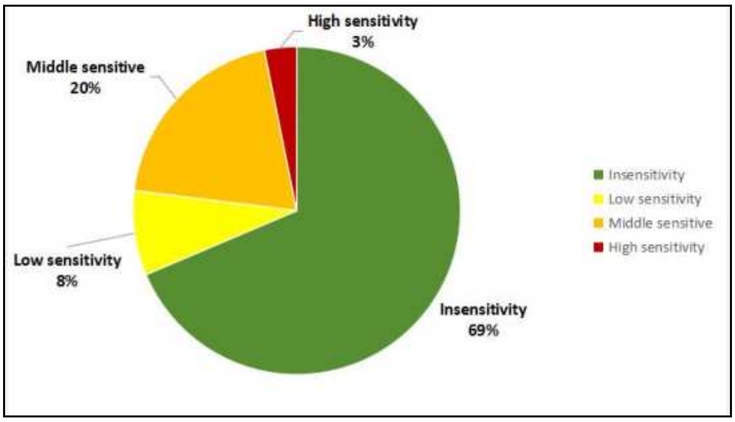

Fig.3 Percent of the Elevation Sensitive Area

Table 3 Elevation Sensitive Area

	Insensitivity	Low sensitivity	Middle sensitive	High sensitivity
Elevation / km^2	8508.05	1034.03	2465.33	392.62

4.1.2 Sensitivity Analysis of the Slope

As can be seen from Figure 4,5, Table 4, the highly sensitive area of slope is 3768.61 km^2, accounting for 30% of the total area, distributed in the northeast of Maoming; the middle sensitive area of slope is 5060.85 km^2, accounting for 41% of the total area, distributed in the central and western regions; the low sensitive area is 1422.14 km^2, accounting for 12% of the total area, mainly south; the insensitive area of slope is 2124.6 km^2, accounting for 17% of the total area, mainly distributed in the plain area in the south. It can also be seen from Figure 4 that the slope sensitivity of Maoming city decreases from the mountains (highly sensitive) in the north to the plain (insensitive) in the south. Therefore, in urban construction, expansion should be considered in the insensitive areas in the south and protecting the highly sensitive areas in the north.

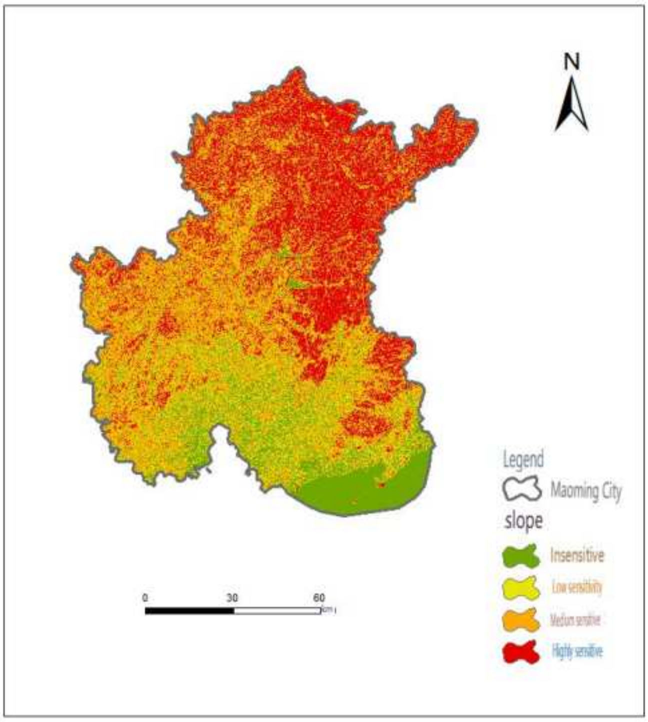

Fig.4 Slope Sensitivity Analyses

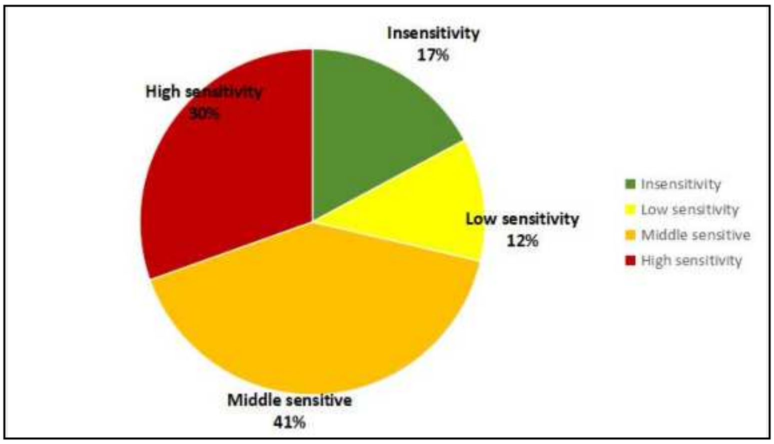

Fig.5 Percent of the Slope-sensitive Areas

Table 4 Slope Sensitive Areas

	Insensitivity	Low sensitivity	Middle sensitive	High sensitivity
Slope area / km^2	2124.6	1422.14	5060.85	3768.61

4.1.3 Aspect Sensitivity Analysis

As can be seen from Figure 6, 7, Table 5, the highly sensitive area of slope direction is 2430.2 km2, accounting for 20% of the total area; the area is 4818.41 km2, 39% of the total area; the low sensitive area is 2220.27 km2, 18% of the total area, mainly distributed in Maoming; and 2907.23 km2, accounting for 23% of the total area, mainly distributed in the southern ocean. As can also be seen from Figure 6, the slope sensitivity of Maoming city decreases from land (highly sensitive) to ocean (insensitive). Therefore, in urban construction, expansion should be considered into the insensitive areas in the southern coastal zone, and appropriate measures should be taken to protect the highly sensitive areas in the north.

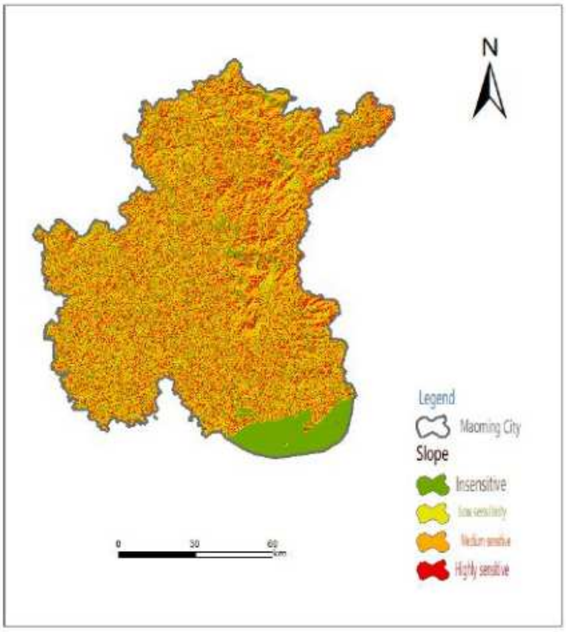

Fig.6 Aspect Sensitivity Analyses

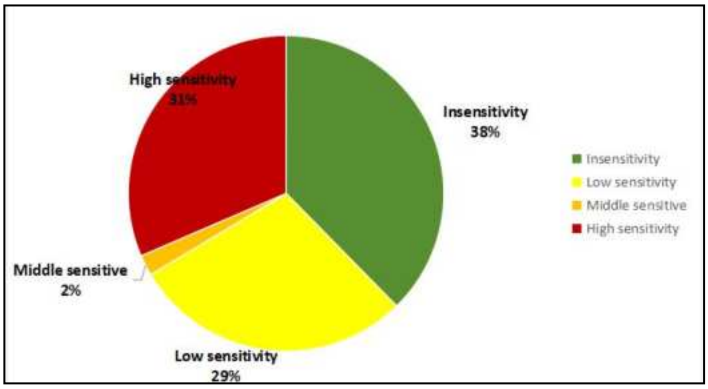

Fig.7 Percentage of Aspect Sensitive Area

Table 5 Aspect Sensitive Area

	Insensitivity	Low sensitivity	Middle sensitive	High sensitivity
Aspect area / km^2	2907.23	2220.27	164.4	2430.2

4.1.4 Sensitivity Analysis of Water Environment

From Figure 8, 9, Table 6, the highly sensitive area of water environment is 5.93 km^2, accounting for 0% of the total area, mainly distributed in the northeast of Maoming; the medium sensitive area of water environment is 164.41 km^2, accounting for 1% of the total area, distributed in northeast Maoming; the low sensitive area of water environment is 1173.07 km^2, accounting for 10% of the total area, mainly distributed in northeast Maoming; the insensitive area of water environment is 11056.71 km^2, accounting for 89% of the total area, mainly distributed in the southern plains. It can also be seen from Figure 8 that the sensitivity of the water environment in Maoming decreases from the mountains (highly sensitive) in the north to the plain (insensitive) in the south. Thus, in urban construction, expansion should be considered in the southern insensitive areas and protecting the highly sensitive areas in the north.

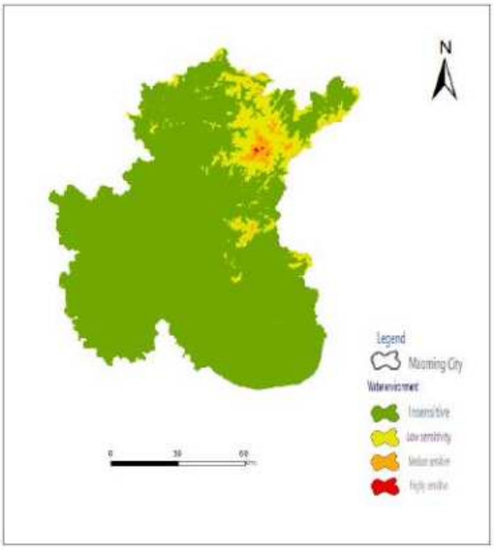

Fig.8 Water Environment Sensitivity Analyses

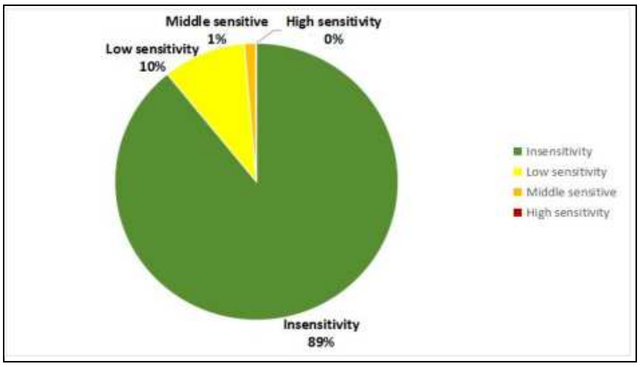

Fig.9 Percentages of the Sensitive Areas of the Water Environment

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https://dx.doi.org/10.22161/ijeab.95.5

Table 6 Area of Water Environment Sensitive

	Insensitivity	Low sensitivity	Middle sensitive	High sensitivity
Water environment area / km^2	11056.71	1173.07	164.41	5.93

4.1.5 Sensitive Analysis of Vegetation Cover

From Figure 10,11, Table 7 shows that the highly sensitive area of vegetation coverage is 9305.99 km^2, accounting for 78% of the total area, distributed in the northern mountainous area; the medium sensitive area of vegetation coverage is 1752.25 km^2, accounting for 15% of the total area, distributed in the central area; the low sensitive area of vegetation coverage is 482.7 km^2, accounting for 4% of the total area, distributed in the southwest; the insensitive area of vegetation coverage is 398.21 km^2, accounting for 3% of the total area, distributed in the southern coast. It can also be seen from Figure 10 that the sensitivity of vegetation coverage in Maoming decreases gradually from the northern mountain (high sensitivity) to the southern plain (insensitive). Therefore, in urban construction, expansion should be considered in the southern insensitive areas and protecting the highly sensitive areas in the north.

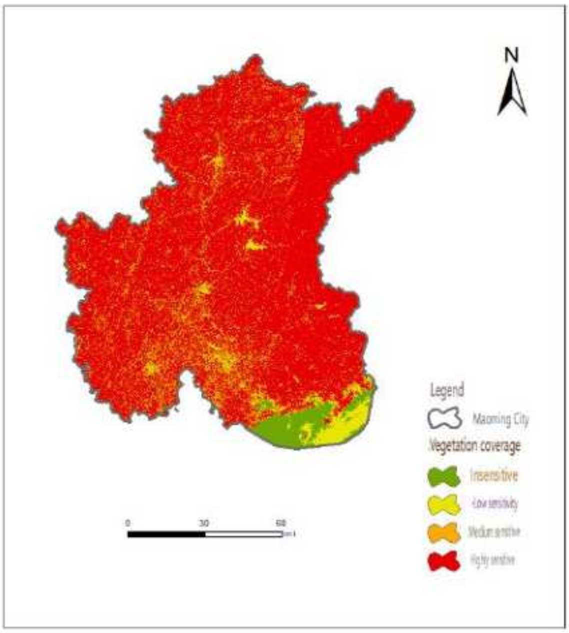

Fig.10 the Sensitivity Analysis of Vegetation Cover

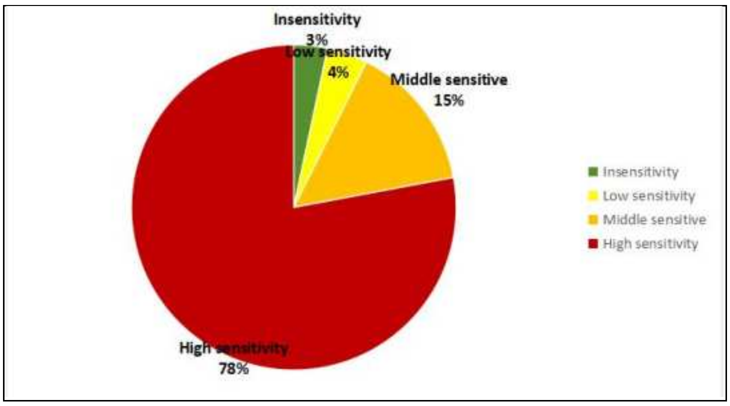

Fig.11 Percentages of Sensitive Areas with Vegetation Coverage

Table 7 the Sensitive Areas with Vegetation Coverage

	Insensitivity	Low sensitivity	Middle sensitive	High sensitivity
Area of vegetation coverage / km^2	398.21	482.7	1752.25	9305.99

4.1.6 Road Sensitivity Analysis

From Figure 12, 13, Table 8, the high sensitivity area is 11139.9 km^2, accounting for 90% of the total area, mainly distributed in Maoming areas; 302.6 km^2, accounting for 2% of the total area, little distribution; the low sensitivity area of the road is 310.7 km^2, accounting for 3% of the total area, mainly distributed in the central hilly area; the insensitive area of the road is 646.81 km^2, accounting for 5% of the total area with little distribution. It can also be seen from Figure 12 that the road sensitivity in Maoming city is basically highly sensitive.

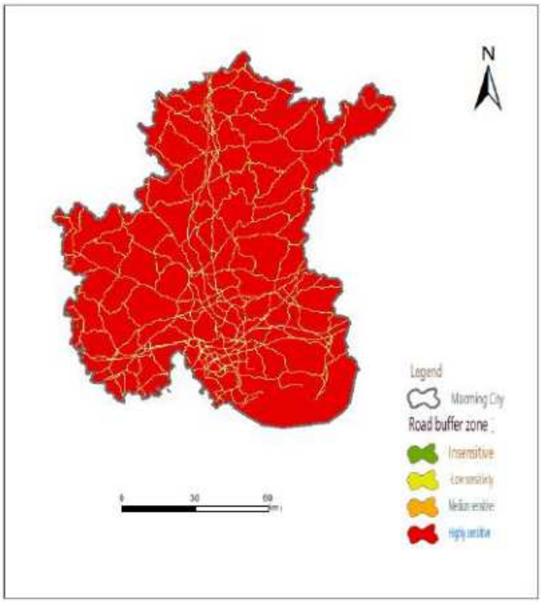

Fig.12 Road Sensitivity Analyses

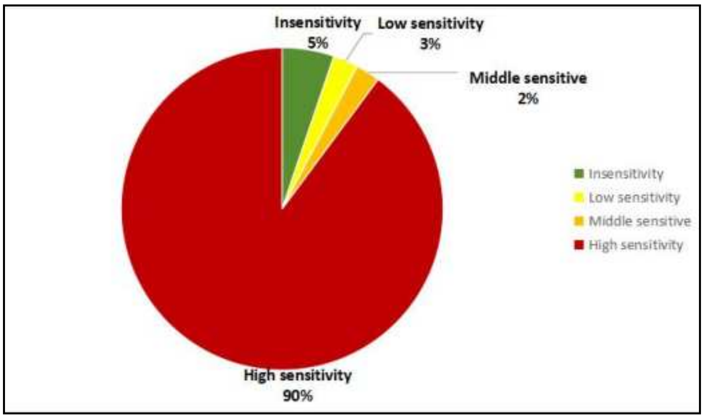

Fig.13 Percentage of the Area of Sensitive Roads

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Table 8 Road Sensitive Areas

	Insensitivity	Low sensitivity	Middle sensitive	High sensitivity
Road area / km^2	646.81	310.7	302.68	11139.9

4.1.7 Land Use Sensitivity Analysis

From Figure 14,15, Table 9, the highly sensitive area of land use is 557.18 km^2, accounting for 5% of the total area, mainly distributed in the southern sea area; 635.52 km^2, 5% of the total area, distributed in the central hilly area; the low sensitive area of land use is 6053.35 km^2, the total area is 51%, mainly distributed in the northern and central hills; the insensitive area of land use is 4703.13 km^2, accounting for 39% of the total area, mainly distributed in the southern plain area. It can also be seen from Figure 14 that the southern plain is mainly insensitive. Therefore, in urban construction, expansion should be considered in the southern insensitive areas and protecting the highly sensitive areas in the north.

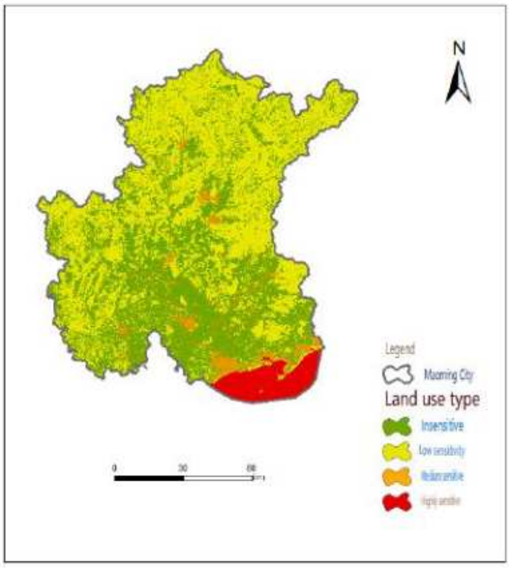

Fig.14 Land Use Sensitivity Analysis

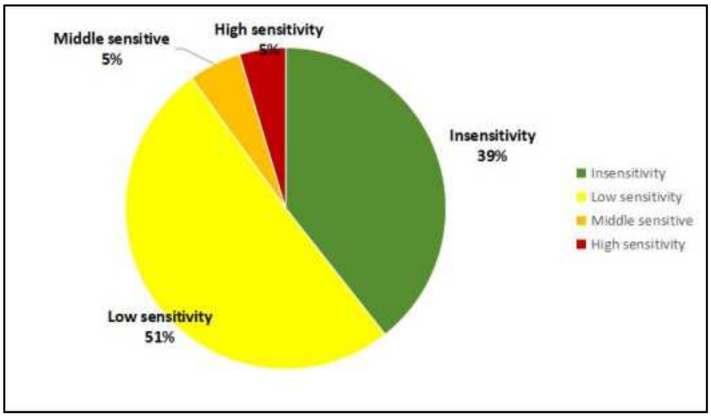

Fig.15 Percentage of Land Use Sensitive Areas

Table 9 Sensitive Areas for Land Use

	Insensitivity	Low sensitivity	Middle sensitive	High sensitivity
Land use area / km^2	4703.13	6053.35	635.52	557.18

4.1.8 Sensitivity Analysis of Population Density

As can be seen from Figure 16,17, Table 10, the highly sensitive area of population density is 11270.0 km^2, accounting for 95% of the total area, mainly distributed in each area of Maoming; the medium sensitive area of population density is 292.1 km^2, or 2% of the total area, with scattered distribution; the low sensitive area of population density is 292.1 km^2, accounting for 3% of the total area; the insensitive area of population density is 1.32 km^2, accounting for 0% of the total area with less distribution. It can also be seen from Figure 16 that the population sensitivity in various areas of Maoming city is relatively high.

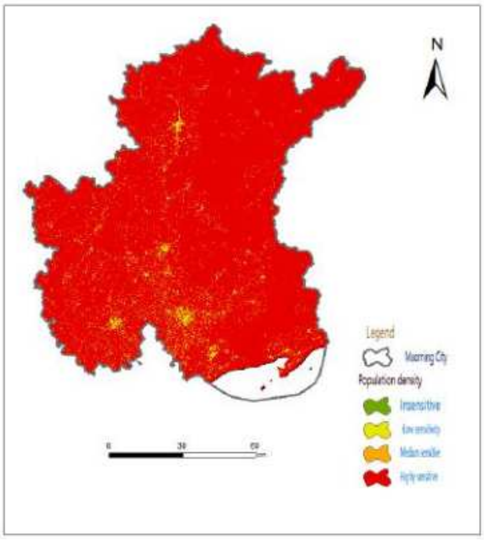

Fig.16 Population Density Sensitivity Analyses

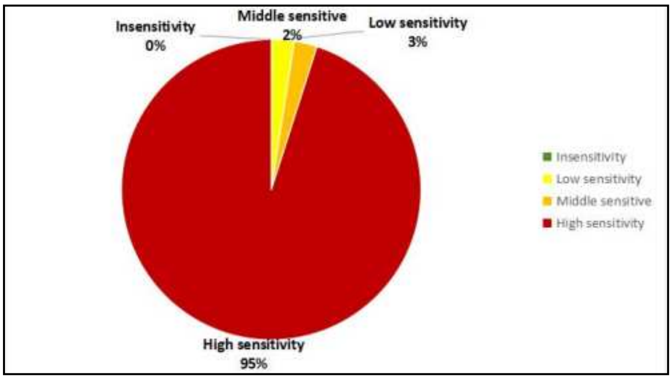

Fig.17 Percentage of Population Density Sensitive Area

Table 10 Population Density Sensitive Areas

	Insensitivity	Low sensitivity	Middle sensitive	High sensitivity
Area of population density / km^2	1.32	292.1	292.1	11270.09

4.1.9 The Sensitivity Analysis of GDP

From Figure 18,19, Table 11, we can see that the area of highly sensitive area of GPT is 11734.5 km^2, accounting for 100% of the total area, mainly distributed in each area of Maoming; the proportion of medium sensitive area of GPT, low sensitive area of GPT and insensitive area of GPT is basically 0. Therefore, the high GDT sensitivity in Maoming should be considered in urban construction.

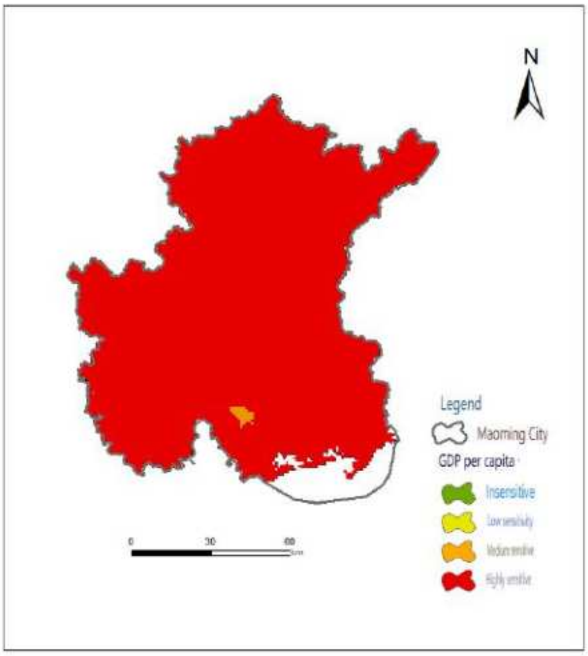

Fig.18 Per Capita GDP Sensitivity Analyses

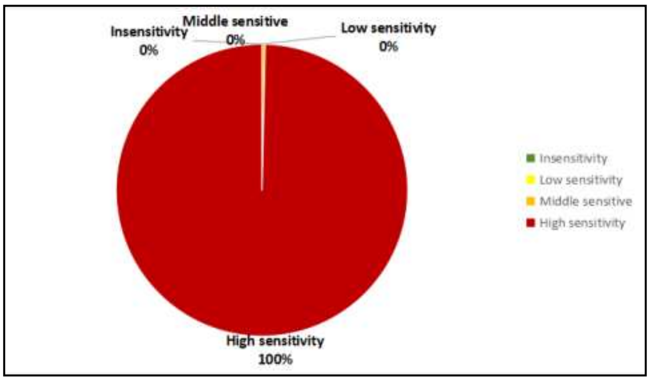

Fig.19 Percentage of Area Sensitive to GDP Per Capita

Table 11 Sensitive Areas with Per Capita GDP

	Insensitivity	Low sensitivity	Middle sensitive	High sensitivity
GDP area / km^2	0	0	42.04	11734.5

V. CONCLUSIONS AND DISCUSSION

5.1 Comprehensive Sensitivity Analysis

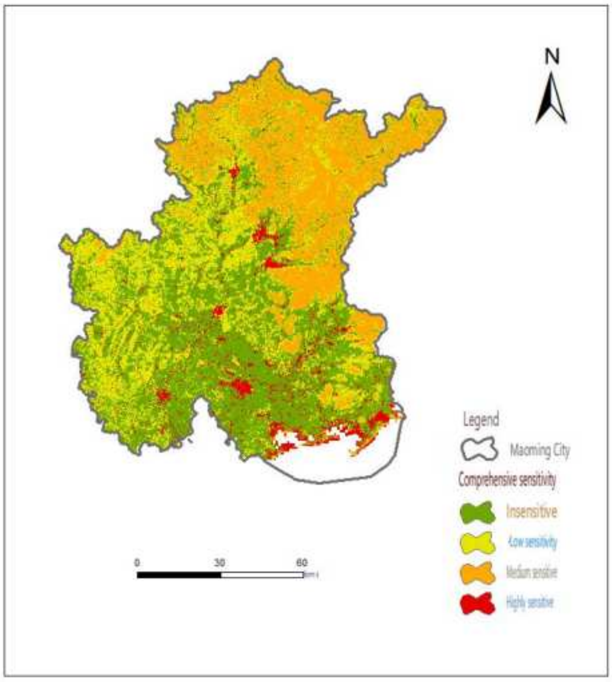

Fig.20 Comprehensive Sensitivity Analyses

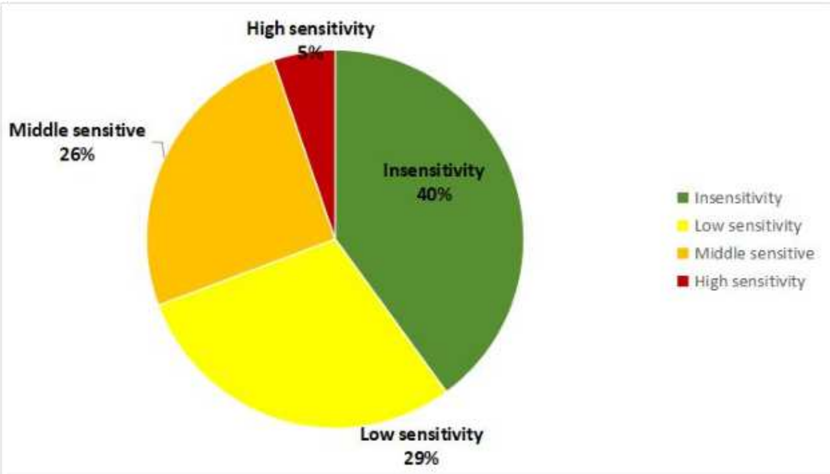

Fig.21 Integrated Sensitivity Analyses

Table 12 Comprehensive Sensitive Areas

	Insensitivity	Low sensitivity	Middle sensitive	High sensitivity
Comprehensive evaluation of the area / km^2	4656.48	3417.81	2959.08	616.68

As shown in Fig. 20.21, Table 12, and the combined statistics (Table 13), Maoming has a relatively low comprehensive ecological sensitivity. Mainly by sensitivity and low sensitivity areas, both account for 69% of the area of Maoming, with an area of up to 8074.29 km^2. Widely distributed in the whole region of Maoming, this part of the region has a relatively stable climate. There are no extreme weather events, such as frequent droughts, floods, or storms; the soil has a better quality; the ability to support a variety of plant growth; not susceptible to erosion or degradation; sufficient in water resources; good water quality; it is conducive to agricultural irrigation and ecosystem maintenance; these areas have a low population density; less non-active industrial and agricultural activities; therefore, the ecosystem has suffered less human disturbance[21][5].

High sensitive area accounts for 5% of the total area, the area of 616.68 km^2, concentrated in greatly influenced by human area. This area of natural environment and ecosystem is relatively fragile, has a strong response to external interference and damage, poor resilience, the climate condition is unstable, may appear as extreme weather events, and may lead to frequent natural disasters. The soil quality is poor, easy to erosion, and is not suitable for crop growth. Water resources shortage; water quality may be polluted, making it difficult to meet the needs of agricultural and domestic water[22]. These areas may face excessive agricultural cultivation, industrial development, and urbanization processes, leading to ecological environment deterioration [5][23].

Table 13 Classification Statistics of Ecological Sensitivity in Maoming

Evaluation factor/Index factors	Insensitivity		Low sensitivity		Medium sensitivity		High-sensitivity	
	Area /km^2	Ratio/ %	Area /km^2	Ratio/ %	Area /km^2	Ratio/ %	Area /km^2	Ratio /%
Elevation	8508.05	68.61%	1034.03	8.34%	2465.33	19.88%	392.62	3.17%
Slope	2124.6	17.17%	1422.14	11.49%	5060.85	40.89%	3768.61	30.45%
Aspect	2907.23	23.49%	2220.27	17.94%	4818.41	38.93%	2430.2	19.64%
Water	11056.71	0.00%	1173.07	9.46%	164.41	0.00%	5.93	0.00%
Coverage	398.21	3.34%	482.7	4.04%	1752.25	14.68%	9305.99	77.95%
Road	646.81	5.22%	310.7	2.51%	302.68	2.44%	11139.9	89.84%
Land use	4703.13	39.36%	6053.35	50.66%	635.52	5.32%	557.18	4.66%
Density of population	1.32	0.01%	292.1	2.46%	292.1	2.46%	11270.09	95.06%
GDP	0	0.00%	0	0.00%	42.04	0.36%	11734.5	99.64%
Comprehensive evaluation	4656.48	39.97%	3417.81	29.34%	2959.08	25.40%	616.68	5.29%

VI. CONCLUSION

For highly sensitive areas, more stringent protection measures should be taken to reduce the impact of external interference and damage. Establish and improve relevant legal and regulatory systems, clarify protection standards and management responsibilities of highly sensitive areas, establish dynamic monitoring systems, and provide a scientific basis for protection management; limit or prohibit development activities that may have a negative impact on highly sensitive areas, such as industrial construction and mineral mining, etc.; repair damaged ecosystems, restore their original ecological functions and services; strengthen environmental protection publicity and education; raise public awareness of the importance of protection of highly sensitive areas; and encourage the public to participate in protection actions [25].

Although the middle sensitive area is not as fragile as the high sensitive area, moderate protection measures still need to be taken to prevent ecological degradation. Conduct land use planning in the sensitive areas to avoid overdevelopment and unsustainable utilization; implement an ecological compensation mechanism to compensate the ecosystem damaged by development activities; strengthen the sensitive areas to ensure that all activities meet the environmental requirements; regularly monitor the ecological conditions in the sensitive areas and detect and handle environmental problems in time. Low-sensitive areas are relatively stable ecosystems compared to high- and medium-sensitive areas, but appropriate protection measures are still needed to maintain their ecological balance [24].

Promote sustainable land use and resource management methods to avoid long-term damage to the ecosystem; conduct environmental education activities to raise residents' awareness of environmental protection and promote eco-friendly behaviors; establish ecological monitoring sites to monitor ecosystem changes and prevent potential environmental problems. Due to its strong anti-interference ability, the protection measures are relatively loose, but still attention should be paid to maintain its ecological balance. Even in insensitive areas, local ecosystems should be protected from unnecessary damage; conduct basic environmental monitoring to ensure that regional environmental quality is not significantly affected; popularize environmental protection knowledge; enhance public awareness of environmental protection; and promote sustainability.

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Economic Analysis of Cost of Cultivation and Benefit Cost Ratio of Cauliflower in Response to Solid and Liquid Organic Mannure

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Abstract— *This study evaluates the economic impact of using solid and liquid organic manures on the cultivation of cauliflower, focusing on the cost of cultivation and the benefit-cost (B:C) ratio. The experiment was conducted at technology park CTAE, MPUAT, Udaipur during Rabi season 2021-22 under controlled conditions, where different treatments involving sole and combined application of organic manures (FYM and vermicompost) and four levels of panchagavya were evaluated on cauliflower crop with three replications under factorial RBD design. The analysis involved calculating the total cost of cultivation, including inputs, labour, and other variable costs, and comparing these costs with the net returns obtained from the crop yield. The B ratio was then determined to assess the profitability of each treatment. Result showed that among organic manures application of OM_3 treatment (50% RDN through FYM and 50% RDN through vermicompost) as soil application was found recorded maximum net return of Rs. 174791.08. Among different levels of panchagavya, application at 5% concentration as foliar spray gave maximum net return of Rs. 164587.74. The interactive effect of organic manures and panchagavya on net return showed that the combined application of OM3 + PG2 (50 per cent FYM + 50 per cent RDN through Vermicompost + 5 per cent Panchagavya) gave maximum net return of Rs. 206075.16 from cauliflower crop and The combined effect of organic manures and panchagavya on B:C ratio showed that the combined application of OM0 + PG2 (control + 5 per cent Panchagavya) gave maximum B:C ratio of 2.90.*

Keywords— ***Cauliflower, Vermicompost, FYM, Panchagavya, Benefit to cost ratio.***

I. INTRODUCTION

Cauliflower (*Brassica oleracea var. botrytis*) is a widely cultivated vegetable crop known for its high nutritional value and strong market demand. The profitability of cauliflower farming is significantly influenced by the costs associated with cultivation and the economic returns obtained. In recent years, there has been an increasing shift towards organic farming practices, driven by the need for sustainable agriculture and the growing consumer demand for organic produce. Organic farming primarily relies on natural inputs, such as solid and liquid organic manures, which are believed to enhance soil health, improve crop productivity, and support long-term sustainability (Patil *et al*., 2019).

Conducting an economic analysis of agricultural practices, particularly by evaluating the cost of cultivation and the Benefit-Cost (B:C) ratio, is crucial for understanding their financial viability. The B:C ratio, which compares the benefits (returns) to the costs of cultivation, serves as a key indicator of economic efficiency. A higher B ratio signifies a more profitable and economically efficient farming practice (Kumar *et al*., 2020).

Solid and liquid organic manures, including traditional preparations like panchagavya, are known to positively impact crop growth and yield by improving soil structure, enhancing nutrient availability, and promoting beneficial microbial activity (Ramesh *et al*., 2021). However, the economic implications of using these organic inputs, particularly regarding cost savings, net returns, and overall profitability, require thorough investigation.

Vermicomposting is a technology for decomposing various kinds of organic waste (both domestic or industrial) into useful material. Vermicomposting is mostly done with the earthworm Eisenia fetida. Vermicomposting can provide easily available nutrients, growth-promoting compounds and a variety of helpful microorganisms such as nitrogen-fixing, phosphorus solubilizing and cellulose decomposing organisms (Suthar 2012).

This study aims to perform an in-depth economic analysis of cauliflower cultivation using various organic manure treatments. By examining the cost of cultivation, net returns, and B:C ratio under different conditions involving solid and liquid organic manures, this research seeks to provide valuable insights into the economic feasibility of organic farming practices. The results will contribute to the understanding of sustainable agriculture and support farmers in making informed decisions about adopting organic farming methods.

II. MATERIAL AND METHOD

The field experiment was conducted at the Technology Park, CTAE, MPUAT, Udaipur, Rajasthan, during the Rabi season of 2021-22. The cauliflower variety 'Pusa Snowball K-1' was sown in a nursery in October. Four-week-old seedlings were transplanted at a spacing of 45 × 30 cm. Full doses of FYM, vermicompost, and their combination were applied before transplanting, according to the treatment plan. Sixteen treatments were evaluated using a Factorial RBD design with three replications.

The details of used two treatment factor respectively organic manures and panchagavya are given under:

Factor A

Organic Manures

OM0: Control

OM_1: 100 % RDN through FYM

OM_2: 100 % RDN through Vermicompost

OM_3: 50 % RDN through FYM + 50% RDN through Vermicompost

Factor B

Panchagavya

PG_0: 0 % (water spray) at 30 and 45 DAT

PG_1: 3% Panchagavya spray at 30 and 45 DAT

PG_2: 5 % Panchagavya spray at 30 and 45 DAT

PG_3: 10 % Panchagavya spray at 30 and 45 DAT

Statistical analysis of data

Factorial Randomized Block Design (RBD) was used to analyse the individual data of the numerous characters evaluated in the experiment, as suggested by Panse and Sukhatme (1985).

III. RESULT AND DISCUSSION

Effect of organic manure

Economic appraisal is the ultimate basis for evaluating the results of any study. In present study the maximum net return of Rs. 174791.08 was found with the application of with OM3 (50 per cent FYM + 50 per cent RDN through Vermicompost). This might be due to the fact that under these treatments the cost of treatments was low as compared to output added, therefore, higher curd yields resulted in higher net returns. However, the minimum net return of Rs. 92897.77 and B:C (0.73) was found with OM1 i.e. 100 per cent RDN through FYM which was significantly lower than the net return (Rs. 150978.36) and B:C (2.74) under control (no organic manure). This might be due to the fact that under control treatments the cost of treatments was nil due to no use of organic manures therefore, the output (yield) increased the B:C ratio. The above findings are also in conformity with the findings of Yadav and Luthra, (2005) in vegetable pea, Kalalbandi *et al.* (2007) in cabbage and Sharma and Bhalla (1995) and Bairwa *et al.* (2009) in Okra.

Effect of panchagavya (PG)

In present study the maximum net return of Rs. 164587.74 was found with PG3 (10 per cent Panchagavya). The increased net return could be explained on the basis of increased curd yield under the 10 per cent panchagavya which was higher than rest of the treatments. The lower net return was obtained under water spray (Rs. 107639.90). Similar finding was recorded through use of organic manures by Bhandari *et al*. (2019) on okra crop.

Interaction effect of organic manures and panchagavya (OMxPG)

The data related to interactive effect of organic manures and panchagavya on net return showed that the combined application of OM3 + PG2 (50 per cent FYM + 50 per cent RDN through Vermicompost + 5 per cent Panchagavya) gave maximum net return of Rs. 206075.16 from cauliflower crop. The next best treatment (100 per cent RDN through vermicompost + 10 per cent Panchagavya) generated a net return of Rs. 190784.64. The minimum net return of Rs.58993.01 was recorded with OM1 + PG0 (100 per cent RDN through FYM + water spray). The data related to combined effect of organic manures and panchagavya on B:C ratio showed that the combined application of OM0 + PG2 (control + 5 per cent Panchagavya) gave maximum B:C ratio of 2.90. The next best treatment (control + 10 per cent Panchagavya) generated a B:C ratio of 2.78. The minimum B:C ratio of 0.47 was recorded with OM1PG0 (100 per cent RDN through FYM + water spray). Similar results are found by Mandloi *et al*. (2008), Chattoo *et al.* (2010) in onion and Negi *et al*. (2017) in broccoli.

Table 1 Effect of organic manures and panchagavya on net return and B:C ratio of cauliflower

Treatments	**Net return (Rs.)**	**B:C ratio**
A. Organic manure		
OM_0	150978.36	2.7
OM_1	92897.77	0.7
OM_2	143801.23	1.2
OM_3	174791.08	1.4
B. *Panchagavya*		
PG_0	107639.90	1.2
PG_1	128191.81	1.4
PG_2	162048.98	1.7
PG_3	164587.74	1.7
Interaction	**Net return (Rs.)**	**B:C ratio**
OM_0PG_0	136203.69	2.58
OM_0PG_1	147206.05	2.71
OM_0PG_2	160102.60	2.90
OM_0PG_3	160401.09	2.78
OM_1PG_0	58993.01	0.47
OM_1PG_1	88696.11	0.70
OM_1PG_2	106797.02	0.84
OM_1PG_3	117104.95	0.90
OM_2PG_0	103159.31	0.91
OM_2PG_1	106039.81	0.93
OM_2PG_2	175221.15	1.52
OM_2PG_3	190784.64	1.62
OM_3PG_0	132203.59	1.11
OM_3PG_1	170825.29	1.42
OM_3PG_2	206075.16	1.70
OM_3PG_3	190060.29	1.54

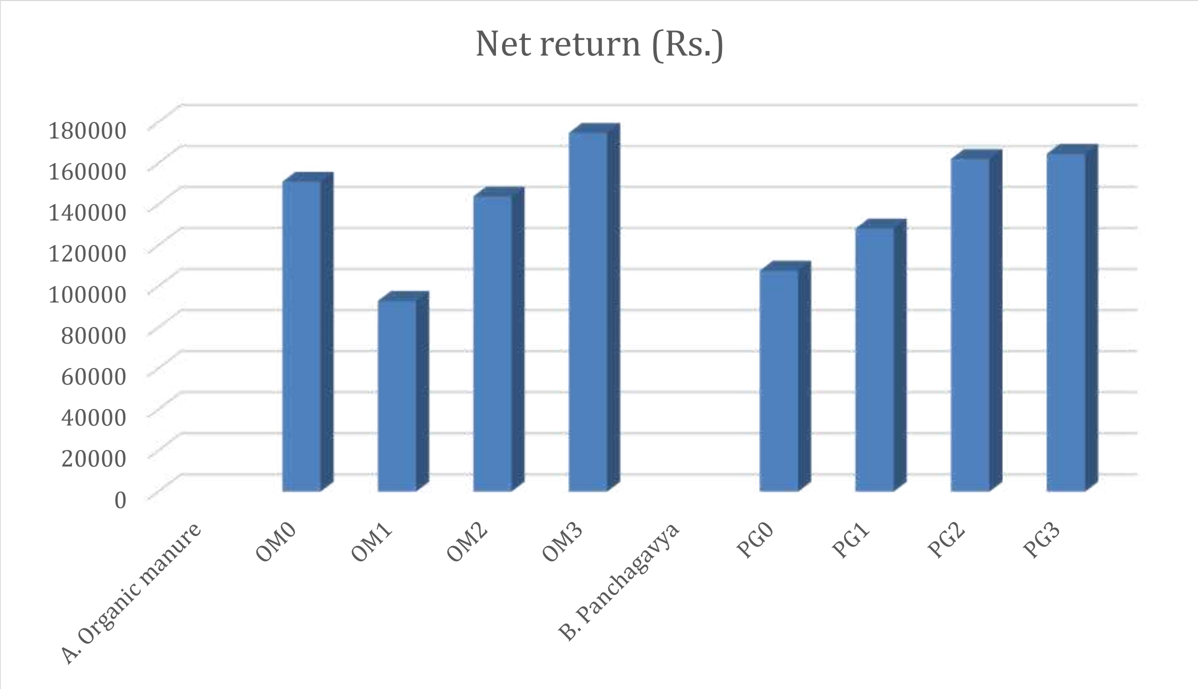

Fig. 1: Effect of organic manures and panchagavya on net returns (ha^{-1}) of cauliflower

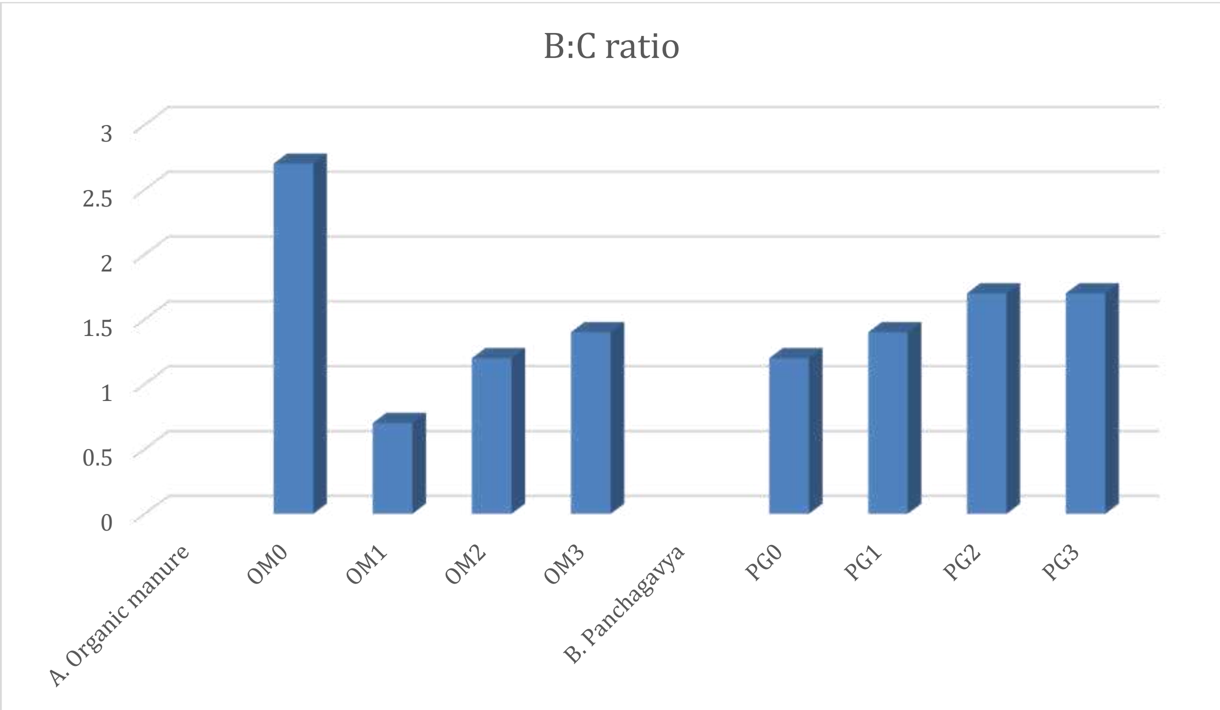

Fig. 2: Effect of organic manures and panchagavya on B:C ratio of cauliflower

General cost of cultivation (Rs/hectare) (Excluding the cost of treatment inputs).

S.No.	Particulars	Units	Cost per unit (Rs.)	Amount (Rs.)
A.	**VARIABLES**			
a)	Labour cost			
I.	**Nursery**			

i.	Nursery preparation and sowing	3 mandays	@ 300	900.00
ii.	Nursery management (2 hours for 30 days)	10 mandays	@ 300	3000.00
II.	**Main field**			
i.	Layout (bed preparation)	16 man days	@ 300	4800.00
ii.	Transplanting	10 man days	@ 300	3000.00
iii	Irrigation	10 man days	@ 300	3000.00
iv.	Manuring and fertilization	5 man days	@ 300	1500.00
v.	Intercultural operations (Hoeing, weeding, earthing up and)	35 man days	@ 300	10500.00
vi.	Spraying	8 man days	@ 300	2400.00
vii.	Picking and harvesting (2 hours for 90 days)	15 man days	@ 300	4500.00
	Total	112 man days	@ 300	**33600.00**
B.	**FIXED COST**			
i.	Land rent and interest on invested money and	15000 + 3000.00	For one crop	18000.00
C.	**MATERIALS INPUT**			
i.	Seeds	400	Rs. 3 per g	1200.00
ii				
	Total cost = (A + B + C)			**54540**

Treatment cost per hectare area of cauliflower

S.No.	Treatment	Treatment Cost (` ha)	Common Cost (` per ha)	Total Cost (` per ha)	Yield (kg/ha)	Gross Return (` per ha)	Net Return (` per ha)	B:C Ratio
1.	OM_0PG_0	0	52800	**52800**	17600.00	**176000**	**123200**	3.333333
2.	OM_0PG_1	1500	52800	**54300**	18600.00	**186000**	**131700**	3.425414
3.	OM_0PG_2	2500	52800	**55300**	19266.67	**192666.7**	**137367**	3.484027
4.	OM_0PG_3	5000	52800	**57800**	20933.33	**209333.3**	**151533**	3.621684
5.	OM_1PG_0	72000	52800	**124800**	41600.00	**416000**	**291200**	3.333333
6.	OM_1PG_1	73500	52800	**126300**	42600.00	**426000**	**299700**	3.372922
7.	OM_1PG_2	74500	52800	**127300**	43266.67	**432666.7**	**305367**	3.398795
8.	OM_1PG_3	77000	52800	**129800**	44933.33	**449333.3**	**319533**	3.461736
9.	OM_2PG_0	60000	52800	**112800**	37600.00	**376000**	**263200**	3.333333
10.	OM_2PG_1	61500	52800	**114300**	38600.00	**386000**	**271700**	3.377078
11.	OM_2PG_2	62500	52800	**115300**	39266.67	**392666.7**	**277367**	3.405609
12.	OM_2PG_3	65000	52800	**117800**	40933.33	**409333.3**	**291533**	3.474816
13.	OM_3PG_0	66000	52800	**118800**	39600.00	**396000**	**277200**	3.333333
14.	OM_3PG_1	67500	52800	**120300**	40600.00	**406000**	**285700**	3.374896
15	OM_3PG_2	68500	52800	**121300**	41266.67	**412666.7**	**291367**	3.402034
16	OM_3PG_3	71000	52800	**123800**	42933.33	**429333.3**	**305533**	3.467959

*Retail sale price of cauliflower @ Rs. 10 per kg

Treatment cost

S. No.	Treatment	Treatment details	Total quantity of input	Rate/kg	Amount (Rs.)
i.	OM_0	Control	0	0 Rs.	0
ii.	OM_1	100% RDN through FYM	24000 kg	3 Rs.	72000
iii.	OM_2	100% RDN through vermicompost	10000 kg	6 Rs.	60000
iv.	OM_3	50% RDN through FYM + 50% RDN through vermicompost	12000 + 5000 kg	3 Rs.+ 6 Rs.	66000
v.	PG_0	Control	0	0 Rs.	0
vi	PG_1	3% *Panchagavya*	15 lit.	100 Rs.	1500
vii	PG_2	5% *Panchagavya*	25 lit.	100 Rs.	2500
Viii	PG_3	10% *Panchagavya*	50 lit.	100 Rs.	5000

IV. CONCLUSION

Conclud that The treatment OM3 (50 per cent RDN through FYM + 50 per cent RDN through Vermicompost) and PG2 (5 per cent Panchagavya) spray at 30 and 45 DAT may be recommended for cauliflower crop to obtain maximum net return of Rs. 174791.08. Among different levels of panchagavya, application at 5% concentration as foliar spray gave maximum net return of Rs. 164587.74. The combined application of OM3 + PG2 (50 per cent FYM + 50 per cent RDN through Vermicompost + 5 per cent Panchagavya) gave maximum net return of Rs. 206075.16 from cauliflower crop and The combined effect of organic manures and panchagavya on B:C ratio showed that the combined application of OM0 + PG2 (control + 5 per cent Panchagavya) gave maximum B:C ratio of 2.90.

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Personal, socio-economic and psychological characteristics of coconut growers

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Abstract**—***The present study to know the personal, socio-economic and psychological characteristics of randomly selected 120 coconut growers from Tiptur, Turuvekere, Chikkanayakanahalli and Sira taluks of Tumkur district was conducted during the year 2022-23. Overall it was found that equal number of coconut growers (42.50 %) were in the old and middle age group respectively, while significant number of coconut growers (37.50 %) were having education upto high school, two-third of coconut growers (69.16 %) were found under the category of medium family size, while two-fifth of coconut growers (40.00 %) came under big farmers category followed by 39.16 per cent under the small farmers category and more than two-fifth of coconut growers (46.66 %) possessed medium level of farming experience. Overall it was found that significant number of coconut growers (44.20 %) belonged to medium category of information seeking behaviour, more than two-fifth of coconut growers (43.33 %) came under medium category of extension participation, two-fifth of coconut growers (40.00 %) belonged to medium category of management orientation. Among the overall coconut growers, it was disclosed that significant number of coconut growers i.e., 46.67 per cent were found equally under the medium category of risk orientation, credit orientation, innovativeness. Overall it was found that slightly more than two-fifth of coconut growers (41.67 %) were having medium level of deferred gratification, significant number of coconut growers (46.67 %) belonged to medium category of scientific orientation and significant number of coconut growers (44.17 %) belonged to medium category of cosmopoliteness.*

Keywords**— Characteristics, Coconut growers, Personal, Psychological, Socio-economic**

I. INTRODUCTION

Plantation crops are an essential part of our agricultural economy and a major factor in the expansion and advancement of the agrarian economies in several Indian states. The plantation crop industry plays a significant role in the overall socio-economic development of the country, as evidenced by its substantial contribution to foreign exchange earnings and the number of direct and indirect jobs it generates. Among the plantation crops, Coconut is one such vital crop which holds a prominent position symbolizing resilience, versatility and cultural significance within the Indian agricultural landscape.

Considering global scenario, India is amongst the largest coconut producing countries with nearly 31% share of global production (Coconut Development Board, 2021)[1]. Coconut cultivation holds particular importance in the Indian circumstances, especially in the state of Karnataka which is known as one of the leading hubs for coconut cultivation. In Karnataka state, Tumkur district is often hailed as 'Land of Coconuts' or 'Kalpatharu Nadu' and it plays an essential role in strengthening the coconut yield of the state. Around 29 per cent of the total coconut cultivation area and nearly 30 per cent of production in the state is contributed by Tumkur district alone (Coconut Development Board 2021-22)[2].

Coconut cultivation is a significant farming activity with substantial economic and cultural significance in many regions. We can say that the success and sustainability of this sector are greatly influenced by the grower's backgrounds, behaviours or characteristics and attitudes. So, studying the personal, socio-economic and psychological characteristics of coconut growers is necessary for several reasons. By understanding these characteristics, we can recognize the factors that drive decision-making, adoption of new technologies and their responses to challenges such as market fluctuations, climate change and resource constraints. This study provides insights into the personal, socio-economic and psychological characteristics of coconut growers practicing coconut farming. These findings can enlighten targeted interventions, policy-making functionaries and extension functionaries about developing support programs designed to enhance productivity, sustainability and the overall well-being of coconut growers. Thus, this study can contribute to strengthening of the resilience and improvement of the coconut farming sector, which is vital for the livelihoods of many rural coconut growing communities.

II. MATERIALS AND METHODS

The present research was conducted in Tumkur district of Karnataka in the year 2022-23 using *Ex-post-facto* research design. As coconut cultivation is being taken up in most of the taluks of the Tumkur district and for the reason that in Karnataka state, Tumkur is one of the top coconut growing districts, it was selected purposively for the study. Considering the highest and lowest productivity in Tumkur district, out of ten taluks, Tiptur, Turuvekere, Chikkanayakanahalli and Sira taluks were selected purposively for the study. By using simple random sampling, thirty coconut growers from each chosen taluk were selected. Thus, the total sample involved was 120 coconut growers from four taluks.

III. RESULTS AND DISCUSSION

Personal, socio-economic and psychological characteristics of coconut growers

One of the goals of the current investigation was the identification of the coconut growers profiles. Following a review of the literatures, several most significant characteristics of coconut growers were chosen and examined. Table 1 summarizes, interprets and presents the results.

Age

From the study it was revealed that in the case of age of coconut growers, significant number of coconut growers in Tiptur taluk (50.00 %) and Chikkanayakanahalli taluk (53.30 %) were found in the middle age group where as significant number of coconut growers of Turuvekere taluk (53.30 %) and Sira taluk (66.70 %) were found in the old age group. Thus, among the overall coconut growers it was revealed that equal number of coconut growers (42.50 %) belonged to both the old and middle age group respectively followed by 15.00 per cent of them in the young age group category. The found pattern may be because of the fact that individuals in the middle age group might have a balance of family responsibilities and farming obligations, making them actively engaged in both their households and farms. In case of old age group of coconut growers some might continue coconut farming as part of their lifestyle and to maintain a source of income during their retirement years. Younger individuals might be increasingly attracted to urban areas for education and employment opportunities, leading to a decreased interest in coconut farming. This result matched those of Nayabhai (2011)[3], Koli (2012)[4], Deepika (2015)[5].

Education

It was revealed that significant amount of coconut growers in Tiptur taluk (33.33 %) had Pre-university education whereas significant number of coconut growers in case of Turuvekere taluk (56.70 %) and Chikkanayakanahalli taluks (43.30 %) had education upto high school. Whereas in case of Sira taluk significant number of coconut growers (36.70 %) had education upto primary school. Ultimately in case of overall coconut growers, significant amount of coconut growers (37.50 %) were having education upto high school followed by 20.00 per cent of respondents having Pre-University education level then followed by 19.20 per cent of respondents having primary school education, 13.33 per cent of respondents were having graduation and above and 10.00 per cent were illiterate. Due to the existence of high schools in rural areas and the recognition of the value of education for one's total growth and development, it was possible that the majority of coconut farmers have completed their high school education. According to investigations by Abhilash (2017)[6], this investigation's findings are consistent.

Family size

The family size in case of all the chosen taluks *viz.*, in Tiptur taluk (60.00 %), in Turuvekere taluk (76.60 %), in Chikkanayakanahalli taluk (66.60 %) and in Sira taluk (73.33 %) was significantly known to be of medium size .

Overall it was revealed that two-third of coconut growers (69.16 %) fell under the category of medium family size followed by 23.33 per cent of them fell under the small family size category then 07.50 per cent of coconut growers fell under the large family size category. The possible cause might be that medium-sized family might provide a better work-life balance for parents, allowing them to engage in farming while also dedicating time to their family's well-being and other interests. While smaller family sizes could be a reflection of changing demographic trends, with younger generations opting for smaller families. Even the availability of good reproductive health treatments increases, families may decide to have fewer children, prioritizing quality over number. In areas with limited educational opportunities and alternative livelihoods, families might choose to have more children who can contribute to farm work. The results are consistent with those of Vikas (2020)[7].

Land-holdings

Half of the coconut growers (50.00 %) in Tiptur taluk and more than two-fifth (46.66 %) of coconut growers in Turuvekere taluk were found to be in big farmer category. while equal number of coconut growers (40.00 %) were found to be in both small and big farmer category in Chikkanayakanahalli taluk. Further it was revealed that noteworthy amount of coconut growers (53.33 %) of Sira taluk were found in the small farmer category. Overall it was found that two-fifth of coconut growers (40.00 %) come under big farmers category followed by 39.16 per cent under the small farmers category and then 20.83 per cent of coconut growers under the marginal farmers category. The inheritance of land from their ancestors, which may have been transferred down the line from generation to generation could be the reason for such land holding. The investigations carried out by Rashmi (2018)[8] was consistent with these findings.

Farming experience

From the investigation it was known that noteworthy amount of coconut growers *viz.*, in Tiptur taluk (56.67 %), in Turuvekere taluk (40.00 %), in Chikkanayakanahalli taluk (46.70 %) as well as in Sira taluk (43.33 %) came under medium level of farming experience. Thus, among overall coconut growers more than two-fifth of coconut farmers or growers (46.66 %) came under medium level of farming experience followed by 30.00 per cent of respondents were belonging to low level of farming experience and then 23.33 per cent of respondents came under high level of farming experience. This may be due to significant number of the coconut growers belong to medium age as well as old age who may have started farming activities by dropping their education and even significant number of coconut growers who had recently involved in farming and the fact that they are young farmers. So a sizable portion of respondents might have fell into the category of having little agricultural experience. According to Kamar (2019)[9], this conclusion is consistent.

Information seeking behaviour

From the investigation it was known that half of the coconut growers in Tiptur taluk (50.00 %) were having high level of information seeking behaviour whereas significant number of coconut growers *viz.*, in Turuvekere taluk (36.70 %), in Chikkanayakanahalli taluk (46.70 %) and in Sira taluk (53.30 %) were considered to have medium level of information seeking behaviour. Overall it was evident that significant number of coconut growers (44.20 %) were considered to have medium level of information seeking behaviour followed by 30.00 per cent were considered to have low level of information seeking behaviour and then 25.80 per cent of the respondents were found to have high level of information seeking behaviour. The respondents pattern of having medium to low level of overall information seeking behaviour is most likely caused by the reason that coconut growers present in isolated or rural areas may lack easy access to information sources from agencies of Government, research conducting institutions and agricultural extension services. Even the respondents had little interest in learning about new crops or technologies, which may have prevented farmers from interacting with the institutional and non-institutional sources of knowledge that were accessible to them. This finding is in consistent with study conducted by Bora *et. al* (2021)[10].

Extension participation

The analysis showed that significantly equal number of coconut growers (43.33 %) in Tiptur taluk were having both medium as well as high level or category of extension participation. While two-fifth of coconut farmers or growers (40.00 %) in Turuvekere taluk found to have medium level of extension participation at the same time more than half (53.33 %) of respondents or coconut growers of Sira taluk were known to have medium level of extension participation. In case of Chikkanayakanahalli taluk half of the coconut growers (50.00 %) were known to possess low level of extension participation. Overall it was revealed that more than two-fifth of coconut growers (43.33 %) were having medium level of extension participation followed by 32.50 per cent were having low level of extension participation and then high level of extension participation was seen in 24.17 per cent respondents. The likely cause of the afore mentioned trend is that respondents are eager to work with extension workers to solve their problems and they are also less interested in participating in extension activities due to a lack of time and even coconut farms spread over large areas where extension services are not easily accessible or require significant travel, coconut growers might be less likely to participate. Mutteppa's (2018)[11] findings are in consistent with the results of the medium category.

Management orientation

Coming to management orientation, significant number of coconut growers *viz.*, in Tiptur taluk (50.00 %) and in Turuvekere taluk (40.00 %) were considered to have medium category of management orientation while in noticing Chikkanayakanahalli and Sira taluks significantly equal number of coconut growers (46.67 %) possessed low category of management orientation. Overall it was known that two-fifth of coconut growers (40.00 %) were possessing medium level of management orientation followed by 34.17 per cent were found to have low level of management orientation and then by 25.83 per cent respondents were found to have high level of management orientation. Individual's innovativeness, cosmopoliteness also the scientific orientation can be frequently influencing factors over management orientation. The medium degree of these qualities among coconut growers may be the likely cause of the respondents medium managerial approach. This research supported the conclusions of Deepika (2015)[5].

Risk orientation

The findings revealed that noteworthy amount of coconut growers *viz.*, in Tiptur taluk (46.67 %), in Turuvekere taluk (43.33 %), in Chikkanayakanahalli taluk (46.67 %) as well as in Sira taluk (50.00 %) were known to have medium level of risk orientation. Thus among the overall coconut growers, it was learnt that noteworthy amount of coconut growers (46.67 %) were found to have medium level of risk orientation followed by 27.50 per cent respondents were possessing low level of risk orientation and then followed by 25.83 per cent respondents were found to belong to high level of risk orientation. This could be because due to the uncertain market conditions, including fluctuating prices and demand, can discourage growers from taking risks with their produce. Even normal human tendency not to take risk might have forced the coconut growers not to involve themselves in taking of the risky decisions in farming. This result supported the conclusions of Mohammed mosif (2015)[12].

Credit orientation

The study revealed that noteworthy amount of coconut growers *viz.*, in Tiptur taluk (50.00 %), in Turuvekere taluk (46.67 %), in Chikkanayakanahalli taluk (43.33 %) as well as in Sira taluk (46.70 %) found to have medium level of credit orientation. Overall, it was learnt that around 46.67 per cent of respondents found to have medium level of credit orientation followed by 27.50 per cent of the respondents were learnt to have low level of credit orientation and then 25.83 per cent respondents had high level of credit orientation. The cause might be that due to respondent's level of education and medium level of cosmopoliteness could have led them to have medium level of credit orientation. Coconut growers might rely on informal sources of credit from local moneylenders or traders. This reliance might be due to easier accessibility, but it can come with risks and elevated interest rates. Even limited understanding of financial concepts and credit mechanisms can make coconut growers hesitant to seek credit or unsure about how to manage loans. This research is in accordance of the conclusions of Jayashree (2013)[13].

Innovativeness

The study found that significantly equal number of coconut growers i.e., 46.67 per cent from the chosen four taluks had medium level of innovativeness. Thus, the study showed that among overall coconut growers, more than two-fifth of coconut growers (46.67 %) were found to have medium level of the innovativeness followed by 28.33 per cent respondents were found to have low level of innovativeness and then by 25.00 per cent of respondents of the investigation were found to have high level of innovativeness. The levels of education and interaction with the outside World could be the probable cause of this moderate propensity for innovation. They may also have observed it in others and taken their time to embrace innovative farming practices, which shows this results are consistent with Mutteppa (2018)[11] findings.

Deferred gratification

The study showed that significant number of coconut growers *viz.*, in Tiptur and Chikkanayakanahalli taluk both with (40.00 %) of coconut growers, in Turuvekere and Sira taluk both with (43.33 %) of coconut farmers or growers were found to have medium level of deferred gratification. Finally among overall coconut growers it was discovered that slightly more than two-fifth of coconut growers (41.67 %) were discovered to have medium level of deferred gratification followed by 31.67 per cent of the respondents were discovered to have high level of deferred gratification and then 26.67 per cent of respondents were revealed to have low level of deferred gratification. The likely answer for found pattern of medium to high level of deferred gratification behavior is that the greater part of the respondents thinks that future uncertainty can be managed now, and as a result, they demonstrated the capacity to make plans for such uncertainties. The results are similar with the results of Rajendra Prasad (2016)[14].

Scientific orientation

The findings revealed that significant number of coconut growers viz., in Tiptur and Chikkanayakanahalli taluk (50.00 %) of coconut growers whereas in Turuvekere and Sira taluk (43.33 %) of respondents or the coconut growers were discovered to have medium level of the scientific orientation. Overall it was learnt that noteworthy amount of coconut growers (46.67 %) were discovered to have medium level of scientific orientation followed by 29.17 per cent were found having low level of scientific orientation and then followed by 24.17 per cent of the respondents were found to have high level of scientific orientation. This may be because a significant portion of coconuts growers were discovered to possess medium to low risk orientation and even low extension involvement/participation, which may have prevented them from adopting scientific methods for coconut farming. Results from Mohammad mosif (2015)[12] validate these finding.

Cosmopoliteness

From the investigation it was revealed that significantly equal amount of coconut growers (43.33 %) in Tiptur and Turuvekere taluks, noteworthy amount of coconut growers (40.00 %) in Chikkanayakanahalli taluk and half of the coconut growers (50.00 %) in Sira taluk found to have medium level of cosmopoliteness. Overall it was discovered that noteworthy number of coconut growers (44.17 %) were discovered to have medium level of cosmopoliteness followed by 28.33 per cent of the respondents were discovered to have high level of cosmopoliteness and then followed by 27.50 per cent of the respondents were found to have low level of cosmopoliteness. The selected villages relatively proximity to the towns and the frequent visits made by the coconut growers either for personal or even farming-related work could be the reason for their medium level of cosmopoliteness. These findings are consistent with those of Yashodhara(2015)[15].

Table 1: Personal, socio-economic and psychological characteristics of coconut growers

Sl. No.	Characteristics	Category	Tiptur (n_1=30)		Turuvekere (n_2=30)		Chikkanayakanahalli (n_3=30)		Sira (n_4=30)		Overall (n=120)	
			f	%	*f*	%	*f*	%	*f*	%	*f*	%
1	Age (Years)	Young (<35years)	3	10.00	2	06.67	11	36.70	2	06.67	18	15.00
		Middle (35-50years)	15	50.00	12	40.00	16	53.30	8	26.70	51	42.50
		Old (>50 years)	12	40.00	16	53.30	3	10.00	20	66.70	51	42.50
2	Education	Illiterate	2	06.67	3	10.00	2	06.67	5	16.70	12	10.00
		Primary school	2	06.67	3	10.00	7	23.30	11	36.70	23	19.20
		High school	7	23.30	17	56.70	13	43.30	8	26.70	45	37.50
		Pre-University	10	33.30	3	10.00	5	16.70	6	20.00	24	20.00
		Graduation and above	9	30.00	4	13.30	3	10.00	0	0.00	16	13.30
3	Family size (No. of members)	<4 members	9	30.00	5	16.60	7	23.30	7	23.33	28	23.33
		4-6 members	18	60.00	23	76.60	20	66.60	22	73.33	83	69.16
		>7 members	3	10.00	2	06.60	3	10.00	1	03.33	9	07.50
4	Land-holdings (acres)	Marginal (< 2.50 acre)	7	23.33	5	16.66	6	20.00	7	23.33	25	20.83
		Small (2.50-5.00 acre)	8	26.66	11	36.66	12	40.00	16	53.33	47	39.16
		Big (> 5.00 acres)	15	50.00	14	46.66	12	40.00	7	23.34	48	40.00
5	Farming experience	Low < (25.97 – 6.83)	8	26.67	8	26.66	11	36.70	9	30.00	36	30.00
		Medium (25.97 $\pm$ 6.83)	17	56.67	12	40.00	14	46.70	13	43.33	56	46.66
		High > (25.97 + 6.83)	5	16.67	10	33.33	5	16.70	8	26.67	28	23.33

	Mean = 25.97 S.D = 13.67											
6	Information seeking behaviour Mean =34.7 S.D =9.96	Low < (34.7 – 4.98)	3	10.00	9	30.00	13	43.30	11	36.70	36	30.00
		Medium (34.7 + 4.98)	12	40.00	11	36.70	14	46.70	16	53.30	53	44.20
		High > (34.7 + 4.98)	15	50.00	10	33.30	3	10.00	3	10.00	31	25.80
7	Extension participation Mean = 4.92 S.D =4.51	Low < (4.92 – 2.25)	4	13.33	8	26.67	15	50.00	12	40.00	39	32.50
		Medium (4.92 + 2.25)	13	43.33	10	33.33	13	43.33	16	53.33	52	43.33
		High > (4.92 + 2.25)	13	43.33	12	40.00	2	06.67	2	6.66	29	24.17
8	Management orientation Mean =55.85 S.D =5.41	Low < (55.85 – 2.70)	5	16.67	8	26.67	14	46.67	14	46.67	41	34.17
		Medium (55.85 + 2.70)	15	50.00	12	40.00	10	33.33	11	36.67	48	40.00
		High > (55.85 + 2.70)	10	33.33	10	33.33	6	20.00	5	16.67	31	25.83
9	Risk orientation Mean =8.24 S.D =1.54	Low < (8.24 – 0.77)	5	16.67	6	20.00	10	33.33	12	40.00	33	27.50
		Medium (8.24 + 0.77)	14	46.67	13	43.33	14	46.67	15	50.00	56	46.67
		High > (8.24 + 0.77)	11	36.67	11	36.67	6	20.00	3	10.00	31	25.83
10	Credit orientation Mean =3.06 S.D =1.13	Low < (3.06 – 0.56)	5	16.67	4	13.33	12	40.00	12	40.00	33	27.50
		Medium (3.06 + 0.56)	15	50.00	14	46.67	13	43.33	14	46.70	56	46.67
		High > (3.06 + 0.56)	10	33.33	12	40.00	5	16.67	4	13.30	31	25.83
11	Innovativeness Mean =7.44 S.D =2.07	Low < (7.44 – 1.03)	5	16.67	6	20.00	11	36.67	12	40.00	34	28.33
		Medium (7.44 + 1.03)	14	46.67	14	46.67	14	46.67	14	46.67	56	46.67
		High > (7.44 + 1.03)	11	36.67	10	33.33	5	16.67	4	13.33	30	25.00
12	Deferred gratification Mean =27.85 S.D =4.31	Low < (27.85 – 2.15)	7	23.33	6	20.00	10	33.33	9	30.00	32	26.67
		Medium (27.85 + 2.15)	12	40.00	13	43.33	12	40.00	13	43.33	50	41.67
		High > (27.85 + 2.15)	11	36.67	11	36.67	8	26.67	8	26.67	38	31.67
13	Scientific orientation Mean =16.36 S.D =1.38	Low < (16.36 – 0.69)	6	20.00	7	23.33	10	33.33	12	40.00	35	29.17
		Medium (16.36 + 0.69)	15	50.00	13	43.33	15	50.00	13	43.33	56	46.67
		High > (16.36 + 0.69)	9	30.00	10	33.33	5	16.67	5	16.67	29	24.17
14	Cosmopoliteness Mean =7.86 S.D =1.26	Low < (7.86 – 0.63)	5	16.67	6	20.00	11	36.67	11	36.67	33	27.50
		Medium (7.86 + 0.63)	13	43.33	13	43.33	12	40.00	15	50.00	53	44.17
		High > (7.86 + 0.63)	12	40.00	11	36.67	7	23.33	4	13.33	34	28.33

f = Frequency and *%* = Percentage

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IV. CONCLUSION

We can say that the personal, socio-economic and psychological characteristics of coconut growers can play immense role in how they make decisions, accept new ideas and respond to the problems in agriculture. Studying these characteristics can help us understand the variables which can affect their overall productivity and farming methods. By identifying these characteristics, we can create policies, support networks and extension interventions more effectively that are suited to the unique requirements of coconut growers by having a deeper knowledge of these qualities for a successful socio-economic growth and development of coconut growers.

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Analysis of Spatiotemporal Characteristics of Urban Heat Island (HUI) Effect in Shantou City based on Landsat Images

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***Abstract*— *With the continuous strengthening of China's economic strength and the acceleration of urbanization, a series of urban ecological problems have also emerged, among which Urban Heat Island (UHI) is one of the more serious issues. This article takes Shantou City as the research object, based on Landsat series satellite images, uses the radiative transfer equation algorithm (atmospheric correction method) to invert the surface temperature of Shantou City, and uses the mean standard deviation method to classify the heat island effect of surface temperature. The results indicate that the area of UHI effect in Shantou is continuously increasing, and there is a phenomenon of transition from low-temperature areas to high-temperature areas. From 2008 to 2021, the UHI area in Shantou exhibited a spatiotemporal variation pattern of scattered, contiguous, and diffusive transfer.*

Keywords*— *Urban Heat Island (UHI); Land Surface Temperature (LST); Urban Heat Island Classification; Spatiotemporal feature analysis; Shantou City

I. INTRODUCTION

The concept of urban heat island (UHI) was first proposed by Manley in 1958, referring to the phenomenon where the temperature in the city is significantly higher than that in the surrounding suburbs [1]. UHI is an environmental phenomenon that occurs during the process of urban economic development and is also a form of "heat pollution." [2]. With the rapid development of urbanization and industrialization and the rapid expansion of urban population, the types of urban surface cover have changed, and the quality of the atmospheric environment continues to decline. Urban water bodies, atmosphere, and surface cover have been disturbed or damaged by human activities. At the same time, the diffusion ability of the thermal environment in the city center slows down, the purification ability of the thermal environment weakens, and the heat accumulation in the city center increases while the heat in the surrounding suburbs decreases, resulting in a vicious cycle of heat transfer between the city and the suburbs[3]. The UHI effect causes a series of environmental problems, which have a serious impact on people's lives and production, such as abnormal climate and environment, warm winters, acid rain, spring sandstorms, high temperatures in summer, deteriorating air quality, and weakened air diffusion capacity.

The urban thermal environment is a unique combination of natural and man-made buildings within a city and is an important component of the urban ecosystem.

As a place where human life and production gather, cities are the most frequent places for energy and information exchange on the Earth's surface [2]. The quality of urban ecology is directly related to people's quality of life, health index, and the economic development of a country. Therefore, improving the quality of human habitation and urban environment index, adhering to the high-quality development of urban economy and ecological environment, and moving towards a sustainable green ecological path are the keys to the rational and healthy development of cities. Studying urban thermal environment can not only comprehensively understand the urban spatial structure and development scale but also guide the sustainable development of urban ecological environment, providing an important basis for improving the environmental quality of human residential areas.

Research on UHI can be divided into atmospheric heat islands and surface urban heat islands. Among them, the UHI is analyzed by establishing mathematical models or using statistical methods based on meteorological station data. In 1972, Rao first applied remote sensing technology to the study of the UHI effect [4]. Due to the advantages of good time synchronization, wide coverage, and high spatial resolution of remote sensing inversion of surface temperature data, it can display the spatial distribution of the thermal environment and compensate for the limitations of uneven distribution and low relative density of meteorological stations on UHI research [5]. With the rapid development of qualitative and quantitative remote sensing technology, remote sensing thermal infrared data has been widely used in land surface temperature (LST) inversion and UHI inspection, becoming an important tool and means that cannot be ignored [6, 7]. In addition, studies have shown that the intensity of UHIs exhibits different characteristics over time, such as strong nighttime intensity and weak daytime midday intensity. The annual variation is characterized by strong autumn and winter seasons and weak summer seasons. The intensity varies with space. For example, the heat island appears in densely populated areas with high building density and the highest concentration of industry and commerce, while the suburbs have better vegetation coverage or dense farmland, resulting in lower heat island intensity.

Based on the above, this study adopts remote sensing inversion technology, utilizes Landsat series satellite images, and uses the support vector machine (SVM) classification method for supervised classification of images. The radiative transfer equation algorithm is used to invert the surface temperature of Shantou City, and the mean standard deviation method is used to classify the heat island effect of surface temperature, focusing on the analysis of spatiotemporal characteristics. By analyzing the spatial distribution conditions and understanding the driving factors, provide a scientific basis for policy planning and improvement measures.

II. STYDY AREA AND DATA SOURCES

2.1 Study Area

The geographical location of Shantou is 116°14'40 "-117°19'35" east longitude and 23°02'33 "-23°38'50" north latitude. The total area of the city is 2064 square kilometers, with a population of 4.68 million and a coastline of 298 kilometers. Shantou City is located in the subtropical monsoon climate zone, with a mild climate throughout the year, abundant sunshine, and abundant rainfall [8]. This climate condition will to some extent promote the UHI effect. The large number of buildings, roads, population agglomeration, and other activities within the city can lead to an increase in surface temperature, making the UHI effect more significant. The administrative district governs six districts, including Jinping, Longhu, Chenghai, Haojiang, Chaoyang, and Chaonan, as well as Nan'ao County (Figure 1). Controlling the mouths of Hanjiang, Rongjiang, and Lianjiang rivers, the Tropic of Cancer spans the entire region, with winding and long coasts and spectacular hills.

Shantou City takes the secondary and tertiary industries as its main economic activity locations. A large number of factories, enterprises, transportation, and other industrial activities will release a large amount of heat, further exacerbating the formation of the urban heat island effect. In the process of urbanization, large-scale land development, cement construction, asphalt paving, and other activities will change the type and nature of surface coverage, increase the surface heat capacity, and further exacerbate the UHI effect. Meanwhile, the disappearance of large-scale green spaces and wetlands has weakened the city's ability to regulate heat, making it more vulnerable to the impacts of climate change and human activities.

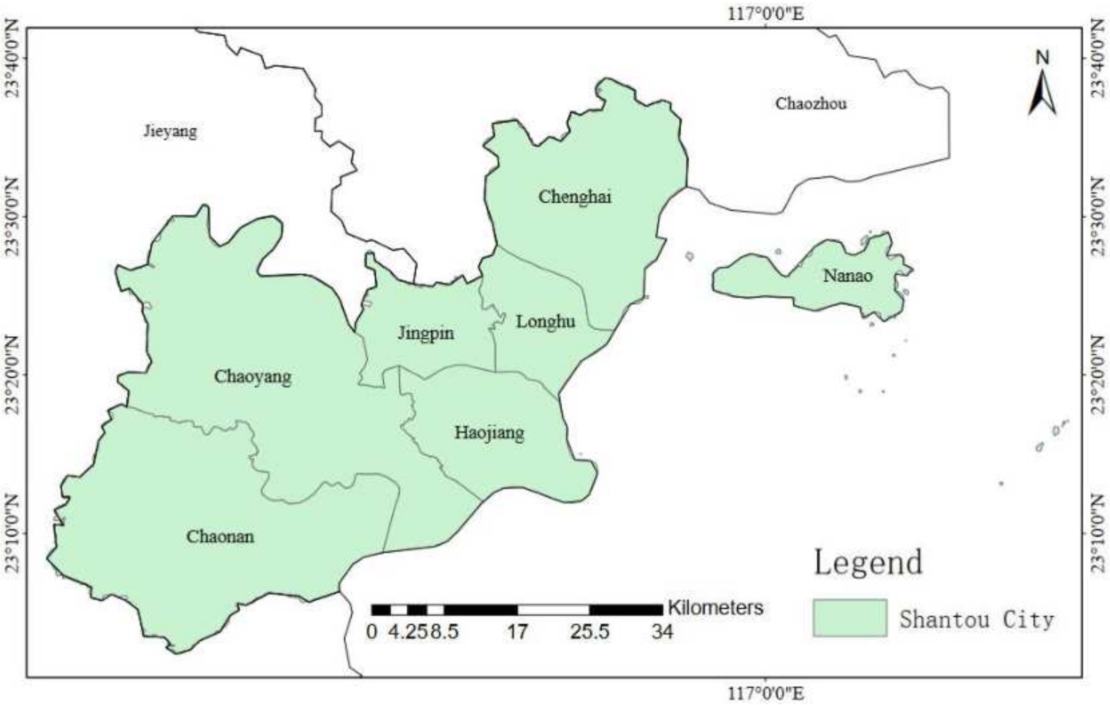

Fig.1 Administrative boundary of Shantou City

2.2 Data Sources

This article uses satellite images from the Landsat series, including Landsat-5/TM data from 2008 and monthly similar images from Landsat-8/OLI in 2013, 2016, and 2021 (Table 2). The remote sensing imagery data are all from geospatial cloud data (https://www.gscloud.cn/search). The image needs to undergo preprocessing, including radiometric calibration and atmospheric correction for each period of the image. Reuse the vector boundaries of Shantou's administrative divisions to extract the scope mask of the research area.

Table 1 Remote Sensing Image Data Sources

Item	Date	Data identification	Sensor type	Spatial resolution
Imagery	2021-2-22	LC81200442021053LGN00	Landsat8_OLI/TIRS	OLI 30m TIRS/100 m
	2016-12-9	LC81200442016344LGN01		
	2013-12-1	LC81200442013335LGN00		
	2008-12-19	LT51200442008354BJC00	Landsat5_TM	TM 30m

III. METHODOLOGY

3.1 Method

In this article, the radiative transfer equation method, also known as the atmospheric correction method, is used to invert the surface temperature of Shantou City. Its principle is to subtract the influence of atmospheric radiation on the surface radiation from the total thermal radiation received by satellite sensors and convert the remaining radiation value into the corresponding surface temperature. That is to say, the total thermal radiation received by the satellite is composed of the thermal radiation value of the atmosphere, the energy reflected by the surface to the sensor, and the energy absorbed by the surface and transmitted to the sensor through the atmosphere. The advantage of the radiative transfer equation is that it is not limited by the thermal infrared band but requires four parameters: atmospheric transmittance, atmospheric upwelling radiation value, atmospheric descending radiation value, and surface emissivity.

Based on the above principles, this study used Landsat 5 and Landsat 8 images as materials. After image preprocessing, NDVI (Normalized Difference Vegetation Index) extraction, vegetation coverage calculation, and surface radiation calculation are performed. Perform radiation calculation and temperature inversion based on the tenth wave band image. Finally, analyze the spatiotemporal changes and estimate the conclusions. The technical roadmap for the research is shown in Figure 2.

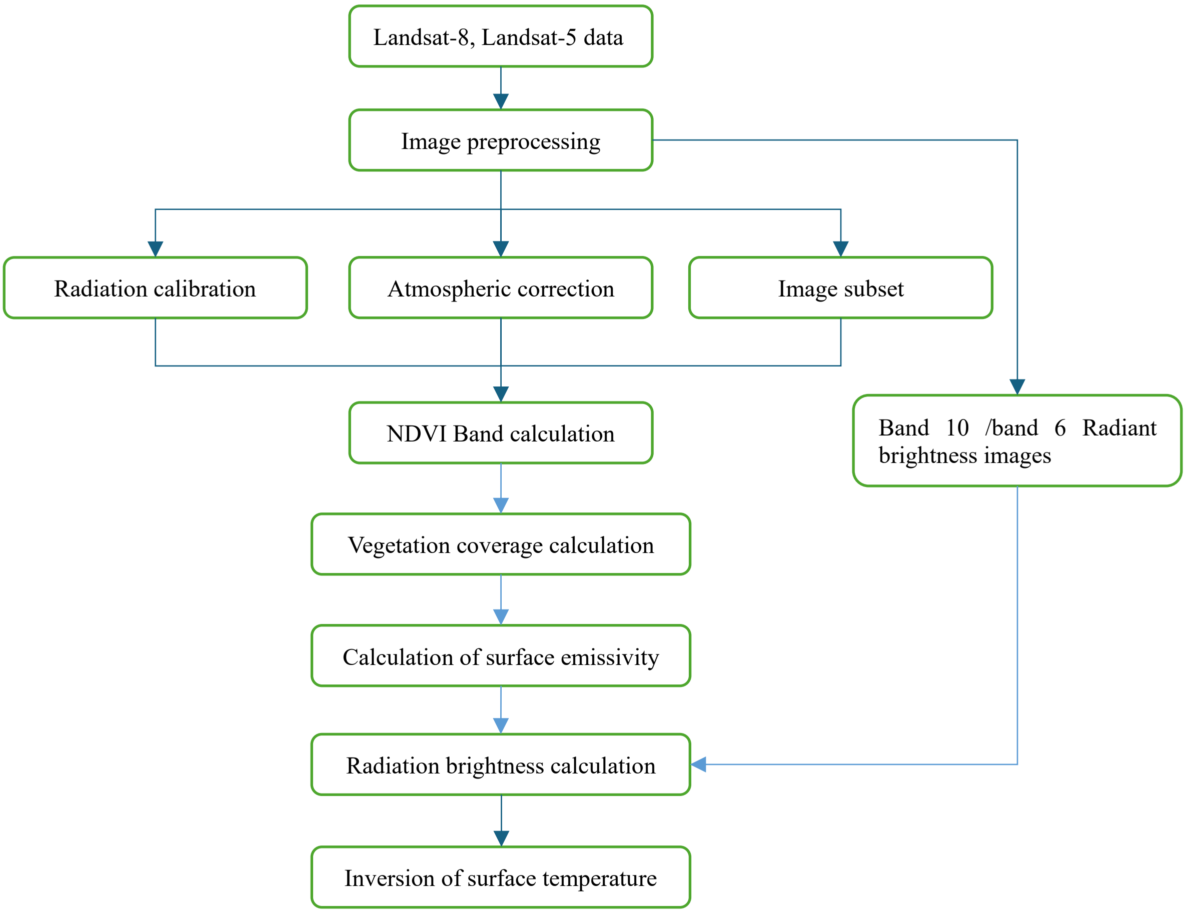

Fig.2 Technical Roadmap

3.2 Urban Surface Temperature Inversion

The physical basis for using remote sensing data to invert land surface temperature (LST) in this study is based on the heat radiation transfer equation quantified by Planck's law. According to the spectral resolution setting of satellite sensors, inversion methods are divided into single channel algorithms, dual channel algorithms (split window algorithms), and multi-channel algorithms. The temperature inversion of single channel algorithms includes the radiative transfer equation algorithm (atmospheric correction method) [9], the single window algorithm [10], the universal single channel algorithm, etc. [11]. After referring to relevant literature, this article uses the radiative transfer equation algorithm to invert temperature.

The basic principle of the radiative transfer equation algorithm is to first estimate the impact of the atmosphere on surface thermal radiation, and then subtract the atmospheric impact from the total amount of thermal radiation observed by sensors on the satellite to obtain the surface thermal radiation intensity, and then convert this thermal radiation intensity into the corresponding surface temperature. When using the radiative transfer equation algorithm for calculation, four parameters are required, namely atmospheric transmittance, atmospheric upwelling radiation value, atmospheric downwelling radiation value, and surface emissivity. The basic calculation of the radiative transfer equation is shown in formula (1):

$$L_\lambda = [\varepsilon B(T_s) + (1-\varepsilon)L\downarrow]\tau + L\uparrow \quad (1)$$

In equation (1): Lλ is the radiance value received by the sensor, measured in W/（m2·sr·μm); ε is the surface emissivity value; B(Ts) is the radiance value of a blackbody in the thermal infrared band at the same temperature, measured in W/（m2·sr·μm）; τis the transmittance value of the atmosphere in the thermal infrared band; L↓ and L↑ are the values of atmospheric upward radiance and atmospheric downward radiance, measured in W/（m2·sr·μm）. The expression for B(Ts) is shown in formula (2):

$$B(T_s) = \frac{[L_\lambda - L\uparrow - \tau(1-\varepsilon)L\downarrow]}{\tau\varepsilon} \quad (2)$$

According to Planck's formula, the surface temperature Ts can be obtained, as shown in formula (3):

$$T_s = \frac{k_2}{\ln\left[\frac{k_1}{B(T_s)}\right] + 1} \quad (3)$$

In equation (3), K1 and K2 are both constants.

Due to different sensors, the corresponding K1 and K2 values also vary. For Band 6 of TM sensor, K1=607.76 W/（m2·sr·μm), K2=1260.56K; For Band 10 of TIRS sensor, K1=774.89 W/（m2·sr·μm), K2=774.89K.

⑵ Extraction of surface coverage index

The process of temperature inversion mainly involves the following steps: First, calculating the values of intermediate variables such as the NDVI, vegetation coverage, surface emissivity, blackbody radiance, etc. Then, substitute these intermediate values into the equation for temperature calculation. The calculation process for each parameter is as follows:

The purpose of the NDVI is to increase the reflection of vegetation in the thermal infrared band and the absorption difference of vegetation in the red band. The calculation formula is shown in equation (4):

$$M_{NDVI} = \frac{N_{NIR} - J_{Red}}{N_{NIR} + J_{Red}} \quad (4)$$

In equation (4), M_{NDVI} is the normalized vegetation index value; N_{NIR} is the reflection value of vegetation in the thermal infrared band; and J_{Red} is the value of vegetation absorption in the red band.

For different remote sensing platform sensors, their near-infrared and red bands also differ. The near-infrared band of Landsat5 is Band4, while the near-infrared band of Landsat8 is Band5. The red light bands of Landsat5 and Landsat8 are Band3 and Band4, respectively.

The vegetation coverage PV is the ratio of the projected area of vegetation on the ground to the total area. The basic calculation principle is the mixed pixel decomposition method, and the calculation formula is as follows (5):

$$P_V = \frac{M_{NDVI} - M_{NDVI_{soil}}}{M_{NDVI_{Veg}} - M_{NDVI_{soil}}} \quad (5)$$

In equation (5), $M_{NDVI_{soil}}$ is the normalized vegetation index value of bare soil or areas without vegetation cover; $M_{NDVI_{Veg}}$ is the normalized vegetation index value of pixels completely covered by vegetation, that is, the normalized vegetation index value of pure vegetation pixels. Take empirical values, $M_{NDVI_{Veg}}$=0.70, $M_{NDVI_{soil}}$=0.05; that is, when the NDVI value of a pixel is greater than 0.70, Pv is taken as 1; when the NDVI value is less than 0.05, PV is taken as 0 [12].

The surface emissivity is the ratio of the radiation emissivity of the surface to the radiation emissivity of a blackbody at the same temperature. The calculation of this value is related to the surrounding environment and the coverage type of the underlying surface. Qin et al. (2004) classified remote sensing images into three types: urban areas, water bodies, and natural surfaces. The values are calculated as follows: The specific emissivity of water body pixels is 0.995, the specific emissivity of natural surface pixels is ε surface=0.962 5+0.0614PV-0.0461PV2, and the specific emissivity of urban area pixels is ε building=0.9589+0.086PV-0.0671PV2.

The values of the atmospheric transmittance τ in the thermal infrared band, the atmospheric upward radiance value L↑, and the atmospheric downward radiance value L↓ are all obtained by searching on the website published by NASA (http://atmcorr.gsfc.nasa.gov).

3.3 Classification Method for Urban Thermal Environment Levels

UHI refers to the phenomenon where the temperature in the city is higher than that in the suburbs. However, defining the heat island area, analyzing the temperature difference between the city and the suburbs, determining the level of thermal environment, and determining the boundaries of each level are also key issues in urban thermal environment research.

The mean standard deviation division method [13] has been widely used in UHI research. By calculating the lowest and highest temperatures obtained from inversion, the mean (u) and standard deviation (std) of the surface are obtained, and five different heat island level zones are divided into strong heat island zone, heat island zone, intermediate zone, green island zone, and cold island zone within a certain range. Li and Ren (2015) [14] used the mean standard deviation method to obtain surface temperature and classify it into different levels in the study of surface temperature inversion and quantification of UHI intensity in Xi'an. Overall, this algorithm can provide a good basis for analyzing the spatial differences of UHI; Wang (2013) [15] conducted a study on the spatiotemporal changes of the urban thermal environment in Shenyang. Based on the mean standard deviation method, the surface thermal field was divided, and the distribution pattern of the thermal environment obtained showed significant spatiotemporal resolution. Therefore, this article uses the mean standard deviation method to divide the surface temperature into five categories based on the thermal field division interval in Table 1.

Table 2 Mean-standard Deviation Temperature Classification

Heat island level	Temperature zone level	The difference in average temperature between urban core and non-core areas
Cold island	Low temperature area	$T_s < \mu - std$
Green island	Sub-low temperature area	$\mu - std \le T_s < \mu - 0.5std$
Normal island	Middle-temperature area	$\mu - 0.5std \le T_s < \mu + 0.5std$
Sub-heat island	Sub-high temperature area	$\mu + 0.5std \le T_s < \mu + std$
Intense heat Island	High-temperature area	$T_s > \mu + std$

IV. ANALYSIS AND RESULTS

4.1 Distribution Characteristics of Spatiotemporal Changes in UHI

From the spatial distribution of the heat island in Shantou City (Figure 3), it can be seen that the areas of high and sub-high temperature zones have been continuously expanding from 2008 to 2021. In 2008, the heat island area was mainly distributed in the coastal and western parts of Shantou City, namely the border between Chaoyang District and Chaonan District and Longhu District, which were relatively scattered and had a small area. From 2013 to 2021, the high and sub-high temperature areas have shown an outward expansion along their original regions, mainly distributed in Chenghai District, Jinping District, and Haojiang District. The intensity of the heat island has increased at the junction of Chaoyang District and Chaonan District, as well as along the coast.

Firstly, the surface temperatures of Shantou City in 2008, 2013, 2016, and 2021 were classified using the mean standard deviation method [13] (Table 3, Figure 4, Figure 5)。 And the spatial distribution and variation trend of surface temperature were observed to exhibit the following characteristics:

1. Low temperature zone: The area of this region has significantly increased from 1.1% in 2008 to 13.99% in 2021. Although 58% of the region remains in a low-temperature state, it is worth noting that 38% of the region has transformed into a sub-low temperature zone, and 4% of the region has warmed up to a medium temperature zone, especially in the southwest of the Chaonan area and the northeast of the Chaoyang area, indicating that local areas are experiencing temperature rise.

2. Sub-low temperature zone: Between 2008 and 2016, the area of this region increased from 22.41% to 25.76%, but after reaching its peak in 2016, it sharply decreased to 8.37% in 2021. In this region, 66% of the area maintained a sub-low temperature state, while 21% of the area cooled down to the low temperature zone, 12% of the area heated up to the medium temperature zone, and 1% of the area further heated up to the sub-high temperature zone, showing complex fluctuations in temperature within the region.

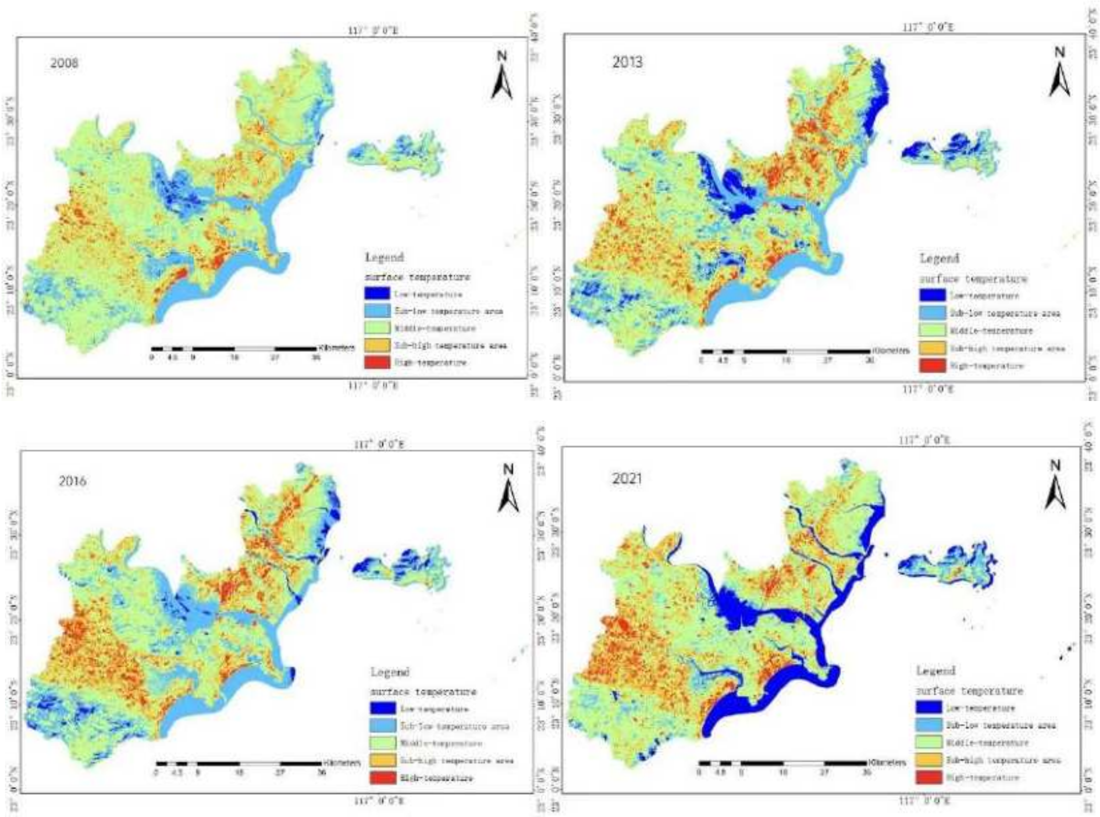

Fig.3 Classification map of Surface Temperature in Shantou from 2008 to 2021

3. Medium temperature zone: From 55.75% in 2008 to 44.18% in 2016, the area of this region shows a decreasing trend. However, from 2016 to 2021, the area of the temperate zone has rebounded, increasing to 48.51%. In this region, 70% of the area maintains a moderate temperature, 11% of the area transitions to a sub-low temperature zone, 16% of the area heats up to a sub-high temperature zone, and 1% of the area transitions to a low temperature zone and a high temperature zone, respectively, showing a polarization trend between heating and cooling in the moderate temperature zone.

4. Sub-high temperature zone: The percentage of area increased from 17.52% in 2008 to 22.27% in 2021, showing a continuous growth trend. In this region, 54% of the area remains in a sub-high temperature state, 22% of the area further heats up to the high temperature zone, and 23% of the area cools down to the medium temperature zone, indicating a coexistence of temperature rise and fall in the region.

5. High temperature zone: The area of high temperature zone increased significantly from 3.21% in 2008 to 6.18% in 2013. In this region, 50% of the area remains in a high temperature state, 34% of the area cools down to the sub-high temperature zone, 15% of the area cools down to the medium temperature zone, and 1% of the area cools down to the sub-low temperature zone, reflecting the trend of cooling in the high temperature zone while maintaining a high temperature state.

In summary, the surface temperature changes in Shantou City not only exhibit diversity in spatial distribution but also reflect the complexity of temperature dynamics within the region under the background of climate warming. Against the backdrop of global warming, temperature changes in different regions exhibit varying trends and amplitudes. The warming in some areas of the low- and sub-low-temperature regions may be due to local climate change and human activities. The warming of the medium and sub-high temperature zones may indicate that these areas are gradually transitioning towards higher temperatures. The changes in the high-temperature zone indicate that although the high-temperature zone has expanded, there are also some areas where the temperature has fallen.

Table 3 Surface Temperature Grade in Shantou from 2008 to 2021

Thermal field grade	2008		2013		2016		2021	
	Area km^2	ratio%	Area km^2	ratio%	Area km^2	ratio%	Area km^2	ratio%
Low temperature area	25.73	1.10	138.98	5.93	72.63	3.10	328.04	13.99
Sub-low temperature area	525.75	22.41	509.29	21.71	604.20	25.76	196.43	8.37
Middle-temperature area	1307.78	55.75	1085.63	46.28	1036.35	44.18	1137.96	48.51
Sub-high temperature area	410.95	17.52	466.86	19.90	478.23	20.39	522.43	22.27
High-temperature area	75.40	3.21	144.85	6.18	154.21	6.57	160.74	6.85

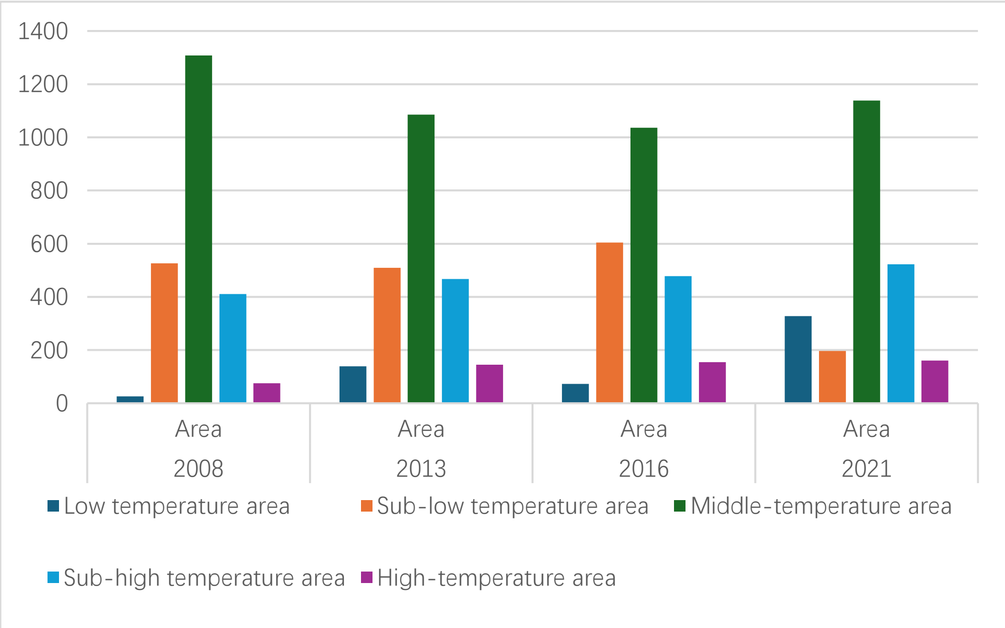

Fig.4 Map of Surface Temperature Grade Area of Shantou from 2008 to 2021

4.2 Driving Factors of UHI Evolution

This article adopts the supervised classification method in the post-classification comparison method [16] and uses the support vector machine method to classify the land use in Shantou City from 2008 to 2021 (Figure 6, Table 4) [17]. Analysis shows that from 2008 to 2021, the increase in urban built-up area and the decrease in bare land and green space are the result of a combination of multiple factors:

1. The acceleration of the urbanization process: With the development of the economy and the increase in population, the acceleration of the urbanization process has led to changes in land use patterns. In order to meet people's demand for housing, commerce, and infrastructure, a large amount of land is used for construction, resulting in an increase in building area and a decrease in bare land.

2. Economic interest-driven: Due to the scarcity of urban land resources, some local governments and developers may be more inclined to use land for profitable projects while neglecting the importance of green spaces.

3. Natural resource development: In some areas, due to natural resource development and other reasons, large areas of green space have been destroyed, resulting in a decrease in green space.

These changes have an impact on the UHI effect: an increase in building area and a decrease in green space exacerbate the UHI effect. Buildings, roads, and other man-made structures absorb more solar energy and release heat, while reduced green spaces cannot effectively absorb heat and provide the function of regulating urban temperature, making the city hotter. The increase in bare land may also have an impact on the heat island effect. Bare land is usually prone to absorbing and storing heat, and the heat absorbed during the day is slowly released at night, causing the city's nighttime temperature to rise and further exacerbating the heat island effect.

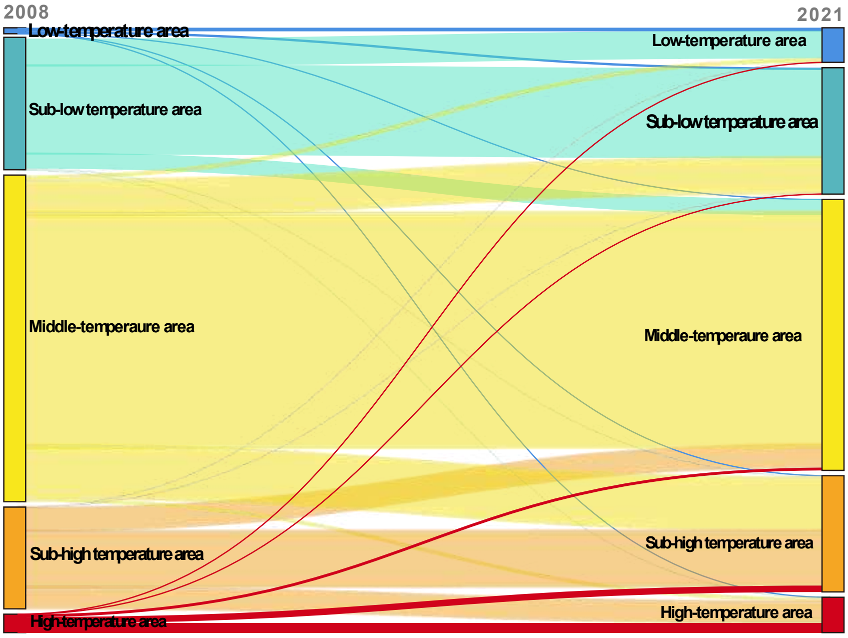

Fig.5 Temporal and Spatial Characteristics of Variation of Surface Temperature Class

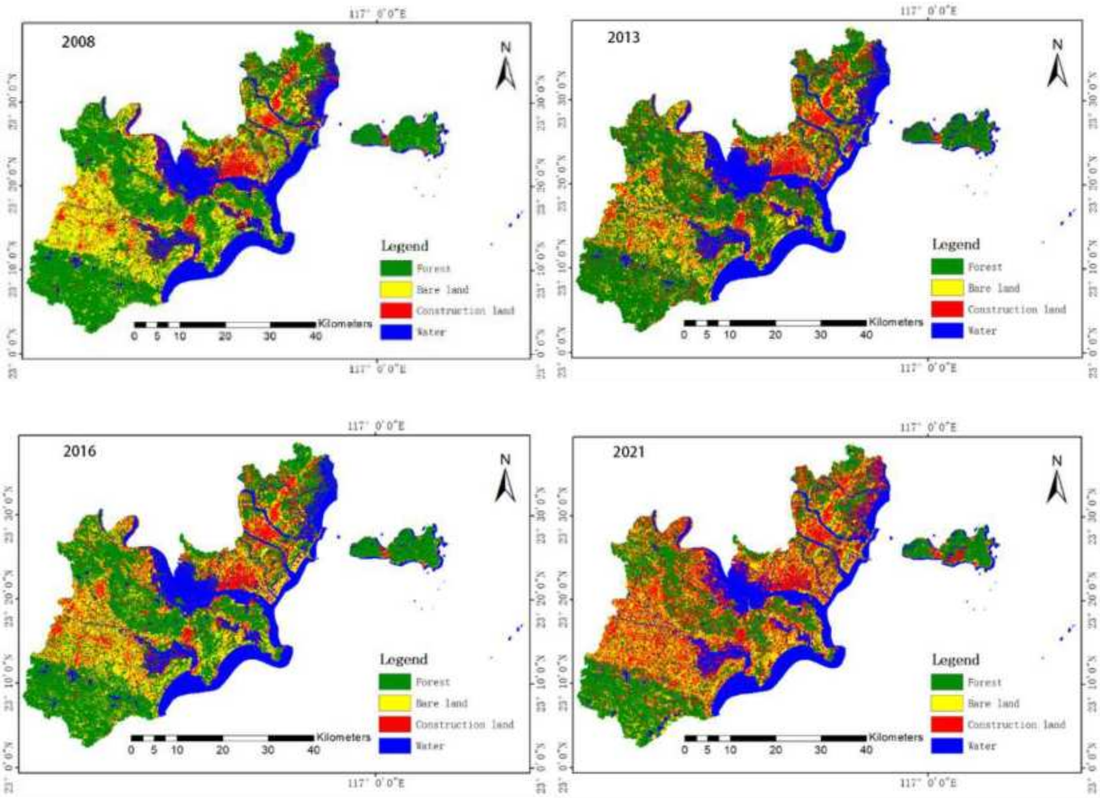

Fig.1 Land Use Classification Map of Shantou from 2008 to 2021

In summary, the increase in urban built-up area, the increase in bare land, and the decrease in green space are the result of multiple factors working together, which have a significant impact on the UHI effect and exacerbate the phenomenon of UHI effect. Thus, effective measures should be taken to plan urban development rationally, protect, and increase green spaces in order to mitigate the adverse effects of the heat island effect.

Table 4 Area and Proportion of Land Use Types in Shantou from 2008 to 2021

	2021		2016		2013		2008	
	Area km^2	ratio%	Area km^2	ratio%	Area km^2	ratio%	Area km^2	ratio%
Construction land	696.03	29.60	391.75	16.66	433.58	18.44	314.27	13.36
Bare land	450.79	19.17	465.35	19.79	394.68	16.78	528.57	22.48
Forest	710.55	30.21	989.35	42.07	1011.32	43.00	1051.29	44.70
Water	494.32	21.02	505.23	21.48	512.10	21.78	457.55	19.46

V. CONCLUSIONS

This article is based on Landsat-5 TM data from 2008, Landsat-8 OLI-TIRS data from 2013, 2016, and 2021, national basic vector data, and relevant theories of thermal environment remote sensing. Using the radiative transfer equation algorithm, the surface temperature of Shantou City in 2008, 2013, 2016, and 2021 was reconstructed, and the UHI intensity and spatial evolution pattern, as well as the thermal environment landscape pattern of Xi'an City, were analyzed. The following conclusions were drawn:

Using the atmospheric correction method to invert the spatiotemporal trend of surface temperature in 2008, 2013, 2016, and 2021. The results indicate that the overall heat island intensity in Shantou City was relatively weak in 2008, with only sporadic high-temperature areas. In 2013, the economy of Shantou City continued to develop, and the degree of greening also increased. The intensity of UHI changed from scattered to patchy distribution in the later stage, and the previous middle area has transformed into a strong heat island area or heat island area. The area of the UHI effect continues to increase with the continuous expansion of cities. In 2016 and 2021, the Green Island District in Shantou City continued to decrease, while the areas of heat island and super heat island districts increased.

(2) In terms of the spatiotemporal characteristics of surface temperature changes, this article uses the mean and standard deviation method to divide the surface temperature of Shantou City into high temperature zones (strong heat island zone), sub-high temperature zones (heat island zone), medium temperature zones (middle zone), sub-low temperature zones (green island zone), and low temperature zones (strong green island zone). Overall, the HUI area in Shantou City has shown a trend of scattered, contiguous, and diffusive transfer from 2008 to 2021. In 2008, the scattered heat island area was distributed in the main urban area, and in 2013 and 2016, it covered the main urban area in a contiguous manner. However, in 2021, the UHI area shifted from the "urban area" to the "suburbs."

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Genetic Diversity of Sweet Potato (*Ipomoea Batatas* (L.) Lam) Accessions from Nigeria and Niger Based on Agro-Morphological

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***Abstract*— *Utmost tropical nations regard the sweet potato(Ipomoea batatas(L.) Lam.) as their most significant chief crop. It's substantially privileged for its capability to deter disaster, improvement, and produce with many inputs. A study was carried out during the 2020 and 2021 growing time seasons in a field trial conducted at the University of Ebonyi State – CAS , to determine variability among sweet potato accessions, and identify traits that are positively and significantly associated with yield and accessions with high yield. A randomized complete block design with three replications was used to determine variability among sweet potato accessions, The results of both years combined statistical analysis indicated that the types significantly varied in terms of all yield and yield- related traits. As a result, the Umu SPO 3 acquired had the topmost values of average root storage in both the 2020 (5.2 cm) and 2021 (2.4 cm) growing seasons. In both 2020 and 2021 growing seasons and over time combined analysis, the haughtiest average root yield (2.67 Kg), and total root yield(8.89 t/ ha) were recorded for Koudakou. PCV was advanced than GCV suggesting a major environmental influence on those characters. Low heritability coupled with high, moderate, and low inheritable advance in percent of mean was observed in all characters. Traits considered in the study revealed positive and significant correlations. The grouping of accessions into two main clusters highlights genetic relationships among them. Understanding these relationships can help breeders identify potential parent lines for cross-breeding, which can lead to the development of new varieties with desirable traits.*

***Keywords*— heritability, correlation, yield-related traits, variability, breeding**

I. INTRODUCTION

Starchy root and tuber crops are a significant global source of carbohydrates, second only to cereals. They contribute a substantial portion of the world's food supply, as well as serving as an important animal feed and raw material for human and industrial products (Chandrasekara & Josheph, 2016). Storage roots like cassava and sweet potatoes, and edible rhizomes like canna and arrowroots, can all be propagated using vegetative parts, including tubers (potatoes and yams), stem cuttings (cassava), vine cuttings (sweet potatoes), and side shoots, stolons, or corm heads (taro and cocoyam) (Chandrasekara & Josheph, 2016; Mohanty et al., 2016). The importance of tropical root and tuber crops to global food security cannot be overstated (Nanbol & Namo, 2019). Sweet potato is a dicotyledonous plant belonging to the Convolvulaceae family. It is an herbaceous perennial vine with medium-sized, sympetalous flowers that are frequently pale violet in color and alternating leaves that can have lobes or not (Alfred et al., 2019). Sweet potatoes are storage roots with a sweet flavor that are largely utilized for human use (storage roots and leaves), with less of them being used as an industrial raw material and animal feed (Yan et al., 2022). Sweet potatoes are prized for their sweetness, high nutritional value, and short (3 to 4 month) growing period (Adepoju & Adejumo, 2015). One of the top seven foods consumed worldwide is sweet potatoes. Because of the quantity and quality of food it generates, it has the ability to ensure food security, particularly for low-income populations (Vargas et al., 2017). The concept of association can be effectively utilized to develop selection strategies for enhancing yield components by examining the correlation between quantitative and qualitative characteristics (Rahman, 2018). Breeders can choose the most desirable features for yield by using genetic indices such as heritability, genetic advance, genotypic, and phenotypic coefficients of variation (Narasimhamurthy et al., 2018).

Sweet potato cultivars, propagation material origin, environment, and soil conditions significantly influence storage root yields across and within plants (Hayati, & Anhar, 2020). Alves et al. (2017) showed that although sweet potatoes exhibit considerable genetic variation, genotypes with desirable traits have been lost due to changes in consumption habits and limited research. It is still necessary to create and introduce new, high-yielding varieties of sweet potatoes with high dry matter and beta-carotene content (Harriman et al., 2017). The major problem for low production output for sweet potato is inadequate supply of improved material for smallholder farmers (Chidozie, 2017; Nanbol & Namo, 2019). Sweet potato production in Nigeria has been low due to limited capital to boost production, use of improved planting materials amongst other factors (Tewe et al., 2003). The existence of genetic diversity in a crop population and proper knowledge on this divergence is of great importance to breeders (Bassey, 2017; Hamidah et al., 2020; Njoku et al., 2017). Because of this, an effort has been undertaken to compile background data on the level of genetic variability present in sweet potato genotypes (Rahman, 2018). The study aims to identify the best accessions for sweet potato cultivation, focusing on storage root yield and nutritional value. This will allow small-scaled farmers to enhance their income by supplying enough tubers to the market and for household consumption. In addition, breeders can select the most promising accessions for future growth and dissemination. The aim of this study is to access genetic diversity across sweet potato accessions and identify traits that are positively related with yield, thus resulting in high agricultural production for small-scaled farmers.

II. MATERIALS AND METHODS

A field experiment was carried out at the University of Ebonyi State–CAS Campus, in southeast Nigeria, between latitude 60° 20'N and longitude 008° 06'E, during the 2020–2021 growth season. According to (Njoku et al., 2017) the average annual minimum rainfall is 1800 mm, the average annual maximum rainfall is 2000 mm, and the average annual minimum and maximum temperatures are 27°C and 31°C, respectively, and average annual minimum and maximum rainfall are 1800 mm and 2000 mm, respectively. Relative humidity peaks at 80% during the rainy season and falls to 60% during the dry season, particularly during the Harmattan era. A total of 20 accessions were accessed in the study, where five accessions were from Niger and 15 were from Nigeria (National Root Crops Research Institute Umudike, Abia State (Table 1). The experiment of the study was in a randomized complete block design (RCBD) in three replications. The experimental area was 330 m^2 (30 m long × 11 m wide). The size of individual plots was 3 m^2 (3 m long × 1 m wide) with a spacing of 0.30 m intra-row and 0.50 m inter-row, giving one row totaling a population of 10 plants per plot. The estimated total plant population for the experiment was 600 plants.

Table 1. Background information of the 20 sweet potatoes accessions assessed for genetic diversity

N°	Acc ID	Accession name	Collection country	Latitude	Longitude	Collection source	Status of sample
1	SP-PhD-2	BUTTER MILK	Nigeria	05°29'N	07°33'E	Field	Landrace
2	SP-PhD-4	NWA OYORIMA	Nigeria	05°29'N	07°33'E	Field	Improved
3	SP-PhD-12	DELVIA	Nigeria	05°29'N	07°33'E	Field	Improved
4	SP-PhD-15	Dan Bouza	Niger	13°18.260' N	002°20.253'E	Field	Landrace
5	SP-PhD-29	Dan Maradi	Niger	13°18.260' N	002°20.253'E	Field	Landrace
6	SP-PhD-20	Koudakou 3	Niger	13°18.260' N	002°20.253'E	Field	Landrace
7	SP-PhD-21	Koudakou 4	Niger	13°18.260' N	002°20.253'E	Field	Landrace

8	SP-PhD-22	Dan Maradi 2	Niger	13°47.013' N	002°59.102'E	Field	Landrace
9	SP-PhD-39	EBO/SP 2	Nigeria	5°28'26'N	007°32'19"E	Market	Landrace
10	SP-PhD-42	EBO/SP 5	Nigeria	5°28'26'N	007°32'19"E	Market	Landrace
11	SP-PhD-46	NSPO 2012-005	Nigeria	5°28'26' N	007°32'19"E	Field	Advanced Line
12	SP-PhD-34	NSPO 2012-022	Nigeria	5°28'26' N	007°32'19"E	Field	Advanced Line
13	SP-PhD-56	NSPW 2012-001	Nigeria	5°28'26' N	007°32'19"E	Field	Advanced Line
14	SP-PhD-52	NSPW 2012-018	Nigeria	5°28'26' N	007°32'19"E	Field	Advanced Line
15	SP-PhD-62	NASPOT 8	Nigeria	5°28'26' N	007°32'19"E	Field	Improved
16	SP-PhD-64	NASPOT 11	Nigeria	5°28'26' N	007°32'19"E	Field	Improved
17	SP-PhD-71	LOURDES	Nigeria	5°28'26' N	007°32'19"E	Field	Landrace
18	SP-PhD-72	Umu SPO 3	Nigeria	5°28'26' N	007°32'19"E	Field	Improved
19	SP-PhD-75	NKWO	Nigeria	5°28'26' N	007°32'19"E	Field	Landrace
20	SP-PhD-77	TIS-87/0087	Nigeria	5°28'26' N	007°32'19"E	Field	Improved

2.1. Data collection

Data on the following characters were acquired from each accession and replication during the experimentation. The data for the quantitative traits were collected as follows: vine length (VL, cm) on five plants per plot, vine internode length (VIL, cm) on five plants during harvesting per plot, mature leaf length (MLL, cm) on five leaves per five plants per plot, mature leaf width (MLW, cm) on five plants at harvest, petiole length (PL, cm) on five plants at harvest, number of branches (NBP) per five plants at harvest, number of roots (NRP) on five plants at harvest, root length (RL, cm) on five roots per plot, root girth (RG, cm) on Root yield (RYP, Kg) per plant during harvest, total root yield (TRY, t/ha) for the entire experiment, biomass (BM, Kg/m2) at harvest, one day after harvest. Data were collected on the following qualitative traits every three months for five plants: plant type, vine pigmentation, number of leaf lobes, leaf lobe type, abaxial leaf vein pigmentation, mature leaf color, petiole pigmentation, storage root shape, storage root skin color, and storage root flesh color. Both quantitative and qualitative data were obtained based on sweet potato descriptors (Huama´n, 1991).

2.2. Statistical analysis

Data were subjected to analysis of variance (ANOVA) using SAS software program version 9.0 (SAS, 2017) to determine the presence of significant variations between accessions. When significant differences were found, the means were separated using the least significant difference (LSD) test at a 5% level of significance. The qualitative data were generated using Excel. Multivariate analysis of agro-morphological data by principal component analysis (PCA) was used to discriminate between the genetic diversity of the sweet potato accessions, and correlations between variables were found using correlation analysis (Sabri et al., 2020; Chukwu et al., 2015)

III. RESULTS AND DISCUSSION

3.1 Analysis of variance and mean performance of sweet potato accessions during 2020 and 2021 growing year

The analysis of variance (ANOVA) means square values of accessions during 2020 and 2021 growing seasons were is presented in Table 2 and supplementary material Table 2. Over the course of several years of growth. ANOVA revealed significant variations in accessions by year in 80% of variables, but no significant differences in biomass (supplementary material Table 2). Based on a combined-year analysis, Umu SPO 3 (300.15 cm), TIS-87/0087 (255.73 cm), NSPW 2012-001 (236.02 cm), and NSPO 2012-005 (207.06 cm) had the longest vine lengths. Whereas, UTY 2014-078 (37.40 cm) had the shortest vine length (see supplementary material Table 2). Umu SPO 3 had the longest vine internode (6.44 cm), followed by NSPW 2012-001 (5.69 cm), TIS-87/0087 (4.98 cm), and Dan Maradi 2 (4.78 cm); UTY 2014-078 had the shortest (1.10 cm). In the two- years combined analysis, Accession TIS-87/0087 (13.84 cm) had the longest average mature leaf length, followed by Umu SPO 3 (13.56 cm), Koudakou 3 (13.51 cm), and Butter Milk (13.33 cm), while UTY 2014-078 (3.76 cm) had the shortest over-year combined length. In the over-year combined study, accession Koudakou 4 (12.57 cm) had the highest mean root number per plot, followed by Koudakou 3 (12.00 cm), Dan Maradi (12.00 cm), and Dan Maradi 2 (9.40 cm), while the UTY 2014-078 (2.33 cm) and EBO/SP 5 (1.67 cm) accessions had the lowest values. Koudakou 3 (2.7 Kg/m2) and Umu SPO 3 (2.4 Kg/m2) had the largest storage root output across the years, followed by Koudakou 4 (2.4 Kg/m2) and Koudakou 3 (1.9 Kg/m2). The lowest root yields were obtained for EBO/SP 5 (0.2 kg/m2) and UTY 2014-078 (0.0 kg/m2). Furthermore, the results showed that Koudakou 3 (8.9 t/ha) had the highest total root yield, followed by Koudakou 4 (8.4 t/ha), Umu SPO 3 (8.0 t/ha), and Dan Maradi (5.5 t/ha). The lowest total root yield was seen in EBO/SP 5 (0.6 t/ha) and UTY 2014-078 (0.1 t/ha).

Table 2.Combined analysis of variance for agro-morphological characteristics of the sweet potato accessions in 2020 and 2021 growing seasons

	Replication (Season)	Year	Accession	Accession*Year	Error
DF	4	1	19	19	75
VL(cm)	5043.99ns	21427.76*	21661.028*	17859.045*	4373.03
VIL(cm)	1.022ns	0.47ns	10.028*	8.039*	1.39
MLL(cm)	15.23ns	88.92*	52.078*	48.58*	7.80
MLW(cm)	1.28ns	29.80*	21.17*	29.24*	3.57
PL(cm)	9.69ns	57.48*	55.96*	61.40*	11.40
NBP	12.31ns	85.92*	47.894*	24.16*	10.60
NRP	4.27ns	754.69*	52.68*	68.47*	21.058
RL(cm)	6.34ns	757.14ns	89.024*	72.22*	20.40
RG(cm)	7.29*	230.47*	5.65*	4.77*	1.25
RYP(Kg)	0.51ns	1.80ns	4.019*	3.021*	0.67
RYPP(Kg/m^2)	3.15ns	5.032ns	4.96ns	5.50*	3.16
TRY(t/ha)	6.061ns	10.38ns	45.99*	35.61*	7.54
BM(Kg)	4103.29*	483.29*	85.15ns	117.28ns	75.81

ns: no significant (p>0.05), *: significant (p<0.05),: **VL**: Vine length, **VIL**: Vine internode length, **MLL**: Mature leaf length, **MLLW**: Mature leaf width, **PL**: Petiole length, **NBP**: Number of branch per plant, **NRP**: Number of roots per plant, **RL**: Root length, **RG**: Root girth, **RYP**: Root yield per plant (Kg), **RYPP**: Root yield per plant (Kg/m^2) **TRY**: Total root yield, MB: Biomass.

3.2 Genetic variability, heritability and genetic advance

The performance of the genotypes for each character is detailed below. The results of the study to determine the extent of genetic variation in relation to 17 characters are presented in Table 3 showing values for phenotypic variance (VP), genotypic variance (VG), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), broad sense heritability (h2b), genetic advance (GA), genetic advance in percent of mean, and coefficient of variation (CV). The genotypic variance and phenotypic variance for vine length were 5762.67 and 26034.06, respectively (Table 3). The phenotypic variance for vine internode length (11.42) was higher than genotypic variance (2.88). GCV and PCV were high (36.45 and 73.42, respectively) (Table 3). The heritability estimates for this trait were low (22.14) and there were high genetic advances (73.57) and low genetic advances (32.05) as a percentage of the mean. The phenotypic and genotypic variances were 59.88 and 14.76, respectively (Table 3). PCV (73.42%) and GCV 36.45%) were high for mature leaf length. The results indicated (24.74 and 5.87) phenotypic and genotypic variance, PCV (57.91%) and GCV (28.20%) were high for mature leaf width. However, the genetic advance estimates were low for mature leaf length and mature leaf width (3.93 and 2.43, respectively), with a low and moderate genetic advance in percent of mean for mature leaf length and width (7.54 and 11.48%) and a less genetic advance in percent (7.54 and 11.48%). Furthermore, the majority of the parameters showed very high PCV values: vine length (97.07) and vine internode length (83.00); high for root girth (145.34), number of roots per plant (116.47), biomass (104.75), and total root yield (234.39). GCV was high, however, for the following: number of branches per plant (42.81), number of roots per plant (44.04), root length (42.95), biomass (14.56), root yield per plot (107.02), total root yield (114.70), root girth (66.97), petiole length (33.79). Consequently, petiole length, number of roots per plot, number of branches per plant, root length, root girth, root yield per plot, total root yield, and biomass were shown to have low values for the heritability estimate in a broad sense. For root yield, genetic advance as a percentage of mean was high (26.43). Additionally, for root girth (20.35), mature leaf length (11.48), and vine internode length (17.50), it was moderate; however, for petiole length (6.66), number of branches per plat (6.99), number of roots per plant (4.80), root length (5.06), total root yield (7.85), and biomass (0.59), the results showed very low genetic advance.

Table 3. Estimation of genetic parameters, heritability, and genetic advance for agro-morphological characters of the sweet potatoes

Characters	Mean	CV (%)	GMS	EMS	VG (δ2g)	VP (δ2p)	GCV (%)	PCV (%)	Heritability h2bs (%)	GA	GA %
VL(cm)	166.23	39.78	21661.03	4373.03	5762.67	26034.06	45.67	97.07	22.14	73.57	0.34
VIL(cm)	4.07	28.97	10.03	1.39	2.88	11.42	41.68	83	25.21	1.76	17.5
MLL(cm)	10.54	26.5	52.08	7.8	14.76	59.88	36.45	73.42	24.65	3.93	7.54
MLW(cm)	8.59	21.99	21.17	3.57	5.87	24.74	28.2	57.91	23.72	2.43	11.48
PL(cm)	11.41	29.61	55.96	11.4	14.85	67.36	33.79	71.96	22.05	3.73	6.66
NBP	8.24	39.52	47.89	10.6	12.43	58.49	42.81	92.86	21.26	3.35	6.99
NRP	7.37	62.24	52.7	21.06	10.55	73.76	44.04	116.47	14.3	2.53	4.8
RL(cm)	11.13	40.56	89.02	20.4	22.87	109.42	42.95	93.95	20.9	4.5	5.06
RG(cm)	1.81	61.92	5.65	1.25	1.46	6.9	66.97	145.34	21.23	1.15	20.35
RYP(Kg)	0.99	83.09	4.01	0.67	1.11	4.68	107.02	219.47	23.78	1.06	26.43
RYPP(Kg/m^2)	0.49	365.4	4.96	3.16	0.6	8.12	158.96	585.52	7.37	0.43	8.73
TRY(t/ha)	3.12	87.95	45.99	7.54	12.82	53.53	114.7	234.39	23.95	3.61	7.85
BM(Kg)	12.11	71.89	85.15	75.81	3.11	160.96	14.56	104.75	1.93	0.51	0.59

Characters	Mean	CV (%)	GMS	EMS	VG (δ2g)	VP (δ2p)	GCV (%)	PCV (%)	Heritability h2bs (%)
VL(cm)	166.23	39.78	21661.03	4373.03	5762.67	26034.06	45.67	97.07	22.14
VIL(cm)	4.07	28.97	10.03	1.39	2.88	11.42	41.68	83	25.21
MLL(cm)	10.54	26.5	52.08	7.8	14.76	59.88	36.45	73.42	24.65
MLW(cm)	8.59	21.99	21.17	3.57	5.87	24.74	28.2	57.91	23.72
PL(cm)	11.41	29.61	55.96	11.4	14.85	67.36	33.79	71.96	22.05
NBP	8.24	39.52	47.89	10.6	12.43	58.49	42.81	92.86	21.26
NRP	7.37	62.24	52.7	21.06	10.55	73.76	44.04	116.47	14.3
RL(cm)	11.13	40.56	89.02	20.4	22.87	109.42	42.95	93.95	20.9
RG(cm)	1.81	61.92	5.65	1.25	1.46	6.9	66.97	145.34	21.23
RYP(Kg)	0.99	83.09	4.01	0.67	1.11	4.68	107.02	219.47	23.78
RYPP(Kg/m2)	0.49	365.4	4.96	3.16	0.6	8.12	158.96	585.52	7.37

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TRY(t/ha)	3.12	87.95	45.99	7.54	12.82	53.53	114.7	234.39	23.95
BM(Kg)	12.11	71.89	85.15	75.81	3.11	160.96	14.56	104.75	1.93

CV: Coefficient of variation, **GMS**: Genotypic mean sum of squares, **EMS**: Error mean sum of squares, **VG**: Genotypic variance, **VP**: Phenotypic variance, **PCV**: Phenotypic coefficient variation, **GCV**: Genotypic coefficient variation, **h^2_{bs}**: Heritability broad sense, **GA**: Genetic advance, **GA (%)**: Genetic advance as percentage of mean. **VL**: Vine length, **VIL**: Vine internode length, **MLL**: Mature leaf length, **MLLW**: Mature leaf width, **PL**: Petiole length, **NBP**: Number of branches per plant, **NRP**: Number of roots per plant, **RL**: Root length, **RG**: Root girth, **RYP**: Root yield per plant (Kg), **RYPP**: Root yield per plant (Kg/m^2) **TRY**: Total root yield (t/ha), **MB**: Biomass (Kg/m^2),

3.3 Pearson Correlation Coefficients

In the year combined analysis, the study found that there was a significant and positive correlation between vine length and the following variables: vine internode length (0.83), mature leaf length (0.67), mature leaf width (0.65), petiole length (0.49), number of branches per plant (0.38), number of roots per plot (0.21), root length (0.36), root yield per plot (0.34), total root yield (0.33). On the other hand, there was a positive non-significant correlation between vine length and root girth (0.12), and biomass (0.041). Mature leaf length (MLL) also showed a significant correlation with mature leaf width (0.79), petiole length (0.61), number of branches per plant (0.55), number of roots per plant (0.28), root length (0.47), root yield per plot (0.36), total root yield (0.36) and biomass (0.29) in the two-year combined analysis. Nonetheless, MLL exhibited a non-significant positive association (-0.0069) and a negative correlation (0.17) with root girth and bloom width, respectively. Additionally, throughout the 2020 and 2021 growth seasons, there was a substantial positive association between the number of roots per plot and all morphological features.

Table 4. Pearson correlation coefficients of different morphological traits of the 20 sweet potato accessions during 2020 and 2021 growing years

Traits	VL	VIL	MLL	MLW	PL	NBP	NRP	RL	RG	RYP	RYPP	TRY	BM
VL	1	0.83*	0.67*	0.65*	0.49*	0.38*	0.21*	0.36*	0.12ns	0.34*	0.084ns	0.33*	0.041ns
VIL		1	0.71*	0.71*	0.57*	0.51*	0.36*	0.43*	0.25*	0.43*	0.12ns	0.41*	0.24*
MILL			1	0.79*	0.61*	0.55*	0.28*	0.47*	-0.0069ns	0.36*	0.095ns	0.36*	0.29*
MILW				1	0.79*	0.58*	0.41*	0.56*	0.23*	0.28*	0.12ns	0.27*	0.27*
PL					1	0.49*	0.32*	0.45*	0.21*	0.25*	0.11ns	0.24*	0.18*
NBP						1	0.46*	0.42*	0.32*	0.27*	0.55*	0.29*	0.28*
NRP							1	0.64*	0.59*	0.71*	0.33*	0.69*	0.27*
RL								1	0.49*	0.57*	0.060ns	0.53*	0.22*
RG									1	0.55*	0.30*	0.49*	0.071NS
RYP										1	0.29*	0.97*	0.19*
RYPP											1	0.35*	0.14NS
TRY												1	0.22*
BM													1

ns: not significant ($p>0.05$), *: significant ($p<0.05$),: **VL**: Vine length, **VIL**: Vine internode length, **MLL**: Mature leaf length, **MLLW**: Mature leaf width, **PL**: Petiole length, **NBP**: Number of branch per plant, **NRP**: Number of roots per plant, **RL**: Root length (cm), **RG**: Root girth (cm), **RYP**: Root yield per plant (Kg), **RYPP**: Root yield per plant (Kg/m^2) **TRY**: Total root yield (t/ha), BM: Biomass (Kg),

3.4 Multivariate analysis

3.4.1 Principal component analysis (CPA)

The study found that four major components with eigenvalues equal to or greater than one explained 83.03% of the variability. PC1 contributed 55.8% of total diversity, representing individual variables. PC2 contributed 14.87%, representing two variables. PC3 contributed 6.77%, and PC4 contributed 5.59%, representing three individual variables. These components represent the equivalent of individual variables. Twenty accessions were tested. (Table 5).The study found four major components, PC1, PC2, PC3, and PC4, accounting for 73.08% of variability.

Table 5. Principal component analysis of 20 sweet potato accessions

Traits	PC1	PC2	PC3
MLL(cm)	-0.28693	-0.08038	0.03593
MLW(cm)	-0.27612	-0.11509	-0.05132
NBP	-0.26595	0.1789	-0.2321
NRP	-0.25476	0.20967	-0.07919
PL(cm)	-0.24396	0.07868	-0.26208
RG(cm)	-0.20994	0.25859	0.10867
RL(cm)	-0.26595	-0.16855	0.20654
RYPP(Kg/m2)	0.09656	0.21789	0.58393
RYP(Kg)	-0.16045	0.43399	0.29576
TRY(t/ha)	-0.12868	0.47411	0.20239
VIL(cm)	-0.28137	-0.00693	0.02524
VL(cm)	-0.22447	-0.09476	0.10727
BM(Kg)	-0.21298	-0.03746	0.05969
D50F	0.27428	-0.12245	0.01119
D50S	-0.27225	-0.16102	0.06469
D80M	-0.22983	-0.18865	-0.07801
FL(cm)	-0.19275	-0.15485	-0.05499
FW(cm)	-0.1401	0.39703	-0.42509
Eigenvalue	10.602	2.825	1.286
PV	55.8	14.87	6.77

VL: Vine length, **VIL**: Vine internode length, **MLL**: Mature leaf length, **MLLW**: Mature leaf width, **PL**: Petiole length, **NBP**: Number of branch per plant, **NRP**: Number of roots per plant, **RL**: Root length, **RG**: Root girth, **RYP**: Root yield per plant (Kg), **RYPP**: Root yield per plant (Kg/m2) **TRY**: Total root yield, **MB**: Biomass, **FL**: Flower length, **FW**: Flower width, **D50S**: Days to 50% sprouting, **D50F**: Days to 50% flowering, **D80M**: Days to 80% maturity. **PV**: Percentage variation

IV. DISCUSSION

4.1 Analysis of variance and mean performance of sweet potato accessions during 2020 and 2021 growing year

Accessions Umu SPO 3, TIS-87/0087 NSPW 2012-001 and NSPO 2012-005 were superior in vine length, vine internode length and mature leaf size. In his examination of five sweet potato varieties. Nazrul (2018) also noted a significant variance in the length of the sweet potato vine, which varied from 119 cm to 192.3 cm. Koudakou 3, Koudakou 4, Dan Maradi 2, and Umu SPO 3 demonstrated superior performance in root number, root yield, and total yield, while EBO/SP 5 and NSPO 2012-005 showed insufficient results. Awel (2018) found variations in the average number of roots per plot, with Kulfo varieties having the lowest average root number per plot and local and Beletech varieties having the highest. Sora (2021) also noted a significant variation in the number of roots per plant. The study found that accession Dan Maradi, Koudakou 3, Umu SPO 3, NSPW 2012-001, and TIS-87/0087 had the longest and widest roots, while UTY 2014-078, Nwa Oyorima, and EBO/SP had the lowest value. In line with our results, Sora (2021) reported that root length varied among the genotypes significantly and ranged from 8.9 cm to 24.8cm.

1.1 Genetic variability, heritability and genetic advance

High PCV values were observed for traits such as total root yield, root yield per plant, root girth, number of roots per plant, biomass, vine length, and vine internode length. GCV was high for root yield per plant, root yield per plot, total root yield, root girth, petiole length, and number of branches per plat, number of roots per plot, and root length. However, GCV moderate for biomass. Mohammed et al. (2015) The study found that vine length had a higher genetic advance percentage, while vine length had less heritability and a lower genetic advance mean. Alemu and Aragaw (2016) study on three sweet potato varieties and eight introductions revealed that genotypic coefficients of variation were smaller than phenotypic coefficients of variation.

1.2 Pearson Correlation Coefficients

The study found a positive correlation between root length, root girth, root yield, biomass (Table 4). The results showed a positive correlation with most traits, except for biomass, which showed a positive non-significant correlation (Table 4). The 2020 and 2021 growing seasons showed a positive correlation between total root yield, and biomass (Table 4). Total root output, biomass ,all had positive correlations throughout the 2020 and 2021 growing seasons.

These outcomes concur with those attained by Ochieng, (2019) and Apon (2016) found a strong positive correlation between vine growth rate, mature leaf size, root yield, storage root diameter, and storage rootstalk length. However, vine internode length had a negative correlation with biomass. These outcomes concur with the conclusions of other researchers (Nwaigwe et al., 2016; Dash et al., 2015; Shrestha, 2016). Apon (2016) and Chukwu et al. (2022) also reported that number of roots per plot had positive direct effects on storage root yield. These results are in agreement with those reported by Mohanty et al., (2016) study found that stored root production per hectare is influenced by plant number, root length, root yield, and starch content, aiding breeders in selecting positive traits and reducing breeding costs and time.

1.3 Principal component analysis (CPA)

PC1 is well correlated with leaf characteristics, such as leaf general outline, and mature leaf length and leaf width while PC2 correlated with flowering rate, root maturity and total root production. These results are in line with those obtained by . Placide et al. (2015) who employed PCA to examine the variation among 54 sweet potato genotypes and discovered that the first seven main component axes had a cumulative variance of 77.83%. There was sufficient variation across the genotypes for our findings . The cluster analysis separated the 20 accessions into two clusters. Cluster 1 consisted of 12 accessions and cluster 2 consisted eight accessions. In a cluster, study of elite sweet potato genotypes from Tanzania for high dry matter content and resistance to the sweet potato viral diseases. Tairo et al. (2008) found two main groups with a low genetic similarity of 0.52. Both of the accession's genes could be utilized to create superior sweet potato varieties that are enhanced for high production potential. The 20 genotypes were grouped into two main groups demonstrating a genetic link between accessions. In contrast, cluster analysis of 116 genotypes in another study produced 12 groupings Mohammed et al., 2015; Chukwu et al 2015).

V. CONCLUSION

The study reveals significant differences in observed characteristics and variance results among 20 sweet potato accessions. It suggests Koudakou 3, Koudakou 4, Dan Maradi 2, TIS-87/0087, Butter Milk, and Dan Bouza as potential parents for genetic improvement and breeding for yield enhancement, based on their widely cultivated history. The majority of the investigated characters had low genetic progress as a percentage of mean, weak heritability, and greater phenotypic coefficients of variation than genotypic coefficients of variation, according to the study's findings. Additionally, accessions Koudakou 3, NSPO 2012-005, Dan Maradi, and Koudakou 4 are great choices for animal feed due to their superior vegetative growth performance.

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Effect of special horticultural practices on physical and chemical parameters in fruit of mango (*Mangifera indica* L.) cv. Ratna

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Abstract— *The investigation was conducted on mango at College of Horticulture, Dapoli, Dist. Ratnagiri (MS) during the year 2020-21 to assess the effect of special horticultural practices on physical and chemical parameters in fruit of mango (Mangifera indica L.) cv. Ratna. The experiment was laid out in RBD with three replications and ten treatments viz; girdling on first fortnight of October (T_1), girdling on first fortnight of November (T_2), girdling on first fortnight of October and November (T_3), girdling on first fortnight of October and tip pruning (T_4), girdling on first fortnight of November and tip pruning (T_5), girdling on first fortnight of October and November and tip pruning (T_6), tip pruning (T_7), removal of new shoots below old shoot (T_8), smudging (T_9) and control (T_{10}). Treatment girdling on first fortnight of October and November and tip pruning resulted highest fruit weight, fruit length, fruit diameter, pulp weight, pulp stone ratio at harvest stage and ripe stage. The chemical parameter TSS, reducing sugar, total sugar, acidity, pH and ascorbic acid were non-significant at both stages.*

***Keywords*— Ratna, Mango, Girdling, Tip pruning, TSS, pH and Ascorbic acid**

I. INTRODUCTION

The mango (*Mangifera indica* L.) is an important commercial fruit crop grown in tropical and subtropical region of the country. Mango is autotetraploid or amphidiploid in nature belongs to family Anacardiaceae and genus *Mangifera*. In India, almost all commercial cultivars are belonging to single species *Mangifera indica* L. It is originated from the Indo-Burma region. Among the various commercial varieties, the variety Ratna was developed by DBSKKV, Dapoli (M.S.) and it is regular bearer. The tree of Ratna is semi-dwarf in nature and the fruits is large ovate in shape (400-500g) with firm and fibreless deep orange colour pulp. Girdling is well known method to induce flower buds and fruiting in fruit crops, girdling or ringing is one of the horticultural practice methods which stops the downward flow of sap through phloem which enhance the flowering, fruit set and fruit size in horticulture plants. Girdling is the removal of the bark in a circular manner of either branch of the plant or woody plant. Late flowering leads to delayed fruit development and harvesting. Pruning is an science and art of removing some plant part or cutting of infected plant parts for better and valuable growth. Shoot pruning reduce the auxin synthesis at the apex of the branches, directing the transport of assimilates and cytokinin's to the axillary buds of branches under flowering condition, including the formation of axillary inflorescence (Srivastava, 2002). Mango flowers can be induced through smudging, an ancient technique. This method is used in some regions of the Philippines to get 'Carabao' and 'Pico' mangoes to flower early. It has been determined that the active ingredient in smearing that causes flowering is ethylene (Dutcher, 1972).

II. MATERIAL AND METHODS

A field experiment was conducted on 30 years old mango trees (cv. Ratna) at college of horticulture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (M.S.) India, Pin- 415712 located between 17°45' N latitude and 73°12' E longitude on West coast of Maharashtra. It has an altitude of 240 m from the MSL. The experiment laid out in randomized block design with three replications and ten treatments *viz*., girdling on first fortnight of October (T_1), girdling on first fortnight of November (T_2), girdling on first fortnight of October and November (T_3), girdling on first fortnight of October and tip pruning (T_4), girdling on first fortnight of November and tip pruning (T_5), girdling on first fortnight of October and November and tip pruning (T_6), tip pruning (T_7), removal of new shoots below old shoot (T_8), smudging (T_9) and control (T_{10}). Each treatment was given two trees. The girdling was done on tertiary branches of experimental tree by giving circular deep cut with help of sharp knife as per treatments. The total 50 branches were girdled per experimental plant. On these plants vegetative shoots were emerged in month of November of the total new shoots. 200 shoots per experimental plant were removed at the point of emergence of mature shoots. The smudging was done in month of December. During smudging, the colour of newly emerged shoots was light green. Smudging was done early in the morning. In the previous day the material like rice straw, dry residues of plant were collected at the base of plant canopy. Then next day early in the morning smudging was done for about 2 hours. The entire process of smudging was performed four times at four days interval. The data on average weight fruit (g), fruit length (cm), fruit diameter (cm), pulp weight (g), pulp to stone ratio at harvest stage and ripe stage were recorded. The chemical parameters *viz*; TSS(°B), reducing sugars (%), total sugar (%), acidity (%) pH and ascorbic acid (mg/100g) were recorded. The reducing sugar were estimated by using Lane and Eynon (1923) method, total sugar was estimated by method given Ranganna (1977) and ascorbic acid content of sample was determined by 2,6- dichlorophenol indophenols titration method described by Rao and Deshpande (2006). The data were analysed by the using statistical methods suggested by Panse and Sukhatme (1995).

III. RESULT AND DISCUSSION

The data on effect of girdling, tip pruning and smudging on physical and chemical parameter of fruits of mango cv. Ratna at harvest and ripe stage. The data are illustrated in Table no. 1(a), 1(b), 2(a) and 2(b) respectively.

Fruit weight, Fruit Length and Diameter at harvest stage

The largest fruit were observed in treatment girdling on first fortnight of October and November and tip pruning (448.27g). The highest fruit length (12.93cm) and maximum fruit diameter (9.55cm) were reported in this treatment. According to Ghadge *et al*. (2017) observed significantly maximum fruit weight (310.66g) with 1.50 cm of girdling width. Nabila et al. (2015) found highest fruit length (2.63 and 2.80) during 2009 and 2010 respectively because of girdling during April in both seasons of the study. Warang (2019) and Nachare (2020) also observed the same results. Improvement in fruit size due to pruning was observed in mango by Fivaz and Stassen, (1997) in mango cv. Sensation. El- sherbini (1992) concluded that fruit diameter and size significantly increased by girdling at stage II of peach cv. Riogrande. The girdling in first fortnight of October did not improve average fruit weight, fruit length and fruit diameter may be due to excess of shoots on tree it may cause lower interception of sunlight inside the canopy which results lower photosynthesis rate and lower supply of photosynthate to fruit. According to E. Lahav *et al*. (1972) due to girdling fruit weight decreases (265g) as compared to control (326g) in 'Ettinger' cultivar of avocado. Also smudging treatment did not influence on fruit weight, length and diameter of mango cv. Ratna. Smudging practice could be location specific and induces flowers only if shoot is in condition to flower. These inferences indicate that this technique could not work under changing climatic condition of Konkan region.

Pulp weight and Pulp to Stone ratio at harvest stage.

The highest pulp weight (341.03g) observed in treatment first fortnight of November and tip pruning and had maximum pulp to stone ratio (6.24) seen in the same treatment. Ghadage *et al.* (2017) reported significantly maximum volume of pulp (190.55 ml) was obtained with 1.50 cm of girdling width. The girdling on 15th July (T_1) produced significantly maximum pulp volume (184.73ml) in mango cv. Alphonso. Similar results with respect to pulp weight (g) and pulp stone ratio were also reported by Bhanupratap *et al*. (2009) in mango cv. Amrapali. Nachare (2020) found maximum weight of pulp (346.40g) in girdling on first fortnight of the September and tip pruning (removal of new shoots) in mango cv. Ratna. However, Soudagar *et al*. (2018) reported that the pulp weight and pulp to stone ratio did not vary due to tip pruning treatments. The lower pulp weight and pulp to stone ratio by girdling in first fortnight of October and smudging can be attributed to minimum fruit size and maximum stone weight.

Table No.1 a) Effect of girdling, tip pruning and smudging on physical parameters of fruit of mango cv. Ratna at harvest stage.

Treatments	Physical parameters at harvest stage				
	Avg. fruit weight (g)	**Fruit length (cm)**	**Fruit diameter (cm)**	**Pulp weight (g)**	**Pulp to stone ratio**
T1	405.23	10.22	8.24	270.67	4.49
T2	407.90	10.72	8.25	280.33	4.87
T3	408.63	11.41	9.15	279.37	4.67
T4	425.10	11.33	9.21	307.20	4.68
T5	446.53	12.60	9.30	341.03	6.24
T6	448.27	12.93	9.55	337.03	6.08
T7	437.17	12.18	8.79	308.20	5.54
T8	445.43	12.43	9.38	323.60	5.65
T9	403.87	10.34	8.16	249.20	4.06
T10	374.27	9.53	7.90	243.21	3.95
Mean	420.24	11.37	8.79	293.98	5.02
SEm ±	1.15	0.24	0.10	3.66	0.12
CD @ 5%	3.42	0.72	0.31	10.87	0.35

Table No.1 b) Effect of girdling, tip pruning and smudging on physical parameters of fruit of mango cv. Ratna at ripe stage.

Treatments	Physical parameters at ripe stage		
	Fruit weight (g)	**Pulp weight (g)**	**Pulp to stone ratio**
T1	387.63	254.80	4.10
T2	389.37	258.93	4.47
T3	392.73	257.87	4.42
T4	404.73	290.43	4.35
T5	414.77	308.17	6.11
T6	418.60	325.13	5.71
T7	407.43	290.30	5.22
T8	411.43	307.63	5.13
T9	362.63	217.20	3.97
T10	341.43	220.93	3.74
Mean	393.08	273.14	4.72
SEm ±	3.62	2.34	0.08
CD @ 5%	10.75	6.96	0.23

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Fruit weight, Pulp weight and pulp to stone ratio at ripe stage

The maximum fruit weight (418.60g) and pulp weight (325.13g) were reported in treatment girdling on first fortnight of October and November and removal of new shoots at ripe stage and maximum pulp to stone ratio observed in treatment girdling on first fortnight of November and tip pruning. There was increase in weight of fruit (g), pulp weight (g) and pulp stone ratio of mango cv. Ratna due to effect of girdling and tip pruning (removal of new shoots). The results in the present investigation are in confirmation with findings of Gopu *et al*. (2014) in mango cv. Alphonso; Warang *et al*. (2019) in mango cv. Alphonso; Nachare *et al*. (2020) in mango cv. Ratna. However, Soudagar *et al*. (2018) reported non-significant effect of tip pruning on mango on fruit length and diameter cv. Alphonso.

TSS, reducing sugar, total sugar, acidity, pH and ascorbic acid.

The effect girdling, tip pruning and smudging does not significantly observe on TSS, reducing sugar, total sugar, acidity, pH and ascorbic acid in fruit at harvest stage and ripe stage. Removal of new shoots, girdling and smudging did not affect TSS, reducing and total sugars of fruit at harvest and ripe stage. Shinde *et al*. (2014) also reported that the different girdling time had non-significant effect on TSS, titratable acidity, reducing sugar, total sugars, and ascorbic acid of fruits in mango cv. Alphonso. Warang *et al*. (2019) found that effect of girdling and removal of new shoot had non-significant effect on acidity, pH and ascorbic acid of fruits in mango cv. Alphonso. Nachare (2020) reported that effect of girdling and tip pruning had non-significant effect on acidity, pH and ascorbic acid of fruits in mango cv. Ratna.

Table No.2 a) Effect of girdling, tip pruning and smudging on chemical parameters of fruit of mango cv. Ratna at harvest stage.

Treatments	Chemical parameters at harvest stage					
	TSS (^{0}B)	**Reducing sugar (%)**	**Total Sugar (%)**	**Acidity (%)**	**pH**	**Ascorbic acid (mg/100g)**
T1	10.27	1.43	3.33	2.65	2.93	66.40
T2	9.83	1.61	3.15	3.25	2.43	65.30
T3	10.50	1.49	3.28	2.77	2.73	68.87
T4	10.67	1.25	3.31	2.96	2.92	65.33
T5	10.37	1.55	3.41	3.27	2.60	76.27
T6	10.20	1.90	3.40	3.20	2.63	74.57
T7	10.70	1.75	3.35	3.53	2.80	65.50
T8	10.63	1.83	3.40	3.23	2.60	66.63
T9	10.35	1.66	3.30	3.17	2.60	70.87
T10	10.23	1.36	3.17	3.24	2.77	71.87
Mean	10.38	1.58	3.31	3.13	2.70	69.16
SEm ±	0.23	0.14	0.13	0.18	0.14	2.93
CD @ 5%	NS	NS	NS	NS	NS	NS

IV. CONCLUSION

From these findings, it can be concluded that girdling, tip pruning (removal of new shoots) and smudging in mango cv. Ratna is beneficial for increasing length of fruit, diameter of fruit, weight of fruit, pulp weight and pulp stone ratio at harvest and ripe stage. The girdling, tip pruning (removal of new shoots) and smudging does not influence the chemical parameters *viz*; TSS, reducing sugar, total sugar, acidity, pH and ascorbic acid in the fruits of mango at both stages.

Table No.2 b) Effect of girdling, tip pruning and smudging on chemical parameters of fruit of mango cv. Ratna at ripe stage.

Treatments	**Chemical parameters at ripe stage**					
	TSS (^{0}B)	**Reducing sugar (%)**	**Total Sugar (%)**	**Acidity (%)**	**pH**	**Ascorbic acid (mg/100g)**
T1	21.17	3.15	12.53	0.22	4.50	50.65
T2	21.88	4.13	14.20	0.18	4.80	56.16
T3	20.79	3.29	12.63	0.19	4.13	59.07
T4	22.47	2.75	12.87	0.23	4.37	57.19
T5	21.81	4.10	13.80	0.18	4.53	51.33
T6	21.44	3.37	14.83	0.19	4.90	52.47
T7	22.54	3.27	14.30	0.20	4.60	53.70
T8	22.39	3.05	13.90	0.20	4.33	54.83
T9	21.78	2.57	12.47	0.21	4.07	56.20
T10	21.51	2.70	12.53	0.22	4.23	47.47
Mean	21.78	3.24	13.41	0.20	4.45	53.91
SEm ±	0.44	0.30	0.68	0.03	0.20	3.14
CD @ 5%	NS	NS	NS	NS	NS	NS

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Effect of International Fund for Agricultural Development (IFAD) on Community-Based Development Programme on Rural Livelihood in Katsina State, Nigeria

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***Abstract*— *Rural development is a veritable tool for fighting poverty and achieving economic prosperity at the grassroots level. The major thrust of this study was to examine the effect of IFAD Community-Based Agricultural and Rural Development Programme on Rural Livelihood in Katsina State, Nigeria. Specifically, the study described the socio- economic characteristics of respondents; identified and described the basic infrastructure provided; determined the effect of infrastructure provided on livelihood of respondents; determined the satisfaction level with the infrastructure provided in the communities and identified and described the constraints to effective performance of IFAD-CBARDP in the study area. A structured questionnaire was used to elicit primary data from 278 respondents. Secondary data were the baseline data of IFAD-CBARDP. Descriptive and inferential statistics (t-test) were utilized for analyses. The findings revealed that, majorities (51%) of respondents were males, with average age of 40 years. About 97% were married, having a household size of between 5-10 persons, with about 68% of the respondent having an educational attainment of primary and secondary school. The result revealed that IFAD-CBARDP had impacted significantly (P 0.1) on the income of respondents at 10% level of probability. The programme had also recorded an increase in the number of assets and employment opportunities provided, after the first phase of the Programme implementation. Satisfaction level of respondents with the infrastructure provided was generally satisfactory. Nevertheless, low level of awareness, cultural factors and inadequate capital were the major constraints to effective performance of the Programme. It is therefore recommended that IFAD-CBARDP should be replicated in other Local Government Areas of the State for wider livelihood improvement. Programme planners and implementers should intensify awareness creation among rural dwellers and adopt the use of Community Driven Development approach (CDD) in the execution of Rural Development projects with poverty alleviation thrust as in the case of IFAD-CBARDP.*

***Keywords*— Rural development, Economic prosperity, poverty alleviation, IFAD-CBARDP**

I. INTRODUCTION

Majority of the world's population live in rural areas where they are engaged in agriculture (Taimi, 2018). Developing countries and their rural areas in particular are characterized by poverty, unemployment, unequal distribution of resources, acute shortage of social, physical institutional infrastructure and increasing rural-urban drift (Williams, 2017). While Poverty is real, endemic and devastating, Nigeria's rural population accounts for over 70 percent of poor households - more than 98 million people, and about 17 million households. The 2003-2004 Nigeria living standard survey indicated that States in the Sahel region recorded the highest incidence of poverty, with about 80 per cent of the population described as poor (IFAD, 2010).

Nigeria's rural people are the most deprived of all Nigerians, having least access to services such as health, educational facilities, and access to modern agricultural input. In essence, infrastructural and institutional arrangements are deficient at the local level where most people who need them live (Voh, 2019).

According to Thor *et al.* (2015) rural transformation denotes a rapid improvement in the life of rural man and his physical environment. Whereas Smith (2013) opined that rural development is almost synonymous with agricultural development, which has been broadened recently to encompass the equitable and balanced transformation of complex social, economic, institutional, political, other relationships and process of rural development, including but not limited to agriculture, education, employment, health care and nutrition, voice in decision- making and actions that affect the lives of rural dwellers.

Similarly, Iro (2018) reported that, some of the rural development focused programs embarked upon by the Federal Government of Nigeria in the last three decades either lacked ecological and institutional focus and framework or members of the ruling party were favored at the expense of members of other parties. Presently with Maduagwu's (2017) comment that Nigeria has over the years embarked on many poverty alleviation programs but majority of these have had appreciable impact, one wonders if true poverty alleviation will not continue to be a mirage.

However, International Fund for Agricultural Development; Community-Based Agriculture and Rural Development Program (IFAD-CBARDP); is an integrated agriculture and rural development program aimed at improvement of livelihood and living conditions of the rural poor with emphasis on women and other vulnerable groups, especially physically challenged and dejected people. The program is jointly funded by International Fund for Agricultural Development (IFAD), Federal Government of Nigeria (FGN), and seven participating States -Borno, Jigawa, Katsina, Kebbi, Sokoto, Katsina and Zamfara; Sixty-nine (69) Local Government Councils (LGCs) in the seven states, where two hundred and seven (207) village areas (VAs) have been selected from the participating Local Government Councils and World Bank (WB) is the cooperating institution (IFAD, 2007).

Objectives of the Study

The broad objective of the study was to examine the effect of IFAD-CBARDP on rural livelihood in Katsina State, Nigeria. The specific objectives were to:

i. describe the socio-economic characteristics of respondents in benefitting communities;
ii. identify and describe the level of accessibility of basic infrastructure provided to the communities by the IFAD-CBARDP;
iii. determine the effect of infrastructure provided by IFAD-CBARDP on the livelihood of the communities;
iv. determine respondents' level of satisfaction with infrastructure provided by IFAD-CBARDP in the communities; and
v. identify and describe the constraints to the effective performance of IFAD-CBARDP in the study area.
vi. Description of study area

This study was conducted in Katsina State, one of the 36 States in Nigeria. The State lies between latitude 11 0 7' and 130 22' North and longitude 60 52' and 90 2'East of the Equator. It is situated within the Sahel-Sudan agro ecological zone of Nigeria. The National population census of 2006 put Katsina State at 5,792,579 people. At 3.2% growth rate projection, by 2013 when data were collected, Katsina State's population was expected to have increased to about 7,223,346 people. The number of farmer's families is 882,692 constituting 12.22% of the total population (NPC, 2006).

Sampling Procedure and Sample size

The study was carried out in three (3) Local Governments of Katsina Senatorial Zone namely Kaita, Jibia and Kusada LGA.

In order to examine the effect of IFAD-CBARDP on rural livelihood of the respondents, a multistage sampling technique was employed to get the respondents. In the first stage, three Local Government Areas were selected purposively, out of the IFAD-CBARDP benefiting LGAs in Katsina state. These were Kaita, Jibia and Kusada LGAs. The selection was based on easy accessibility, familiarity and spread. In the second stage, simple random sampling technique was used to select two benefiting villages from each Local Government Area, making a total of six villages. These are Yanhoho and Yandaki Kaita LGA, Dutsin Safe Daddara in Jibia LGA, Kofa and Yashe in Kusada LGA. Thirdly, the sample size was determined using raosoft calculator at 5% error margin as shown in the table below.

Table 1: Distribution of Sample Size by Local Government Areas

Local Government Areas	Beneficiary Villages	No. of Household Heads	Respondents 5%
Kaita	Yanhoho	180	54
	Yandaki	160	46
Jibia	Dutsin Safe	180	52
	Daddara	160	32
Kusada	Kofa	180	50
	Yashe	140	44
Total		**1,000**	**278**

Analytical Techniques

The following analytical and statistical tools such as: Descriptive statistics and inferential Statistics (t –test) were utilized to capture the stated objectives of the study.

Inferential statistics (t-test)

The t- test was used to determine the effect of infrastructure provided on the livelihood of respondents before the program and after the program implementation in the study area and to test the hypothesis of the study at (P< 0.1%) level of significance.

The general formula of the t-test is given as:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1{}^2 - s_2{}^2}{n_1 - n_2}}}$$

Where:

$t =$ t-value

$\bar{x}_1 =$ the mean sample of respondent's income in benefitting communities before initiating the IFAD-CBARDP.

$\bar{x}_2$ = the mean sample of respondent's income in benefitting communities after initiating the IFAD-CBARDP.

S^2 = sample standard deviation for respondents' income in benefitting communities before initiating the program.

S^2 = sample standard deviation for respondents' income in benefitting communities after initiating the program

n_1 = sample size of respondent's income in benefitting communities before the program.

n_2 = sample size of respondent's income in benefitting communities after initiating the program.

II. RESULTS AND DISCUSSION

Socio-economic Characteristics of Respondents.

The socio-economic characteristics of the respondents identified were: gender, age, marital status, household size, educational level, membership of cooperative societies, experience in IFAD-CBARDP and accessibility to credit are presented in Table 2 and explained below.

Table 2: Socio economic characteristics

Gender	Frequency	Percentage (%)
Male	185	66.5%
Female	93	33.5%
Total	**278**	**100%**
Age (Years)	Frequency	Percentage (%)
20 – 29	22	7.91
30 – 39	89	32.01
40 – 49	97	34.89

50 – 59	54	19.42
60 – 69	16	5.76
Total	**278**	**100%**
Status	Frequency	Percentage (%)
Single	89	32.01%
Married	175	62.95%
Widow	14	5.04%
Total	**278**	**100%**
Size	Frequency	Percentage (%)
1 – 5	62	22.30
6 – 10	142	51.08
11 – 15	37	13.31
16 – 20	23	8.27
21 – 25	14	5.04
Total	**278**	**100%**
Level	Frequency	Percentage (%)
No Education	81	29.14
Adult Education	54	19.42
Primary	133	47.84
Secondary	109	39.21
Tertiary	15	5.40
Others	27	9.71
Total	**278**	**100**
Years	Frequency	Percentage (%)
1 – 3	97	34.89
4 – 6	147	52.88
7 – 9	34	12.23
Total	**278**	**100%**
Years	Frequency	Percentage (%)
1 – 3	59	21.22
4 – 6	191	68.71
7 – 9	28	10.07
Total	278	100%
Status	Frequency	Percentage (%)
Accessible	113	40.65
Not Accessible	165	59.35
Total	**278**	**100%**

Source: Field work (2023)

From the Table above, the data revealed that 185 which constitutes 66.5% of the respondents were males and 93 of the respondents representing 33.5% were females. This showed that both genders were adequately represented in the IFAD-CBARDP, with slight variation in favor of male respondents.

The age of the respondents ranged between 30 to 49 years have the highest response. This implies that, the respondents were middle aged and still active and could participate adequately in development programs. The age distribution as evident in the data was expected to have positive influence on the respondent's participation in IFAD-CBARDP, which invariably meant better livelihood.

It was also observed that most of the respondents were married which consist of 175 representing 62.95%. This shows that most of the respondents would have greater responsibility than the single or widow, which may encourage respondents to be committed towards their participation in IFAD- CBARDP. Perez-Morales (2011). There is a trend for rural youth to start work responsibilities at an earlier age than urban youth. He further stated that normally, young people in rural areas get married earlier than their peers in urban zones. It means that rural youth become involved in adult responsibilities before urban youth.

The house hold indicate that about half (51.08%) of the respondents had 6-10 people in their households, while, 22.30% had household size of less than 5 people. This implies that respondents had dependents to cater for and their participation in programmes like IFAD-CBARDP could help in engaging them on the farm and improving their livelihood.

On educational qualification more than half (78%) of the respondents had educational qualifications mostly primary and secondary school level. Such level of education may facilitate the respondents' participation in the IFAD-CBARDP. The respondents with no formal education were about 22%, of the respondents.

The Participants of IFAD-CBARDP belong to cooperative society; the maximum number of years spent as members of cooperative society was 9 years and a minimum of 1 year. The result revealed that, respondents with 4 – 6 years of membership duration constitute 53% while 35% had 1-3 years of membership of cooperative society. With this level of membership duration, it could be said that majority of the respondents have had long duration of experience as members of cooperative group which can facilitate understanding of the programme due to interaction among members.

The result in the above table revealed that, the majority (69%) of the beneficiaries had between 4 and 6 years of experience in IFAD-CBARDP activities in the programmme. Whereas 21% of the respondents had experience of 1 to 3 years and the lowest percentage was (10%) which falls within 7 to 9 years of experience in IFAD-CBARDP. These years of experience in the programme were expected to translate into better utilization and understanding of the programme which may invariably result into better income as well as standard of living.

It was also observed in the table above that 59% of the respondents had no access to credit facilities. This low access to credit could be attributed to the fact that IFAD-CBARDP seldom grants financial credit to participants. Rather, participants are trained in entrepreneurial development. Ekong (2003) asserts that credit is a very strong factor that is needed to acquire or develop any enterprise; its availability could determine the extent of production capacity.

Table 3: Distribution of infrastructure Provided in order of respondent's benefits (n=278)

Infrastructure	*Frequency	Percentage	Ranking
Water/Borehole	256	92.09	1st
Schools	224	80.58	2nd
Health centre	202	72.67	3rd
Para vet clinic	76	27.34	4th
Culvert	41	14.75	5th
Market shade	37	13.31	6th
Vocational Centre	21	7.56	7th
Latrine	18	6.47	8th
Staff Quarters	9	3.24	9th

***Multiple responses**

The table above shows that provision of water/borehole ranked 1st among the infrastructure provided by IFAD-CBARDP in the study area accessible to about 92% of the respondents. Schools provided ranked 2nd among the infrastructure provided accessible to 80% of the respondents. This could improve the level of literacy in the area of study and subsequent economic development. Other infrastructure accessible to the respondents were health centres (72%), Para vet clinic (27%), culvert (14%) and Market shade (13%) which were ranked 3rd and 4th. Staff quarters was the least accessible infrastructure to the respondents and ranked 9th with 3% of the sampled respondents highlighting accessible to the infrastructure. Hence, the functional status of these amenities provided may bring about income savings stemming from reduced expenditure on the items which can be diverted to other areas of consumption such as food which may improve the feeding standard of the respondents. Thus, the infrastructure in question may bring about development to the area of study which may transform the lives of the residents as well as improve their livelihood.

Effect of IFAD-CBARDP on Assets of the Beneficiaries

Table 4: Distribution of respondents according to assets possessed (n = 278)

Assets owned by respondents	*No of items owned before Prog.	*No of items owned after Prog.	Differential
Radio	58	82	24
TV	36	53	17
VCD	36	58	22
Refrigerator	20	48	28
House purchased	16	23	7
House Built	22	35	13
Bicycle	10	19	9
Motorcycle	25	32	7
Car	3	9	6
Lorry	2	6	4
Pick up Van	8	14	6

*** Multiple Responses**

The result in the Table above revealed that, there was an increase in information asset acquisition (radio, 24; TV, 17 and Compact disc, 22) by respondents after the first phase of IFAD- CBARDP. This is an indication that the level of awareness and enlightenment among the respondents is on the increase. There were increases in the number of houses purchased and built as well as household property such as refrigerator. Generally, there was a significant improvement on the rate at which the respondents acquired properties. This is an indication that over the years of the program income of the respondents increased. This indicated that, IFAD-CBARDP had been able to have positive effect to the respondents' livelihood in terms of ownership of assets by respondents. This is in line with the report of IFAD (2011) on Women's Empowerment Mainstreaming and Networking (WEMAN) under IFAD where, the program reported a concrete positive change on women in terms of secure access to land, division of labour between women and men, increased quality of produce, equal sharing of benefits and increasing incomes of the participants.

Hypothesis testing

Table 5: Effect of IFAD-CBARDP on the income of respondents (n= 278)

	N	Before	After	Differential
Mean annual Income	278	₦155, 613	₦ 241, 603.8	₦ 85,990.8
Variance		3.597E+10	9.75E+10	
t – Cal		1.98*		
t – Critical		1.65		

*Significant at (p< 0.1%) level of probability

The results as presented in the Table above revealed the respondents mean annual income before the program (₦155, 613) and after the program implementation (₦241, 603.8) per annum, with a differential amount of ₦85, 990.8. The data were also tested using t-test independent sample. The result indicated that, t-cal (1.98) was greater than the t-critical (1.65). Therefore, the mean difference on the income of respondents before and after the IFAD-CBARDP implementation was significant at (p 0.1) level of probability.

Employment Opportunities provided by IFAD-CBARDP

Table 6: Employment Opportunity Provided by IFAD-CBARDP (n =278)

Employment opportunities	*Frequency	Percentages(%)
Trading	221	79.45
Carpentry	220	79.14
Blacksmithing	178	64.03
Food processing	224	80.58
Tailoring	235	84.53
Embroidery making	188	67.63
Knitting	188	67.63
Bricklaying	163	58.63
Fishing	161	57.91

***Multiple responses**

From the above Table, it was observed that among the employment opportunities provided by IFAD CBARDP, most respondents (84%) participated in tailoring, followed by food processing (80%), trading (79%), carpentry (79%), knitting and embroidery making (67%), blacksmithing (64%), and fishing was the least (57%) participated employment opportunity by respondents. As evident from the result in the Table, the programme had various packages of employment opportunities' that really engaged the respondents in relevant areas of specialization. Involvement of the respondents in various activities of the programme could generate more income thereby improving the livelihood of respondents. Lawanson (2012) revealed the universality of informal economic activities particularly home-based enterprises, as a major source of employment and income in urban and rural areas.

Respondents' Level of Satisfaction with the Infrastructure Provided

Table 7: Respondents' satisfaction level with infrastructure provided (n=278)

Infrastructure	Total weighted scores	Mean weighted scores	Overall perception
Farm inputs	4455	3.9	High
Voc. Centres	4040	3.8	High
Water/ Borehole	4317	3.7	High
Health facilities	4575	3.5	High
Schools	4642	3.4	High
Credit facilities	5617	2.8	Low

Provision of farm inputs

It was observed that the respondents recorded high satisfaction with provision of farm inputs provided by IFAD-CBARDP as indicated by the weighted mean ($\overline{X}$) which exceeds the mean score of 3.9 which is >3 (Table 4.14). From the result, the respondents may experience improvement in farm productivity as well as encouragement in the area of farming and other related activities.

Vocational skills/ training centres

Result presented in Table 4.14 revealed that the respondents' perception with vocational skills/centres provided by IFAD-CBARDP was high because weighted mean ($\overline{X}$) of 3.8. was recorded. This result may mean that provision of vocational skills has created employment / skills acquisition opportunities for the benefitting respondents which may have resulted to higher income generation and invariably better livelihood

Provision of water/borehole

It was observed in Table that provision of water by IFAD CBARDP recorded high satisfaction to the respondents with weighted mean of 3.7 which exceeds the mean ($\overline{X}$) score of 3. Therefore, the respondents were satisfied with the water/ borehole provided by the programme. Water, a necessity of life is provided by the programme to aid level of living and minimise scarcity. Thus, provision of water had brought about improvement in water supply which minimizes cost of water procurement in benefitting communities.

Health Facilities Provided

The weighted mean ($\overline{X}$) for health facilities provided by the programme was presented in

Table 4.12. It revealed high satisfaction with a weighted mean of 3.5 implying an overall perception of satisfaction with health facilities provided because the weighted mean was greater than the mean ($\overline{X}$) score of 3. The result therefore indicates that provision of health

facilities would upgrade the health status of the benefitting respondents. Provision of health facilities in the area also implies that diseases can easily be eradicated, thereby improving the health status of benefitting communities for improved labour force.

Provision of Schools

The result in Table 4.13 revealed high satisfaction with provision of schools in the area. The weighted mean of satisfaction level obtained from the respondents was 3.4, exceeding the mean ($\overline{X}$) score of 3. Provision of schools may bring about upgrading of the educational status of the residents in benefitting communities, which invariably reduce the level of illiteracy, improvement in the enrolment of pupils as well as saving of income which could have been used for taking the pupils to other places for education. Formal education serves as a spinning factor for adoption and participation of individuals in programmes.

Credit facilities

Result for the level of satisfaction for credit facilities provided by the programme indicated a weighted mean ($\overline{X}$) of 2.8 which is lower than the mean score ($\overline{X}$ = 3) of satisfaction

perception by the respondents (Table 4.13), meaning that provision of credit facilities have not met the satisfaction level of the respondents. This implies that, the beneficiaries need other forms of credit to boost their productivity which would bring about improved standard of living. If credit is invested into an enterprise it is expected that it should lead to higher levels of output and better standards of living, but in case the credit is not accessed on time and inadequate, it may, more often than not, lead to misapplication of funds. Hence, the expected effect of such funds will not be felt on the enterprise. Also, if the credit is invested in consumption purpose, it may not likely lead to an improvement of output or livelihood.

Constraints Faced by Respondents in IFAD-CBARDP.

Table 8: Constraints encountered by beneficiaries of IFAD-CBARDP (n=278)

Constraints	*Frequency	Percentages	Ranking
Low awareness	161	57.91	1st
Cultural barrier	152	54.68	2nd
Inadequate capital	143	51.44	3rd
Illiteracy	120	43.17	4th
Inadequate facilities	120	43.17	4th
Inadequate mobility	16	5.76	5th
poor leadership	13	4.68	6th

***Multiple responses**

This section analysed the constraints faced by the beneficiaries of the programme. Various factors such as low level of awareness, cultural barriers, inadequate capital and illiteracy were ranked 1st, 2nd, 3rd and 4th respectively (Table 4.14) as factors affecting the programme. Information creates awareness, which can lead to development. Most of the respondents were noticed to be married women, according to the culture, they are not supposed to associate with other people especially men. This impedes information and participation of an individual in a programme.

III. CONCLUSION

This study was aimed at providing useful and basic information on the effect of IFAD- CBARDP on the livelihood of the participants. It was found that rural infrastructure provided was beneficial and mostly satisfactory to the beneficiaries of the programme. Hence, the assets and income of participants‟ as well as employment/ skills acquisition opportunities had also increased as a result of the programme intervention. Respondents‟ satisfaction level on infrastructure provided by IFAD-CBARDP was high. The null hypothesis which stated that "IFAD-CBARDP have not improved the livelihood of people in benefitting communities in the study area" was rejected and the alternative accepted. Meaning that, IFAD-CBARDP had improved the livelihood of people in benefiting communities of the study area. It was therefore concluded that, IFAD-CBARDP had impacted positively on the lives of the beneficiaries in Katsina State, Nigeria.

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Direct sowing-Alternate Method of Transplanting Rice

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***Abstract*— *Rice (Oryza sativa) is the major food crop in terms of production and economy and grown in all ecological regions of India. Rice is cultivated traditionally through transplanting of 20-25 days old seedling in the country. Due to unavailability of suitable technology for rice cultivation, there is a huge yield gap in rice production. Country has made target of self-sufficiency in rice production. This target can be achieved through adoption of Direct seeded rice cultivation technology of rice cultivation which also helps to adapt in the climate change scenario. Due to issues of water scarcity and expensive labour, direct seeded rice cultivation technology is adopting worldwide. To study the direct sowing of rice to overcome the difficulty of scarce and costly labor in transplanted rice, KVK Guntur has conducted an OFT in Guntur district. The study was carried out **in** two villages of Guntur district namely Morampudi and Kanteru villages in the years 2019-20 and 2020-21. From each selected village, 5 farmers practicing DSR and 5 farmers practicing Conventional Transplanting method during the same season were selected. The average yield was considerably high in TR (67 qtl/ha) compared to DSR (66 qtl/ha) method of cultivation. The total cost of cultivation in DSR was estimated to be Rs.47,000 per hectare. The total cost of cultivation in TR was estimated to be Rs. 53,000 per hectare. DSR with suitable conservation practices has potential to produce slightly lower or comparable yields as that of TPR and appears to be a viable alternative to overcome the problem of labor and water shortage. Despite controversies, if properly managed, comparable yield may be obtained from DSR compared with TPR.*

***Keywords*— Direct seeded rice, Transplanted rice, weed management, on farm trail**

I. INTRODUCTION

Rice (Oryza sativa) is the major food crop in India and occupies highest area among the cereal crops. Rice provides about 20 per cent of the global average calorie intake and its cultivation occupies 11 per cent of world agricultural land. Asia dominates the world in rice production as it accounts for about 90 per cent of world's rice area and 92 per cent of production. Direct seeded rice in Asia occupies about 28.3 Mha which is approximately 21 per cent of the total rice area in the region (Toriyama, 2005). Countries like USA and Australia extensively practicing direct seeding of rice are with profitable results as it avoids all the negative externalities in transplanting.

Rice is cultivated in India in a very wide range of ecosystems from irrigated to shallow lowlands, mid-deep lowlands and deep water to uplands. In India, transplanting is the mostly adopted method of rice establishment. However, depletion of water resources is forcing farmers to shift to Direct Seeded Rice (DSR). The direct seeding of rice refers to the spreading of seeds in fields before or immediately after pre-monsoon showers.

The need to increase productivity against rising labour costs for transplanting has led to a considerable increase in directs seeding in recent decades, particularly in South and Southeast Asia. The main motivating factor for shift in rice establishment method from transplanting to direct seeding in India is response to labour scarcity

(Balasubramanian, 2002) and lack of technically feasible transplanters. Direct seeded rice, a common practice before green revolution in India, is becoming popular once again because of its potential to save water and labour (Gupta et al.,2006).

Due to water scarcity and expensive labour, direct seeded rice cultivation technology is adopting worldwide. Direct seeded rice is a resource conservation technology and reduces water and labor use by 50%. Productivity of DSR is 5-10% more than the yield of transplanted rice. It offers a very exhilarating opportunity to improve water and environmental sustainability.

Direct seeding can be categorized as (1) Wet-DSR, in which sprouted rice seeds are broadcast or sown in lines on wet/puddled soil, and (2) Dry-DSR, in which dry rice seeds are drilled or broadcast on unpuddled soil either after dry tillage or zero tillage or on a raised bed. Another category of DSR is water seeding, in which sprouted rice seeds are broadcast in standing water. Wet-DSR is primarily done to manage the labor shortage, and is currently practiced in Malaysia, Thailand, Vietnam, the Philippines, and Sri Lanka. Furthermore, weed infestation is the major problem, which can cause large yield losses in direct seeded rice. Weed management in DSR can be done through chemical, hand weeding or stale seed bed method.

II. MATERIAL AND METHODS

The study was carried out **in** two villages of Guntur district namely Morampudi and Kanteru villages in the years 2019-20 and 2020-21. The major soils of this area are shallow to deep black soils. From each of the selected villages farmers were selected based on the extent of area under cultivation. From each selected village, 5 farmers practicing DSR and 5 farmers practicing Conventional Transplanting method during the same season were selected.

Table 1. Classification of direct-seeded rice (DSR) system

S.NO	System of direct seeding	Seed bed condition and environment	Sowing method practiced	Suitable ecology /environment
1.	Direct seeding in dry bed	Dry seeds are sown in dry and mostly aerobic soil	Broadcasting, Drilling or sowing in rows at depth of 2-3 cm	Mainly in rain fed area, some in irrigated areas with precise water control
2.	Direct seeding in wet bed	Pre germinated seeds sown in puddled soil, may be aerobic or anaerobic	Various	Mostly in favorable rainfed lowlands and irrigated areas with good drainage facility
3.	Direct seeding in Standing Water	Dry or Pre germinated seeds are sown mostly in anaerobic condition in standing water	Broad casting on standing water of 5-10 cm	In areas with red rice or weedy rice problem and in irrigated lowland areas

Source : (Joshi *et al*., 2013)

III. RESULTS AND DISCUSSION

In DSR the total cost of cultivation was found to be lower by 11.32 per cent (Rs.47,000/ha) when compared to TR (Rs.53,000/ha) method of cultivation. The total cost of cultivation in DSR was estimated to be Rs.47,000 per hectare. The total cost of cultivation in TR was estimated to be Rs. 53,000 per hectare (Table 2).

The average yield was considerably high in TR (67 qtl/ha) compared to DSR (66 qtl/ha) method of cultivation. The actual percentage yield difference is approximately **1.49%**, with TR yielding more than DSR. The gross returns obtained were Rs.1,21,605 and Rs.1,19,790 per ha for TR and DSR of rice cultivation respectively. The net returns were higher in DSR (Rs.72,790/ha) than that of TR (Rs.68,605/ha), this was due to high cost of cultivation in transplanted rice. The results were on par with the findings of Vinay et al. (2016) whose results showed that net returns were higher in direct seeded rice when compared to transplanted method of paddy cultivation. This was compliant with the findings of Yadav et al. (2013).

Table 2. Comparative cost of cultivation of paddy under TPR and DSR methods

Details	Transplanted rice (Rs per hectare)	Details	Direct seeded rice (Rs per hectare)
Land Preparation Cost (Ploughing, levelling, and puddling)	10000	Land Preparation Minimal, as less puddling is required:	9000
Labour Cost (Nursery preparation and transplanting)	9000	Labor Cost (Direct seeding and subsequent weeding)	5000
Seed cost	3000	Seed cost (Higher seed density)	4000
Water cost (Continuous flooding)	14000	Water cost	12000
Other costs (fertilisers and pesticides)	9000	Other costs (fertilisers and pesticides)	9000
Plant protection measures (weeds, insect pests and disease control)	8000	Plant protection measures (weeds, insect pests and disease control)	8000
Total cost of cultivation	53,000	Total cost of cultivation	47,000
Yield (q/ha)	67	Yield (q/ha)	66
Gross returns	1,21,605	Gross returns	1,19,790
Net returns	68,605	Net returns	72,790
B: C Ratio	1.2:1	B: C Ratio	1.5:1

IV. CONCLUSION

DSR looks to be a good substitute for TPR in light of the manpower and water shortage issues. With the right conservation techniques, DSR can deliver yields that are somewhat lower or comparable to TPR values. Disagreements notwithstanding, DSR can give yields that are comparable to TPR if handled correctly. DSR crops may partially or completely fail because to weeds if they are not effectively controlled. The dynamics of nutrients in soils under DSR require a great deal of investigation on the scientific front. Additionally, studies are required on weed control in DSR and soil ecology in rice fields. A site-specific production technology package for various rice production systems must be developed under various rice production zones.

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Performance Analysis of Front-Line Demonstrations on Green Gram (*Vigna Radiate* l.) in Jodhpur District of Western Rajasthan

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***Abstract*— *Pulses being rich in quality protein, minerals and vitamins are inseparable ingredients of diet of majority of indian population. Despite high nutritive value of pulses and their role in sustainable agriculture desired growth rate in production could not be witnessed. The domestic production of pulses is consistently below the targets and actual domestic requirements are also higher, due to this pulses are being imported. The Krishi Vigyan Kendra, Jodhpur-II (Phalodi) has carried out frontline demonstrations on greengram crop varieties GM-6 and IPM 205-7 covering an area of 30 ha of farmer's field to exhibit latest production technologies and compared it with farmer's practice. The study in total 50 frontline demonstrations were conducted on farmer's fields in villages viz. Kali-mali and Baori of Jodhpur district of Rajasthan state during 2020 and 2022, to demonstrate production potential and economic benefit of improved technologies comprising sowing method, nutrient management and chemical weed management and adoption of whole package of practices for crop. After sowing of seed, application of weedicide Imazethapyr 10SL as early post emergence at 50 gm a.i. per ha in 500 liters of water used for effective control of the weeds during kharif season in rainfed condition. The findings of the study revealed that the demonstrated technology recorded a mean yield of 687 kg/ha which was 23.7 % higher than obtained with farmers practices (555 kg/ha). Higher mean net income of Rs. 31285/ha with a Benefit:cost ratio of 3.05 was obtained with improved technologies in comparison to farmers practices (24710).The frontline demonstrations conducted on greengram crop at farmer's field revealed that the adoption of improved technologies significantly increased the yield as well as yield attributing traits of crop and also the net neturns higher than the farmer's practices. So, there is a need to disseminate the improved technologies among the farmers with effective extension methods like training and demonstrations. The farmers should be encouraged to adopt the recommended package of practices realizing for higher returns.*

***Keywords*— Adoption, Frontline demonstration, Greengram, Productivity**

I. INTRODUCTION

Pulses are the major source of dietary protein for the majority of population in our country. Besides being the source of protein, pulses contribute substantially to food production system by enriching the soil through biological nitrogen fixation and improving soil physical conditions. Though pulses are consumed all over the world, its consumption is higher in those parts of the world where animal proteins are scarce and expensive (Ofuya and Akhidue, 2005). Pulses are important food crop for human consumption and animal feed. Being leguminous in nature, they are considered to be important components of cropping system because of their viability to fix atmospheric nitrogen, add substantial amounts of organic matter to the soil and produce reasonable yields with low inputs under harsh climatic and soil conditions (Rakhode *et al*. 2011). Moong- wheat cropping system is predominant and its continuously practiced by farmers in the arid zone of Rajasthan (Dhaka *et al*. 2016). There is evidence of system productivity stagnation, nutrient water imbalances and increased insect-pest and diseases incidence due to prolonged use of this cereal dominated system source. Greengram (*Vigna radiate* L. Wilczek.) is the third important pulse crop in india. It can be grown both as *kharif* greengram and summer greengram. With the advent of short duration, MYMV (Mungbean yellow mosaic virus) tolerant and synchronous maturing varieties of greengram (55-60 days) there is a big opportunity for successful cultivation of greengram in greengram-wheat rotation without affecting this popular cropping pattern.

Greengram belonging to family leguminoseae, is a tropical and sub-tropical grain legume, adapted to different types of soil conditions and environments (*kharif, spring and summer*). It ranks third in India after chickpea and pigeonpea. It has strong root system and capacity to fix the atmospheric nitrogen in to the soil and improves soil health and contributes significantly to enhancing the yield of subsequent crops (Tomar *et al.* 2012). Greengram yield is also affected by insects-pests and diseases, especially by greengram yellow mosaic virus (GYMV) and *Cercospora* leaf spot (CLS). There is a strong need to develop the lines/varieties which give outstanding and consistent performance in *kharif* season over diverse environment. Development of varieties with high yield and stable performance is a prime target of all greengram improvement programmes. The total production of pulses in India was 25.42 million tonnes from the area of 29.80 million hectares with the productivity of 853 kg/ha (Anonymous, 2020). Whereas, in Rajasthan, the total *kharif* pulses production was 3.57 million tonnes from the area of 5.53 million hectares with productivity of 639 kg/ha (Anonymous, 2019). The greengram production among *kharif* pulses was 1.09 million tonnes from the area of 2.39 million hectares with productivity of 458 kg/ha in Rajasthan (Anonymous, 2023). In Jodhpur district, the greengram crop is grown in an area of 258797 ha with an annual production of over 153840 million tons (GOR, 2023).

The Front Line Demonstration is an important method of transferring the latest package of practices in totality to farmers. By which, farmers learn latest technologies of oilseeds and pulses production under real farming situation at his own field. Further, these demonstrations are designed carefully where provisions are made for speedy dissemination of demonstrated technology among farming community through organization of other supportive extension activities, such as field days and farmers convention. The main objective of the Front Line Demonstration is to demonstrate newly released crop production and protection technologies and management practices at the farmers' field under different ago-climatic regions and farming situations. While demonstrating the technologies at the farmer's field, the scientists are required to study, the factors contributing to higher crop production, field constraints of production and thereby generating production factor and feed-back information. Front Line Demonstrations are conducted in a block of ten hectares of land in order to have better impact of the demonstrated technology on the farmer's and field level extension functionaries with full package of practices. Keeping in view the present study was done to analyze the performance and to promote the Front Line Demonstration (FLD) on greengram production.

I. MATERIALS AND METHODS

Present study was conducted on FLD greengram in rainfed condition in Jodhpur district of Rajasthan state. In total 50 frontline demonstrations were conducted on farmers' field in villages of Kali-mali and Boari of Jodhpur district of Rajasthan, during *kharif* season 2020 and 2022 in rainfed condition. Each demonstration was conducted on an area of 0.4 ha, adjacant-to the demonstration plot was kept as farmer's practices. The package of improved technologies like line sowing, nutrient management, seed treatment and whole package were used in the demonstrations. The variety of greengram GM-6 and IPM 205-7 were included in demonstrations methods used for the present study with respect to CFLDs and farmer's practices are given in Table 1.

In case of local check plots, existing practices being used by farmers were followed. In general, soils of the area under study were Loamy fine to Coarse and medium to low in fertility status. The spacing was 30 cm between rows and 10 cm between plants in the rows. The thinning and weeding was done invariably 35-40 days after sowing to ensure recommended plant spacing (10 cm) within a row (30 cm) because excess population adversely affects growth and yield of crop. Seed sowing was done in the first week of July, with a seed rate of 20 kg/ha. Other management practices were applied as per the package of practices for *kharif* crops by Department of Agriculture, Agro-climatic ZoneIa - Arid Western Plains Zone (DOA, 2022). Data with respect to grain yield from CFLD plots and from fields cultivated following local practices adopted by the farmers of the area were collected and evaluated. Potential yield was taken in to consideration on the basis of standard plant population (404440 plants/ha) and average yield per plant 22.5 gm/plant under recommended package of practices with 30 X 10 cm crop geometry (Chandra, 2010). Different parameters as suggested by Yadav *et al.* (2004) was used for gap analysis, technology index and calculating the economics parameters of greengram. The details of different parameters and formula adopted for analysis are as under:

Extension gap = Demonstration yield – Farmer's practice yield

Technology gap = Potential yield - Demonstration yield

Technology index = Potential yield - Demonstration yield/Potential yield x 100

Additional cost (Rs.) = Demonstration Cost (Rs.) - Farmers' Practice Cost (Rs.)

Effective gain = Additional Returns (Rs.) - Additional cost (Rs.)

Additional returns = Demonstration returns (Rs.) - Farmer's practice returns (Rs.)

B: C ratio =Gross Returns/ Gross Cost

Table 1. Package of practices followed by farmers under FLD

Particulars	**Technology Interventions**	**Farmer's practices**
Variety	GAM-5, GM-6, IPM 205-7 and MH-421	Local cultivar
Seed rate	20 kg/ha	15 kg/ha
Soil treatment	Trichoderma spp. @ 2.5 kg/ha cultured with 100 kg FYM	No use
Seed treatment	Carbendazim 50 WP @ 2.0 g/kg Seed	No seed treatment
Time of sowing	First week of July	Second week of July
Method of sowing	line sowing, 30 cm (row to row) and 10-15 cm (plant to plant)	Broadcasting
Fertilizer management	15:40:0 (NPK kg/ha)	Use of urea 50 kg/ha and DAP 150 kg/ha
Weed management	Early post emergence application of Imazethapyr 10 SL 500 ml/ha followed by manual weeding at 35-40 DAS	No use
Water management	Light irrigation at flowering and pod formation stage	No use
Plant protection	Sucking pests - Dimethoate 30 EC @ 1 lit./ha and Imidacloprid 200 SL @ 150 ml/ha Pod borer - Quinalphos 25 EC	Products suggested by local pesticide dealers

II. RESULTS AND DISCUSSION

Seed yield (kg/ha): The productivity of greengram under improved production technology ranged between 640-735 kg/ha with mean yields of 687 kg/ha and overall production 1375 kg/ha in two years (Table 2). The productivity under improved technology was 640 and 735 kg/ha during 2020 and 2022, respectively as against a seed yield range between 530 to 580 kg/ha under farmer's practice. In comparison to farmer's practice, there was low than CFLD plots of 20.75 and 26.72% in productivity of greengram under improved technologies in 2020 and 2022, respectively. The increased grain yield with improved technologies was mainly because of line sowing use of nutrient management and weed management. The present findings confirm the findings of Singh and Meena (2011), Poonia and Pithia (2011), Meena*et al.* (2012). Math *et al.* (2012), Raj *et al.* (2013) and Meena and Singh (2017). They found more gain yield of CFLD plots than the existing practices.

Gap analysis: Evaluation of findings of the study (Table 3) stated that an extension gap of 110 to 155 kg/ha was found between demonstrated technology and farmer's practice and on average basis the extension gap was 132.5 kg/ha. The extension gap was highest (155 kg/ha) during 2022 and lowest (110 kg/ha) during 2020. Such gap might be attributed to adoption of improved technology especially high yielding variety (IPM 205-7)sown with the help of seed cum fertilizers drill with balanced nutrition, weed management and appropriate plant protection measures in demonstrations which resulted in higher grain yield than the traditional farmer's practices. The study further exhibited a wide technology gap during different years. It was lowest (460 kg/ha) during 2020 and highest (466 kg/ha) during 2022. The average technology gap of both the years was 463 kg/ha. The difference in technology gap in different years is due to better performance of recommended varieties with different interventions and more feasibility of recommended technologies during the course of study. Similarly, the technology index for all demonstrations in the study was in accordance with technology gap. Higher technology index reflected the inadequate transfer of proven technology to growers and insufficient extension services for transfer of technology. On the basis of two years study, overall 40.27% technical index was recorded, which was lowest (38.75 %) during 2022 and highest (41.80%) during 2020. Hence, it can be inferred that the awareness and adoption of improved varieties with recommended scientific package of practices have increased during the advancement of study period. These findings are in the conformity of the results of study carried out by Chandra (2010), Meena and Singh (2016), Meena and Singh (2017), Singh and Chauhan (2010), Dayanand *et al.* (2012), Meena *et al.* (2012) and Rajni *et al.* (2014).

Table 2. Technical impact of green gram crop demonstrations during 2020 & 2022

S. No	Crop	Variety	Technology Demonstrated	Area (ha.)	No. of Demonstration	Potential yield (q/ha)	Yield of the crop under demonstration (Kg/ha)			Yield under local check (Kg/ha)	Increase in yield (%)
							Highest	Lowest	Average		
1	2	3	4	5	6	7	8	9	10	11	12
2020	Green gram	GM-6	Timely sown HYV	10	25	11	700	490	640	530	20.75
2022	Green gram	IPM 205-7	Timely sown HYV	20	25	12	900	660	735	580	26.72
Average	-	-	-	15	25	12	800	575	687	555	23.73

Table 3. Yield gap of variety of green gram crop during investigation year

Years	Variety	Technology gap (Kg/ha)	Extension gap (Kg/ha)	Technology index (%)
2020	GM-6	460	110	41.80
2022	IPM 205-7	466	155	38.75
Average	-	463	132.5	40.27

Table 4. Economic impact of green gram crop

Variety	Average Cost of Cultivation (Rs./ha)		Additional cost in demo. (Rs./ha)	Average Gross Return(Rs./ha)		Average Net Return (Rs./ha)		Additional returns in demo. (Rs./ha)	Benefit-Cost Ratio	
Plots	Demonstration plot	Local check plot	-	Demonstration plot	Local check plot	Demonstration plot	Local check plot	-	Demonstration plot	Local check plot
2020	14910	13690	1220	41990	34450	27080	21760	5320	2.81	2.71
2022	15210	13290	1920	50700	40950	35490	27660	7820	3.30	3.07
Average	15060	13490	1570	46345	37700	31285	24710	6570	3.05	2.89

Economics: Different variables like seed, fertilizers, bio-fertilizers and pesticides were considered as cash input for the demonstrations as well as farmers practice and on an average additional investment of Rs. 1570 per ha was made under demonstrations. Economic returns as a function of gain yield and Minimum Support Price (MSP) sale price varied during different years. The maximum returns (Rs. 50770) during the year 2022 were obtained due to high grain yield and higher MSP sale rates as declared by GOI. The higher additional returns and effective gain obtained under demonstrations could be due to improved technology, non-monetary factors, timely operations of crop cultivation and scientific monitoring. The lowest and highest benefit cost ratio (BCR) were 2.8 and 3.3 in 2020 and 2022, respectively (Table 4) depends on produced grain yield and MSP sale rates. Overall average BCR was found 3.05. The results confirm with the findings of front line demonstrations on pulses by Yadav *et al.* (2004), Gauttam *et al.* (2011), Lothwal (2010), Chaudhary (2012), Dayananda *et al.* (2012), Meena and Dudi (2012) and Meena and Singh (2017).

III. CONCLUSION

It is concluded that Front Line Demonstrations (FLD) was an effective tools for increasing the productivity of greengram. The frontline demonstrations conducted on greengram at the farmers' field revealed that the adoption of improved technologies significantly increased the yield as well as yield attributing traits of the crop and also the net returns to the farmers. So, there is a need to disseminate the improved technologies among the farmers with effective extension methods like training. Kisan ghosthies, field days, exposure visits and demonstrations. The farmer's should be encouraged to adopt the recommended package of practices realizing for higher returns. This created greater curiosity and motivation among other farmers who do not adopt improved practices of greengram cultivation. These demonstrations also built the relationship and confidence between farmers and scientists of KVK. It was also concluded that beside other practices of weed management, insect-past management and water stress to be given due to attention to enhance greengram production in the area. This will subsequently increase the income as well as the livelihood of the farming community of the district.

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Rethinking Food Processing for a Sustainable Future: A Review of Innovative Nonthermal Technologies

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Abstract— *Agricultural innovation offers a solution to mounting pressures on the global food system, which must provide safe, nutritious, and environmentally sustainable consumable goods at increasing volumes if demands are to be met. The potential of nonthermal technologies as promising alternatives to conventional thermal treatments for sustainable food processing and preservation is discussed in this review. Here we investigate four of such emerging nonthermal technologies that include High-Pressure Processing (HPP), Pulsed Electric Fields (PEF) and Irradiation, and Cold Plasma. This blog takes a deeper dive into its principles, use cases, and pros and cons. On the other hand, nonthermal technologies are energy-sparing, improve the nutritional quality of food products, and reduce loss due to processing but above all provide improved environmental performance. The energy-saving potential of these technologies can be large, while maintaining food in its original nutritive and sensory shape but with extended shelf life and lower carbon footprint. Nevertheless, scalability, cost-efficacy regulatory approval, consumer acceptance (Diaz-Ruiz Pletsch Concordet; Chellaram Barragan Maheswari), integration with the reference's infrastructure, or optimized process parameters are themselves challenging. Developing a solution to these challenges and promoting nonthermal processing technologies are strategic priorities that will be critical for future food production... With time, advances in research and developments of this important field would give rise to the wide-scale application of nonthermal processing This review aims to provide a full overview of potential benefits entailed by each innovative technique along with its limitations as well as informing stakeholders and future directions.*

Keywords— ***HPP, PEF, FAO, Cold Plasma, O2***

I. INTRODUCTION

The global food system is being shaped under intense pressure to produce enough safe, nutritious, and environmentally responsible for a world population of over 7 billion (Varzakas & Smaoui, 2024). Mechanized food processing is one solution to this problem (Zou & Mishra, 2024). Still, it inefficiently uses water and energy, providing yet another barrier to traditional farming (FAO 2017) which will be needed more than ever as the world population reaches 9.7 billion by 2050 (Nadathur, Wanasundara, Marinangeli, & Scanlin, 2024). Although these traditional thermal processing methods efficaciously guarantee the safety of food and prolong its shelf-life, they have drawbacks that further harm the sustainability of their respective food systems (Rabiepour, Zahmatkesh, & Babakhani, 2024). The thermal techniques require a lot of energy, use considerable amounts of water, and can have some changes in the food quality from nutritional (to sensorial (Fang et al., 2023). As a result, research efforts have been aimed at non-conventional and advanced technologies as promising alternatives to thermal treatments in the context of sustainable food processing and preservation (Safwa, Ahmed, Talukder, Sarker, & Rana, 2023). Nonthermal processing implies that the techniques used do not rely on heat to inactivate microorganisms, and enzymes and influence biochemical reactions taking place within food products (Allai, Azad, Mir, & Gul, 2023). Thus, these methods promise to be more energy-efficient and environmentally benign alternatives for processing food with retention of the nutritional, sensory as well and functional properties (Ali, Liao, Zeng, Manzoor, & Mazahir, 2024). In this broad review paper, we explore the nascent nonthermal technologies that are poised to change our approach to how food is processed and distributed. In this section, we will explore a wider spectrum of technologies including high-pressure processing (HPP), pulsed electric fields (PEF), cold plasma, and irradiation to understand how they work, where they are used currently or proposed in the future for positive input into promoting sustainability within our global food system. High-pressure processing (HPP) is a non-thermal technology based on the use of pressure at high levels of up to 600 MPa that inactivates microorganisms and enzymes while preserving all sensory, and nutritional qualities of food products (Keyata & Bikila, 2024). The value of this technology has been demonstrated across a range of commodities from juices, guacamole, ready-to-eat meats, and shellfish being shelf life extended without thermal pasteurization (Lohita & Srijaya, 2024). Pulsed electric fields (PEF) processing is a method using short high high-voltage electrical pulses to disintegrate the cell membranes of microorganisms by which they become inactivated (Preethi, Lavanya, Pintu, Moses, & Anandharamakrishnan, 2024). For instance, PEF has been effective in the pasteurization of liquid foods like milk or fruit juice without tremendously increasing nutrient and flavor loss when compared to conventional thermal heat treatments (Preethi et al., 2024). A non-thermal process, cold plasma is capable of inactivating a wide range of pathogens and food poisoning microorganisms on the surfaces as well as packaging material (Rahdar, 2023). It has potential application in the clean-up of produce, meat, food contact surfaces, etc. (Deliephan, Subramanyam, & Aldrich, 2023). This approach could also be utilized for the purification of environments or as a means to indirectly combat microorganisms on or within packaging materials, or under modified atmosphere packaging (MAP) conditions, thereby improving the safety and freshness of products (Barjasteh, Kaushik, Choi, & Kaushik, 2024). Irradiation, which includes the use of ionizing radiation like gamma rays, electron beams, or X-rays, can effectively reduce the microbial content in food products with little heat impulse (Bhagya, Reshmi, Waghmare, Moses, & Anandharamakrishnan, 2024). Irradiation has been approved for use in spices, poultry, and fruit as a method to maximize food safety and shelf-life (Buvaneswaran, Ukkunda, Sinija, & Mahendran, 2024). This review will focus on the benefits and sustainability of nonthermal identified technologies including energy efficiency, nutritional preservation, food waste reduction (which also includes spoilage bacteria) environmental impact. Challenges and future directions for scalability and cost-effectiveness, regulatory acceptance and consumer adoption, integration with existing infrastructure (such as providing poultry-compatible electrodes), and optimization of process parameters will be discussed. New nonthermal processing alternatives will allow us to do our part in helping create a stronger, more sustainable global food system that delivers safe and nutritious foods to the inhabitants of the world by generation.

II. NONTHERMAL FOOD PROCESSING TECHNIQUES

2.1. High-pressure processing (HPP)

High-pressure processing (HPP) is a non-thermal technology in which foods are subjected to pressures of 100-600 MPa, causing the elimination and inhibition of microorganisms with retention of sensory and nutritional characteristics that result from exposure conditions as well (Ozkan, Subasi, Capanoglu, & Esatbeyoglu, 2023). The technology has been used to generate shelf-stable food products including juice, guacamole, ready-to-eat meats, and shellfish, as well as several dairy foods without heat pasteurization for extended storage (Saifullah, Stanley, Zare, Juliano, & Hunt, 2023). During HPP, materials are subjected to high pressure which causes the proteins and enzymes in them as well as microorganisms that populate those ingredients to denature and thereby become inactive (Nath, Pandiselvam, & Sunil, 2023). The pressure is densities spread across the food product to ensure microbial inactivation throughout and minimal taste, texture, and nutritional change of foods (Lohita & Srijaya, 2024). HPP comes with a range of benefits, including improved food safety; better nutritional quality, and increased shelf-life (hence reduced wastage) (de Chiara, Castagnini, & Capozzi, 2024). On the other hand, its use is limited to huge amounts of capital and operational expenses along with lesser scalability as well as specialized equipment and facilities requirements (Moro-Visconti, 2024).

2.2. Pulsed electric fields (PEF)

Pulsed Electric Fields (PEF) - PEF is a nonthermal method that uses short high-voltage electrical pulses in the range of typically 20-80 kV/cm to disrupt cell membranes of microorganisms and thus cause a molecular leakage resulting in their inactivation (Martínez, Delso, Álvarez, & Raso, 2020). Applications Good for PEF have shown the potential for pasteurizing liquid foods such as milk and fruit juices while maintaining most of the natural nutrients, and flavor compounds that would otherwise degrade during traditional thermal pasteurization (Morales-De la Peña, Rábago-Panduro, Soliva-Fortuny, Martín-Belloso, & Welti-Chanes, 2021).

The processes are based on the application of high electric fields to food held between two electrodes, resulting destruction or disruption of cell membrane permeability (Demir, Tappi, Dymek, Rocculi, & Gomez-Galindo, 2023). This causes permeabilization such that the microorganisms are inactivated without significantly heating (Cui et al., 2022). The opportunity for PEF technology lies in improving food safety, a better quality of nutrients, and saving fuel as compared to traditional thermal pasteurization (Arshad et al., 2021). Nonetheless, this method encounters certain difficulties, such as the limited applicability of established food models to both solid and semi-solid food items (Kupikowska-Stobba, Domagała, & Kasprzak, 2024). Additionally, the requirement for specialized apparatus for the preparation and consumption experiments with PFMs may exceed the financial means of classroom educational settings (Ch'ng, 2024). Furthermore, there is a risk that the sensory qualities of specific food products might be adversely affected due to changes in texture or color dispersion during the chewing process.

2.3. Cold Plasma

Cold plasma is also called nonthermal plasma, produced by the ionization of gas at low temperatures usually up to atmospheric pressure (Yepez, Misra, & Keener, 2020). The technology is also known to be a powerful long-term disinfectant, capable of inactivating many microorganisms on the surfaces of food and within packaging (Shahi et al., 2021). Applications of cold plasma such as decontamination of fresh produce, meat, and food contact surfaces from pathogens (e.g., E. coli O157:H7), or in new packaging materials to improve the safety behavior along with shelf-life are very promising (Umair et al., 2023). Cold plasma provides antimicrobial activity due to generation of reactive species such as free radicals, ions, and UV photons that interact with microorganisms causing cell damage (Dharini, Jaspin, & Mahendran, 2023). Cold plasma can be made with different methods including dielectric barrier discharge, corona discharge, and also plasma jet (Anuntagool, Srangsomjit, Thaweewong, & Alvarez, 2023). As compared to traditional thermal decontamination methods cold plasma technology has several advantages improved food safety, reduced usage of chemicals, and energy conservation (de Araújo Bezerra et al., 2023). However, ultrasound for food processing also has limitations in penetration depth (independent of wavelength), possible adverse effects on food quality, and the need to study process parameters further or develop appropriate scientific knowledge/pathways behind them besides standardizing protocol components so that they comply with regulations.

2.4. Irradiation

Irradiation is a non-thermal process that leads to a significant reduction in the microbial load of food, using any source of ionizing radiation like gamma rays, electron beams, or X-rays without inducing major thermal damage (Danyo, Ivantsova, & Selezneva, 2023). Irradiation of food including spices, poultry, and fruits has been approved as a way to enhance safety (Mondal & Akhtaruzzaman, 2024). Irradiation functions by altering the molecular structure of microbial DNA resulting in loss or impairment of their reproduction, present study, and hence causes deactivation (Rai & Dutta, 2024). It is conducted in specialized facilities, with the intensity and duration of radiation specifically adjusted to achieve targeted microbial lethality without detrimentally affecting quality or safety (Chmielewski, 2023). Some of the advantages of irradiation for foods are improved food safety, shelf-life extension, and reduced chemical usage as compared to other preservation methods (Allai et al., 2023). Nevertheless, it also has drawbacks like a negative perception among consumers and to some extent, possible adverse impacts on the nutritional quality of food requirements for specialized premises and adherence with regulatory framework.

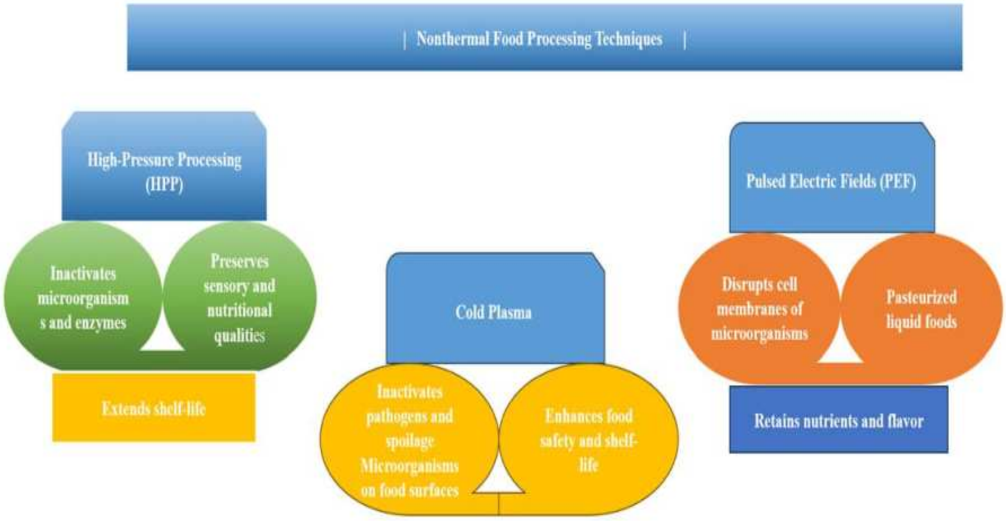

Fig.1: Nonthermal food processing techniques

III. BENEFITS AND SUSTAINABILITY CONSIDERATIONS OF NONTHERMAL FOOD PROCESSING

The non-thermal food processing technologies have been getting attention in the past few years, which is mainly due to their potential benefits as well as sustainability concerns (Bigi et al., 2023). In this review, we elaborate on the energy-saving potential and nutritional retention of nonthermal processing methods compared to traditional thermal treatment, in combination with reduced food waste as well as lower environmental impact.

3.1. Energy efficiency

Food processing by nonthermal technologies contributes to a greater energy efficiency of up to 20 times than thermal methods, such as conventional food preservation techniques (Bigi et al., 2023). Nevertheless, the reduced energy consumption associated with these methods is probably a result of the lower temperatures at which they function or the more precise delivery of energy (Amanowicz, Ratajczak, & Dudkiewicz, 2023). Consequently, HPP employs extremely high pressures (usually ranging from 400 to 600 MPa) to deactivate microorganisms and enzymes without the need for substantial heat treatment (Kateh, Purnomo, & Hasanah, 2024).

This pressure method obviates the need for high-temperature annealing, which carries a heavy toll on energy (Khanna, 2023). Likewise, PEF is another emerging technology that has been used to impact the cell membrane of microorganisms by applying low-duration voltage electrical pulses rather than long thermal processing (Poompavai & Gowri Sree, 2023). Cold Plasma processing is even better as it creates a reactive and low-temperature environment to kill food surface decontaminant so that the reliance on thermal energy can be cut off (Nwabor et al., 2022). These non-thermal processing techniques can decrease the energy requirements of food manufacturing, potentially leading to lower operational expenses for manufacturers (Pereira & Vicente, 2010). Additionally, these approaches are more environmentally benign, which suggests that their carbon emissions would be less than those of traditional thermal processing methods (S. Khan et al. 2022; Jayakumar et al., 2023). This translates directly to modified atmosphere packaged products with a dramatic decrease in O_2 and an increase in CO_2 (Liang et al., 2024). These intrinsic characteristics are noteworthy as they do not pose a risk of packaging leakage; instead, they can be managed throughout the nonthermal processing stage (10), which will diminish energy usage akin to conventional cooking methods—only more efficiently! (nonthermal processes require less power generation and involve lower greenhouse gas emissions).

3.2. Nutritional preservation

Non-thermal food processing excels in maintaining the food's native nutritional, sensory, and functional properties, among other significant advantages (Q. Wang et al., 2023). In recent times, non-thermal techniques have emerged as viable substitutes for traditional pasteurization or sterilization in the preservation of food, particularly for retaining heat-labile essential components—such as vitamins, minerals, and antioxidants—that are often degraded by conventional thermal treatments (Bhavya &

Hebbar, 2023; Karim et al., 2023).For instance, various studies have demonstrated that non-thermal processing methods, like pulsed electric field (PEF) treatment, result in superior retention of vitamin C, carotenoids, and polyphenols in fruit juices compared to heat-pasteurized products (Al-Juhaimi et al., 2018; Ghanem et al., 2024).

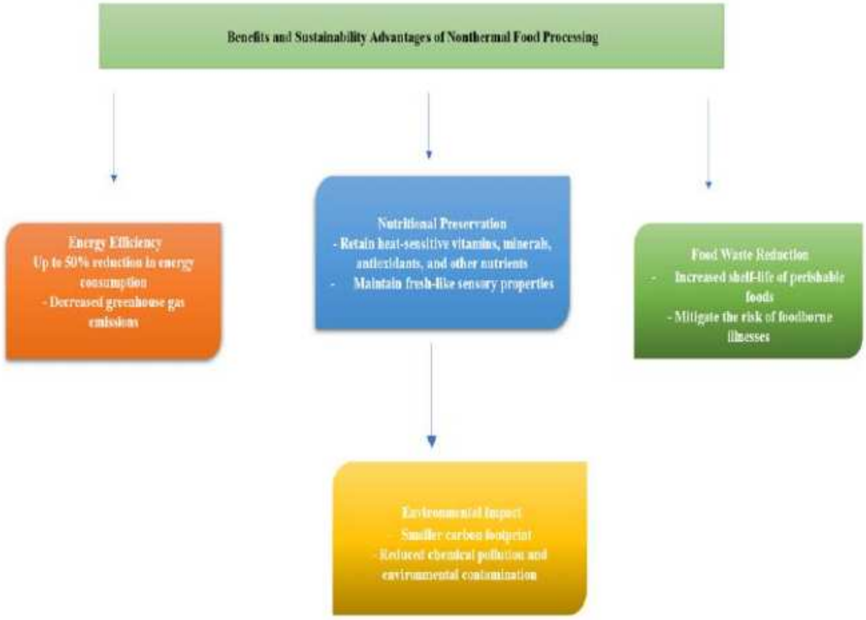

Fig.2: Benefits and sustainability considerations of nonthermal food processing

The antioxidant content in PEF-treated milk or fruit juice is comparable to that of fresh products (Šalaševičius, Uždavinytė, Visockis, Ruzgys, & Šatkauskas, 2023). Furthermore, the application of pulsed electric field (PEF) technology is linked to the conservation of flavors and fragrances that closely mimic those found in fresh food items (del Carmen Razola-Díaz et al., 2024). In a parallel manner, Cold Plasma treatment has demonstrated its efficacy in the eradication of surface pathogens from fresh agricultural products while exerting a negligible effect on the sensory and nutritional quality of the goods (Y. Wang et al., 2024). Non-thermal processing holds the promise of enhancing human health and well-being by reducing the degradation of bioactive compounds during food production and distribution while preserving the natural nutritional and functional properties of foods (Núñez-Delgado, Mizrachi-Chávez, Welti-Chanes, Macher-Quintana, & Chuck-Hernández, 2024; Sharma et al., 2024). This aligns with the growing consumer trend toward less processed, whole foods that maintain their nutritional integrity.

3.3. Food waste reduction

Nonthermal food processing technologies too, have the potential to decrease waste across the supply chain (by sustaining the shelf-life and safety of those products) (Režek Jambrak, Nutrizio, Djekić, Pleslić, & Chemat, 2021). HAPP and PEF both have the ability to inactivate spoilage microorganisms as well as enzymes, thus preserving perishable food items such as fruit juice, meat products, or dairy applications for an extended period (Amit, Uddin, Rahman, Islam, & Khan, 2017).

The longer shelf-life could mean fewer losses in storage, transportation, and retail display as well as by consumers due to spoilage (Mortazavi, Kaur, Farahnaky, Torley, & Osborn, 2023). Furthermore, enhancing the microbial safety of foods processed without heat can help decrease the incidence of foodborne illnesses and as a result, lower the amount of waste caused by product recalls or consumers' reluctance to purchase affected items following outbreaks (Islam et al., 2022; Wansink, 2004). Nonthermal processing can help support the broader sustainability of the food system by reducing food waste (Djukić-Vuković, Mladenović, Pejin, & Mojović, 2022). Less food waste means better use of resources, lower environmental impacts, and more available food - all essential for improving global sustainability of the world's environmental challenges, as well to ensure long term availability.

3.4. Environmental impact

The use of nonthermal food processing technologies can save significantly more energy and offer greater environmental benefits compared to thermal methods for the preservation of foods other than dehydrated products (Zou, Khan, et al. 2024; Boateng, 2024). Low power use:

This is the most critical pro of using renewable energy while it performs (Jenkins & Ekanayake, 2024). Nonthermal techniques such as high-pressure processing or pulsed electric fields typically function at a lower temperature; thus the minimum stress is needed for heating and cooling steps accompanying them providing essential energy-saving (Bigi et al., 2023; Brito & Silva, 2024). Meaning, lower greenhouse gas emissions and carbon footprint for food processing facilities (Zou, Hussain, et al. 2024; Shabir et al., 2023). In nonthermal processing, heat-induced nutrient and quality degradation can also be minimized thus further raising yield while reducing food wastage along the supply chain (Safwa et al., 2023). Decreased food waste contributes to reduced resource inefficiency and the environmental impact of wasted food that is generated, transported, and disposed of (Onyeaka et al., 2023). Other nonthermal technologies (ie, UV light; cold plasma) also have the potential to minimize water consumption and wastewater generation in comparison with traditional cleaning and sanitization methods (Gururani et al., 2021; Mumtaz et al., 2023). These technologies can support food processing sustainability, for the international community as well by conserving water and reducing the load on wastewater treatment infrastructure (Javan et al., 2023; Obaideen et al., 2022). "Moreover, the incorporation of nonthermal technologies can facilitate the development of closed-loop or circular production systems, where waste streams and byproducts from high-value processing steps are effectively utilized, thereby minimizing the environmental footprint associated with food processing operations." (Almaraz-Sánchez, Amaro-Reyes, Acosta-Gallegos, & Mendoza-Sánchez, 2022; Kabir, Akter, Huang, Tijing, & Shon, 2023; Paini et al., 2022). This also validates the broader pivot towards a more circular food economy, which minimizes waste and resource consumption (Zhang, Dhir, & Kaur, 2022). In sum, the environmental advantages of nonthermal food processing technologies i.e. low energy consumption along with reduced footprint in terms of greenhouse gas emissions; potential to combat waste across various stages from farm-to-fork and value realization opportunities for water streams/wastes is a sustainable route toward future safe food manufacturing strategies.

IV. CHALLENGES AND FUTURE DIRECTIONS

4.1. Scalability and cost-effectiveness

Despite the environmental and quality benefits, large-scale implementation of nonthermal food processing technologies in the industry is challenging from a scalability perspective as well as cost-effectiveness (Chacha et al., 2021). A significant hurdle to the widespread adoption of nonthermal technologies is the substantial upfront investment required for specialized equipment and infrastructure needed for industrial-scale production (Rajabloo, De Ceuninck, Van Wortswinkel, Rezakazemi, & Aminabhavi, 2022). Nonthermal processes may require more complex and elegant machinery relative to conventional thermal processing systems rendering such apparatus costly especially for smaller-scale food industries (Keşa et al., 2021; Noble, Todorova, & Yarovsky, 2022). Further, full-scale finite element nonthermal models have yet to be developed based on model parameter selection accompanied by process simulations along with the assessment of operational costs against all other forms or terms comprises an appropriate challenge (Duchnowski & Brown, 2024; Melchiorri, 2024). For these reasons, practical and economic evaluations of waste-water treatments with ozonation are necessary in terms of energy consumption, throughput rates, and integration into existing processing lines (Monje et al., 2022; Thakur et al., 2023). In turn, researchers and food industry stakeholders aim to overcome these challenges through the inclusion of different methods to increase quality assurance while minimizing defects (Antony et al., 2024; I. Khan et al. 2023). This has included the design of more compact, modular equipment as well as adjusting process parameters to improve energy efficiency and throughput in all different temperature ranges (Allouhi, Rehman, Buker, & Said, 2023; Tilahun, 2024). Collaborative industry-academia partnerships and supportive policies, and incentives can encourage the deterrence of financial constraints faced by industries in adopting these non-thermal technologies into their processing lines thus helping to invest substantially in scaling up research and development (Wyns, Khandekar, & Groen, 2019). Still, as that technology develops and economies of scale benefit the industry at large; nonthermal will become increasingly cost-competitive with thermal standards in terms of both capital and operating costs - making these sexy solutions ever more viable for broad adoption across food.

4.2. Regulatory approval and consumer acceptance

Such nonthermal processing methods may find a variety of potential applications in the food industry, but regulatory approval and consumer acceptance can be obstacles to their implementation (Zhao, de Alba, Sun, & Tiwari, 2019). Regulatory bodies must establish rigorous guidelines for the approval of new processing technologies, and food safety as well as product quality are always priority concerns (Okpala & Korzeniowska, 2023). Nona thermal processing technologies such as high-pressure, pulsed electric fields, cold plasma, etc., require an adequate amount of research and testing to ensure pathogens' inactivation along with retention of food quality (nutritional), preservation attributes (Delbrück, 2022; Galanakis, 2015).Therefore, the information about processes needed for certification under different storage events could be a laborious job for stakeholders) Regulations in different countries and regions differ (Zeberer), which makes the uptake of these technologies more difficult Aside from regulatory clearance, consumer liking must pave the way for a successful deployment of nonthermal processing (Hassoun et al., 2023). Many consumers are not familiar with or misinformed about these new technologies, and communication and education programs may be needed to clarify the facts accurately so that confidence can grow (Allchin, 2023). Managing the level of consumer regard to food safety, nutrition, and transparency is key for overcoming apprehensions about nonthermal-processed food products (and another study focused specifically on APP-treated beef); Nevertheless, a long-term sustainable partnership among food industry stakeholders together with regulators and consumer groups is essential to accelerate the acceptance process and also provide mechanisms for enhancing consumer awareness regard nonthermal methods that would increase trust in such technologies.

4.3. Integration with existing infrastructure

Integrating nonthermal processes into current food manufacturing sites and the logistics of the supply chain may be quite challenging (Chakka, Sriraksha, & Ravishankar, 2021). The incorporation of these new technologies may necessitate large investments, in terms of changes to current processing setups infrastructure, equipment upgrades, and modifications to existing workflows (Atkinson, Gesing, Montagnat, & Taylor, 2017). Nonthermal processing methods can require food manufacturers to retrofit their sites for niche equipment and operating systems (Hussain et al. 2024; Aguilar et al., 2019). Examples of such adjustments include the retrofitting or reconfiguration of production lines, as well as updating storage and transportation systems to accommodate these changes in processing techniques (Carman, 2002) (Krishnan, Yonca, & Comes, 2023; Moreno-Rangel & Dalton, 2023). In addition, any nonthermal approaches must be economically viable and suitable for implementation further downstream within the wider food supply chain to ensure that they are generic enough concerning packaging, distribution, or retail handling (Sovacool et al., 2021). There are also the logistics, e.g. cold chain or batch sizes - which means careful planning and implementation are required here as well (Richards & Grinsted, 2024). To combat integration problems, food processors and equipment makers are starting to work more closely together as they develop new modular nonthermal processing systems that can be easier to integrate into operations (Picart-Palmade, Cunault, Chevalier-Lucia, Belleville, & Marchesseau, 2019). Current research and development in that area are focused on the creation of these solutions which can significantly reduce any potential impact on existing food processing procedures while helping to smoothen both integration and acclimatization processes for non-thermal technologies (Bigi et al., 2023; Picart-Palmade et al., 2019).

4.4. Optimization of process parameters

Integrating nonthermal processes into current food manufacturing sites and logistics of the supply chain may be quite challenging (Kumar, Panghal, & Garg, 2024). The incorporation of these new technologies may necessitate large investments, in terms of changes to current processing setups infrastructure, equipment upgrades, and modifications to existing workflows (Luna, 2024; Shukla & Dubey, 2024). Nonthermal processing methods can require food manufacturers to retrofit their sites for niche equipment and operating systems (Luna, 2024). Examples of such adjustments include the retrofitting or reconfiguration of production lines, as well as updating storage and transportation systems to accommodate these changes in processing techniques (Carman, 2002) (Moreno-Rangel & Dalton, 2023). In addition, any nonthermal approaches must be economically viable and suitable for implementation further downstream within the wider food supply chain to ensure that they are generic enough concerning packaging, distribution, or retail handling (Sovacool et al., 2021). There is also the logistics, e.g. cold chain or batch sizes - which means careful planning and implementation are required here as well (Altekar, 2023). To combat integration problems, food processors and equipment makers are starting to work more closely together as they develop new modular nonthermal processing systems that can be easier to integrate into operations (Bramsiepe et al., 2012). Current research and development in that area are focused on the creation of these solutions which can significantly reduce any potential impact on existing food processing procedures while helping to smoothen both integration and acclimatization processes for non-thermal technologies.

4.5. Future perspectives

In this ever-changing global scenario of the food industry, innovative nonthermal processing technologies discussed in the review could play a major role and are very promising to bring revolution in food materials treatments. One clear direction for the future is increasing the scalability and cost-effectiveness of nonthermal systems. Future work should focus on accelerating R&D, to refine the design and manufacturing of these technologies so that they can eventually be fully integrated within the fabric of existing food processing infrastructure at a cost-performance level competitive with traditional thermal methods. Advances in system engineering, materials science and in process automation will be necessary for the scale-up of non-thermal technologies to their full potential. Next to the technical improvements, nonthermal processing will have to be widely introduced as part of an integrated chain in close collaboration between researchers, regulatory bodies and the food industry. The task of setting rigorous standards around safety and quality (health considerations aside), as well as, education knowing that this is happening are some immediate areas for necessary attention. Because consumer acceptance is key to adopting new food technologies, strategic communication and transparency will be essential in earning the confidence needed for nonthermal processing methods to attain more widespread use within our mainstream food supply chains. The continuous optimization of process parameters and investigation of alternative nonthermal methods will overcome these potential issues to deliver products with replicable product quality, safety, and sensory attributes. By examining the synergistic effects associated with combining different nonthermal technologies, new areas could be targeted for diversifying applications and broadening horizons towards revolutionary food processing solutions. It would also consider the logistical challenges of integrating nonthermal technologies into current food supply chains. New ways of transportation and storage solutions along with the establishment of decentralized processing facilities will inevitably play a part in revising current bottlenecks - via its seamless inclusion into the supply chain. In short, progress in nonthermal food processing will not work without the multi-topic and transdisciplinary detail gaze. Interdisciplinary connections between food scientists, engineers (from process to material science), and sustainability experts can help catalyze the translation of novel concepts from ideas into practical solutions. The combined effort from both organizations will play a critical role in leading the evolution of the food system to become even more sustainable, resilient, and climate-friendly moving forward.

V. CONCLUSION

Recent years have seen nonthermal processing methods such as High-Pressure Processing (HPP), Pulsed Electric Fields (PEF), and Cold Plasma surfaces, providing alternative solutions to sustainability issues in food production and supply chains. All of these emerging technologies provide a range of benefits to create more sustainable and resilient global food systems. These methods of nonthermal processing maintain the nutritional and quality properties of food products which are susceptible to degradation by heat process, consequently enabling producers to prepare healthier as well as more pleasurable food items. Besides, these efforts display exceptionally good energy efficiency as compared to traditional thermal processing reducing the related power usage and greenhouse gas emissions by a large factor. This improved energy efficiency and minimized environment impact fits right within global efforts to combat climate change, and its built around new sustainable methodologies. Moreover, the use of non-thermal technologies helps to prevent food waste along the supply chain thanks to prolonged shelf-life for perishable foods with controlled essential attributes. This comprehensive use of the cutting-edge technology will be instrumental to ensuring that food production and consumption become more sustainable in order to meet global concerns about resource conservation, environmental integrity and depletion or shortage.

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Review on Effect of various feed additives on Pig production performance

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Abstract— *This review provides an exhaustive examination of the efficacy and mechanisms of action of various feed additives in pig diets, including acidifiers, essential oils, prebiotics, probiotics, and feed enzymes. The additives' impact on growth performance, gut health, and antibiotic reduction is critically evaluated. The review elucidates the additives' mechanisms of action, encompassing antimicrobial activity, immune modulation, and nutrient digestion enhancement. A meta-analysis of the additives' effects on growth performance metrics, including average daily gain and gain-to-feed ratio, is presented. The review highlights the necessity for further research to optimize additive usage and elucidate their effects on pig production. Additionally, the importance of tailoring diets to meet the specific needs of young pigs and promoting gut health and development is emphasized. This comprehensive review synthesizes the current state of knowledge on feed additives in pig diets, providing valuable insights for researchers, producers, and industry stakeholders.*

Keywords— ***Pig farming, Feed additives, Probiotics, Essential oils, Enzymes, Antibiotic alternatives.***

I. INTRODUCTION

Pig farming is a common practice in various parts of India, particularly in the South-Central and North Eastern Regions (NER). Each region has its own locally adapted pig breed, and most households raise one or two pigs annually (Mahak *et al.*, 2020). Pigs are highly valued for their ability to convert kitchen and agricultural waste into nutrient-rich fertilizer, and their meat is consumed occasionally, often as part of local celebrations (Bujarbaruah *et al.*, 2007; McAuliffe *et al.*, 2017). Although pork consumption has a long history in India, the smallholder model of raising pigs as part of diverse agro-ecosystems defines much of the country's pig and pork history (Das and Bujarbaruah, 2005; Kakati *et al.*, 2019).

According to the 20th Livestock Census of India, the country's pig population is approximately 9.06 million (Indian Livestock Census, 2019), which is a small fraction of the global pig population of around 900 million (FAOSTAT Databases, 2020). India's pig population has been declining over the past 15 years (Indian Livestock Census, 2019).

Various feed additives have been widely used in the swine feed industry to improve growth performance without negatively affecting average daily gain (ADG). These additives include acidifiers, essential oils (EO), direct-fed microbials (DFM), yeasts, copper (Cu), zinc (Zn), betaine, chromium (Cr), conjugated linoleic acid (CLA), and L-carnitine. These additives have antibacterial and immune-promoting properties, which help control pathogens and maintain a balanced gut microbiota (Nguyen *et al.*, 2020; Espinosa *et al.*, 2021; Zamojska *et al.*, 2021; Stevanovic *et al.*, 2018; Dumitrache *et al.*, 2019; Belkova *et al.*, 2018). Exogenous enzymes, such as carbohydrases, proteases, and phytases, are also added to improve nutrient digestibility and potentially positively impact gastrointestinal health and immune functions (Aranda-Aguirre *et al.*, 2021; Jerez-Bogota, 2020). This review aims to provide an overview of the available additives for pig diets, their mechanisms of action, and recent results from growth performance and digestibility experiments. However, it is not an exhaustive review of each additive.

II. FEED ADDITIVES

As ingredients or combinations of ingredients added to the basic feed mix or parts thereof to fulfill a specific need. Usually used in micro quantities and requires careful handling and mixing. Feed additives have emerged as a game-changing component in pig production. As the industry strives to meet the growing demand for pork, understanding the role and impact of these feed additives has become crucial for producers seeking to optimize their operations.

Many feed additives have been evaluated that are aimed at either

- Enhancing the pigs' immune response (e.g. immunoglobulin; ω-3 fatty acids, yeast derived ß glucans)
- Reducing pathogen load in the pig's gut (e.g. organic and inorganic acids, high levels of zinc oxide, essential oils, herbs and spices, some types of prebiotics, bacteriophages, anti-microbial peptides).
- Stimulate establishment of beneficial gut microbes (probiotics and some types of prebiotics).
- Stimulate digestive function (e.g. butyric acid, gluconic acid, lactic acid, glutamine, threonine, cysteine, and nucleotides).

2.1 Antimicrobials:

The positive effects of feeding acids to pigs on gut health and development, and indirectly on pig health and productivity, may be attributed to various factors, including:

Antimicrobial activity of non-dissociated organic acids

1. Lowering digesta pH, in the stomach, aiding protein digestion
2. Lowering stomach emptying rate
3. Stimulating (pancreatic) enzyme production and activity in the small intestine
4. Providing nutrients that are preferred by intestinal tissue thereby enhancing mucosal integrity and function.

The use of organic and inorganic acids in pig diets has beneficial effects, particularly for newly-weaned pigs (Blank *et al.*, 1999; Mroz *et al.*, 2006). The effectiveness of acid feeding varies depending on the types and combinations of acids, the animal's state, and feed characteristics, such as buffering capacity (Blank *et al.*, 1999; Mroz *et al.*, 2006). A relatively recent development is the encapsulation of acids for targeted delivery to different gut segments, which has shown promising results (Piva *et al.*, 2007). This technique allows for delayed absorption and more effective delivery of acids to the distal ileum, caecum, and colon. Additionally, feeding acids in specific salt forms, such as potassium-diformate, can raise acid levels in the distal ileum and improve growth performance (Canibe *et al.*, 2001; Overland *et al.*, 2000). Furthermore, medium-chain fatty acids have strong antimicrobial properties (Decuypere and Dierick, 2003)

2.2 Pre and probiotics:

A probiotic is defined as a live microorganism which when administered in adequate amounts confers a health benefit on the host (FAO/WHO 2002). For young piglets, a probiotic is expected to deliver at least one of the following functions to the GIT:

- Stimulating the development of a healthy microbiota—predominated by beneficial bacteria.
- Preventing enteric pathogens from colonization.
- Increasing digestive capacity and lowering the pH.

- Improving mucosal immunity.
- Enhancing gut tissue maturation and integrity.

Recent studies have shown that piglets exhibit a positive growth response to dietary supplements containing a combination of Bacillus lichiniformis and Bacillus subtilis (Kremer, 2006). Various Lactobacillus and Bifidobacterium species have also been found to improve the performance of newly-weaned piglets (Stein and Kil, 2006). For instance, Lactobacillus sobrius 001T has been shown to have a probiotic effect by reducing ileal ETEC abundance and promoting growth in piglets challenged with ETEC K88 (Konstantinov, 2005). However, some studies have reported no response or even adverse effects of probiotic supplementation in piglets (Jost and Bracher, 1999; Lallès *et al.,* 2007). These inconsistent findings highlight the complexity of probiotic development and application, emphasizing the need for further research to understand the underlying molecular mechanisms and modes of action. The gut microbiota plays a crucial role in pig health, and increasing the population of beneficial bacteria such as Bifidobacterium, Lactobacilli, and Eubacteria can improve animal health and reduce disease risk (Roberfroid *et al*., 2010; van der Aar *et al*., 2017). As these beneficial bacteria grow, they produce more lactic and acetic acid, which lowers the intestinal pH and increases fermentation. This leads to an increase in short-chain fatty acids (SCFA) and a decrease in pathogenic bacteria (Smiricky-Tjardes *et al*., 2003).

2.3 Feed enzymes:

The main goal for using exogenous feed enzymes in swine diets has been to improve the nutritive value of feedstuffs. This is achieved through several mechanisms including the breakdown of anti-nutritional factors present in feed ingredients, elimination of nutrient encapsulation effect thus increasing availability, breakdown of specific chemical bonds in raw materials that are otherwise not cleaved by endogenous enzymes, thus releasing more nutrients, and complementation of the enzymes produced by young animals (Simon, 1998; Bedford and Schulze, 1998).Majority of the vegetable feedstuffs used in swine diets contain a considerable amount of non-starch polysaccharides (NSP) whose anti-nutritional effects are well-established and has been a subject of intense research (de Lange *et al.,* 2000).

Similar observations were made regarding NSP hydrolysis products from wheat and flaxseed. These findings can be attributed to various mechanisms, including the possibility that hydrolysis products interfere with pathogen attachment to the intestinal mucosa, a crucial step in infection. Additionally, these products may act as prebiotics (Cummings and MacFarlane, 2002), promoting the growth of lactic acid-producing bacteria, as demonstrated by Högberg and Lindberg (2004) and Kiarie *et al*. (2007). Therefore, it has been hypothesized that supplementing swine diets with enzymes to digest soluble NSP will reduce intestinal microbial load, increasing nutrient availability to the host and minimizing the growth of pathogenic bacteria.

2.4 Essential oils:

Essential oils, volatile plant components, have been used in food preparation and other applications for centuries. These oils are generally recognized as safe (GRAS) by the US Food and Drug Administration (FDA) and have been used as flavorings, preservatives, perfumes, and in over-the-counter medicines. Many essential oils exhibit strong antimicrobial activity (Kalemba and Kunicka, 2003), particularly those with phenolic structures (Dorman and Deans, 2000). The antimicrobial activity of phenolic essential oils, such as carvacrol and thymol, is attributed to their delocalized electrons and hydroxyl group on the phenolic ring (Ultee *et al*., 2002). These oils damage the bacterial cell membrane, disrupting pH homeostasis and inorganic ion equilibrium, leading to the collapse of the proton motive force and ATP depletion (Ultee *et al.,* 2002). Essential oils also show selectivity, with some studies reporting greater inhibition towards Gram-negative bacteria like Salmonella and E. coli than Gram-positive Listeria monocytogenes (Lin *et al*., 2000).

For ADG (average daily gain), there were 20 comparisons between pigs fed a control diet or diets with added EO (Essential oils) with an average of a 5.8% improvement (range between −2.9 and 18.8%) in pigs fed EO. There were 17 comparisons for G:F (gain-to-feed ratio) between pigs fed a control diet or diets with added EO with an average of a 5.8% improvement (range between −2.6 and 19.9%) in pigs fed EO. Fourteen comparisons evaluated BF between pigs fed a control diet or diets with added EO with an average of a 2.7% decrease (range between −14.2 and 6.3%) in pigs fed EO. For percentage lean, there were 9 comparisons with an average of a 0.9% improvement (range between −2.5 and 2.8%) in pigs fed EO. For LMA/LD, (loin muscle area, loin depth) there was an average of a 1.9% improvement (range between −6.3 and 12.3%) in pigs fed EO. Overall, the results indicate that essential oils (EO) had a positive impact on average daily gain (ADG) and gain-to-feed ratio (G:F). Adding EO alone or in combination with acids shows promise in improving growth performance. However, it is important to note that the current body of research on EO's effect on growth performance is limited, and only three studies were conducted in the US. Therefore, the benefits of using EO in US-based conditions are uncertain. Further experiments are necessary to determine the effects of including EO in the diets of grow-finish pigs. (Rao *et al.*, 2023).

III. CONCLUSION

A conclusion section must be included and should indicate clearly the advantages, limitations, and possible applications of the paper. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. Large amounts of research have been conducted evaluating the impact of a wide range of feed ingredients and feed additives on various aspects of gut health and development in pigs, to improve growth performance around the time of weaning while minimizing the use of antibiotics and rather expensive feed ingredients, such as milk products. A better understanding of the mechanisms whereby nutrients, feed ingredients and feed additives influence animal physiology will lead to the development of alternatives to in-feed antibiotics. Given the considerable advances made in the understanding of intestinal nutrient utilization and metabolism, a complimentary goal in nutrition might be to formulate young pig diets with the specific task of optimizing the growth, function and health of the gut.

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Genetic diversity of Yeast (*Saccharomyces cerevisiae*) Strains by using RAPD Marker

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Abstract**—** *The term 'wine' is applied to the product made by the alcoholic fermentation by yeast in which the sugars are converted into alcohol and carbon dioxide. Genetic similarity was calculated using Jaccard's similarity coefficient and cluster analysis revealed two major clusters. The diversity at molecular level was analyzed with elucidian distance of 0.40. Out of ten wine yeast strains studied at molecular level, two strains showed maximum similarity i.e. 79 % between them viz. NCIM 3045 and 3200. Genetic diversity was analyzed based on data obtained by 11 RAPD primers. Most of the primers were found 85.71 to 100% polymorphic in nature.*

Keywords**—** ***Molecular markers, DNA, Yeast Strains. Genetic diversity. PCR.***

I. INTRODUCTION

The phenotypic diversity of brewing yeasts enables brewers to achieve the flavor, aroma, and other sensory properties that beer consumers seek. Brewers utilize pure strains of yeast for most industrial beer production. The impacts of yeast on beer are numerous and diverse [7]. the technological differences among yeast strains depend on their intraspecific genetic diversity [4]. The most significant roles of this microbiota are acidification, flavour formation, and leavening of the dough, where yeast produces aroma compounds and CO2 [1]. The heterogeneity between the *S. cerevisiae* populations may provide different functional traits for sourdough yeast [11].

Molecular markers are valuable tools to assess this heterogeneity and analyse the population structure of yeast from different geographical origins. Up to now, several molecular markers such as inter-simple sequence Repeat (ISSR), randomly amplified polymorphic DNA (RAPD), simple sequence repeat (SSR), and single-nucleotide polymorphisms (SNPs) have been employed to evaluate the genetic variation and population structure of *S. cerevisiae* strains from sourdough and other food matrixes [3,5,7,10,]. The RAPD method has been widely applied in the genetic fingerprinting of food yeast or bacterial isolates [9]

II. MATERIAL AND METHODS

A. Isolation of Genomic DNA Each Yeast Strains: Ten Yeast Strains (NCIM-3045, NCIM- 3185, NCIM-3189, NCIM-3200, NCIM-3283, NCIM-3287, NCIM-3205, NCIM-3095, NCIM- 3315, and NCIM-3215). Determination of quantity and quality of isolated DNA.

B. PCR Amplification: Isolated Yeast strains DNA Optimization with RAPD Primers for Analysis genetic diversity. PCR reaction component and PCR cycle as shown in Table No. 01 and 02.

Table No. 01: PCR components and stock solutions for RAPD

Sr. No.	Components	Stock	Require	Volume/ µl
1.	D/W	---	---	18.5
2.	PCR buffer	10X	1X	2.5
3.	Primer	10 pm/ µl	10 pm	1.0

4.	dNTPs	25 mM	0.2 mM	0.2
5.	$MgCl_2$	25 Mm	1.5 mM	1.5
6.	*Taq* DNA	5 U/µl	1U/ µl	0.3
7.	DNA	50ng/µl	30ng	1.0
			Total	**25 µl**

Table No.02 Cyclic parameter of thermal cycler for RAPD

Step	Temp (°C)	Duration	Cycles	Function
1.	94	2 min	1	Initial denaturation
2.	94	30 sec	40	Denaturation
3.	36	45 sec		Annealing
4.	72	2 min		Extension
5.	72	10 min	1	Final extension
6.	4	∞	1	Hold

C. Agarose gel electrophoresis

DNA sample was diluted with appropriate quantity of sterilized distilled water to yield a working concentration of 25ng/µl for RAPD markers analysis. Used for screening 28 RAPD primers. The technique uses the repeat anchored primers of short oligonucleotide (16-17 bp) for DNA amplification by PCR. The amplified products were resolved on 1.5% agarose gel at 100 V for 1.5 hour. The gel was stained with ethidium bromide (5µl/100ml).

Data analysis was performed using NTSYS-PC (Numerical Taxonomy System, Version 2.02). The SIMQUAL programme was used to calculate the Jaccard's coefficient. Dendrogram was constructed using unweighted pair group method for arithmetic mean (UPGMA) based on Jaccard's coefficient.

III. RESULTS AND DISCUSSION

A. Genetic diversity analysis

Overall all 11 primers were generated total 498 amplicons with an average of 45.27 amplicons per primer. Out of 498 amplicons, 438 amplicons were found polymorphic, it showed 93.56 % polymorphism. Similarly, out of the total amplicons, 60 amplicons were found monomorphic. It showed 6.44 % monomorphism and the average number of monomorphic amplicons per primer were 0.55. All these primers had produced maximum percent polymorphism i.e. 100 % except primer M-13, OPB-10, SC-02 and OPA-04 which showed the minimum percent polymorphism (Fig 01).

Genetic relationship between 10 strains of wine yeast were determined on the basis of presence of band was scored as (1) and absence as (0) was subjected to NTSYS pc2.02 software to calculate similarity among them and dendrogram was depicted by using Jaccard's similarity coefficient. The genetic similarity matrix obtained by Jaccard's similarity coefficient (Figure 01) ranged from 0.39 to 0.79 among ten wine producing strains of *Saccharomyces cerevisiae* based on RAPD profiling. The diversity at molecular level was analyzed with elucidian distance of 0.40. Out of ten wine yeast strains studied at molecular level, two strains showed maximum similarity i.e. 79 % between them viz. NCIM 3045 and 3200.

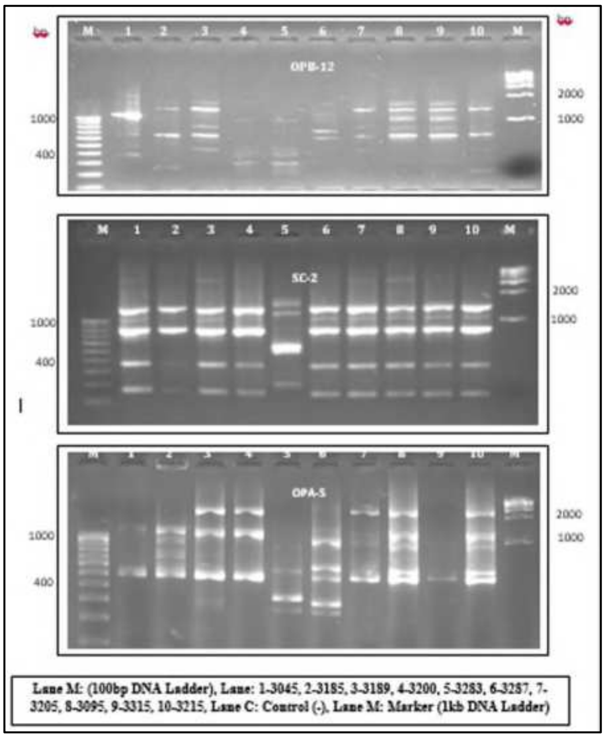

Fig.1: DNA fingerprinting of 10 wine yeast strains by using RAPD primers

B. Dendrogram Analysis

Dendrogram generated based on UPGMA analysis of RAPD data grouped all these strains of *s. cerevisiae* were grouped in to two major clusters A and B. The cluster A contains 09 strains viz. 3045, 3200, 3189, 3287, 3095, 3185, 3215, 3205 and 3315 of wine yeast while cluster B contain 01 strain i.e. 3283 of wine yeast i.e. NCIM 3283 and shared 39% similarity with all other strains (Fig 02).

The cluster I comprised cultures NCIM 3045 and 3200 together showed 100% similarity with each other. The member 3283 maintained its separate cluster.

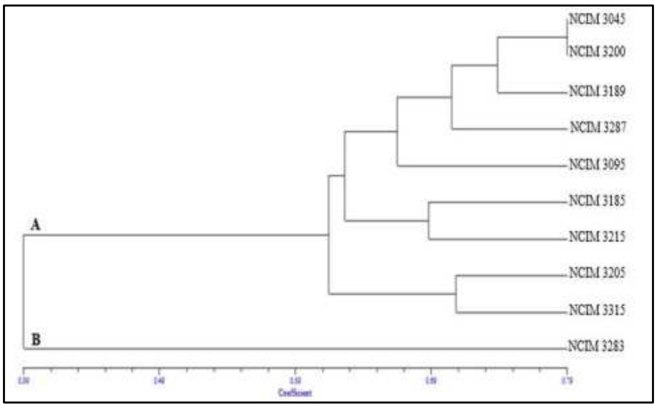

Fig.2: Dendrogram for 10 wine yeast strains based on NTSYS-pc UPGMA clustering method with generic similarity from DNA based RAPD markers analysis

IV. CONCLUSIONS

The RAPD molecular marker system found efficient to discriminate diverse population of *Saccharomyces cerevisiae.* Twenty Eight RAPD primers were screened out of them eleven primers had shown amplification of which AB1-15, 1283, OPB12, OPO4, SC1 and OPB01 these six primers showed 100% polymorphism. RAPD OPA 05, M-13, OPB 10, SC2 and OPA04 had shown 80%, 85.71%, 88.89%, 88.89 % and 85.71% polymorphism respectively.

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Practice of compost use in urban farming: Opportunities and constraints in the West Region, Cameroon

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***Abstract*—** *Urban agriculture is an ancient economic activity that sustains urban livelihoods. Composting as an alternative method of waste treatment and compost use in urban farming has led to sustainable practices. This paper sets to examine the opportunities and barriers of compost use under the lens of the Social Practice theory. Adopting a mixed methods approach, data was collected during a questionnaire survey of 265 households purposively selected from the urban and peri-urban quarters, eleven (11) in-depth interviews with stakeholders and a focus group discussion with compost users. Quantitative data from questionnaires were analyzed statistically using SPSS while qualitative data from interviews and focus group were treated using content and thematic analysis with the help of Atlas.ti. Findings revealed that compost use practices are favored by the availability of compost and technical assistance provided to farmers. Municipal compost production has increased from 60tons to 600tons per year over a period of 10 years and private composting is greatly improved. Nevertheless, small scale famers have constraints which are technical, experience and knowledge, financial, institutional and policies. Farmers in the peripheries (45%) tend to compare compost with mineral fertilizers and are reluctant to change their old practices. State extension services promote mineral fertilizers over compost but farmer-to-farmer experience sharing has informed practices. The existing regulatory landscape has not encouraged compost use and traditional practices persist. Adopting sustainable practices require policies that prioritize compost use.*

***Keywords*— Compost, practices, social practice theory, opportunities, constraints, Cameroon.**

I. INTRODUCTION

The world's population is rapidly growing and feeding the growing population while keeping the urban ecological footprint has been a great challenge for agriculture today[1]. Urban agriculturalists are concerned with maximizing profits through intensification and use of more inputs such as chemical fertilizers [2,3]. However, the negative impacts of intensified forms of agriculture on the environment and human health have motivated the adoption of new input types such as organic manure and new farming systems [4,5]. Among the good practices of urban agriculture, the adoption and use of compost has been given considerable attention [6]. Organic matter add nutrients to the soil, maintains and builds up the soil structure that provides an aerated moisture retentive conditions and allow increased microbial activity to take place[7,8]. The economic, health, environmental and agronomic importance of compost used in farming have been substantially documented [4,7,9, 10]. However, the rate of adoption of such a practice in developing countries is timid. This paper thus seeks to investigate the opportunities and constraints for compost use in urban farming in towns of the South.

The practice of circular agriculture that is well developed in countries of the North is still more common in African countries today but the evidence base for the existing practices, norms and behaviors remains weak [11]. The practice of minimizing food losses by using waste streams and transforming them into valuable agricultural inputs for food production is an important principle of circular economy that has made the waste stream a valuable resource in the urban food production systems [5].

Compost use in farming is important in upgrading waste streams but the extent to which compost is integrated into urban farming depends on the opportunities and constraints that range from technologies, waste separation, local and national regulations, cultural acceptance and the market demand for compost-based products [9, 12,13].

The adoption and use of compost in urban farming is timid but gradually gaining grounds in African towns [14]. Using the example of Cameroon, he demonstrated that the use of compost for lettuce production is ecologically and economically advantageous for farmers than mineral fertilizers but regrets that its popularization has not been encouraged by the government. Compost unavailability, lack of good compost marketing systems and policy limitations in the domain of organic fertilizer use are major constraints for compost use [15]. Using the case of France, [16] demonstrated that although compost users in urban areas share the same views on the benefits of compost, they consider regulations to be overly rigid. Equally, the application of compost is associated with drawbacks such as toxicity, compost dose, and by practices which either replaces other fertilizer types by compost or associate it with chemical fertilizers [6]. Given a multitude of waste management options in developing countries, [5] argues that farmers need to be given the opportunity to experiment the new practices and feel confident about their usefulness and that individual model farmers or farmer groups can facilitate the adoption of new practices and disseminate information about the benefits of the mew practices.

In Response to the rising demands for organic products, the Dschang municipality in the West Region of Cameroon pioneered the valorization of food waste by turning it into compost. However, waste streams are still under-utilized and at times overlooked by actors of the food production system, thus limiting possibilities of generating health, economic and environmental benefits. Given that constraints and opportunities for compost use in urban farming are likely to differ between countries of the North and those of the South, this work explores the situation in developing countries, which is less documented, and informs practices developed within the Dschang municipality in Cameroon.

Theoretical Framework: Compost use as a Social Practice among urban farmers

The adoption and use of compost in urban farming has been theorized using the social practice theory (SPT) approach. Social practice theory has dimensions that vary from material, competences, things, knowledge systems and culturally-grounded social structures [17, 18, 19]. Since the year 2000, this theory has been used sufficiently to theorize unsustainable consumption practices that lead to food waste [20, 21, 22, 23, 24, 25, 26] but Its contribution in understanding composting and compost use as a practice offers a new perspective. The adoption of compost calls for change in farming techniques, practices, culture and redesign of infrastructure. Integrating compost has the potential to make farming practices more sustainable and improve economic and environmental benefits. The change in behavior should be intended and competences built [17]. The practice of compost use in agriculture in developing countries, however, has a long history even though it was not named as such. However, the intriguing question is; how do we change or shift everyday old and culturally-grounded practices to be more economically and environmentally sustainable?. Studies by [4] and [10] have shown that composting practices and compost use techniques have evolved due to changes in knowledge systems and culturally grounded-structures.

Practices are social phenomena whose performance requires the reproduction of cultural meanings, skills and competences and technological products. [27] identified three elements; material, competence and meaning, which must be brought together to perform a practice. In composting and compost use, materials include technologies and physical entities required in the process, competences include compost application skills and handling techniques while meanings represent social norms, ideas and motivations. These elements are useful in explaining the transformations of practices and diffusion of compost among farmers [28]. Chemical fertilizer in farming is a common practice among gardeners in Dschang town [29]. The integration of compost is recent and for such a practice to be sustainable, farmers must be willing and able to keep the practices alive. The SPT is fundamental in this work as it focuses on the practices and the manner in which they are reproduced rather than on individual, institutions or programs [30, 31]. It is based on this theoretical backdrop that opportunities and constraints for compost use in urban farming have been examined with the aim to inform policies and make practices sustainable.

II. MATERIALS AND METHODS

Study area

Located between longitudes 10°01" and 10°06" and latitudes 5°29" and 5°24", Dschang is the head quarter of the Menoua Division in the West region of Cameroon. It covers an area of 123km^2 with an urban center estimated at 7 km^2. Dschang has an equatorial monsoon climate with two distinct seasons. The rainy season runs from mid-March to mid-November and a dry season from mid-

November to mid-March. Average rainy season rainfall amounts of 2500mm and temperatures of about 21°C have favored the cultivation of both seasonal and perennial crops [32]. Urban and peri-urban agriculture is rapidly developing with the rise of commercial food crops [33]. These are market garden crops like tomatoes, cabbages and huckleberry. Off-season maize and beans are also grown there. Although sufficiently practiced, urban and peri-urban agriculture comes up against the problem of space; it is practiced in specific areas such as swamps and lowlands [29] and in areas awaiting construction of urban infrastructure (Figure 1).

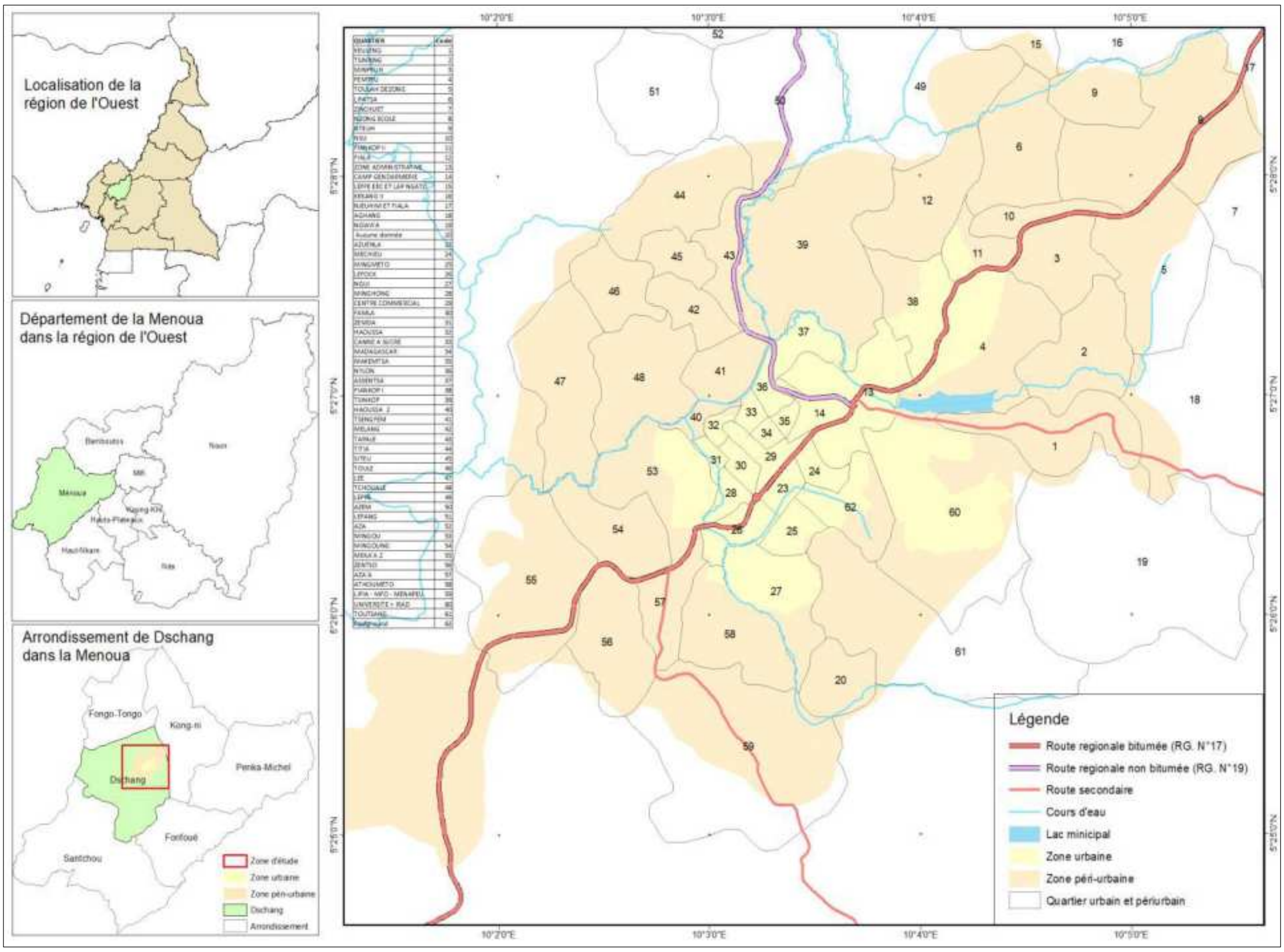

Fig.1: Localization of Dschang town

Source: Administrative boundary data taken from BD Atlas, 2018 edition and equipment data taken from the city's POS and the open Street Map site.

Data collection and treatment

Data for this study was collected using qualitative and quantitative techniques. This mixed methods approach improves data validity thanks to both methodological and data triangulation [34]. Fieldwork survey was carried in Dschang from the 24th of March 2020 to the 12th of September 2020. First was the administration of a household questionnaire followed by key informant Interviews and a focus group discussion with compost users. A semi-structured questionnaire was administered to 265 purposively selected households in five quarters of Dschang town (Table 1) These quarters were chosen based on their socio-demographic characteristics and their accessibility (Table 1), with a coverage rate of 22.7%. Before the survey proper, pre-test surveys were conducted in 10 households to ensure the validity and reliability of data collection tools. The household questionnaire survey was carried out through a data collection interface previously mounted on smartphones. Interviews were conducted with 11 stakeholders from diverse stakeholder groups (Table 2).

Table 1: Number of questionnaire distribution in households per quarter

Quarters	Characteristic of quarters	Total number of households	Number of Questionnaires
Ntseug	-Middle class settlement -located at the peri-urban area -Plannified quarter -Irregular waste collection by council	183	40
Fiankop 2	Zone of very high waste production - low income and inaccessible quarter - linked to the waste collection system by the council	220	51
Haoussa 2	Muslimquarter(specific socio-cultural composition) - Waste disposal into nature -Spontaneous and peri-central	205	49
Asseitsa	Plannified -Middle income -Peri-central quarter - Regular waste collection	340	75
Vallée (Paidground)	Student residential area -Accessible - Served by council waste collection	220	50
Total		1168	265

Table 2: Stakeholders involved in the promotion and use of compost in Dschang

Stakeholder group	Number interviewed	Name of Participant	Zone of activity
Farmer Groups	02	Jardin Polyvalent Tsenbeurg	Peri-urban area
		Yiwiyi Partnership	Urban area
Municipal Authority	03	Head of compost valorisation Unit	Urban/ Peri-urban
		Director of AMGED (Municipal waste management agency)	Urban/ Peri-urban
		Head of compost commercialisation Unit	
NGOs	01	GAAD	Urban/ Peri-urban
Private	01	Mineral fertilizer commercial agent	Urban/ Peri-urban
Government	03	Agricultural extension agents	Urban/ Peri-urban
	01	Divisional Delegate of Agriculture and rural development	Urban/ Peri-urban

To compliment results gotten from household questionnaires and interviews, 12 individual compost users participated in a focus group discussion. The focus group was made of 4 farmers using only municipal compost, 3 farmers using private and family compost, 2 farmers using agro-compost and 3 compost retailers. The group was made up of 40% male and 60% female and discussions lasted for about an hour. Though discussions were guided, participants were given the opportunity to share their experiences with the use of compost.

Data obtained from these sources was analyzed using quantitative and qualitative techniques. Questionnaires were coded and treated using Excel and SPSS version 20. Interviews were transcribed and analyzed using thematic and content analysis with the aid of Atlas.ti software. The coding consisted of organizing and classifying the text to get explanations that permit us to understand the data content. The thematic analysis consisted of exploring the links existing between statements and meanings in respondent's discourse. Excerpts were extracted to support the established arguments.

III. RESULTS AND DISCUSSIONS

Forms of Compost-based urban farming in the West Region of Cameroon

Urban farming is an important economic activity in urban areas as it provides food for the urban households and sustains them economically. Dschang dwellers know the importance of urban farming and gardening but only about 51% of households practice urban agriculture. Those practicing urban agriculture are involved either in urban farming, urban gardening or both.

Urban farms are generally larger parcels of land (more than a hactare) occupied mostly cereals (Plate 1). The use of chemical fertilizers is still common with urban farms, where farmers either use for specific crops such as maize or associate with organic manure.

Plate 1: Urban farms in Dschang town

The act of dumping waste to decompose naturally is practiced mostly in urban farms. The dominant crop type is maize although polyculture and crop rotation are practiced. Crops with high water requirements are cultivated in the wet season due to water availability from rainfall while the dry season is meant for very short-cycled crops that require less water. Most urban farms are cultivated only in the wet season due to limited irrigation possibilities. Farms are prepared in the dry season and planting done with the arrival of rains. It is practiced mostly on state land reserves and on private lands found mostly at the urban peripheries.

Unlike urban farms, gardens are smaller in sizes, generally less than a hectare and contain mostly market gardening crops (Plate 2). The cultivation of urban gardens is intensive and the use of compost dominates. Farmers who use chemical fertilizers in their farms do not apply them on market gardening crops. They argued that their short-cycled and leafy nature do not permit chemical fertilizers to effectively act on the crops and as such, consuming such crops have negative health consequences. Cultivation is all year round and during the dry season crops are irrigated with water from streams and boreholes. The dominant cropping type is monoculture and crop rotation is equally carried out, especially as crops are short-cycled (Plate 2).

Plate 2 : Urban gardens in Dschang

The use of organic manure in farming is a long aged tradition that has evolved with time. Food waste, animal droppings, wood ash and crop residues are traditionally buried into furrows where they decay to form humus. This indigenous practice which was considered as means of waste disposal has improved on food production practices and yields. In the last two decades, this traditional composting by small farmers has been replaced by chemical fertilizer in pursuit for greater yields.

Opportunities for the adoption of compost-based agriculture

Composting and compost availability

Compost is either produced by farmers themselves (20%) or at the municipal composting platforms (80%). Composting practices and compost types vary. Household survey revealed that 39.43% of farmers burry their kitchen waste in pits where it decays into humus, 31% put in bags while 22.57% carry their waste to the community composting. The other 8% use on-farm composting in which crop residues and kitchen waste are deposited along furrows where it decomposes into manure. Interviews with Yiwiyi partnership, a farming group in Dschang (20/06/2020) revealed that on-farm composting is a common practice among resource-poor farmers who cannot afford municipal compost and operating mostly at the peri-urban areas. These groups of compost users have adopted other practices such as collecting debris from waste collection points, using animal dung and wood ash. Family composting has equally been put in place by AMGED, especially in polygamous homes. At the moment, more than 20 family composting bins have been constructed and placed under the control of organized families.

At the level of the municipality, two composting platforms have been put in place; one in Ngui and the other in Siteu. The objective was to produce good quality compost and make it available to small scale farmers. This has encouraged many urban farmers and gardeners to use compost because it is readily available. The head of the municipal composting unit revealed during an interview (5/06/ 2020) that since 2015, the quantity of compost produced has increased from 60.3 tons to 543.78 tons per year in 2020 while the number of compost users have practically tripled within the same period. The introduction of agro-compost (25% fowl dung and 75% municipal compost) has increased the rate of adoption among small scale farmers as it produces yields within just a single farming season. Focus group discussions revealed that farmers who own land are likely to go in for municipal compost while those renting land have a tendency for agro-compost. This is because compost is a soil amendment that nourishes the soil and improves yields after a long period of time while agro-compost nourishes the plants directly. Hence agro-compost is used for short-cycled crops.

Compost sales promotion and technical assistance to compost users

The production of compost at the municipal platform attracts a cost which should be reflected in the price of compost. However, prices have been subsidized and compost sold to farmers at relatively low prices. Promotional campaigns organized by AMGED usually come up at the beginning of the planting season and communicated in the media and public gatherings. As ascertained by the head of compost commercialization unit (05/06/2020), the production cost of a 50kg bag of compost is approximately 4000fcfa but compost is sold to farmers at 2000fcfa. During promotional campaigns, the price goes down to 1500fcfa and farmers are communicated about the offer. To ensure proximity with farmers, AMGED have compost retailers all over the Sub Division. Compost from the municipal platform is given to them at a discount to sell to farmers after convincing them with practical examples on their own farms.

Technical assistance on compost applications is equally provided. AMGED have recruited agricultural engineers that accompany compost users in their farms and carry out demonstrations. Demonstration plots are equally created in different localities and farmer- field -schools are organized frequently. These fora enhance the effective transmission of basic principles and good practices in compost use. Besides, a simple-to-apply technical guide has been elaborated to enable farmers apply appropriate dosages for compost and agro-compost (Table 3).

Table 3: Technical guide on the application of municipal compost and agro-compost

Indicated Volume	Compost	Agro-compost
One 10 liters bucket	6kg for a linear hole of 6-8 meters	5kg for a linear hole of 12m
One 15 liters bucket	9kg for a linear hole of 9-11 meters	7.5kg for a linear hole of 15meters
Recommended Dosage	2.5kg per line/m	2kg per line/m
	$4kg/m^2$	$3.5kg/m^2$

Source: AMGED,(2020)

The compost valorization agent indicated that mastering the compost application guide have motivated farmers to adopt and use compost from the municipal platform. During an interview, the head of the compost valorization unit (06/06/2020) said « …..*mastering the technical guide and making farmers use appropriate dosage have improved on yields and increase the demand for compost…* ». Farmers understanding of compost as a soil amendment with long term benefits and not a just a fertilizers has been successful thanks to efforts of the valorization unit.

Transition to organic farming

In towns such as Dschang and Baffoussam, organic farming (use of natural manure and compost) is gaining importance and attracting many urban farmers and consumers. The questionnaire survey revealed that 23% of urban households do not consume vegetables cultivated with chemical fertilizers. Whether it is the influence of mood, social class or mere imitation, field findings have revealed that the trend is rising. The Delegate of Agriculture and Rural Development for Menoua (19/08/2020) stated that "*Dschang dwellers gradually understand the negative health consequences related to the consumption of chemical-fertilizer based products. From public opinion and the media, people have known that many emerging diseases have been attributed to the consumption of chemical fertilizer-based products and genetically modified plant and animal products*". This awareness and desire to consume healthy have reduced the use of chemical fertilizers, increased the rate of adoption of compost and played an important role in the transition. Although more than 70% of urban farmers still use chemical fertilizers, the rate of selective application is on the rise. This practice consists of using different fertilizer types for different crops and at different growth stages. It was observed that market gardening crops such as huckleberry and other short-cycle crops are cultivated with organic manure while perennial crops such as plantains, tree-crops and long cycle-crops such as maize are cultivated with chemical fertilizers. More than 50% of mixed farm owners are from the lower class and consume mostly private compost or collect debris from waste collection points as revealed during the focus group discussions. In an interview (06/06/2020) the compost valorization agent working with AMGED acknowledged that sensitization against the practice of collecting debris from waste collection points into the farms has significantly increased municipal compost use in urban gardens.

The NGO GADD has equally played an important role in the transition. In efforts to promote biological farming and compost use, GADD developed a policy to encourage young people in this sector by providing support through what they call "incentive policy". The coordinator (10/08/2020) said "*any youth who sets up a 300m*^{2}*organic farm is given five bags(250kg) of compost, accompanied* *technically in the farm, trained on compost production techniques and assisted in the certification and commercialization of products".* To ensure that the products are actually organic, they have set up a Participatory Guarantee System (PGP) that allows them to ensure the quality of their products and the respect of good practices in the production process. This has increased the rate of compost use significantly.

Barriers for the adoption of compost-based farming

Poor mastery of application guide and inadequate experience with compost

During focus group discussions conducted on the 9th of August, 2020, compost users indicated that lack of experience with and knowledge about using compost and the non-mastery of technical guide are barriers for compost application among households. Household survey showed that 65% of compost users do not respect the dosage nor the application procedures outlined in the application guide. The guide prescribed application in three stages; 1. Construction of linear holes of 5 to 10 cm deep on the ridges, 2. Placing compost along the holes and covering with a layer of soil and 3. Watering for 5 to 7 days before sowing the seeds. Interviews with compost valorization agents (06/06/2020) revealed that most farmers simply spread compost on the surface of ridges without respecting either the dosage or the stages due to lack of knowledge. He said « *most small-scale farmers do not get the message. We recommend for example that they use between 10 and 15 tons per hectare but it is not respected".* He added that differences in agronomic requirements for specific crop types and edaphic conditions in various farms, farmers have considered compost use challenging. For instance, a soil that is rich in nitrates (previously had nitrogen fixing crops) will require more compost than agro-compost. This is an aspect that makes compost use difficult among farmers because majority does not have such background information.

Inadequate experience with and knowledge of compost has made farmers to compare compost with other fertilizer types. Compost is a soil amendment and not just a fertilizer. Despite the proven long term benefits of compost to the soil and plants, many scale farmers are still reluctant to adopt it because they expect yields within a short period of time. Such farmers expressed dissatisfaction after using municipal compost as quoted« *.....I got the adverts on the radio talking about municipal compost and i bought four bags to try. I respected the procedures given us on how to apply it but frankly speaking, i am disappointed with the results. Bananas that i cultivated with the compost did not do well as compared with the one i cultivated with pig dung.... »* (Urban farmer, 19/08/2020). This attitude has discouraged many farmers from using municipal compost but has enabled some farmers to produce their own compost. Reacting to this, another compost user (21/08/2020) said *« .... We have been producing our own compost in the pit behind the house because i tried municipal compost three years ago and it did not do well. I bought only two bags to experiment and since then, i have not bought it again…… ».* The rate of dissatisfaction was reported to be higher among farmers renting land.

Stringent urban tenure system

The tenure system refers to the manner in which land is acquired and used in the urban space and the actors involved. The Dschang urban planifcation document of 2013 makes provision for urban agriculture but in practice; most of these spaces initially kept for agriculture are gradually being occupied by habitats and other infrastructures such as playgrounds, car parks and temporary markets. This practice which is done in complicity with the local authorities has negative impacts on urban agriculture and compost use. In conformity with the Cameroon Code of Urbanism, the construction of habitats and other urban infrastructure must occupy 60% of the total land space while 40% is kept for other activities. Although this provision does not really define the type of activity meant for the remaining 40%, it could be exploited for urban agriculture.

Compost use requires long-term investments and secured tenure systems. Following a household questionnaire survey, 38.5% of farmers bought the land they are farming on, 27% are renting, 11% inherited from their parents, 8.5% are care-takers while 11% were freely given to cultivate (Fig 2).

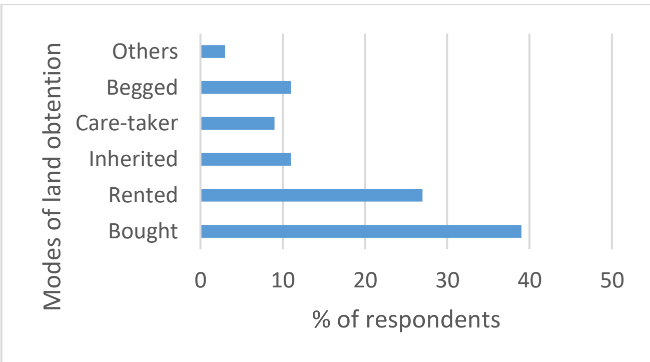

Fig.2: Mode of land acquisition

The buying of land in town is mainly for construction but those with more space always keep aside a portion for gardening. Most urban farms are plots that are awaiting construction and cultivation is just temporal. Owners of such plots either cultivate by themselves or rent them out to those who express the desire. The renting price varies depending on the size of the plot, its location and on the negotiation between the rentee and the renter. In most cases, the agreements are verbal with no legal binding contracts. This has discouraged long term investments because those renting have no guarantee over land. For instance, the director of Yiwiyi pertnership (13/08/2020) said « We *rented a 3600m² piece of land but the landlord refused giving us a three year contract and accepted just a one year contract. This has prevented us from using only compost because the future of the farm is uncertain and investments in compost are expected to yield maximum profit in about three to four years of cultivation".* The is valid for the 11% who begged land to cultivate and the 4% cultivating on roadsides and other public spaces without any authorization. This tenure system shows that more than 50% of urban farmers are not the real owners of the land they cultivate. Their temporal and insecure occupancy status is a constraining factor for the adoption of compost use. Rentage is done without legally binding contracts and rights of users are usually abused as usage rights can be stopped without any prior notice and without considering previous and not-yet-yielding investments such as the application of compost.

Difficulties in transporting and handling compost

Compost is bulky and heavy. Field surveys revealed that households at the peri-urban areas wishing to use municipal compost are not certain about its availability when they need and also identified the high cost of transportation as a barrier. Interviews with the head of the compost commercialization unit of AMGED (05/06/2020) revealed that farmers who buy compost from the municipal platforms are transported free of charge to their farms but there is no transportation for small scale farmers who buy a few bags. He said « famers *who buy more than 10 bags (500kg) are assisted with transportation ».* This encouraging strategy has not favored small scale farmers wishing to embark on compost use.

During focus group discussions, compost users were unanimous that due to the bulkiness of compost and the large quantities needed for use in farming practices, the high transport cost and bad roads limits the distribution and use of municipal compost. The cost of transportation of about 500fcfa per 50kg bag of compost has made it difficult for those at the peri-urban areas to adopt and use compost. One farmer (24/06/2020) said « the *problem of getting compost to per-urban farms has negatively affected compost distribution and use among the resource-poor farmers. It becomes very expensive for them and they prefer mineral fertilizers which they consider profitable* ».

The difficulties of small scale farmers in transportation compost, prompted AMGED to put in place compost retail points at the peripheries to ensure proximity with farmers. This was intended to boast compost use at the peripheries but discussions during the focus group revealed that compost is heavy and difficult to handle, it smells badly and bags constantly tear while in the store. They also mentioned that the reduction in volume and moisture content of compost during storage is a disadvantage. Retailers received complaints from compost users in which some are considering compost as unfinished products, unlabeled bags and any waste could be sold in place of compost, product not fine enough and doubts on the fertilization qualities of the product. The observation made after this discussion is that the current intermediaries or retailers do not know compost very well and are therefore not totally convinced about its goodness. This explains why farmers have strong affinity for agro-compost than compost.

Institutional and policy limitations

The production, distribution and use of organic amendments and mineral fertilizers in Cameroon are a sovereign responsibility of the Ministry of Agriculture and Rural Development (MINADER). Nevertheless, several other ministerial departments are involved in this sector such as the Ministry of the Environment and Nature Protection (MINEP), the Ministry of Commerce (MINCO), the Ministry of Health (MINSANTE) and the Ministry of Scientific Research and Innovation (MINRESI) and the Ministry of Finance (MINFI). The multiplicity of ministerial departments involved especially in the importation and commercialization of mineral fertilizers have led to inefficiencies through the duplication and waste of capital resources and poor enforcement of regulations.

In addition to these ministerial departments, there is a complex regulatory and judicial framework at the interface of environmental, agriculture and health issues and at different policy levels. Outstanding regulations include;

- The framework law N°96/12 of August 05, 1996, relating to the management of the environment;

- Law No. 2003/007 of July 10, 2003 governing the fertilizer sub-sector.

It follows from the framework law Order No. 0069/MINEP of March 08, 2005. This order provides carrying out an impact study in the event of the introduction of new fertilizers or new agricultural practices. The law of July in its chapter 3 reserved for the inspection and quality control of fertilizers provides in article 9 (1) that samples should be taken for laboratory analysis. It also provides that any fertilizing material placed on the market must be effective, must be harmless to humans, animals and the environment. In addition, the new standard of the French Agency for Standardization [35] on organic amendments recommends a safety assessment of all raw materials used in the manufacture of organic amendments. These laws are not enforced in the field. The 2004 law on decentralization have created more complex and sometimes contradictory legislative landscape with conflicts of authorities. The director of AMGED (11/05/2020) ascertained that the institutional and policy sectors in charge of farm inputs in Cameroon have made compost unattractive despite efforts made by municipalities and NGOs. He added that policies have created disincentives for the adoption and use of compost.

The use of mineral fertilizer in Cameroon is high especially among large scale famers. Mineral fertilizers are imported and promoted at the local scale by agents of multinational companies in complicity with state agents. Interviews with an extension worker(22/08/2020) revealed that between 1990 to 2001, fertilizer was subsidized at almost 50% but with the removal of subsidies in recent times, the government still considers mineral fertilizer as a zero-rate policy and cut import taxes. The production of compost is not encouraged at the national level. Rather than supporting municipalities using composting as alternative method of waste treatment, the Cameroon government has recently signed an agreement with the Chinese to mount chemical fertilizer plant in Douala. The plant is intended to produce 80,000 tons of ammonia and 130,000 tons of urea per year and could cover the annual consumption of Cameroon which is currently about 200,000 tons. Concluding on this, another fertilizer sales agent (22/08/2020) working with an international company that deals with chemical fertilizer said the Cameroon government have no good intentions in the promotion of organic fertilizers.

In addition to these disincentive measures of the government, the municipal authorities in have accused extension agents of the Ministry of Agriculture and Rural Development for discouraging compost use. The head of the compost commercialization agent (05/06/2020) reacting to this point saying "*despite our efforts in compost production and promotion, extension services are not helping us in the field. They are supposed to disseminate information on the availability of compost and schooled farmers on its use but rather, they cooperate with multinational firms and promote chemical fertilizers for personal financial gains*". This is due to the non-enforcement of the above mentioned legislation and lack of accompaniment measures at the local level.

IV. DISCUSSION

Composting and compost use in urban farming is a long time practice in Africa even though it was not called as such. Given the evolution in composting techniques, knowledge systems and competences, new practices have emerged. The social practice theory have been used to study food consumption practices that produces waste [23, 24, 26] without looking at compost use as a practice that require specific knowledge-base, competences and materials. Attempting to bridge this knowledge gap, this work examined the opportunities and barriers for implementing compost-based urban farming in Dschang in order to inform policies and make practices sustainable. The economic, environmental and health benefits of compost have been sufficiently demonstrated[10,14, 36].

Findings have shown that compost availability at the municipal platforms, affordable prices, technical assistance provided to farmers and the transition to organic farmer have encouraged the adoption and use of compost. Effective Ccmposting and compost application requires appropriate techniques, materials and competences [13, 16]. The Dschang municipality produces about 600 tons of compost annually and has trained families on composting techniques. Compost application techniques and guidelines are disseminated by AMGED and GADD, a local based NGO but surveys revealed that 45% of farming households in Dschang do not respect such techniques but rely on local practices. Practices such as mixing compost with wood ash, mixing compost with animal droppings and on-farm composting along furrows have been identified. These associations have given a positive image to compost, promoted farmer-to-farmer diffusion of good practices thus increasing the rate of adoption in Dschang. Compost is sold to farmers at a subsidized rate of 2000fcfa per 50kg bag and 1500fcfa during promotional campaigns as an incentive to boast adoption. Studies by [36] demonstrated that increasing compost production in Cameroon had the potential to substitute mineral fertilizer use among urban farmers. Using an economic model, he opined that increasing compost production could save about 18.55% of the annual imported mineral fertilizer quantity and prevents close to 8.47% of annual import expenditure. The transition from conventional farming to biological farming in Dschang is powered by GADD. Organic farming defined by the Federation organization of organic agriculture movement [37, 38] as a production system that maintains and improves the health of soils, ecosystems and people have encouraged compost use in Dschang. The Participatory Guarantee System of certification for organic products put in place have been reported to have encouraged compost use in Cameroon[36] but the "natural without certification" that refers to traditional practices with low use of inputs have promoted diverse composting options.

Despite the opportunities identified, this work evaluated barriers to the application of compost in urban farming. Barriers include; technical and informational, experience and knowledge, financial and transportation, land tenure, policy and institutional [16, 39]. However, local practices persist. For instance, resources-poor households have opted for on-farm composting by burying kitchen along furrows, using animal droppings, wood ash and so on rather than using municipal compost. The overarching challenge come from institutional and policy limitations. Law No. 2003/007 of July 10, 2003 governing the fertilizer sub-sector in Cameroon pay more attention to mineral fertilizer than compost while diverse institutions in the sector have created a confused legislative landscape. For example, using the case of Yaounde town in Cameroon,[36] revealed that the policy of decreasing the transport rate of compost could encourage farmers in the urban peripheries and villages to substitute mineral fertilizers with compost. It is thus evident that policies of popularization of compost can ensure sustainable practices.

V. CONCLUSION

This article examined opportunities and barriers for compost use in urban farming under the lens of the social practice theory. Using a mixed method approach, findings revealed a number of opportunities and barriers that range from on-farm practices to policies and institutions. Compost in its diverse forms has a long time history in agriculture. Old traditional practices that required farming with very little input still persist in the peri-urban areas. Such indigenous knowledge systems and culturally-grounded social structures are important dimensions of the social practice theory. Since the year 2010, Dschang municipality for instance have embarked on a compost production project that have seen quantities increased from about 60 tons in 2013 to 600tons per annum in 2020. The provision of technical and material assistance to farmers, subsidization of compost prices have been identified as an incentive to compost use practices. Also, the emerging environmental and health crisis frequent among urban populations have motivated the transition from conventional type of farming that lay emphasis on mineral fertilizers to organic farming with use of compost. Organic farmers are accompanied by GADD and sustainable practices have evolved. Nevertheless, technical, experience and competences, knowledge, financial, policy and institutional barriers abound. Small-scale farmers with unstable and short term land occupancy status prefer mineral fertilizers to compost. They tend to compare compost with mineral fertilizers from the yield perspective, neglecting the fact that compost is a soil amendment with long term benefits. The existing regulatory landscape has not promoted the use of compost and policies are limited. Hence, while encouraging the traditional farming practices with fewer inputs, policies and programs of compost popularization should be prioritized in the fertilizer policy of Cameroon.

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Feasibility of Winter Oyster- Milky Mushroom Cropping Sequence for Year-Round Production under Assam Condition

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Abstract— *The study was carried out during kharif and rabi season of 2018-19, 2019-20 and 2020-21 at 20 numbers of farmers field having low technology mushroom house at different locations of Assam. Existing farmers practice ie. growing of winter Oyster Mushroom alone from October to February under which farmers can grow two crops per year , was taken as control for comparision of farmer's income with tested practice that is Winter Mushroom followed by Summer Mushroom Cropping sequence . The specific objective of the study was to demonstrate the double cropping of Mushroom Farming viz. Winter Oyster Mushroom followed by Milky Mushroom. The study showed that under the tested double cropping sequence, five crops comprising three crops for Winter Mushroom (September to March)and two crops for Summer Milky Mushroom (April to August)can be grown per year. It was observed that in a 15 feet X 18 feet low technology mushroom house, 400 bags per batch can be accommodate. The winter Oyster and Milky Mushroom cropping system produced the average winter Oyster yield of 2931.6kg per year from 3 batches (400 bags/batch)and an average Milky Mushroom yield of 1240kg from 2batches (five batches in a year)compared to an average yield of 1320kg per year from 2 batches in a year (400 bags per batch) obtained at farmers practice. The percentage yield increase of Winter Oyster – Milky Mushroom cropping sequence (average of three years) over farmers practice was recorded as 216%. The economic analysis showed that growing Milky Mushroom during summer season enhance additional income to the growers who usually grow winter oyster mushroom as single crop for 5 months. Hence growing Winter Oyster Mushroom – Milky Mushroom crop sequence for the year round is a potential income generating enterprise which can be adopted by farmers and unemployment youth of Assam.*

Keywords*— *Year round, Milky mushroom, Winter Oyster , cropping sequence, Assam

I. INTRODUCTION

Mushroom which is considered as "Power House Of Nutrient is rich in proteins, dietary fibre, vitamins and minerals like Cu, Zn and Mg in traces with attractive flavor, rich in medicinal properties like antiviral, antitumor and anti cancer. Mushroom cultivation can directly improve livelihoods through economic, nutritional and medicinal contributions.

In Assam, the agro-climatic conditions as well as locally available raw material make mushroom cultivation an economically viable proposition and hence it can be taken up on a large scale by individual entrepreneur. However, the commercial cultivation of mushroom is very conspicuous. Growers of Assam are mainly engaged in cultivating Oyster Mushroom *(Plurotus spp.)* during the winter month, they are not as much of aware of other summer verities for round the year production. Household cultivations have not been seen due to the lack of awareness and scientific knowledge on summer mushroom for year round production. This creates a problem to sustain the market chain in the summer season.

Milky mushroom (*Calocybe indica*), the third commercially grown mushroom in India, has long shelf life, sustainable yield, delicious taste, unique texture and cholesterol free foods with certain important medicinal properties including their antiviral effect. It is an excellent source of thiamine, riboflavin, nicotinic acid, pyridoxine, biotin and ascorbic acid. The Paddy straw was found to be the best substrate for cultivation of milky mushroom (Maurya et al., 2019).which is locally available in Assam. As during summer, the temperature and relative Humidity of Assam are very much suitable for Milky Mushroom cultivation, the Mushroom growers of Assam can cultivate this crop during summer season along with winter grown Oyster mushroom.

Considering the importance of Mushroom as potential income generating agribusiness (Chang and Miles 1990), it is the need of the hour to make the population aware about the year round Mushroom farming in order to enhance their livelihood both economically and nutritionally. The present study was carried out to find out the feasibility of Winter Oyster –Milky mushroom crop sequence in Assam condition.

II. MATERIALS AND METHODS

The study was carried out at 20 numbers of farmers field having low technology mushroom house at different locations of Kamrup district of Assam during 2018-19, 2019-20 and 2020-21 covering total 10 villages. Farmers were selected on the basis of their interest on Mushroom farming. The required inputs like quality spawn, polypropylene bags along with technical guidance were provided accordingly.

Considering the climatic condition two varieties of Mushroom *viz.* Winter Oyster (*Pleurotus s*pp.) and Milky Mushroom (*Caelocybe indica*) were tested to find out the feasibility of best cropping sequence for year round production in Assam. The cultivation techniques were adopted as standard techniques given by Directorate of Mushroom Research, Solan, Himachal Pradesh and the standard cultivation techniques (Singh et al.,2011).The experiment was conducted in the standard size of 15 feet X 18 feet low technology mushroom house where 400 bags per batch were accommodated. The spawning of Winter Oyster and Milky Mushroom was done through freshly prepared, 15 days old spawn. A moisture content of about 65% was maintained in the wet substrate prior to spawning. Spawning was done @ 5% by wet weight basis of the ready substrate in polypropylene bags of 60 × 40 cm size with 100 gauge thickness. The spawn bags were tricked by the help of sterilized needle to allow the air flow. After spawning, the bags were shifted in to cropping room and kept in dark place where temperature in between (25-30 0C) and relative humidity (85-90%) were maintained till mycelium colonized the substrates. Cultivation process of Milky mushroom is similar as with Oyster mushroom while only additional process of casing is done.(S. Maheshwari,K Chetan et al 2018)

During *rabi* season, the spawning of bags of the first batch of Winter Oyster were done in the month of September 2018 which were completed its cycle in the month of November. The second spawning of batch were started in November and completed its production period during the month of January followed by 3rd crop cycle of same variety which were finally completed by March2019.To find out the cropping sequence, immediately after harvesting of 3rd batch of winter Oyster, the first batch of summer Milky mushroom spawning bags were hanged in the same unit of all the locations in the month of April which was continued to produce fruiting bodies up to the month of June . Then the 2nd batch of the same variety was spawned which was continued up to the month of August(Table 1). This way, under the tested double cropping sequence, five crops comprising three crops for Winter mushroom (September to March) and two crops for Summer Milky Mushroom (April to August) were grown in a year. Existing farmers' practice, i.e., growing of winter Oyster Mushroom alone from October to February under which farmers can grow two crops per year , was taken as control for comparison of farmer's income with tested practice that is Winter Mushroom followed by summer mushroom Cropping sequence. The similar experiment was conducted in three consecutive years. The temperature and humidity of all the units were recorded with the help of thermo hygrometer. The different parameters of fresh yield, cost of production, total production , net income were determined to evaluate the performance of the varieties. Yield was determined by weighing the fruiting bodies of both fresh and dry mushroom and the total yield was determined by adding the yield of 3flushes of the mushroom.

Biological efficiency: Biological efficiency of mushrooms was calculated by dividing weight of fresh mushroom yield (in Kg) by weight of air dried substrate (in Kg) and multiply by 100

$$\text{Biological efficiency} = \frac{\text{Yield of fresh mushroom in kg}}{\text{Total weight of dry substrate used in kg}} * 100$$

Gross return: The total monetary returns of the economic produce obtained from the varieties gowned included in the system were calculated based on the local market price. The total return was expressed in terms 100bags.

Net Return: This has been calculated by subtracting the cost of cultivation from the gross return.

The average profitably index of each unit was calculated by estimating the benefit cost ratio.(BCR).

III. RESULTS AND DISCUSSION

The data presented in Table 2 and Fig. 1 revealed that , the winter Oyster and Milky Mushroom cropping system produced significant yield over farmers practice. Where the average winter Oyster yield of 2931.6kg per year from 3 batches and an average Milky Mushroom yield of 1240kg (two batches in a year) were obtained compared to an average yield of 1320kg from 2 batches in a year obtained at farmers practice. The total average yield of 4171.6kg from round the year(from 5 batches ,per batch comprises 400 bags) was observed .Hence, it is highly significant as on the farmers practice. Similarly Krishnamoorthy *et al*.,(2000),Mahalakshmi *et al.,* (2019) reported that on seasonal performance of Oyster mushroom the yield performance is poor in the summer season. They have also lowest primodial fruit bodies in the summer season. Uppadhyay *et al,*(2003)and Tripathi *et al*., (2005) also reported that maximum yield of Oyster Mushroom and Milky crop sequence was observed during October to February. Hence by adopting this cropping sequence additional yield could get by farmers by maintaining the spawning time(Table.1).

Data presented in the table 3.revealed the incremental yield (Kg/400bags) of the round the year production of Winter Oyster and Milky Mushroom crop sequence over farmers practice. It was observed that , an average incremental yield of 2851.60 kg (from 5 batches, one batch comprises of 400 bags) was observed in demonstration., Hence, farmers will highly benefited by adopting Winter Oyster-Milky Mushroom crop sequence instead of single crop in a year. Similarly. Uddin *et al*.,(2011) reported that instead of single crop, mushroom variety grown in different season crop sequence showed the benefit of Mushroom growers.

The table .4, Revealed the biological efficiency of crop grown under demonstration and farmers practice. The BE of winter oyster under demonstration was 162.6% ,Milky mushroom was 103.3%,whereas under Farmers practice, BE was 110.0% . It was observed(Fig3,4) that at the time of cultivation of Winter Oyster Mushroom (Sept to March) the Average temperature was ranges from 20-30 ^{0}C and in the case of Minimum temperature the range was 8-21^{0}C . Similarly Relative humidity was 80-90%. During the period of cultivation of Milky Mushroom average maximum temperature of 31-33 was recorded. The present findings was conformity with Tripathi et al.,(2005)who suggested that better growth of Oyster mushroom was found in the temperature range of 20-30 0C with relative humidity of more than 85%.And also during the cultivation time of Milky mushroom, Temperature range of 31-34 0 C was observed which was reported earlier by Sing *et al*.,(2011) .

Data presented In the Table No. 5 anf Fig.2 showed the Gross cost, Gross return and Net return of both demonstration as well as farmers practice. The Net Return of Rs. 4,00,596.00/-was estimated for year round production of 5 batches of crop (3batch of Winter Oyster and 2 batch of Milky Mushroom,one batch comprises 400bags) and for farmers practice net return of Rs 96,283.00 was estimated for growing single crop . But by looking the data of Incremental return of Demonstration over FP Rs. 3,04,313.00/- was calculated.

Table:1.Year wise spawning and harvesting date of Winter Oyster- Milky Mushroom crop sequence

Year	Demonstration										Farmers Practice			
	Winter Oyster						Milky Mushroom				Winter Oyster			
	Spawning of batch1	Last harvest of Batch 1	Spawning Batch2 March	Last harvest of Batch2	Spawning Batch3	Last Harvest of Batch 3	Spawning Date of batch1	Last Harvest of Batch1	Spawning Date of batch1	Last Harvest of Batch2	Spawning Date of batch1	Last harvest of Batch 1	Spawning Date of batch2	Last harvest of Batch 1
2018-19	01-9-18	10.11.18	11.11.18	20.1.19	21.1.19	31.3.19	1-4-19	22-6-19	23.6.19	31.8.19	30.10.18	20.12.18	25.12.18	20.2.19
2019-20	01-9-19	15.11.19	16.11.19	27.1.20	28.1.20	31.3.20	1.4.20	18.6.20	19.6.20	31.8.20	6.11.19	2.01.20	8.01.20	25.2.20
2020-21	01-9-20	11.11.20	12.11.20	25.1.21	26.1.21	31.3.21	1.4.21	13.6.20	14.6.20	31.8.20	2.11.20	3.01.21	5.01.21	28.2.21

Table 2: Yield (Kg/400 bags) of Round the Year production of Winter Oyster and Milky Mushroom and Farmers' Practice

Year	Yield under Demonstration			Yield under Farmers' Practice
	Winter Oyster*	Milky**	Total***	Winter Oyester**
2018-19	3128.00	1216.00	4344.00	1320.00
2019-20	2863.00	1136.00	3999.00	1296.00
2020-21	2804.00	1368.00	4172.00	1344.00
Average	2931.60	1240.00	4171.60	1320.00

* indicate yield from 3 batches

** Indicate yield from two batches

*** Indicate yield from round the year demonstration of 5 batches

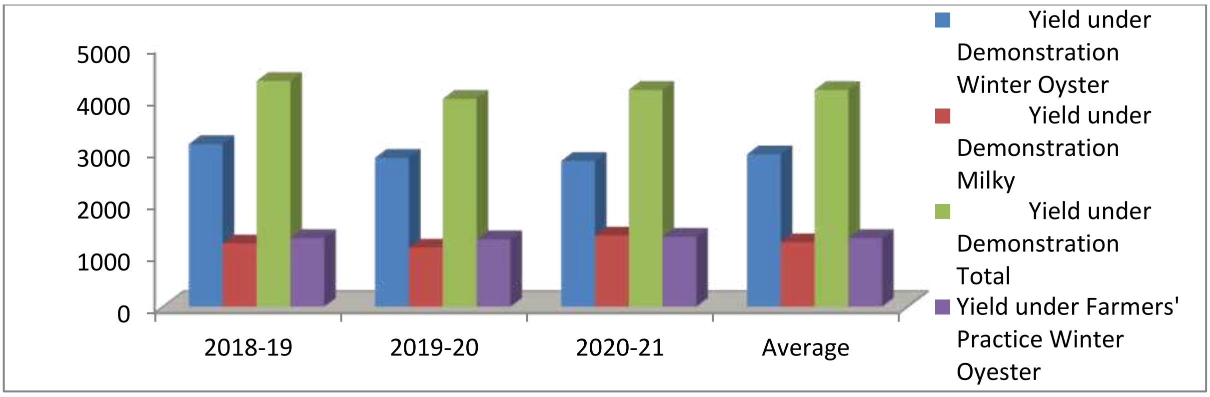


Fig.1: Yield (Kg/400 bags) of Round the Year production of Winter Oyster and Milky Mushroom and Farmers' Practice

Table 3: Incremental Yield (Kg/400 bags) of Round the Year production of Winter Oyster and Milky Mushroom over Farmers' practice

Year	Yield under Demonstration	Yield under farmers' Practice	Incremental Yield of Demonstration over Farmers' practice	Percent increase
2018-19	4344.00	1320.00	3024.00	229.09
2019-20	3999.00	1296.00	2703.00	208.56
2020-21	4172.00	1344.00	2828.00	210.42
Average	4171.60	1320.00	2851.60	216.00

Table.4: Biological efficiency (BE)of Winter Oyster- Milky Mushroom cropping sequence and Farmers' Practice

Biological efficiency(%)		
Demonstration		FP
Winter Oyster	Milky	Winter Oyster
162.6	103.3	110.0

Table. 5: Economics (Rs.)of of Round the Year production of Winter Oyster and Milky Mushroom over Farmers' practice

Particulars	Demonstration			Farmers' Practice
	Winter Oyester*	Milky**	Total***	Winter Oyester**
Average Yield (Kg/ 400 bags)	2931.60	1240.00	4171.60	1320.00
Total Cost	85,386.00	51,810.00	1,37,196.00	62,117.00
Gross Return	3,51,792.00	1,86,000.00	5,37,792.00	1,58,400.00
Net Return	2,66,406.00	1,34,190.00	4,00,596.00	96,283.00
Incremental return of Demonstration over FP			3,04,313.00	
B:C	4.12	3.59	3.91	2.55

* indicate cost/ return from 3 batches

** Indicate cost / return from two batches

*** Indicate cost / return from round the year demonstration of 5 batches

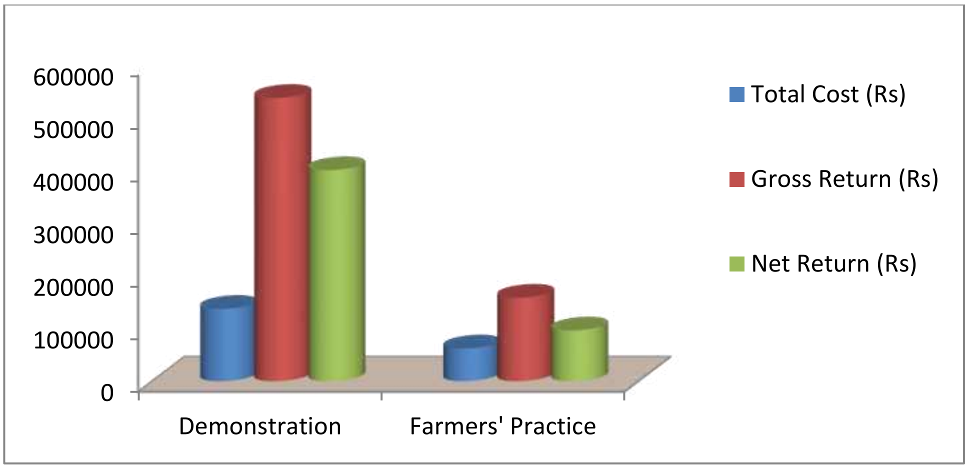
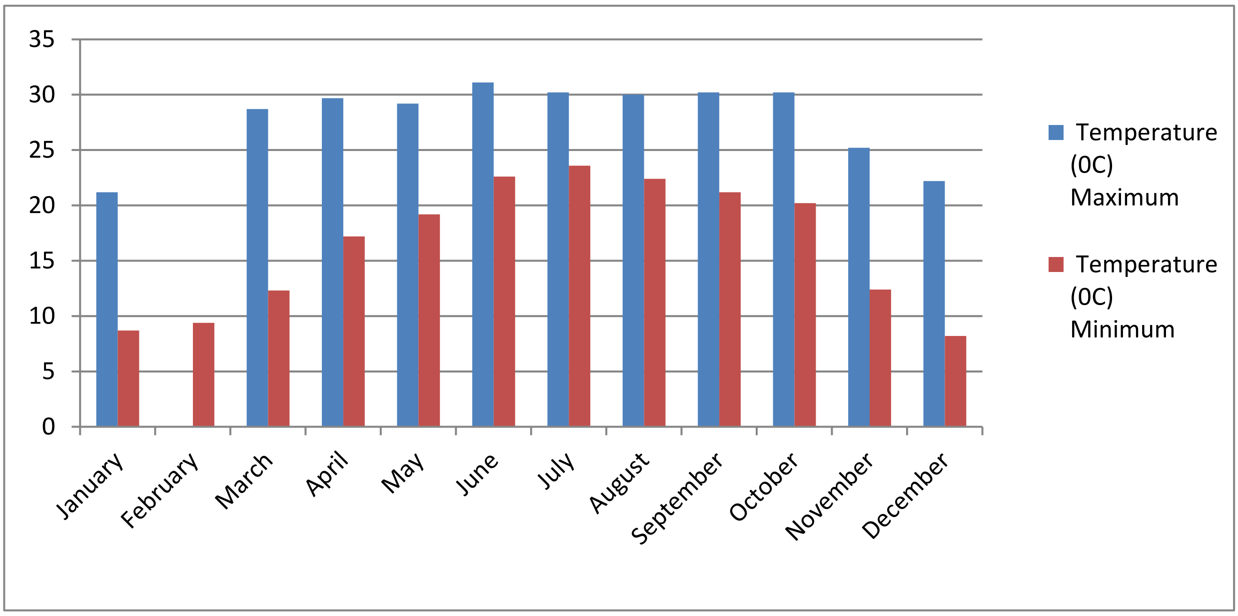


Fig. 2: Economics(Rs.) of of Round the Year production of Winter Oyster and Milky Mushroom over Farmers' practice



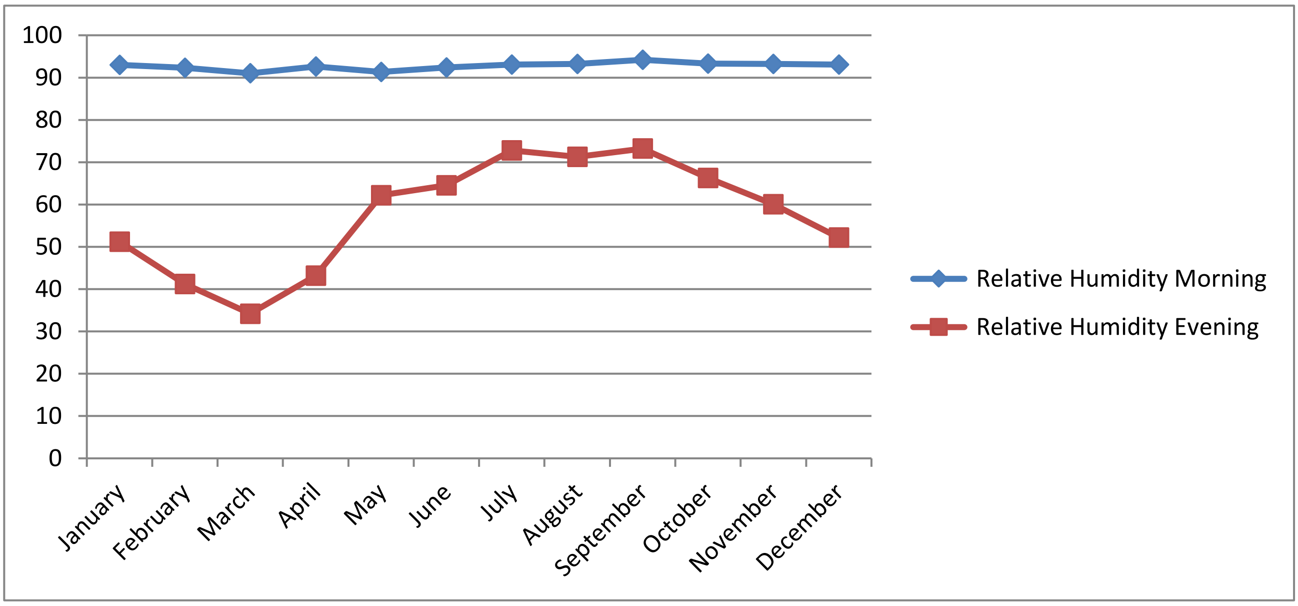


Fig.3&4: Meteorological Parameters during experimental period

Plate 1: Photograph under Experiment

IV. CONCLUSION

Hence in a 15 feet X 18 feet mushroom house, the winter Oyster and Milky Mushroom cropping system produced the average winter Oyster yield of 2931.6kg per year from 3 batches (400 bags/batch)and an average Milky Mushroom yield of 1240kg from 2batches (five batches in a year)compared to an average yield of 1320kg per year from 2 batches in a year (400 bags per batch) obtained at farmers practice. The percentage yield increase of Winter Oyster – Milky Mushroom cropping sequence (average of three years) over farmers practice was recorded as 216%. The economic analysis showed that growing Milky Mushroom during summer season enhance additional income to the growers who usually grow winter oyster mushroom as single crop . Hence growing Winter Oyster Mushroom – Milky Mushroom crop sequence for the year round is a potential income generating enterprise which can be adopted by farmers and unemployment youth of Assam.

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A Review on Solar Powered Maize Dehusker cum Sheller for Sustainable Agriculture

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***Abstract*— *Maize (Zea mays) in India ranks third in total production and productivity and fifth in total area. Since last one decade, maize cultivation area is continuously increasing to encounter the rising demand in the world. Shelling is one of the most important post harvesting operation which is used to separate the grains from ear heads and prepare its quality for the market. Maize grain harvesting consist of the dehusking operation for removal of outer cover and shelling operation for separations of grains from ear heads. This review aims to collate and present an overview of design, fabrication, and performance of a maize dehusker cum sheller consisting of feed hopper with a flow rate control device, dehusking unit, shelling unit, cleaning unit and power system. The performance of the machine was evaluated in terms of throughput capacity, dehusking efficiency, shelling efficiency, cleaning efficiency and mechanical damage. Solar power is ideally used in India due to location factor and also gives the benefit to the environment as renewable energy. Solar power operated maize dehusker cum sheller gives a significance in many rural locations of most developing countries were grid connected electricity is either unavailable or unreliable or too expensive so using of solar power is beneficial.*

Keywords*— *Maize, Dehusking, Shelling, Solar photovoltaic, Renewable, Agriculture

I. INTRODUCTION

Maize (called corn in the United States, Canada, and Australia) is the most widely produced important cereal crops in the world. This cereal, which originated in Mexico, is now grown in at least 164 countries around the world with a total production of more than 1 billion metric tons in 2013.It provides staple food to many populations. In developing countries maize is a major source of income to farmers among whom many are resource poor. Maize contains approximately 72% starch, 10% protein, and 4% fat, supplying an energy density of 365 Kcal/100 g and is grown throughout the world. Maize position as third largest crop of the India after rice and wheat, and it has significance as a source of a huge number of industrial products besides its use as human food and animal feed. Maize in India, contributes nearly 9 % in the national food basket. Maize is also a versatile crops. Maize is one of the agricultural semi-finished products. Every part of maize has profitable value as the grain, leaves, main crop stalk, tassel and cob can all be used to produce a large variety of food and non-food products. Maize is called as queen of cereals because it has highest genetic yield optional in all cereals and also called as king of fodder. In India maize is grown in all the seasons.

Dehusking and shelling of maize cob are the most important operations of maize. After harvesting with sickle and dehusking of cob is done by manually that is outer cover is removed and further traditionally grain is obtained by shelling the cob i.e. by beating the dehusked cobs with sticks or with fingers or sickle, etc. This action is mostly done by farmer women. In India, most of the farmers shell maize by mainly three methods namely shelling cob grain by hand; hand operated maize sheller and beating by stick method were carried for removing maize kernel from the cob. The maize dehusker cum sheller was designed and built to improve the standards of living of people living in villages of developing countries. There are several motor or engine, tractor operated maize dehusker shelling machines for dehusking and shelling purpose. This synopsis on the design and development of solar powered maize dehusker cum sheller that will separate husk from the ear head and will remove corn from corn kernel.

Solar power operated maize sheller gives a significance in a saving of fuel cost, electrical energy & also it is a more useful in an area where electricity as a major problem.

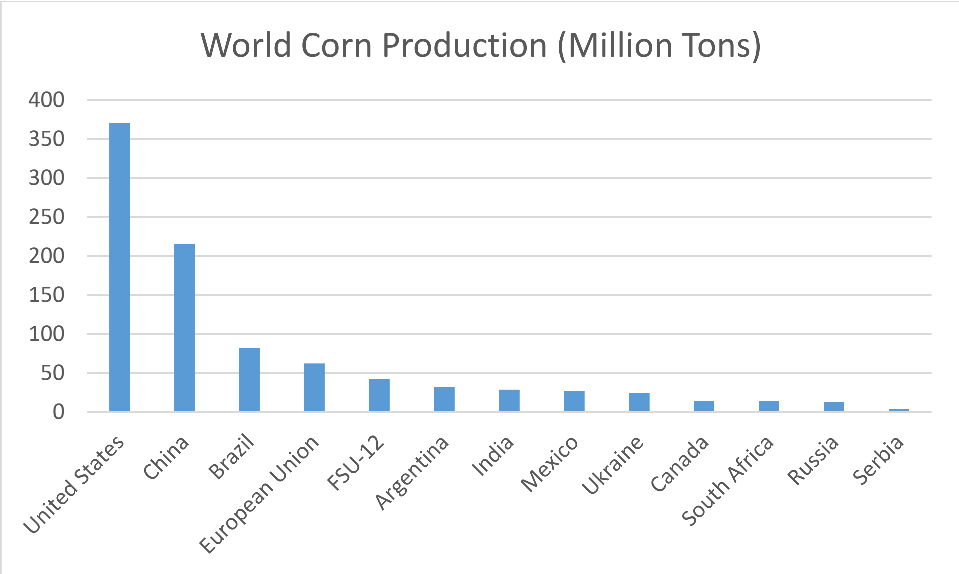

Fig 1 World corn producing countries. (2017-2018) [70]

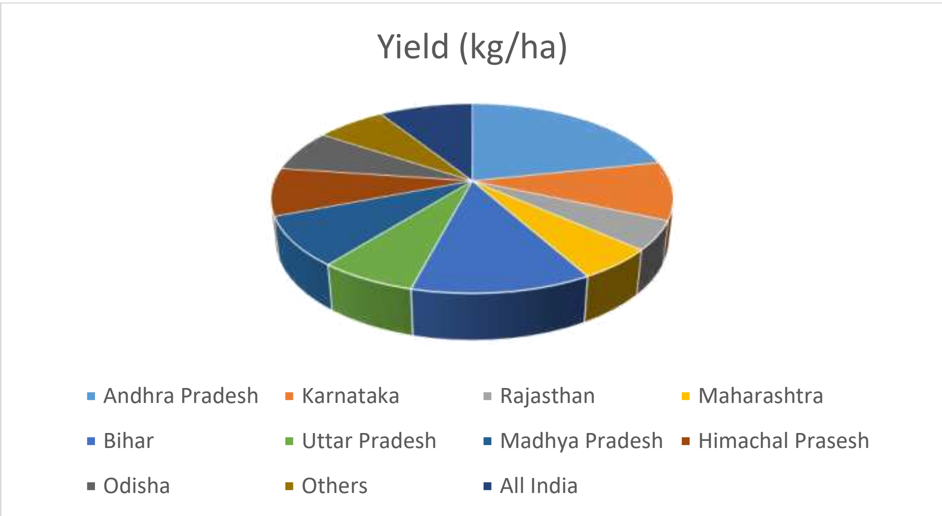

Fig 2 Maize state wise yield of India. (2015-2016) [80]

II. ENGINEERING PROPERTIES OF MAIZE

The development of dehusker cum sheller for maize cobs requires the knowledge of engineering properties such as physical [shape and size, roundness, arithmetic and geometric mean diameter, sphericity, surface area, bulk density and true density], moisture content, test weight of grains and grain to dry matter [husk and grain free cob] ratio], aerodynamic [terminal velocity] and frictional [angle of repose and coefficient of friction] properties of maize grains. [6] Measurement of dimensions of materials plays a key role in deciding the volumetric capacity of hopper, clearances in concave, concave & sieve opening size, also a frictional property for deciding the tilt of sides in the hopper and sieve inclination.[6]

2.1 Physical properties of maize grains.

The physical properties of the maize samples were determined at the desired moisture content levels of 12, 14, 16, 18 and 20 (% w.b.) and they concluded that average three axial dimensions, sphericity, surface area, volume, thousand grain weight, true density, porosity and the static coefficient of friction were found to be increased and the bulk density was found to be decreased with increase in moisture content from 12 to 20 (% w.b.); all at an average temperature of 30°C.[1]

The physical properties viz., unit mass of the cob with and without husk varies from 246.92±37.49 to 371.53±68.16, linear dimension varies from 44.40±253 to 289.90, geometric mean diameter is in the range of 82.80 ± 4.92 mm to 86.60 ± 5.50 mm, arithmetic mean diameter is in the range of 123.70 ± 11.47mm to 126.20± 13.4mm, cross sectional area of the corn cobs varies from 644.50 ± 675.20mm² to 3803.4 ± 803.71mm² and shape index is in range of 5.61 ± 0.88 mm to 6.546 ± 0.96 mm also the average husk percentage content on the corn cob was in the range of 19% to 32% and thousand kernel weight of the selected corn cob verities varies from 80.50 ± 1.51g to 321.85 ± 17.18g, respectively. [2]

Three varieties of maize seed PMH-1, PMH-10 and PIONEER-3396 were evaluated for their engineering properties in the laboratory. Therefore, the physical properties of the maize seeds such as size, shape, hundred grain weight, angle of repose, bulk density and coefficient of static friction are important from engineering point of view and were studied for the development of metering mechanism of maize planter. Fifty seeds of each variety (PMH-1, PMH-10 and PIONEER-3396) were tested and observed for shape and size of the seeds. During observations their geometric mean diameter comes out to be 7.33 mm, 7.06 mm and 7.68 mm for PMH-1, PMH-10 and PIONEER-3396, respectively. The average value of angle of repose during study was observed to be 28.59°, 27.10° and 28.66° for PMH-1, PMH-10 and PIONEER-3396, respectively. The roundness observed in the laboratory was 0.74, 0.74 and 0.66 and their sphericity was 0.78, 0.79 and 0.75 for PMH-1, PMH-10 and PIONEER-3396, respectively. Bulk density for the three varieties of maize was 733.88 kgm-3, 750.01 kgm-3, 741.27 kgm-3 and the value of Coefficient of static friction was 0.64, 0.58 and 0.55 for PMH-1, PMH-10 and PIONEER3396, respectively. [3]

The physical and engineering characteristics of food material are crucial for efficient equipment design. In the present study the above characteristics were accessed for maize, pearl millet and soybean at moisture content 6.40%, 7.95% and 5.25% in the order. Data revealed that highest length, breadth and thickness (L.B.T) and geometric mean diameter (GMD) was found in maize. Test weight and thousand kernel weight ranged between 718.33 g to 791.33 g and 10.72 g to 330.21 g in the sequence, being highest for maize in both cases. The average bulk density and true density were 0.72 to 0.79 g/cc, 1.04 to 1.24 g/cc, respectively. Soybean exhibited maximum porosity trailed by maize and pearl millet. Among the grains, pearl millet had highest internal friction while maize and soybean portray the highest external friction. Referring to angle of repose, soybean showed highest value followed by maize and pearl millet. [4]

The geometric, gravimetric and frictional properties were measured at different levels of moisture content from 8.7 to 21.7% d.b. The results obtained showed that the changes in moisture content of maize kernel lead to minimum variation in geometric properties. The principle dimensions such as length, width, thickness, geometric mean diameter and surface area increased linearly while volume, 1000 kernel weight and sphericity of maize kernels increased in a non-linear manner with increase in moisture content. An increase in bulk density and true density was observed whereas the porosity decreased nonlinearly in the fixed range of moisture content (8.7, 13, 17.4 and 21.7% d.b). [5].

The physical properties such as mean linear dimensions such as length, width and thickness of maize grain were found as 10.99 mm, 8.18 mm and 5.15 mm, respectively. The mean length, diameter and weight of un-dehusked cob were 179.36 mm, 53.88 mm and 212.76 g, respectively, with a Standard Deviation [SD] of 29.56 mm, 4.37 mm and 13.56 mm, respectively. The Physical properties viz., roundness, arithmetic mean diameter, geometric mean diameter, sphericity, surface area, bulk density, true density, bulk density, true density, moisture content, test weight of grains [W1000] and grain to straw [husk and grain free cob] ratio were observed as 0.28, 8.15 mm, 7.69 mm, 0.69, 209.17 mm^2, 0.74 g cc^{-1}, 1.03 g cc^{-1}, 276.58 g and 3.30, respectively [6].

The physical properties that affect equipment design, processing, storage and transportation of high quality protein maize (SWAM 1) seeds as a function of moisture content varying from 9.38 to 32.7% (db). The length, width, thickness and the geometric diameter increased linearly from 9.80 to 10.55, 8.60 to 9.06, 4.00 to 4.75 and 6.85 to 7.69 mm, respectively. The sphericity index, seed volume, seed surface area and thousand seed mass also increased linearly from 69.89 to 72.85, 99.36 to 138.56 mm, 124.55 to 157.76 mm^2 and 240.36 to 303.71 g, respectively. Bulk density, true density and porosity decreased linearly from 1.109 to 1.057 g/m^3 1.365 to 1.176 g/m^3 and 18.75 to 10.12%, respectively. [7]

1. hysical and mechanical properties of food crops gain importance during design, improvement and
2. optimization of separation and cleaning.
3. hysical and mechanical properties of food crops gain importance during design, improvement and
4. optimization of separation and cleaning.

The Physical and mechanical properties of maize seeds gain importance during design, improvement and optimization of separation and cleaning at a moisture content in the range of 5.15 to 22% (d. b.).The average length, width, thickness and arithmetic diameter were increased by 6, 2.2, 1.66 and 3.3%, with increasing moisture content, respectively. In the moisture range from 5.15 to 22% (d. b.), the results showed that, the porosity from 31.41 to 45.98%, the static angle of repose from 42 to 57º, the thousand seed mass increased from 267.7 to 305.8 g. The bulk density decreased from 679.1 to 632 kg m^{-3} and true density increased from 999.33 to 1170.49 kg m^{-3}. [8]

The effect of moisture content on some physical properties and mechanical behavior of corn grains under compression load of two varieties of corn (Sc704 and Dc370). They used the four levels of moisture content which is ranging from 4.73-22% wet base (w.b.) for Sc704 variety and 5.15-22% w.b. for Dc 370variety. As the increasing of moisture content thousand grain weight, true density and porosity increased from 271.0 to 321.4 g & 267.7 to 305.8g, 1250 to 1325 kg/m^3 & 997 to 1170 kg/m^3 and 43.2% to 51.02% & 31.90% to 45.98% but bulk density decreased from 710 to 649 kg/m^3 & 679 to 632 kg/m^3 for Sc704 and Dc370, respectively. Also as increasing of moisture content the static coefficients of friction on various surfaces, namely, galvanized iron, plywood and plastic also increased linearly. The mechanical properties of corn like average rupture force and rupture energy calculated for both the varieties and they found that Dc370 had higher rupture force than Sc704 in all moisture content levels and the variance of rupture energy data for Sc704 was greater than those of Dc370.[9]

8 hysical and mechanical properties of food crops gain importance during design, improvement and
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11 optimization of separation and cleaning.

A database of physical and engineering properties of grains of some main and popular feed, industrial crops. The studied crops viz., fennel flower, rice (Giza 101), rice (Giza 177), broad bean, corn (hyb. 310), corn (hyb. 352), wheat (Giza 9) and wheat (Giza 168) and their selection was based on their recent coverage area and the expected future expansion of each variety. Various physical properties including grain dimensions (length, width and thickness), the weight of thousand grain, bulk density, percent of sphericity, projected area, were determined at storage moisture content 7-12% (w. b.). The physical properties of seed used to select the proper separating and cleaning equipment and the main dimensions were considered in selecting and designing the suitable size of the screen perforations. [10]

The physical properties of sweet corn seed as a function of moisture content in the range of 11.54-19.74% (d. b.). The average length, width and thickness were 10.56 mm, 7.91 mm and 3.45 mm, at moisture content of 11.54% (d. b.), respectively. The thousand seed mass increased from 131.2 to 145.5 g and the sphericity increased from 0.615 to 0.635 with the increase in moisture content from 11.54 to 19.74% d.b. The projected area increased from 59.72 to 75.57 mm^2 and the porosity increased from 57.48% to 61.30%. The bulk density decreased linearly from 482.1 to 474.3 kg/ m^3, whereas the true density increased from 1133.8 to 1225.5 kg/ m^3. [11]

Physical properties viz., length, breadth, surface area, roundness, equivalent diameter, sphericity, seed weight, and true density, angle of repose and coefficient of restitution maize, red gram and cotton seeds. Thickness and cell diameters of the seed metering discs were designed in reference to the maximum breadth and length of seeds. Both roundness and sphericity affect seed flow through the various components of the planter. Roundness of maize, red gram and cotton were 1.14 ± 0.14, 1.15 ± 0.10 and 1.26 ± 0.10, respectively, while sphericity of these seeds in the natural rest position were 0.621 ± 0.065, 0.75 ± 0.016 and 0.550 ± 0.016, respectively. [12]

The maize physical and mechanical properties as related to combine cylinder performance. The maize kernel damage, breakup, efficiency, shelling efficiency and concave separation were measured in stationary rasp bar-bar cylinder for three maize varieties over three harvest dates. Results were discovered important effect of the maize varieties and harvest dates on physical and mechanical properties. [13]

a. Aerodynamic properties

The aerodynamic property, i.e. terminal velocity of maize varied from 14.56 to 15.6 m s-1 with 0.43 m s-1 SD, whereas the mean terminal velocity of husk was 1.2 m s^{-1}. [6] The terminal velocity of sweet corn seed increases from 5.56 to 5.79 m/s. [11]

The aerodynamic properties including terminal velocity, drag coefficient and Reynolds's number were determined at storage moisture content 7-12% (w. b.),the average terminal velocities of grains were 4.17, 7.32, 7.02, 20.16, 15.34, 14.69, 8.00 and 7.58 m/s for fennel flower, rice (Giza101), rice (Giza 177), broad bean, corn (hyb. 310), corn (hyb. 352), wheat (Giza9) and wheat (Giza 168) respectively.[10] The results showed that Reynolds's number of the terminals velocity of the studied grains exceeds the critical velocity of Reynolds's number (RN=2100) in the range of turbulent flow except the fennel flower seeds.[10]

b. Frictional properties

The average value of angle of repose during study was observed to be 28.59°, 27.10° and 28.66° for three varieties of maize seeds are PMH-1, PMH-10 and PIONEER-3396, respectively. The value of Coefficient of static friction was 0.64, 0.58 and 0.55 for PMH-1, PMH-10 and PIONEER3396, respectively. [3] The highest coefficients of friction were found on the concrete surface followed by wooden slab and aluminum sheet.[5]

The coefficient of friction of maize seed on compressed plastic, plywood and galvanized iron sheet surfaces were increased from 0.36 to 0.67, 0.36 to 0.6 and 0.38 to 0.57, respectively.[8] The frictional properties of maize such as angle of repose was found 22.76˚ and coefficient of friction was 0.31 [grain-grain], 0.35 [grain-fly wood], 0.44 [grain-MS sheet] and 0.50 [grain to wood]. [6] Static coefficient of friction of maize (SWAM 1) was found to increase on plywood, galvanized iron, aluminum and stainless steel surfaces and it increased logarithmically from 0.55 to 0.91; 0.52 to 0.81, 0.49 to 0.70, and 0.46 to 0.68, respectively. Angle of repose increased linearly on plywood, galvanized iron, aluminum and stainless steel surfaces from 18.91 to 29.05, 17.00 to 26.96, 15.93 to 23.98 and 15.55 to 22.19°, respectively. [7]

The mechanical properties including angle of repose and coefficient of friction were determined at storage moisture content 7-12% (w. b.).The obtained data showed that it was the use of stainless steel or galvanized iron in manufacturing of seed hopper used in planting machines, silos and storage containers with side's inclination of 40° allow easy sliding of grains. [10]

The static coefficient of friction of sweet corn increased for all four surfaces, namely, rubber (0.402–0.494), aluminum (0.321–0.441), stainless steel (0.267–0.401) and galvanized iron (0.364– 0.477). [11]To ensure free flow of seeds (maize, red gram, cotton) the slope of the seed hopper was, therefore, fixed at 30°, which is modestly higher than the average angle of repose of seeds. [12].

III. DESIGN & DEVELOPMENT OF MACHINE

3.1 Chute design

An improved design of chute for safe feeding of the crop in the thresher is based on the different test reports, research, papers, technical literature and existing threshers‟ information have been compiled for maize crop. The recommended cylinder peripheral speed was 750 to 1220 m min-1 with concave clearance of 22 to 30 mm. [32].

Design of the threshing chute on the basis of anthropometric dimensions of 95th percentile bellow height of Indian male population. The minimum height of feeding chute from standing platform was not more than 100-105 cm. They recommended minimum length of feeding chute as 100 cm and 15º inclination with base of feed chute from horizontal in standing position. [42]

3.2 Cylinder & Concave design

Multi-crop thresher designed by using of a spike tooth cylinder and inverted bar type closed concave. He had reported that for to breaking bunches better spike tooth concave helped and provided more complete threshing and separation whereas non meshing spike tooth concave was only practical in the inverted position where gravity provided continuous self-cleaning. [34]

Wire loop cylinder for threshing of maize grains and found that the better threshing performance with using of wire loop cylinder in place of rasp –bar cylinder [35]

Development of a low damage maize shelling consisted of three inclined rollers rotating in the same direction but at different speeds at an angle of 20° with the vertical . The ears were fed axially between the rollers through a gap of 33 mm. The test was carried out at the moisture contents of 16%, 18%, 20%, 22%, 24% at a speed of12000 rpm, 1100 rpm, 1000 rpm 900 rpm, respectively. The shelling capacity and shelling efficiency found to be 330 kg per hectare and 97.4%, respectively at 1200 rpm and moisture content below the 20%. It was found that the breakage was low in hand and high in combine shelling compared to the roller sheller. [33]

3.3 Power source

In many regions of the India maize shelling is done manually, this method is conventional but output and productivity from that method is low. Manual shelling of maize is a time-consuming and tedious operation. Traditionally maize is threshed by shelling cob grain by hand and beating the cob by stick. Four method of maize shelling namely shelling cob grain by hand, octagonal maize sheller, hand operated maize sheller and beating by stick method were carried for removing maize kernel from the cob. In shelling cob grain by hand agricultural worker remove the grain from cob by using his thumb first make a line, after that they rub the cob by another shelled cob to remove the grain, due to rubbing action grains were detached from the cobs.[39]

3.3.1 Human power

In a design of the hand operated axial flow maize dehusker-sheller operated by farm women, the peripheral cylinder tip speed of 5.6 to 5.7 m/s was found optimum from grain breakage point of view. The output capacity with machine was 60 kg/h at feed rate of 80 kg un-dehusked cob/h .The dehusking efficiency was 100%. Shelling efficiency 98.85% and grain breakage 0.3% at 5.6 m/s cylinder speed. [20].

The output in terms of dehusking shelling maize cob was reported that 30 kg per hectare with 8.3% grain damage in traditional system (dehusking by hand and shelling by beating wooden sticks). The hand operated maize dehusker cum sheller was most suitable for farm women workers. [21]

3.3.2 Mechanical power

Broadly speaking, mechanical power includes stationary oil engines, tractors, power tillers and self-propelled combines.

The power operated maize dehusker sheller may be suitable for strong group of farmers i.e. medium and large farmers while in the country, about 80.3% of farmers of marginal and small group operates 36% of the area. [21]

3.3.2.1 Tractors

Design and evaluation of the performance of tractor operated stationary threshing machine at Egypt for wheat crop. The feed rate decreased with the cylinder speed 900 to 1100 rpm and increased with the cylinder speed from 600 to 1100 rpm. For all cylinder speeds, the feed rate increased linearly as the hole diameter increased from 22 to 45 mm. The hole diameter not having appreciable influence on the seed damage. Increasing the cylinder speed or decreasing the hole diameter reduced the straw length under chapping section. Optimum operating condition for threshing wheat decided as 1000 rpm with concave clearance of 45 mm hole diameter [31].

Design of an axial flow thresher for seed crops. The major features of the thresher were minimum injury to seed, higher seed recovery and good seed quality, easy feeding and less fatigue to labour. It has provision of easy adjustment of concave clearance, sieve clearance and slope of sieves. At optimum combination of cylinder speed and concave clearance at different seed moisture contents to thresh oil seeds and pulse crops, the performance parameters were within acceptable ranges of visible seed damage ≤ 2% and threshing efficiency ≥ 95% with threshed seed germination of green gram (88%), black gram (90%), soybean (90%), chickpea (90%) and sunflower (86%). The unit could be operated by a 22 kW tractor or a 7.5 kW electric motor. [26]

Development and evaluation of a power operated wheat thresher. It was observed that maximum threshing efficiency of 95.3% can be achieved by threshing the wheat crop at peripheral speed of 1027 m min-1 (500 rpm) at 9.25% moisture content when the concave clearance was 1.3 cm. [30] It was also found that net unit threshing cost per quintal of wheat was Rs. 13.63 when threshed by this equipment when compared to Rs. 14.94 by traditional methods. [29]

3.3.2.2 Power tillers

In an impact assessment of PAU maize dehusker cum sheller observed that threshing capacity of the machine was between 400-510 kg/h at different M.C. of cob i.e. 14-20% (db.), where the Dehusking efficiency at 16% M.C. & 740 RPM was maximum 85%. The grain breakage & unthreshed grain percentage was minimum at cylinder speed of 740 RPM. [18]

3.3.2.3 Engines

The development of a new power sheller that could reduce grain damage and broken corn cobs. The SENAPIL sheller was operated by 6.5 to 8.5 hp diesel engine with highest shelling of capacity 4.82 t h-1 which significantly higher than the SLM's (local maize sheller operated with 6.5 hp diesel engine) effective capacity (2.57 t/h).local sheller. New machine was worked on the principle of the reduction of the normal stress during the shelling process by developing a concave system that could vibrate without causing great impact on the maize grain. To do this, the concave system was suspended using a rubber spring to minimize impact. [27]

3.3.4 Electrical power

Design& development a maize dehusker cum sheller (MDS) which is operated by 2.23 kW electric motor having capacity of 600 kg/h. The developed trapezium shaped MDS machine having overall dimensions of 1200× (500 & 610) × 810mm (length × (top & bottom) ×height). For machine performance & seed quality parameters the selected operational parameters viz. cylinder peripheral speed (7.1 m/s), concave clearance (25mm), & feed rate (600 kg/h) were studied. The performance of machine under these parameters were reported that the dehusking efficiency of 99.56%, shelling efficiency of 98.01%, cleaning efficiency of 99.11%, total loss of 3.63%, machine capacity of 527.11 kg/kW-h & germination percentage of 98.93%. These recommended that overall machine performance was satisfactory for maize dehusking cum shelling operation and for producing of maize grains for seeding purpose. [24]

At MPUAT, Udaipur 5.5 KW motor operated whole crop maize thresher was developed by using of spick tooth cylinder. This machine performed simultaneously the dehusking-shelling of maize cob and stalk was converted to chaff. [51]

The design and fabrication of corn shelling and threshing machine basically compromises of separate shelling chamber, threshing chamber, collecting tray and motor (2HP). The arrangement of these parts is connected by belt and pulley mechanism. The weight was only 95 Kg. After testing the machine, the production rate for threshing operation was 300 kg/h and for shelling 300 kg/hr. At last the germination test was carried out for corn seeds threshed by the machine and it were found that time required to grow from seed was about 48 hours. [19]

Design and construction of very low and affordable cost maize sheller from locally available materials. This machine was constructed for shelling of maize cob i.e. it separates the grains from the cob with its threshing efficiency was 99.2% and breakage losses were insignificant and the capacity of threshing of maize is 200 kg/h. The machine is less bulky, simple and effective with its self-cleaning ability [25]

At TNAU, Coimbatore the power operated maize dehusker-sheller was developed i.e. 10 hp motor operated and it removes the outer sheath and shellers the maize cobs simultaneously i.e. dehusking & shelling is done at the same time. The machine has lugs on dehusker-sheller cylinder of square solid blocks types and has helically louvers at start and end of cylinder. [30]

IV. ERGONOMIC DESIGN OF MACHINE

4.1 Manually operated

Ergonomic evaluation of hand operated maize sheller on farm women. The results shows that the hexagonal tubular maize Sheller saves almost half the time and increases working efficiency 79.24 per cent and reduces 87.94 per cent drudgery of farm women over traditional practice. The cleaning efficiency was also found to increase 6.6%. Comparison with traditional method, Hexagonal tubular maize sheller shows easy in operation no muscle strain, low cardiac cost, less energy expenditure while using traditional practice. Hence, maize sheller is best option for the women, it saves not only the time but increases the efficiency of farm women twice. [36]

The efficiency assessment of maize sheller in context of drudgery of farm women. It is concluded from the study that manual maize shelling is a strenuous activity leading to pain in Neck, back, Shoulders, Wrist and Finger. Time taken in shelling grain from one cob quiet higher from the maize sheller. Manual maize shelling is moderately heavy work but it can be lightened by the use of maize sheller. Musculoskeletal pain is considerably reduced with maize sheller. If talking in monetary terms, maize sheller saves Rs.90/day. Hence maize sheller is good option for removing maize from the cobs, it saves not only the time but also increases the efficiency of farm women almost by twice and save cardiac cost of worker per unit of output in comparison to the hand shelling. It eliminated the chances of injury to finger and is very comfortable hand-operated tool. [38]

A physiological evaluation of different manually operated maize shelling methods. The mean oxygen consumption rate (OCR), ΔOCR, heart rate (HR), ΔHR for octagonal maize sheller was lowest among all method of maize shelling and highest for beating by stick method. The energy expenditure rate was highest for beating by stick method (3084 kcal / min) and lowest for octagonal maize for octagonal maize sheller (1.52 kcal/min). Energy expenditure rate for shelling cob grain by hand and octagonal maize shelling operation could be scaled in "Very light" category of work load. Whereas the hand operated maize sheller and beating by stick method could be scaled as in "Light" category of work load. For maize shelling operations octagonal maize sheller and hand operated maize shelling are superior than shelling cob grain by hand and beating by stick method. [39]

The effect of power output and pedaling rate on physiological responses of 12 men on computerized bicycle ergometer at five levels of power output (30-90 W) and seven levels of the pedaling rates (30-90 rpm). Analysis of data indicated that physiological responses were significantly affected with power output as well as pedaling rate. Increase in physiological responses (heart rate and oxygen consumption rate) over rest (delta values) were significantly higher when pedaling frequency was 30rpm and above 50 rpm. There was no significant difference between physiological responses at 40 and 50 rpm. Physiological responses increased linearly with power output and were significantly different at different power outputs. The delta values of physiological responses at 60 W power output and 50 rpm pedaling rate (variation in heart rate (¯HR) = 40 beats min-1 and variation in oxygen consumption rate (¯VO2) = 0.56 l min-1) were within acceptable limits for continuous pedaling work. From the result of the study it was concluded that for daylong pedaling work the power output of the Indian agricultural workers should be limited to 60 W and the pedaling rate should be 50 rpm. [40]

The energy expenditure of woman laborers for maize shelling using tubular, modified tubular and hand operated maize shellers and they compared the energy expenditure with the traditional method of shelling. For operating the maize sheller they were selected the three female subjects with similar anthropometric parameters and they estimated that for operating the different manual shellers the average energy expenditure was 5-6 kcal min-1. The output of the hand operated maize sheller was 23 kg/h, which is 92% higher than the hand operated, modified tubular and tubular maize sheller and which saves energy expenditure by 80%, 60% and 52%, respectively, as compared to the traditional method. For these shellers the energy requirement to work without fatigue was 2200 kcal/day. [44]

If the equipment was developed for women workers as in most of the cases the equipment like dehusker-sheller were suitable for women workers also suits to the men workers because the ergonomical characteristics like anthropometrical dimensions, muscular strength of women workers, aerobic capacity, etc. were less than men workers hence, a hand operated maize dehusker cum sheller has been designed developed and fabricated for dehusking-shelling of un-dehusked cobs. [45]

4.2 Power operated

An ergonomic evaluation of one of the commonly used maize sheller cum dehusker machine in Maharashtra state. Various key postures of the workers are analyzed and evaluated the risk during the poster. Tools like digital human manikin (DHM) & Rapid Upper Limb Assessment (RULA) are used in this study. Ergonomics analysis of maize sheller cum dehusker was performed for both 5^{th} and 95^{th} percentile male operators. DHM technique can be successfully used to develop the ergonomically sound products based on anthropometric data of user population. The ergonomically designed machines/equipment's can reduce drudgery, increase efficiency, safety and comfort. [37]

The analytical studies on strength parameters of Indian farm workers and its implication in equipment design. The strength parameters of 105 agricultural workers (75 male and 30 female) were measured on "strength measurement setup" comprising load cell with digital indicator. The average push strength for male and female workers (with both hands in standing posture) was found to be 248.2 and 171.0 N, respectively whereas the pull strength in standing posture was 232.3 and 141.7 N, respectively. These strength parameters were found to play a significant role in design of manually operated push-pull type equipment. The right hand push and pull strength for male and female agricultural workers were within the range of 49.7 to 96.5 N which prominently assist in the design of joystick, gear shift lever and handle lever. The mean value of maximum right leg strength in sitting posture for male and female workers were 394.2 and 280.5 N, respectively which were found useful in the design of clutch pedal, brake pedal, accelerator pedal, pedal operated thresher and other foot operated controls. Average torque strength of both hands in standing posture for male and female workers were found to be 209.93 and 117.72 N-m, respectively which can be used in the design of manually operated equipment like chaff cutter, sugarcane crusher, slicer, threshers etc. These parameters can be utilized in the design of manually operated push-pull equipment, workplace design, gear shift lever, handle lever, gear control lever, design of pedal for accelerator, clutch & brake, and other foot operated controls. [41]

Development of a grain threshers based on ergonomic design criteria and they resulted that thresher injuries result in crush/amputations of upper limb. Chute design has an important bearing on injuries. Increased heights and chute cover lengths are recommended for safer operations. Height of platform and work posture were found to influence the injury outcome hence the design modification of the chute & height difference of platform and chute can reduce the possibility of injury among threshers operators. The modification are under consideration for changing the thresher design standards by Bureau of Indian Standards (BIS).[28]

A cost effective, improved design for safe operation of threshers based on ergonomic principles. The study was done in villages of Sonipat district of Haryana State and Baraut district of Uttar Pradesh. They interviewed all the injured victims with serious cuts or amputations taking treatment in nearby hospitals. Found that 4% of victims were under 16 years, 82% in 16-45 years and 14% over 45 years. The right hand was involved in 80% cases, left hand was involved in 15% and other body parts 5%. Thirty-five cases involved amputations of the right hand fingers, right hand, right forearm, left hand fingers and left hand. They analyzed machine parts associated with injuries revealed that the threshing drum and the feeding system were involved in 52 cases, belt and pulley in 6 cases and rest by any other machine part. Chute design has an important bearing on injuries. Increased chute heights and chute cover lengths are recommended for safer operation. Height of platform and work posture were found to influence the injury outcome. Design modifications of the chute and a height difference of platform and chute can reduce the possibility of injury among thresher operators. The modifications are under consideration for changing the thresher design standards by Bureau of Indian Standards (BIS). [43]

V. PERFORMANCE EVALUATION OF MACHINE

5.1Crop type, variety, moisture content

Manual shelling of maize was time consuming and tedious operation. The few existing mechanized shellers on Nigerian farms were imported and out of reach of the rural peasant farmers that were characterized by small holdings and low income. The power requirement of such shellers was high and hence, the prime mover was very expensive. The kernel damage and cob breakup decreased significantly with later harvest date. The shelling capacity was not significantly influenced by harvest date or maize variety. Generally, the performance of the maize sheller was not influenced by maize the variety; therefore, the maize sheller can comfortably be used to shell local maize varieties. [55]

The performance of threshers influenced by some known crop parameters and machine variables. Each or combination of these parameters had influencing effects on the grain damage and threshability. The influence of both threshability and grain damage translate to measurable grain losses if not properly managed. [56]

Testing of the performance of maize sheller using an international standard codes to study the general qualities and design of sheller. The results showed that the shelling efficiency of the sheller varies with feed rate, moisture content, and speed of the shelling unit. The machine had a cleaning efficiency of 93, 87, 85 % and shelling efficiency of 98, 95 and 94% when shelling of maize with a moisture content of 11, 20 and 25%, respectively, with a fan unit speed of 750 rpm and shelling unit speed of 400 rpm. The sheller had a capacity of 260 kg/h. The performance tests proved that at shelling unit speed of 450 rpm the sheller performed better with minimum losses and high efficiency. [59]

Three levels of grain moisture content and cylinder speed, three types of local maize shellers were tested. As an increase of the moisture content of maize the effective shelling capacity decreased and increased with an increase of the cylinder speed. With increasing moisture content of maize and cylinder speed mechanically damaged maize increased but the total drying cost decreased. [61]

The performance parameters of threshing unit in a single plant thresher and the results showed that the effects of variety on the on the damaged grains percent and power requirement of the threshing unit were significant at probability level of 1 % & 5 % respectively. The effect of crop moisture content was significant at probability level of 1% on the threshing loss and power requirement. With increasing of drum speed at all varieties, threshing loss decreased. At all drum speed levels, by increasing drum speed, damaged grain percent increased. At each drum speed levels, the mean of power requirement at wet condition of paddy was significantly higher than dry condition of paddy. [49]

The factors affecting corn kernel damage in combine cylinders. Concluded that as the kernel-moisture content decreased, the kernel size decreased, indicating kernel shrinkage as they dried, Kernel strength and stress increased as kernel moisture decreased. Kernel detachment force was independent of kernel moisture or other kernel properties. As the kernel moisture decreased, kernel damage decreased. No differences in kernel damage were obtained for field shelling and lab shelling of ears. Planting date did not affect kernel damage. The most important plant properties influencing mechanical damage were kernel detachment force, kernel strength, initial and final kernel thickness (kernel deformation), and cob strength. Low kernel damage was associated with low detachment force, high kernel strength, low kernel deformation, low cob strength. By changing plant characteristics, such as reducing detachment force and increasing kernel strength, it should be possible to reduce kernel damage during combining. [72]

Ear head axis parallel to cylinder axis orientation suffered the minimum damage, followed by ears fed randomly to the cylinder and the highest damage was suffered by ears fed with their axis perpendicular to the cylinder. At 20 to 22% moisture content, the minimum damage for all orientations was obtained. They found that as an increase in moisture content and cylinder velocity the corn kernel damage increased. [68]

The effect of moisture content on maize shelling speed using a manually operated hand sheller. Twenty unthreshed maize cob samples (A-J) were used for analysis. The result indicated that sample J, after sixty nine hours (69th) oven drying recorded the lowest moisture content (15.10% w. b.) and the fastest shelling speed (0.75 rpm) compared to sample. A (24 h drying time) which had the highest moisture content (28.99% w. b.) and lowest shelling speed (0.96 rpm). It was observed that sample J with the shortest shelling duration had the smallest grains weight (84.2 g), while sample A recorded larger grain weight (162.9 g) due to differing moisture content of the maize grains. The data generated was analyzed and compared using statistical means, percentages and figures for pictorial presentation. It was recommended that maize cobs be dried properly to enable easier and faster shelling operation with less fatigue and minimum grain damage. Lower the moisture content then the faster the shelling speed. [22]

5.2 Cylinder speed & concave clearance

The performance assessment & optimization of maize dehusker cum sheller. In present study, the medium sized electric motor (2.23 kW) operated maize dehusker cum sheller (MDS) was developed and evaluated for selected operational parameters, viz. cylinder peripheral speed (6.2, 6.6, 7.1 and 7.6 m/s), concave clearance (20, 25, 30 and 35 mm) and feed rate (400, 600 and 800 kg/h). The machine performance parameters revels that, the dehusking efficiency and shelling efficiency were showed increasing trend with cylinder peripheral speed (S) from 6.2 to 7.6 m/s; whereas decreasing trend against increase in Concave Clearance (C) from 20 mm to 35 mm. The total losses of grains in machine were found lowest between feasible at 25 to 30 mm of C for all feed rates (F). In seed-quality parameters, the decreased germination percentage with increase in S was observed. The increased broken grains (%) and seed-coat damage (%) were identified with increased in S and decrease in C as well as F. The highest desirability value (obtained from numerical optimization technique) was obtained for operational parameter combination of S at 7.1 m/s with C at 25 mm under 600 kg/h of F. The performance of machine was also satisfactory for producing maize seeds for seeding purpose without compromising its performance. The optimum operating conditions of cylinder peripheral speed, concave clearance, & feed rate were 7.1 m/s, 25 mm, 600kg/h, respectively. [15]

In the analysis of variance for damaged maize kernel percentages kernel moisture content and cylinder speed were highly significant The total damage increased from 26% to 41% as cylinder velocity increased from 450 to 650 rpm & the minimum total damage was sustained at 23% moisture content (w. b.). They found that for cylinder velocities, the mechanical damage by the laboratory sheller ranged between 26.3 and 42%. [66]

The Percentage of maize grain damage caused by the cylinder and concave before and after the grains were shelled from the cob. He investigated that grain damage was caused due to effect of cylinder velocity and grain moisture content. In the shellers cylinder velocity of 7 m/s and 11 m/s were used and maize varieties were shelled with grain moisture content of 15%, 20% and 15%. As an increase in moisture content and cylinder velocity damaged grain percentage were increased. The concave clearance, physical and morphological properties of maize ear and feeding rate effect on the mechanical damage. [60]

The investigation of the effective factors on threshing loss, damaged grains percent and material other than grain to grain ratio on an auto head feed threshing unit. At all tests, the stalks flow axially through the drum without clogging between drum and concave and also in chain conveyor and rail The effects of crop moisture content condition, variety and drum speed were significant on threshing loss. In general, mean of threshing loss at dry condition of crop was higher than wet condition of crop. Optimum speed of drum was 650 rpm because threshing loss and damaged grains percent were equal to zero at this level of drum speed. The main effects of crop moisture content conditions, variety (at probability level of 5%), drum speed (at probability level of 1%) and double interactions (at probability level of 1%) were significant on the damaged grains percent. Damaged grains percent at wet moisture content condition of crop was lower than at dry moisture content condition of crop. The main effects of crop moisture content conditions (at probability level of 5%), variety and drum speed and their interactions (at probability level of 5%), drum speed and interactions (at probability level 1%) were significant on the MOG/Ratio .In general, MOG to grain ratio at tests with dry crop was higher than wet crop. Increasing of drum speed increased the MOG to grain ratio significantly. [16]

The optimum clearance between the cylinder peg & concave is found to be between 1.8 cm and 2.4 cm at feeding rate of 1 or 2 maize cobs per minute and between 2.2 cm and 2.6 cm at feeding rate of 3 to 6 maize cobs per minute. It was also found that the optimum speed of the cylinder is between 600 rpm and 700 rpm, irrespective of the feeding rate. Found that a dehusking, shelling, grain cleaning efficiency about 99.5%, 98%, 99.2% respectively. The capacity of the machine varies from 10kg to 40 kg of maize cobs per hour, depending on the feeding rate. [17]

The effect of operating speed and cob size on performance of a rotary maize sheller reported that the shelling capacity of the maize sheller for all categories of maize cobs initially increased in a curvilinear fashion with increase in operating speed up to about 70 rpm and thereafter it was almost constant. Further the shelling capacity at a particular operating speed decreased with increase in maximum diameter of cobs. It is recommended that the operating speed of the maize sheller should range between 70 and 80 rpm to achieve higher shelling capacity and shelling efficiency at lower operating torque. [48]

Effect of operating factors for an axial –flow corn shelling unit on losses and power consumption. The main conclusions for the study were: the rotor speed (RS) significantly affected shelling unit loss (TL), with increased RS reducing TL; the moisture content (MC) and rotor speed (RS) significantly impacted on the grain breakage, with increased MC and RS resulting in an increased tendency for grain breakage; the moisture content (MC), feed rate (FR) and rotor speed (RS) significantly affected power consumption (P), with increased MC, FR and RS increasing consumption.[14]

Short duration test for maize thresher and his data resulted that the machine was stable and strong and its speed of operation was 60 rpm with the shelling capacity of the machine was 100.25 kg/h & cleaning and shelling efficiency of 99.37% and 99.95% respectively. The breakage was 0.406 % which was well within the prescribed limit for such machines. Also the labour requirement was reduced by 89.60%. [52]

The cylinder speed was primarily influences the damage caused to the seed than that of concave clearance although the concave clearance was an important parameter as well. Impact force was the primary threshing action for detachment of grain from the ear head. In all types of threshers the most crucial adjustment for control of impact was the cylinder tip speed. [71]

The study concluded that the shelling efficiency increased with reduction in concave clearance and increased in cylinder speed. The round and rasp bars members shelling less than the square section members and shelling decreased with grain moisture content. The grain damage was lower at lower value of the concave clearance and higher at higher cylinder speed. [69]

Nature of maize kernels damage inflected in the shelling crescent of grain combines. This study investigated the percentage of the corn kernel damage was caused by the cylinder and the concave before and after the kernels were shelled from the cob and the effects of kernel moisture contents, cylinder speeds, and the different concave zones on these two categories of damage. The sheller constructed from John Deer Model 95 combine parts. The cylinder diameter was 55.88 cm and the clearance was fixed at 2.54 cm at front and 1.59 cm in the rear. The cylinder speed of 440, 540 and 640 rpm were used. About 50% of the mechanically damaged maize kernel consists of sieved through 4.76 mm consists of embryo and pericarp damage. [64] The amount of seed damage was directly proportional to the impact energy and inversely proportional to the seed moisture content. [65]

The performance of tractor operated combine for maize shelling machine was tested on maize with and without husk. The performance of the machine was evaluated in terms cylinder loss, capacity, and grain crack age. It was concluded that the combine gave satisfactory results for husked maize at a speed of 500 rpm, concave of 25 mm and feed rate of 3 tons per hour. Whereas for the un-husked maize the satisfactory results were obtained at a cylinder speed of 575 rpm and cylinder concave clearance of 25 mm and the capacity of the machine was found to be 2- 2.5 tons per hour. The damage in case of husked and dehusked maize was found to be 2.72 (maximum) and 2%, respectively. [63]

The manually powered sheller at a speed of 60 rpm can provide a continuous flow and they achieved the shelling effectiveness of 67%, with a throughput of 6.82 kg/h and a low kernel-breakage factor of 0.09. For achieving the stripping this sheller uses abrasion between a rotating shelling-disc and stationary concave compartments. This design was preferred, because of its low breakage factor, low human energy expenditure, rapid operation for the kernels in addition to relatively little dust being emitted during shelling; hence leading to a relatively-healthier local atmosphere for the operator so its wider use was therefore recommended. [53]

5.3 Types of threshing cylinder

The power operated maize sheller was developed and its performance was evaluated. The maize sheller consisted of a cylinder and a concave. The cylinder made up of high carbon steel of size diameter 6.5 cm and length 15 cm, having beaters which rotates along the cylinder and separates grains from the cobs. While the concave was fabricated using 6 mm size mild steel rods. The length of concave was 60 cm with slotted opening size of 7.0cm×1.0cm. The developed power operated sheller had the shelling efficiency, total recovery, breakage and shelling capacity of 98.51, 66.62, 1.60 percent and 402.01 kg/h, respectively, at a cylinder speed of 350 rpm. [47]

The development of pedal operated maize dehusker, hand operated maize dehusker, pedal operated maize dehusker cum- sheller, pedal operated maize dehusker-sheller, power operated maize dehusker and power operated maize dehusker-sheller at MPUAT, Udaipur. Dehusker unit was made up of using a pair of rubber and spirally welded MS rod on steel rollers also some serrated blades were used lengthwise to facilitate the dehusking. Half of the cylinder length with rasp bars and the other with rubber strips in octagonal cylinder to act as dehusker and sheller, respectively in one cylinder. [57]

The performance evaluation of a developed maize sheller. A simple, efficient, less tedious machine for shelling maize has been developed. Materials used in fabricating the machine are affordable and locally available. ODEDI maize shelling machine can shell maize of various sizes and has a shelling efficiency is 91.29 % and minimal 0.12 % grain damage with an average shelling capacity of 55 kg/hr. [46]

The performance of existing maize shellers in Bangladesh. At present, there are three basic designs of mechanized maize sheller models exist in the country. They are Spike-pinion (SP) type, Spiral rasp-bar cylinder (SBC) type and Parallel rasp-bar cylinder (PBC) type. The design of Binimoy (SP) and Sarker (SP) models is same and technical performances are almost similar and satisfactory. Based on the shelling capacity these models are suitable for small farm holdings. The design of Farida (SBC), Rahman (SBC) and Uttaran (SBC) models is same, except the size. The technical performances of Farida (SBC) and Rahman (SBC) models are slightly better than the Uttaran (SBC) model. This is because of the workmanship and adjustment made by the operator during operation. The technical performances of these sheller models are satisfactory. Based on the shelling capacity and economic returns these models are suitable for large farm holdings and custom-hire service. Farida (SBC), Rahman (SBC) and Uttaran (SBC) models have higher shelling capacity and have higher benefit-cost ratios, Gross Margins (GM) and Net Margins (NM). Partial Budget (PB) analyses indicate net gain in favour of these models over low capacity models and appear as most beneficial for custom-hire service. Economic analysis suggest that hand sheller could be beneficial for very small farm holdings, Binimoy (SP) and Sarker (SP) models for small farm holdings and Farida (SBC), Rahman (SBC) and Uttaran (SBC) models for medium to large farm holdings and custom-hire service.[50]

Different types of hand operated maize shellers viz., hand held tubular maize sheller, wooden maize sheller, rotary disc type and bench mounted tubular maize sheller and they compared their performance with manual method of maize shelling. In terms of kernel output, operational cost and performance index bench mounted tubular and rotary disc type maize sheller well performed. [58]

A shelling machine consisting of shelling unit, reduction unit i.e. worm and worm gear type and single-phase one hp electric motor. The developed power operated maize sheller was tested at load for short duration's operations as well as in laboratory. The analysis of data collected during the short duration tests revealed that the shelling capacity of the machine was 100.25 kg/h with shelling efficiency of 99.95%.

The performance of a tractor powered maize sheller, shelling with tractor wheels, the traditional shelling techniques were evaluated in terms of shelling efficiency, grain damage and grain output. The test result reported that shelling of maize with tractor wheels acquired the highest percentage of grain damage. The tractor powered maize sheller has maximum grain output of about 80 kg/ha was obtained as compared to 30.90 kg/ha by shelling with tractor wheels and 13.19 kg/ha with the traditional shelling techniques and it shows that shelling with tractor wheels had the lowermost shelling efficiency of about 73.76% when compared with the other shelling methods. [54]

Table 1: Performance of different threshers.

Sr. No.	Equipment	Power source	Type of threshing element	Dehusking & Shelling efficiency,%	Output capacity, kg/h	References
1	Maize dehusker cum sheller	2.23kW motor	Parallel-staggered-parallel lugs	94.59-97.13	600	83
2	Maize dehusker-cum-sheller	12 hp power tiller	Peg type	72 & 85	400-510	18
3	Hand operated maize dehusker-sheller	2 women	Solid lugs, rasp bar, spike tooth, square solid lugs	100 & 98.8	60	20
4	Maize dehusker-sheller	2.23kW motor	Peg type	99-99.7 & 97.5-98.4	10-40	17
5	Rotary maize sheller	7.5kW motor	Shelling plate	98.52-99.3	250.50-384.66	48
6	Manually powered continuous flow maize sheller	Human power	Rotating disk, 2 concave stationary compartments, spikes	67	6.82 for 99 Seconds	53
7	Hand operated maize desheller	Human power	-	99.95	24	78
8	Maize threshing machine	5 hp motor	Threshing bars	99.2	200	25
9	Corn shelling & threshing machine	2 hp motor	-	90 & 90	300	19

10	Local maize sheller	3.72kW motor	Rasp-bar	90.6-99.2	325.2-327.7	55
11	Maize sheller	2.23kW motor	-	91.29	55	46

VI. SOLAR PHOTOVOLTAIC SYSTEM AND ITS UTILIZATION

6.1 Paddy winnower

The solar photovoltaic operated paddy winnower. It was observed at the feed rate 120 Kgh^{-1} overall output capacity at 30 cm distance was found to be maximum (119.77 kg h^{-1}), as compared to output capacity at 20 cm (119.30 kg h^{-1}) and 10 cm (118.74 kg h^{-1}) respectively. The weighted average cleaning efficiency at 30 cm distance (93.00%) was found to be maximum as compared to cleaning efficiency at 20 cm (89.13%) and 10 cm (62.24 %), respectively. The average cleaning efficiency of SPV operated paddy winnower was more than 90% with low operating cost of 0.25 Rs kg^{-1}. The developed SPV operated paddy winnower provided the solution for on farm paddy winnowing without dependency on natural wind velocity and secure electricity supply. [73]

Development of the solar power operated paddy winnower. Performance was carried out at three feed rates for PLR 1100 type paddy variety 171.43 $kg.h^{-1}$, 200 $kg.h^{-1}$ and 240 $kg.h^{-1}$ and for RGL 2537 type paddy variety 200 $kg.h^{-1}$, 240 $kg.h^{-1}$, and 267 $kg.h^{-1}$ respectively. The paddy winnower was mounted with 0.25 hp DC motor and connected to a 150 watt photovoltaic solar panel. The highest cleaning efficiency of about 94% was achieved for feed rate 171.43 kg/h at main outlet. The highest output capacity of 223.47 kg/h was achieved at feed rate of 267 kg/h. It was observed the cleaning efficiency of both the paddy varieties was decreased on increasing the feed rate. [74]

6.2 Solar water pump

Photovoltaic solar water pumps are available to pump from anywhere in the range of up to 200m head and with outputs of up to 250m³/day. In general photovoltaic pumps are economic compared to diesel pumps up to approximately 3kWp for village water supply and to around 1kWp for irrigation. Solar Photovoltaic (SPV) sets represent an environment-friendly, low-maintenance and cost effective alternative to irrigation pump sets which run on grid electricity or diesel. It is estimated that India's potential for Solar PV water pumping for irrigation to is 9 to 70 million solar PV pump sets, i.e. at least 255 billion lit/year of diesel savings. [75]

Different types of solar energy systems like as solar photovoltaic and solar thermal for pumping water, drying crops, cooling the storages and producing heating/cooling greenhouses. It was been proven that photovoltaic systems and thermal system would be the suitable options in agricultural application and especially for the distant rural area. [76]

6.3 Tracking system

The automatic solar tracker system which ensures 25 to 30% of more energy conversion than the existing static solar module system. Although ASTS is a prototype towards a real system, but still its software and hardware can be used to drive a real and very huge solar panel. A small portable battery can drive its control circuitry. Therefore by just replacing the sensing instrument, its algorithm and control system can be used in RADAR and moveable dish antennas. [77]

It deals with the efficiency of solar cell with and without tracking system. It also includes a proposed plan of simple dual axis tracking device which is based on servo motors which are in turn interfaced using arduino microcontroller kit. The instructions to the servo motor comes from highly efficient light dependent resistors which are responsible for moment of PV panels towards maximum light intensity. The use of stepper motors in solar trackers enables accurate tracking of the sun and light dependent resistor are used to determine the solar light intensity. Solar tracking system based on microcontroller and also describes about the simple and attractive features of tracking system. This solar tracker operation costs and maintenance cost are comparatively low. [62]

Solar tracking system is a power generating method from sunlight. This method of power generation is simple and is taken from natural resource. This needs only maximum sunlight to generate power. It helps for power generation by setting the equipment to get maximum sunlight automatically. This system is tracking for maximum intensity of light. When there is decrease in intensity of light, this system automatically changes its direction to get maximum intensity of light. Solar tracking system I reached up to the movement of stepper motor. Movement of motor by signal from light sensing circuit when the intensity of light is maximum is done. [67]

7. Cost economics of operation

Different machines used for dehusking and shelling of maize was evaluated of their economic and technical feasibility and for optimizing their operating parameters. [82]

The development of the following equipment related to dehusking and dehusking-shelling [57]

1. Hand operated maize dehusker
2. Pedal operated maize dehusker
3. Pedal operated maize dehusker-cum-sheller
4. Pedal operated maize dehusker-sheller
5. Power operated maize dehusker
6. Power operated maize dehusker-sheller

On the basis of performance of each machine different combinations for maize dehusking and shelling were suggested for the small and marginal farm holdings. It was found that the pedal operated maize dehusker sheller (single cylinder) was best suited having total area of 10 hectare and production of less than 300 quintal of maize cobs that is for small and marginal farmers. The power operated machines were found to suitable for large farmers having total area of more than 30 ha and annual production more than 1000 quintal.

7.1 Fixed cost

The total production cost of MDS was ₹ 34,500. The dehusking and shelling hiring price were 5/qt based on machine feed rate of 600 kg/h with 250 annual working hours (8-year life time) and considering annual cost of operation (Fixed + running = ₹ 7762.5 + ₹ 12 118.7). The payback period (Investment/net annual return = ₹ 34500/ ₹ 46064) was found to be 0.74 year. The benefit cost ratio (Discounted return/ discounted cost = ₹441,597/₹ 196512) was found to be 2.24. [83]

The cost of use of machine calculated with power tiller as prime mover has been found to be Rs. 371/hr or Rs. 68.70 / q, whereas, in traditional method, it was 375.00 Rs. /q. There is net saving of Rs. 306/q with respect to manual threshing. [18]

Cost of fabricating (manufacturing) the final prototype came to Rs.14, 500/ (290 $). The cost of getting one kg maize grain with hand operated maize dehusker sheller came to Rs.1.15 Fixed cost of maize dehusking shelling per kg maize grain with hand operated maize dehusker – sheller consist of depreciation cost using straight line method, interest on investment, insurance and shelter cost of machine is ₹1,305, ₹997.5, ₹290 respectively. Hence total fixed cost Rs. /annum ₹ 2,592.5. [20]

The virtual prototype modelling and analysis of low cost hand operated maize desheller. The analysis of data collected during the short duration test revealed that the machine is stable and strong and its speed of operation 60 rpm was quite satisfactory. The shelling capacity of the machine was 24 kg/h with shelling efficiency of 99.95 % and cleaning efficiency of 99.37%. The breakage percentage was 0.406 which is well within the prescribed limit for such machines. The labour requirement wasreducedby89.60%using this machine [78]

The result of comparison of power operated maize sheller with manual shelling of indicated that for 25% internal rate of return (IRR), power operated maize sheller appearance like a wise investment of 5-8 acres. They stated that, it makes economic sense to operate shellers at higher capacities and along with the high capital cost to save large numbers of labour to farmers and maize sellers hence power operated maize sheller can able to overcome the shortage of expensive labour during peak harvesting season and it saves the cost. [79]

A tubular maize sheller was tested on farm women and the results revealed that the shelling efficiency of tubular maize sheller as compared to hand shelling was 26 kg/ha. Hence about 43% saving in cost of workers per unit of output is done in comparison to the hand shelling. [23]

Three levels of grain moisture content and cylinder speed, three types of local maize shellers and the results indicated that the optimum moisture content of maize for shelling, using sheller types SLM, KWT and TMO, was 32.5, 35.0 and 35.0% (w. b.), respectively. The minimum total costs of shelling and drying were Rs. 3,573/t, Rs. 3,176/ t and Rs. 3,315/t while the optimum grain mechanical damage was 18.4, 17.8 and 21.1%, respectively. [81]

7.2Variable cost

Variable cost of maize dehusking shelling per kg maize grain with hand operated maize dehusker –sheller consist of repair and maintenance costs, (Rs. / annum 30 % of cost of maize dehusker sheller), Workers charge (Rs. / annum No. × h × charge) is ₹ 4,350.0, ₹ 6,800.0. Hence total variable cost (TVC) / annum, Rs. 11,150.0 [20].

VII. CONCLUSION

Maize is most important cereal crop in the world agricultural economy. Dehusking and shelling of maize are the major operations of maize after the harvesting. Traditionally dehusking and shelling is done by manually with help of sickle or by beating of stick. These requires more labors and also these are time consuming operations. After that engine, motor, tractor, power tiller operated maize dehusker cum shelling machines are come out. These are machineries are unsuitable where electricity is major problem, also easily unviability of fuel in rural areas. Tractor operated maize dehusker cum shellers are unaffordable for marginal farmers. Solar operated maize dehusker cum sheller is more significant where electricity is major problem in a rural areas. Using of Solar power gives the benefit to the environment as renewable energy, it saves fuel cost.

Design and development of solar powered maize dehusker cum sheller is more reliable for marginal and small farmers. Engineering properties of maize plays a key role while designing of maize dehusker cum sheller. Performance of machine depends upon a design of cylinder, concave clearance, and speed of cylinder, feed rate, and moisture content of maize. An axial flow spike tooth type machine gives a better performance in terms of dehusking, shelling, cleaning efficiency.

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Coconut Oil Salve from Gamal Tree Leaves (Gliricidia sepium) as an Alternative Treatment for Lumpy Skin Disease (LSD) in Cattle

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Abstract — *Lumpy Skin Disease (LSD) is an infectious skin disease caused by the Lumpy Skin Disease Virus (LSDV), posing a significant threat to cattle and buffalo farming. This research aims to determine the effectiveness of a salve made from gamal tree (Gliricidia sepium) leaves and coconut oil for the treatment of LSD in cattle. The study is divided into two parts: 1) the production of Gamal Leaf Oil Salve (SMDG), involving the collection of gamal leaves and the creation of a salve by mixing gamal leaves with coconut oil; and 2) the application of SMDG to cattle exposed to LSD with three concentrations: 1) 50%: 500 grams of gamal leaves in 1 liter of coconut oil (SMDG 50%); 2) 75%: 750 grams of gamal leaves in 1 liter of coconut oil (SMDG 75%); 3) 100%: 1000 grams of gamal leaves in 1 liter of coconut oil (SMDG 100%). The data were analyzed using Kruskal-Wallis, and significant differences among treatments were further analyzed using Mann-Whitney comparisons. The results of the study indicate that the application of Gamal Leaf Oil Salve (SMDG) with a concentration of 100% resulted in the highest recovery compared to concentrations of 75% and 50% for cattle exposed to LSD. Nodules began to flatten, and ulcers started to dry on the seventh day (Day 7), where in Experiments S2 and S3, the results were relatively similar with sizes ranging from 1 to 1.5 cm, which was better than in S1 where nodule size was 1.5 to 2 cm. A concentration of 100% SMDG is safe for use as a botanical antiviral and can reduce nodule size and dry ulcers in the treatment of Lumpy Skin Disease (LSD) after 14 days of application.*

Keywords— ***Lumpy Skin Disease (LSD), Gamal Tree Leaves (Gliricidia Sepium), Coconut Oil***

I. INTRODUCTION

Lumpy Skin Disease (LSD) is an infectious skin disease caused by the Lumpy Skin Disease Virus (LSDV), a DNA-genetic material virus from the Capripoxvirus genus and Poxviridae family, which is non-zoonotic in nature. This virus commonly affects cattle and buffalo, with no reported occurrences in other ruminants such as goats and sheep. LSD is also known as Pseudo-urticaria, Neethling virus disease, exanthema nodularis Bovis, and knopvelsiekte [1]. LSD was first discovered in Zambia, Africa, in 1929 and became endemic, progressively spreading across Africa, the Middle East, southeastern Europe, Central Asia [20]. Subsequently, LSD outbreaks occurred in Southeast Asia, specifically in Bangladesh in July 2019, followed by India and China (August 2019), Taiwan and Nepal (June 2020), Bhutan, Vietnam, and Hong Kong (October 2020), Myanmar (November 2020), Thailand (March 2021), and Cambodia, Malaysia, and Laos (May 2021).

The primary transmission of the LSD virus occurs mechanically through arthropod vectors such as mosquitoes (Culex mirificens and Aedes natrionus), biting flies (Stomoxys calcitrans and Biomyia fasciata), and male ticks (Riphicephalus appendiculatus and Amblyomma hebraeum). Direct transmission occurs through direct contact with skin lesions, while indirect transmission occurs through contaminated equipment and tools, such as barn clothing, barn equipment, and syringes. Furthermore, that intrauterine transmission is possible, with the virus being transmitted from infected cow mothers to calf offspring through milk secretion and injured skin [37].

Lumpy Skin Disease poses a significant threat to cattle and buffalo farming due to its potential to cause acute or subacute diseases in all age and breed categories, especially in young cattle and those in the peak of lactation/nursing. Clinical symptoms of LSD are influenced by age, breed, and the immune status of the animals. The main clinical sign of LSD is skin lesions in the form of nodules ranging from 1 to 7 cm, typically found on the neck, head, legs, tail, and udder. In severe cases, these nodules can be found all over the body. The appearance of these nodules is usually preceded by a fever exceeding 40.5°C. If left untreated, these skin nodules can become necrotic and ulcerative. Other clinical signs include weakness, nasal and ocular discharge, swelling of the subscapular and prefemoral lymph nodes, and edema in the legs. Additionally, LSD can lead to abortion, decreased milk production in dairy cows, infertility, and prolonged fever [35]. The incubation period for LSD ranges from 1 to 4 weeks, with a mortality rate below 10% and a morbidity rate around 45%.

In January 2023, Lumpy Skin Disease had infected cattle in the Garut Regency of West Java Province, causing significant economic impacts on the livestock industry. Affected animals tend to experience permanent skin damage, reducing their commercial value. As of now, there is no specific treatment for diseases caused by viruses, including Lumpy Skin Disease (LSD). Treatment for LSD is symptomatic, focusing on addressing clinical symptoms and supportive measures to improve the condition of infected livestock. Infected cattle are given drugs to alleviate disease symptoms such as fever and skin pain, with the goal of accelerating recovery and enhancing the animal's immune resistance. The use of medicinal plants by communities is one approach to addressing health problems, especially in treating diseases. Traditional medicine is preferred due to its accessibility to the public in terms of both cost and material availability [10]. Additionally, the potential side effects of chemical drugs in animal husbandry need to be considered, as they can have adverse effects on both livestock and their products. The occurrence of side effects from chemical drug use has led many farmers to return to using natural remedies, aligning with the current back-to-nature concept. Utilizing locally available plants, such as gamal tree (Gliricidia sepium) leaves, for herbal medicine purposes is one way to address the challenges posed by LSD.

Gamal tree (Gliricidia sepium) is commonly used as a protective plant in tropical regions, and its leaves (in fresh form) are utilized as forage for ruminant livestock due to the presence of coumarin, a primary allelochemical. This natural compound has the potential to replace synthetic herbicides or serve as a foundation for the synthesis of biodegradable chemical herbicideS. Allelopathic plants or products are believed to be less harmful to the environment than synthetic herbicides because they degrade easily. Furthermore, gamal tree leaves can function as an insecticide, bactericide, larvicide, and plant-based anti-inflammatory agent. Gamal tree leaves can be used to treat dermatitis, itching, act as an insect repellent, treat rheumatism, heal wounds, and address skin diseases/scabies. The active chemical composition in gamal tree leaves (G. sepium) includes active phytochemical compounds such as flavonoids, sterols, alkaloids, glycosides, tannins, saponins, medicarpin, coumarin, and coumaric acid [2]. The LD50 value of gamal tree leaf methanol extract in rats is higher than 5000 mg/kg body weight, demonstrating its safety [30]. A chemical substance is classified as non-toxic, non-fatal, or non-hazardous if the LD50 is greater than 5000 mg/kg body weight [28].

Gamal tree leaves contain coumarin, a chemical compound belonging to the class of organic compounds called benzopyrones. Coumarin possesses various biological properties, including antimicrobial, antiviral, anti-inflammatory, antidiabetic, antioxidant, and enzyme inhibition activities. Different derivatives of coumarin exist, such as umbelliferone (7-hydroxycoumarin), which acts as a strong ultraviolet-absorbing compound and an antioxidant; aesculetin (6,7-dihydroxycoumarin), commonly used as a sunscreen but also reported as a photosensitizer for DNA damage; herniarin (7-methoxycoumarin), considered a methoxy derivative of coumarin or a methyl derivative of umbelliferone [31]; psoralen (furanocoumarin), used for photochemotherapy to treat psoriasis and vitiligo; and imperatorin, reported to be used for respiratory and gastrointestinal disorders, acting as a diaphoretic, antipyret.

Palm oil is an excellent oil for the skin as it functions effectively as a moisturizer, preventing dry and flaky skin [38]. The fatty content in coconut oil is beneficial for moisturizing both the skin and hair. Lauric acid triglycerides (the main fatty acid) in coconut oil have a high affinity for hair proteins. Due to their low molecular weight and straight linear chains, they can penetrate the hair shaft, preventing hair protein damage. The gamal tree leaves contain a relatively high level of coumarin (around 1000 ppm) [40]. Furthermore, that coconut oil is one of the best natural nutrients for hair, promoting hair growth and effectively reducing protein loss that can lead to various quality issues in hair growth [38].

The objective of this research is to determine the effectiveness of various doses of a combination salve of coconut oil and gamal tree leaves for the treatment of Lumpy Skin Disease (LSD) in cattle.

II. MATERIALS AND METHODS

The research material consisted of 20 infected beef cattle with Lumpy Skin Disease (LSD) owned by farmers in the Garut Regency, West Java Province. The research was conducted through an experimental method designed with two variable observation groups: (1) Concentration of salve with coconut oil and gamal tree leaves, and (2) Application of salve with coconut oil and gamal tree leaves on experimental animals (cattle infected with LSD).

All experimental cattle were provided with basal food in the form of pasture grass, while drinking water was given ad libitum. They received supportive treatment to improve the condition of the infected livestock, including the administration of antipyretic and multivitamin drugs. Three concentrations were used in this study: 1) 50%: 500 grams of gamal leaves in 1 liter of coconut oil (SMDG 50%); 2) 75%: 750 grams of gamal leaves in 1 liter of coconut oil (SMDG 25%); 3) 100%: 1000 grams of gamal leaves in 1 liter of coconut oil (SMDG 100%). The experimental cattle were divided into four groups (each consisting of 5 cattle): Group 1 (SMDG 50%), Group 2 (SMDG 75%), Group 3 (SMDG 100%), and Group 4 (Control group treated with antibiotics, antipyretics, anti-inflammatory, and multivitamins for 5 days). Treatment was administered once daily for 14 days, applying SMDG using a brush/sponge and rubbing it on the entire skin surface of LSD-infected cattle.

Preparation of Gamal Leaf Salve with Palm Oil:

Gamal leaves selected for treating Lumpy Skin Disease (LSD) in cattle were mature and estimated to contain high levels of coumarin (around 1000 ppm). The preparation of Gamal Leaf Oil Salve (SMDG) was conducted according to the modified method by Philipine Medicinal Plant 2009. Fresh gamal leaves were finely chopped or blended and mixed with coconut oil. The mixture was then heated to boiling for one hour. After boiling, the heat was reduced, and it continued to be heated for another hour, totaling two hours of heating. After cooling, the gamal leaf salve and palm oil were topically applied to the entire skin surface of LSD-infected cattle. Healing parameters were based on the reduction in nodule size and the drying of ulcers/wounds on the skin surface.

Data Analysis

The collected data were analyzed using the Kruskal-Wallis analysis. Significant differences among treatments were further analyzed using the Mann-Whitney comparison analysis.

III. RESULT

The. The clinical symptoms of Lumpy Skin Disease (LSD) are influenced by the age, breed, and immune status of the livestock. The main clinical sign of LSD is skin lesions in the form of nodules/bumps ranging from 2-5 cm, typically found on the neck, head, legs, tail, and udder. In severe cases, these nodules can be found on almost all parts of the body. Nodules with a diameter of 2-5 cm on the skin, especially on the head, neck, limbs, udder, genitalia, and perineum, appear within 48 hours after the onset of fever. These nodules are circumscribed, hard, round, and elevated on the skin, subcutaneous tissue, and even muscles. Larger nodules can become necrotic, eventually fibrotic, and persist for several months (sitfasts), with scars lasting a long time. Small nodules may heal without causing significant effects. Myiasis in nodules can occur, and vesicles, erosions, and ulcers may occur on the oral mucosa, alimentary canal, trachea, and lungs [20]. The research results indicate that the size of nodules and ulcers after treatment with gamal leaf oil salve (SMDG) is presented in Table 1.

Table 1: Post-Topical Treatment Conditions of Nodules and Ulcers with EMDG

Treatment	**n**	**1**	**7**	**14**	**Explanation**
S1. 50 % SMDG	5	-	+	++	Not healed
S2. 75 % SMDG	5	-	++	+++	Improving
S3.100% SMDG	5	- -	++	++++	Unhealed
Ivermectin	5	- -	++	++++	Unhealed

Nodule and Ulcerative Scores on Day

Explanation:

(-) No change yet.

(+) Partial improvement (50%), nodules are shrinking with a diameter of 1.5-2 cm, ulcers are still wet.

(++) Significant improvement (75%), nodules are shrinking (1-1.5 cm), ulcers are starting to dry.

(+++) Nodules 90% smaller, 0.7-1.0 cm, and ulcers are drying.

(++++) Nodules are gone, and ulcers are dry (healed).

Based on the data in Table 1, it is evident that the application of Gamal leaf oil salve (SMDG) with a concentration of 100% resulted in the highest healing compared to using concentrations of 75% and 50% for cattle exposed to LSD. This is presumed to be due to the higher content of coumarin, saponin, and tannin in SMDG 100%, giving it a higher efficacy in deactivating the LSD virus and reducing inflammation. Coumarin possesses various biological properties, including antimicrobial, antiviral, anti-inflammatory, antidiabetic, antioxidant, and enzyme inhibition activities [31]. Furthermore, that Gliricidia sepium leaves contain various active phytochemical compounds such as flavonoids, sterols, alkaloids, glycosides, tannins, saponins, medicarpin, coumarin, and acids [2]. Tannins play a significant biological role as protein precipitants and metal chelators, suggesting their potential as biological antioxidants [24]. That saponins can lower cholesterol, exhibit antioxidant properties, act as antivirals, and have anticarcinogenic effects, as well as influence rumen fermentation [11, 34].

Analysis of variance on the average reduction in nodule size showed statistically significant differences ($P<0.05$) between treatment S3 and S1 starting from week 1 (after 7 days of treatment) with a decrease in nodule size and drying ulcers. Subsequently, in treatment S3, there were no statistically significant differences ($P>0.05$) in the healing parameters (nodules no longer visible, and ulcers dried) after 14 days of treatment compared to the control treated with a single dose of ivermectin.

The research results indicate that nodules start to flatten, and ulcers begin to dry on the seventh day (7). In Experiment S2 and S3, the results are relatively similar with sizes of 1-1.5 cm, and they are better than in S1, where nodule size is 1.5-2 cm, as presented in Table 2 / Figure 2.**

Table 2: Progress of Gliricidia Leaf Oil Ointment Treatment in Lumpy Skin Disease (LSD) Cases

Date	Development of the Case	Images		Assessment Scoresof Gliricidia Ointment Therapy
		Left	Right	
2/16/2023	The initial report indicated the presence of LSD symptoms, specifically bloody lumps on the cattle.			-
2/27/2023	The Gliricidia leaf ointment was applied daily, and the progression of the case showed the healing of the skin lumps.			++
3/8/2023	As the case progressed, the wounds showed improvement, healing, and drying.			+++

Explanation:

(-) No change in Gliricidia leaf ointment therapy.

(++) Significant improvement in Gliricidia leaf ointment therapy; the wound starts to dry.

(+++) The wound is drying, and healing is observed.

The occurrence of scab peeling after SMDG application is suspected to be due to the presence of one of the coumarin derivatives (furocoumarin) in Gliricidia leaves, which acts as an active photosensitizer. Furocoumarin induces phototoxicity when exposed to sunlight, marked by increased capillary blood flow on the skin surface and damage to skin tissue cells (scab peeling). This aligns with Letteron et al. [27], stating that one coumarin derivative, furocoumarin, can reversibly alter the detoxification ability of an organism or irreversibly inhibit cytochrome P450 detoxification enzymes. Furthermore, that scab peeling will occur more quickly if the livestock is exposed to sunlight post-treatment [32].

In this study, it is presumed that palm oil also provides significant benefits. Palm oil may adhere longer to the skin, not dissipating when the cattle move, moisturizing the skin to accelerate the softening and easy peeling of scabs. This aligns with Vala and Kapadiya [38], stating that palm oil serves as an effective moisturizer preventing dry and peeling skin, providing essential proteins needed for hair growth, and repairing damaged hair. Lauric acid triglycerides (main fatty acid) in palm oil have a high affinity for hair protein due to their low molecular weight and straight linear chain, penetrating the hair shaft and preventing hair protein damage [18, 27].

IV. CONCLUSION

A concentration of 100% SMDG is safe for use as a botanical antivirus and can reduce nodule size and dry ulcers in the treatment of Lumpy Skin Disease (LSD) after a 14-day application.

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Further research is needed for extract formulation in stability tests to ensure that Gliricidia leaf oil ointment can be stored for an extended period at room temperature.

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Price Behaviour of Tomato in Major Markets of Nagpur District

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Abstract*— *This research undertakes a comprehensive analysis of trends, variability, and seasonal fluctuations in arrivals and prices as well as the interrelationship between arrivals and prices of selected vegetable in kalamna, kalmeshwar and kamthi Markets of Nagpur District, Maharashtra for the year (2014-2023) by utilizing secondary data sourced from the website (www.agmarknet.nic.in).An analysis of market arrivals and prices of Tomato reveals a positive trend in arrivals and prices across all the three Nagpur District markets, Although statistical significance was only observed in two markets excluding kalamna market. Highest variability in Tomato arrivals i.e 82.04 was recorded in kamthi APMC, Nagpur while Pt. Jawaharlal Nehru Market Yard, Kalamna, Nagpur saw the highest price variability i.e 86.30. In contrast lowest variability in Tomato arrival i.e 62.84 was recorded in Pt. Jawaharlal Nehru Market Yard ,Kalamna, Nagpur and lowest price variability i.e 80.20 was observed in kamthi APMC, Nagpur. Highest seasonal indices for Tomato arrivals and prices observed in December and October at Pt. Jawaharlal Nehru Market Yard, kalamna, Nagpur. March and July at kalmeshwar APMC, Nagpur and December and July at kamthi APMC, Nagpur. A statistically significant negative correlation was observed between arrivals and prices of Tomato in the Nagpur markets except for kalmeshwar market which shows positive correlation.

***Keywords*— Tomato, Trend, Arrival, Price, Seasonal indices, Variability, APMC.**

I. INTRODUCTION AND OBJECTIVES

A well functioning Agriculture Market is crucial for farmers to plan, produce, and market their crop effectively. Under the X FY plan, the scheme aims to expand it's coverage to an additional 2000 agricultural markets, bringing the total to 9300 markets. By the end of the plan, 37% of the country's 7300 wholesale markets (27350 markets) will have online facilities. Tomato is the second most prominent vegetable crop, after potato, in terms of cultivation, and also leads the market in canned vegetable production.It scientifically classified as lycopersicon esculentum Mil and a member of the Solanaceae family, originated in Tropical America and was introduced to other regions in the 16th century, becoming widely popular within the last ninety years **.** And recognized as a highly productive and protective food, providing ample amounts of Vitamin A and C and Minerals such as Iron and Phosphorous. Global Tomato production was approximately 189 million metric tones. Andhra Pradesh led India in Tomato production, contributing 20.2% to the national total. Tomato cultivation in Maharashtra is prominent in several regions, including Narayangaon near Pune, Nashik, beed and Pusegaon. Price volatility in agricultural commodities is a pervasive phenomenon primarily attributed to seasonal fluctuations, biological characteristics of crops and significant dependence on climatic conditions. Variability in Tomato prices are a major determinant of income instability for the cultivator. Understanding the relationship between arrivals and prices is essential for analyzing price volatility over time. Pricing signals play a crucial role in influence production, consumption, and marketing strategies across time, form, and location, promoting an examination of the growth trends. Considering the above context the objectives of this study can be outlined as follows.

1)To analyze the market trends in Tomato arrivals and prices in selected markets of Nagpur District.

2)To measure the variability in arrivals and prices.

3)To examine the seasonal fluctuations in market arrivals and prices.

4)To investigate the correlation between Tomato arrivals and prices.

II. MATERIALS AND METHODS

The study relies on existing secondary data collected over a 10 year period from (2014 -2023). The data on monthly arrival and prices for Tomato was derived from the major markets specially Kalamna, Kalmeshwar and Kamthi situated within the District Nagpur and the website (www.agmarknet.nic.in). The selection of these markets was based on geographical location and the quantity of produce handled.

Analytical Tools:-

The study's objectives and the nature of the data collected guided the selection of statistical analysis methods.

A) Estimation of Compound Growth Rates:-

The exponential growth function was applied to analyze the growth of arrivals and prices.

$Y = ab^t$ ------------------------------- (1)

Where,

Y = Depended variable for which growth rate is to be estimated

a = Intercept (constant)

b = Regression coefficient

t = Time variable

This equation is calculated following the transformation of (1) as shown below.

Log Y = Log a + Log b --------------- (2)

Then the relationship is used to calculate the percent annual compound growth rate.

CGR = [Antilog (log (b)) – 1] x 100 -------------- (3)

The significance of regression coefficient was tested using student's t-test.

B) Coefficient of Variation: -

The variability in arrivals and prices of Tomato crop at major APMC's in Nagpur District was analyzed using the below given formula.

CV = SD/Mean × 100

Where,

CV = Coefficient of Variation

SD = Standard Deviation

C) Seasonal indices:-

Seasonal indices were calculated by Moving Average Method**.**

$$SI = \frac{\text{Monthly avg. of arrival and prices}}{\text{avg. of monthly avg.}} X100$$

Where,

SI = Seasonal indices

avg. = average

D) Correlation Coefficient:-

The correlation method is applied to study the relationship between arrivals and prices.

$$rxy = \frac{nxy - {}^{-}x\ {}^{-}y}{\sqrt{[n\Sigma x^2 - (x^2).[n^{-}y^2 - (y^2)]}}$$

Where,

r = correlations

x = x variables

y = y variables

COV(x, y) = covariance between x and y

n = number of pairs of score

^{-}xy = sum of the pairs of x and y

III. RESULTS AND DISCUSSION

3.1 Growth and Variability in arrival and prices of Tomato at major APMC's in Nagpur District:-

Trend analysis illustrates the magnitude and direction of variation over a period of time. The examination of variability in monthly arrivals and prices reveals the effectiveness of the marketing system in managing market supply. Table No.1 Represent, in Pt. Jawaharlal Nehru Market Yard, Kalamna, Nagpur the compound growth rate in arrival of Tomato was 0.38 i.e positive and non-significant and for prices 8.17 i.e positive and non-significant. In kalmeshwar APMC, Nagpur the compound growth rate in arrival of Tomato was 32.36*** i.e positive and significant at 1 percent and for prices 4.76* i.e positive and significant at 10 percent. In kamthi APMC, Nagpur the compound growth rate in arrival of Tomato was 10.83*** i.e positive and significant at 5 percent and for prices 4.74* i.e positive and significant at 10 percent. The highest CV of arrival was 82.04 of Tomato in Agriculture Produce Market Committee, kamthi, Nagpur and in prices 86.30 in Pt. Jawaharlal Nehru Market Yard, Kalamna, Nagpur. And the lowest CV of arrival was 62.84 of Tomato in Pt. Jawaharlal Nehru Market Yard, Kalamna, Nagpur and in prices 80.20 in Agriculture Produce Market Committee, Kamthi, Nagpur.

Table No. 1 Compound Growth Rate and Coefficient of Variation of arrival and prices of Tomato in major APMC's of Nagpur District

Sr.No.	Name of Markets	CGR		CV	
		Arrival	Prices	Arrival	Prices
1.	Pt. Jawaharlal Nehru Market Yard, Kalamna, Nagpur	0.38	8.17	62.87	86.30
2.	Kalmeshwar APMC, Nagpur	32.36***	4.76*	70.49	83.32
3.	Kamthi APMC, Nagpur	10.83**	4.74*	82.04	80.20

* = Significant at 10 percent (table T value is 1.833 for decades and 1.729 for whole period)
** = Significant at 5 percent (table T value is 2.262 for decades and 2.093 for whole period)
*** = Significant at 1 percent (table T value is 3.250 for decades and 2.861 for whole period)

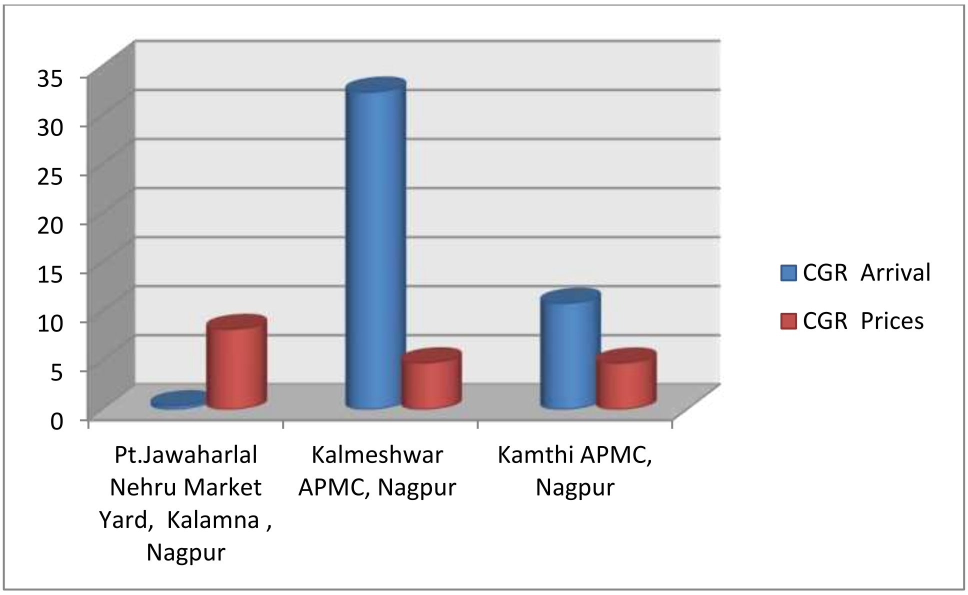

Fig.1. Compound Growth Rate of arrival and prices of Tomato

3.2 Seasonal indices in arrival and prices of Tomato:-

Seasonal fluctuations in prices and arrivals are driven by variations in produce available and demand across different seasons, exhibiting an inverse relationship between supply and demand. Table No. 2 Represents that maximum arrival was 117 for the month of December and for prices 176 in the month of October and minimum arrival was 79 for the month of April and for prices 48 in the month of March of Tomato in Pt. Jawaharlal Nehru Market Yard, Kalamna, Nagpur. For Kalmeshwar APMC, Nagpur the maximum arrival was 138 for the month of March and for prices 214 in the month of July and minimum arrival was 76 for the month of May and for prices 34 in the month of March of Tomato. For Kamthi APMC, Nagpur the maximum arrival was 139 for the month of December and for prices 222 in the month of July and minimum arrival was 71 for the month of July and for prices 36 in the month of March of Tomato.

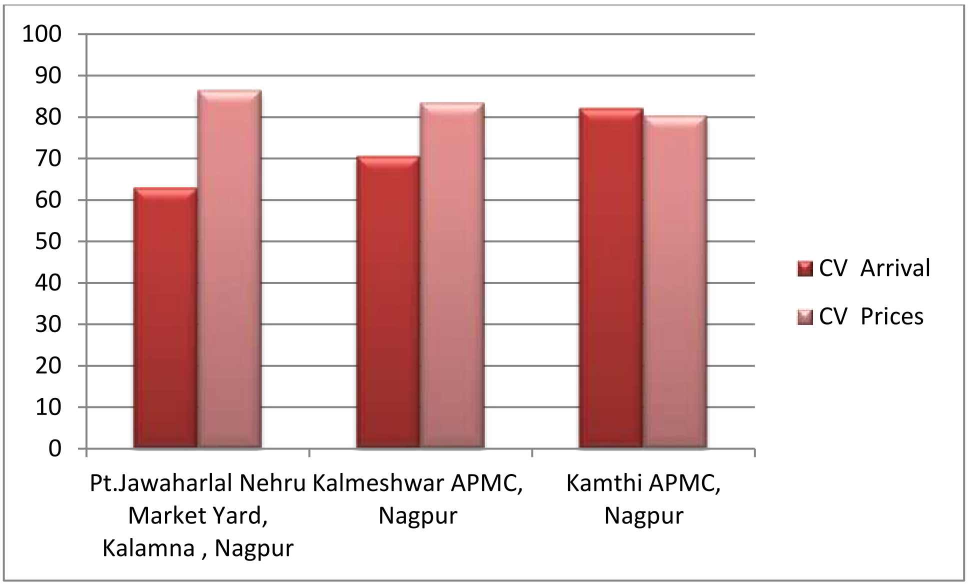

Fig.2. Variability in arrival and prices of Tomato

Table No. 2 Seasonal Indices of arrivals and prices of Tomato in major APMC's of Nagpur District from (2014-2023)

Months	Pt. Jawaharlal Nehru Market Yard, Nagpur (2014-2023)		Kalmeshwar APMC, Nagpur (2014-2023)		Kamthi APMC, Nagpur (2014-2023)	
	Arrivals	Prices	Arrivals	Prices	Arrivals	Prices
January	114	63	108	38	127	49
February	103	60	102	37	105	42
March	105	48	138	34	119	36
April	79	54	78	51	119	47
May	88	90	76	92	92	87
June	91	119	90	130	87	137
July	99	138	83	214	71	222
August	101	111	93	186	72	149
September	97	120	98	111	83	102
October	99	176	97	121	89	126
November	102	133	105	120	90	137
December	117	80	126	60	139	61

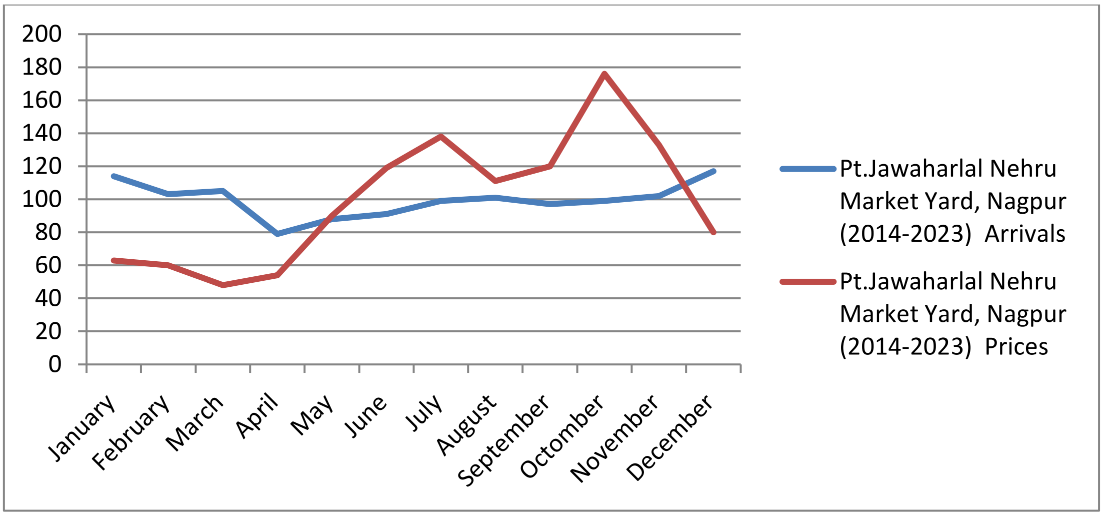

Fig.3. Seasonal indices in arrival and prices of Tomato at Kalamna APMC, Nagpur.

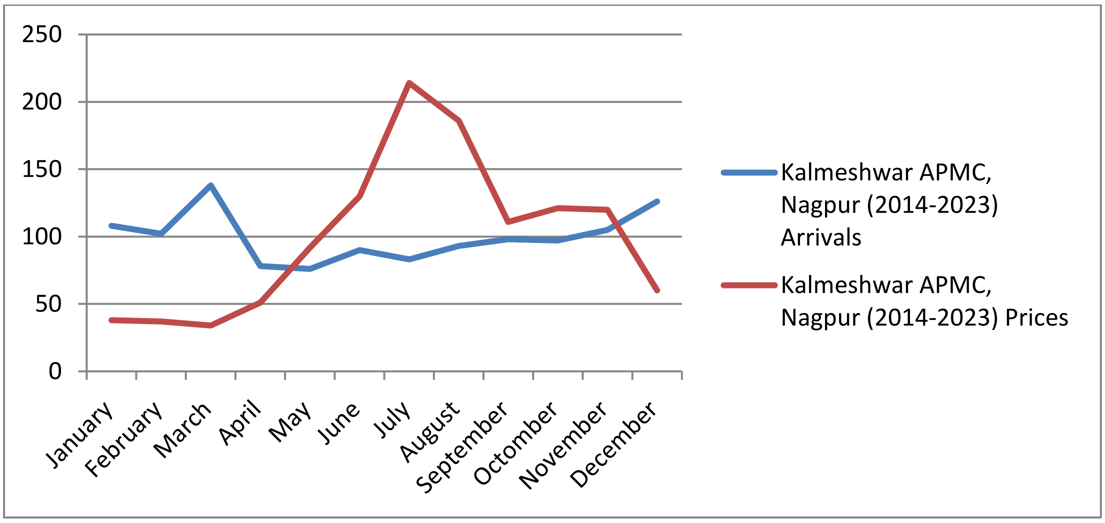

Fig.4. Seasonal indices in arrival and prices of Tomato at Kalmeshwar APMC, Nagpur.

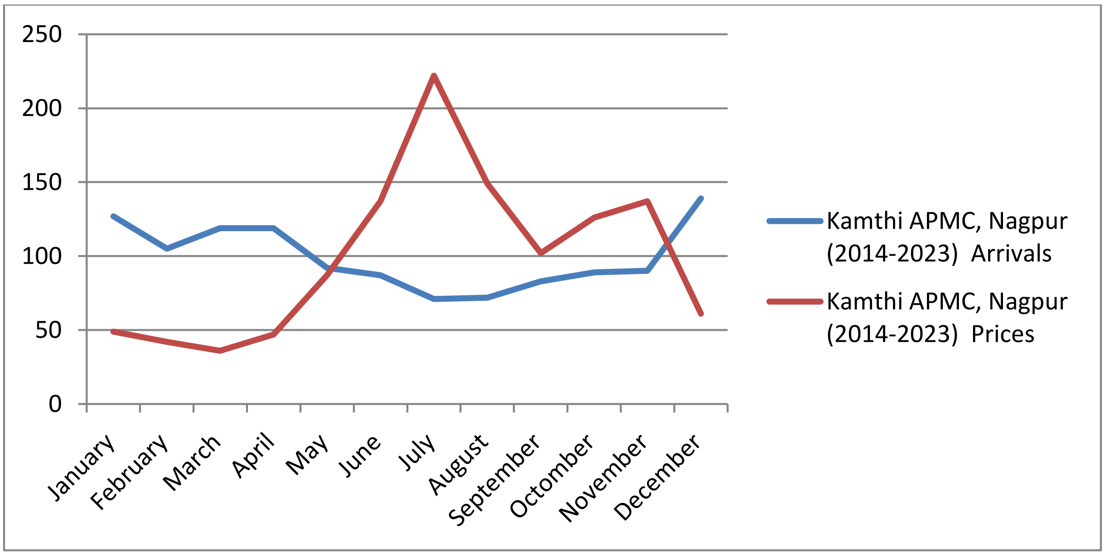

Fig.5. Seasonal indices in arrival and prices of Tomato at Kamthi APMC, Nagpur

4.3 Relationship between arrival and prices of Tomato of selected APMC's in Nagpur District:-

Vegetable prices are significantly influenced by market arrivals. The degree of relationship between market arrivals and prices was investigated through correlation coefficient calculation. Table No.3 Represents that the highest correlattion is - 0.40 is negative and significant at 10 percent level in the month of May in Pt. Jawaharlal Nehru Market Yard, kalamna, Nagpur. In kalmeshwar APMC, Nagpur the highest correlation is 0.51 is positive and significant at 5 percent level in the month of February. And in Kamthi APMC, Nagpur the highest correlation is -0.51 is negative and significant at 5 percent level in the month of December for Tomato.

Table No. 3 Correlation Between arrival and prices of Tomato for selected APMC

Months	Pt. Jawaharlal Nehru Market Yard, Nagpur (2014-2023)	Kalmeshwar APMC, Nagpur (2014-2023)	Kamthi APMC, Nagpur (2014-2023)
January	-0.23	0.17	-0.35*
February	0.18	0.51**	0.19
March	0.24	-0.19	0.11
April	-0.39*	0.18	-0.16
May	-0.40*	-0.03	-0.03
June	0.34*	0.27	0.42*
July	0.32	0.15	0.07
August	0.08	-0.23	0.40*
September	-0.29	0.19	0.08
October	-0.22	0.32	-0.20
November	0.10	0.35*	-0.09
December	0.11	0.15	-0.51**

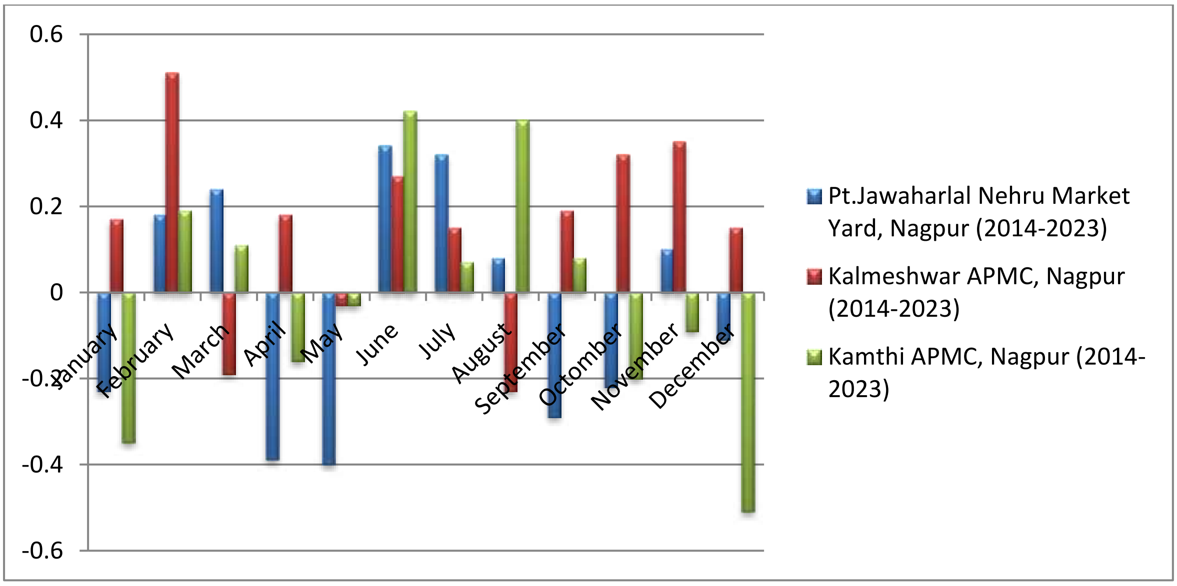

Fig.6. Relationship between Tomato arrival and prices at selected APMC's in Nagpur District

IV. CONCLUSION

An analysis of market arrivals and prices of Tomato in three Nagpur District markets reveals a positive trend in arrivals across all markets, although statistical significance was only observed in two markets, excluding Kalamna market. A significant and positive trend in current prices was observed across all markets, with the exception of kalamna market, where the trend was found to be non-significant. Kamthi APMC, Nagpur recorded the highest variability in Tomato arrival, while Pt. Jawaharlal Nehru Market Yard, Kalamna, Nagpur saw the highest price variability. In contrast, Pt. Jawaharlal Nehru market Yard, Kalamna, Nagpur had the lowest variability in Tomato arrival, and Kamthi APMC, Nagpur had the lowest price variable. The maximum seasonal Indices for Tomato arrivals and prices occurred in December and October at Pt. Jawaharlal Nehru Market Yard, Kalamna, Nagpur. March and July at kalmeshwar APMC, Nagpur and December and July at kamthi APMC, Nagpur. The correlation analysis revealed a negative correlation at 10 percent significance in Pt. Jawaharlal Nehru Market Yard, kalamna, Nagpur . A positive correlation at 5 percent significance in kalmeshwar APMC, Nagpur. And a negative correlation at 5 percent significance in kamthi APMC, Nagpur.

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Ethnoveterinary Practice May be an Alternative to Antibiotics in Dairy Cattle

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***Abstract*— *Ethnoveterinary practices in India have their origins in ancient times, characterized by the transmission of indigenous knowledge, beliefs, and skills related to the diagnosis, treatment, and management of diseases in both animals and humans. These practices, preserved and refined over generations, have evolved into cost-effective alternatives to conventional medicine, particularly benefiting small-scale farmers. In contemporary veterinary medicine, the integration of ethnoveterinary practices presents a viable strategy for reducing the overreliance on antibiotics. These traditional methods not only support growth and productivity in livestock but also offer effective solutions for the prevention and treatment of common animal diseases. The adoption of such practices holds significant potential in addressing the escalating threat of multidrug-resistant pathogens. Many such plant based remedies are there in veterinary practice that can be used as a preliminary alternative to antibiotic use in primary health care of the animals. However, to fully harness the benefits of ethnoveterinary medicine, further research is needed to validate these practices, including studies on dosage, duration, pharmacokinetics, pharmacodynamics, and toxicity patterns including residual effects as they also do contain potent active principles.*

***Keywords*— Ethnoveterinary Practice, Antibiotic alternative, Pharmacology**

I. INTRODUCTION

Ethnoveterinary practices, which date back to the domestication of various livestock species, represent an ancient approach to animal healthcare. These practices involve the use of indigenous knowledge, beliefs, and skills related to the care and management of humans, animals, and birds (Mc Corkle, 1986). Known as ethnoveterinary practices (EVPs), this branch of science is gaining increasing attention in the field of ethnobotany, particularly in Western countries (Lans et al., 2006). India, with its vast repository of ethnoveterinary knowledge, is emerging as a potential 'EVP hub,' thanks to decades of practical experience. Traditionally, these practices are grounded in the use of plant-based formulations and other locally sourced, affordable ingredients. Livestock owners and individuals with deep-rooted knowledge of veterinary medicine traditionally classify, diagnose, prevent, and treat common animal ailments using these methods. The use of such traditional medicines for animal healthcare not only significantly reduces costs but also ensures accessibility for the average farmer.

II. ANTIMICROBIAL RESIDUE AND AMR

The introduction of exotic cattle strains has led to increased milk production but has also made these animals more susceptible to diseases. The misuse of antibiotics in dairy animals has resulted in elevated antibiotic residues in animal products like milk and meat. Antibiotic resistance (AMR) is a global concern, posing serious risks to both human and animal health, with predictions of 10 million deaths annually by 2050. In India's livestock sector, there is an urgent need to shift from expensive antibiotics and chemical veterinary drugs to more cost-effective herbal remedies derived from medicinal plants. An intervention impact study, currently under publication, shows a significant reduction in the incidence of mastitis, enteritis, repeat breeding, and cowpox from 2016 to 2019 when herbal alternatives were utilized. Additionally, a microbiome analysis of milk from cows with mastitis, conducted before and after treatment with EVP, revealed a marked decrease in the abundance of mastitis-causing bacteria, including Streptococcus, Staphylococcus, the Enterobacteriaceae family, and Pseudomonas, with levels dropping to a minimum after just six days of treatment (Nair and Punniamurthy, 2023).

In order to lessen the reliance on antibiotics and other chemical medications in veterinary healthcare, herbal ethno-veterinary practices (EVP) are significant alternatives. EVP would prevent the issue of antimicrobial resistance (AMR) and aid with the decrease of antibiotic and other chemical drug residues in animal products. EVP will result in more livestock wellbeing and safer, more affordable dairy products. In the long run, this strategy will improve both human and environmental wellbeing. Farmers have discovered that recently made EVP formulations are quite helpful in controlling and preventing specific clinical problems in livestock. Three years of using herbal formulations for a variety of clinical diseases in cattle in a chosen area has shown a general decrease in the incidence of cowpox (100%), repeat breeding (96%), enteritis (63.6%), and mastitis (83.3%). Furthermore, it has been noted that in approximately 88% of milk samples, there was no discernible antibiotic residue. Farmers were able to save 75% of their livestock's medical costs on average because to these inexpensive herbal mixtures (Nair and Punniamurthy, 2023).

Mastitis and ethnoveterinary treatment

Ethno-veterinary medicine (EVM) is the application of humankind's expertise, abilities, practices, habits, and credence in managing and safekeeping the well-being of their animals . These hands-on skills are shared or transferred from age to age only through the oral medium . Both the scientific and consumer communities are increasingly turning to herbal plants as health promoters. In the interests of the foremost availability of these products and the cheap manufacturing costs around these items, studies using local plants must of necessity encompass multiple geographical locations. Kalayou et al. (2012) investigated the antibacterial potency of several plant species against mastitis, with *Croton aurea*, Croton macrostachyus, *Achyranthes aspera, Nicotiana tabacum* and *Vernonia* species producing the most promising effects of all tested plants. Findings by Serunkuma et al. (2017) established the efficacy of the acetone extract of the *Acacia nilotica* bark and the *Tetradenia riparia* flower against bacterial species cultured from mastitis samples from a farm. Across the board, the development of *S. agalactiae, S. uberis, E. coli* and *S. aureus* was suppressed by a methanol extract derived from *Spathodea campanulata*. Globally, the use of diverse plants from distinct geographical terrains to treat livestock infections remains common. In-vitro assays into medicinal plants reveal their potency as antibacterial, anti-inflammatory or immune-modulatory agents.

Mastitis is a disease in which the highest quantity of antimicrobials are used for the therapy as well as the prevention. Application of Ethno-Veterinary Medicine in the Treatment and Management of Mastitis Ethno-veterinary medicine is a local animal healthcare system that incorporates traditional beliefs, knowledge, skills, methods, and practices. It includes the traditional treatment of veterinary illnesses, as active substances to be extracted, the delivery route, and the medicinal purpose (prophylaxis or therapeutics), the method used to make ethno-veterinary medications differs. Infusions, decoctions, powders, drips, fumes, pastes, and ointments are made from medical plants, animal products, minerals, and other inorganic ingredients accessed by livestock owners and ranchers. These might be treated topically with drenches, or intra-nasally with smoke, vaccines, or suppositories, vapors, or massages (Ajose et al., 2022).

Abbasi et al. (2013) reported that paste made from the fruit juice of *Citrus limon* and sugar fed to animals and applied topically to the mammary glands for 10-15 days is used to treat mastitis in buffalo, cattle and goats. Also, the application of a paste of 200 g of fresh crushed roots of *Withania somnifera* to the udder of a cow and goat respectively for up to a week successfully treats the diseased condition. It is also noteworthy to state that the preparation and application of the smoke of the leaves and branches of *Peganum harmala* over a period of about 5 days successfully treats mastitis in cattle and horses. The *antiinflammatory* effects of the topical application of the extract of fresh leaves of *Rumex nepalensis* to the affected part for about 5 days has also been reported. A poultice of young twigs of Calotropis procera applied to a swollen udder also relieves pain and inflammation.

Ethno-veterinary medicinal plants used in the dairy and livestock farming (Ajose et al., 2022)					
Scientific name	**Family**	**Life form**	**Plant part used**	**Animal**	**Use/disease**
Erysimum melicentae Dunn.	*Brassicaceae*	Herb	Whole plant	Cattle and sheep	For general health improvement
Becium obovatum (E. Mey. Ex Benth. In E. Mey.) N.E. Br.	*Lamiaceae*	Herb	Root	Livestock	Mastitis, Black leg, listeriosis/encircling disease, diarrhea
Malva parviflora	*Malvaceae*	Herb	Whole Plant	Cattle	Mastitis
Brucea antidysenterica	*Simaroubaceae*	Tree	Leaf	Cattle	Mastitis
Acorus calamus L.	*Acoraceae*	Herb	Rhizome	Cows, Sheeps, Goats, Donkeys, Camels, Buffaloes	Mastitis, Anaplasmosis, constipation, heal wounds, dysentery, body tonic, gastric problems, bloating, indigestion, urinary disorder
Prosopis juliflora (Sw.) DC.	*Mimosaceae*	Shrub	Leaf	Cattle	Infections
Triticum sp.	*Poaceae*	Herb	Aerial parts, Bran	Livestock	Mastitis, breast lumps, difficulty of birth, retained placenta, increasing egg production
Arachis hypogea L.	*Fabaceae*	Shrub	Seed and seed oil	Goat and cattle	Increased milk production
Peganum harmala L.	*Zygophyllaceae*	Herb	Leaf, branches	Buffalo, Cattle, Dog	Mastitis
Citrus limon (L.) Osbeck	*Rutaceae*	Tree	Fruit	Buffalo, Cattle, Goat	Mastitis
Withania somnifera (L.) Dunal	*Solanaceae*	Shrub	Root	Buffalo, Cattle, Goat	Mastitis

Natural products and/or organic by-product forms continue to play a pivotal role in the medication upshot process. As a result, biological diversity offers an endless supply of new chemical entities (NCEs) with their potential as therapeutic leads. These NCEs are derived productsgenerated by plants to shield them from herbivores and pathogens, or to attract pollinators. An herbal mixture of *Aloe vera* (L.) Burm. -F., *Curcuma longa* L. and calcium hydroxide, as documented by a traditional healer, was reported to be efficient against mastitis causing pathogens. Apart from this, many more plants are being used for the treatment and control of bacterial mastitis in cows and thus reducing the incidence of mastitis.

Ethno-veterinary medicinal products, preparation and administration for the treatment and control of mastitis		
Plant	**Plant part**	**Administration/dosage for cows**
Allium sativum L.	Rhizome	250 g, grinded with butter and administered orally for 7 days
Allium cepa L.	Bulb	Heated in oil, given as food supplement once per day during 2 or 3 days or until the animal gets better (topical application and vaginal washes)
Asphodelus tenuifolius Cav.	Aerial part	Heated with barley peels (topical application)
Amomum subulatum Roxb.	Fruit	25 g, given orally for 3 days.
Brassica compestres + *Curcuma longa*	Seeds + root	250 g seeds are grinded with 50 g root and administered orally for 5 days
Brucea antidysenterica JF. Mill	Seed	Add 1 L of water to the ground fresh seed given orally once per day for 3 days
Peganum harmala + *Triticum sativum*	Fruit + stem crushing (hay)	50 g + 2 Kg, fumigation of harmal by putting it on fired hay under the affected udder for 4 days
Capsicum annuum	Fruit/whole plant	50 g, given orally for 8 days
Sesamum indicum	Seed oil	250 ml, mixed oil in 1.5 L of milk whey, and given orally for 7 days
Citrus limon	Extract	With raw sugar given orally for 5 days
Osyris quadripartita Decn.	Root	Pound the fresh root and mix with water, filter and administered orally for 6-7 days, daily
Gossypium hirsutum L.	Flowers	250 g, boiled in 1 L water to 250 ml, then drenched for 3 days
Galium aparine L.	Vine	500 g, given as decoction drench for 3 days
Chenopodium ambrosioides L.	Leaf	After grinding the fresh leaf, mix with water to prepare (liquid) 1 L then it is given orally once
Solanum spp.	Leaf	The fresh leaf and root are chewed by the local healer and spit to the mouth of the animal for 2 days
Artemisia herba-alba Asso	Aerial part	Heated with barley peels and/or aggaya (topical application)
Ricinus communis L.	Leaf	Pound about 50 g of fresh leaf and mix with 1 L of water then administered orally 1 L/day (every morning) for 2 days
Cynomorium coccineum L.	Whole plant	Wash with decoction water
Hordeum vulgare L.	Seed	Roasted seeds mixed with water
Ziziphus spina-christi	Leaf	The leaves are ground and applied on the affected teat

		quarter
Achyranthes aspera + *Commicarpus podunculosus*	Root + leaf	The fresh root of an A*chyranthes aspera* is chopped and bounded together with a leaf of *Commicarpus podunculosus*. This will be mixed with water and given orally

Other bacterial diseases where plants can be used alternatively.

Many plants or the parts are also used in different types of wounds infected by different type of bacteria with good success (Verma et al., 2023).

1. *Corymbia citriodora* (Lemon-scented gum): The essential oil extracted from the leaves and fruits of this plant, when administered at doses of 0.125, 0.25, and 0.5 mg/kg, demonstrated 100% efficacy in sheep. The treatment induced the formation of vacuoles, muscular disorganization, and alterations in the mitochondrial profile.
2. *Ocimum tenuiflorum (Tulsi):*The aqueous ethanol extract of *Ocimum tenuiflorum* exhibited antibacterial activity at concentrations ranging from 0.5 to 1000 µg/mL against Gram-positive bacteria, including *Staphylococcus aureus*, CNS, and *Streptococcus agalactiae*, but was ineffective against Gram-negative bacteria.
3. *Argemone mexicana Linn.* (Kateli ka phool): Aqueous extracts prepared from 100 g of leaves and 100 g of fruits of *Argemone mexicana* are applied topically to treat foot infections.
4. *Bambusa arundinacea* (Bamboo): The rhizome and fresh leaves of bamboo, used in equal amounts, are applied for therapeutic purposes.

Ethnoveterinary practices present a promising alternative to the use of antibiotics, but more rigorous studies, including those with proper control groups and double-blind methodologies, are necessary to identify potential candidates for new drug discovery. The author contends that homeopathic products lack proven efficacy against bacterial diseases in livestock when compared to placebos, and they are no more effective than placebos. Therefore, it is advisable not to recommend them for treating cattle ailments. There is significant potential in screening plants for active principles that could serve as alternatives to synthetic antibiotics or antimicrobial drugs. However, as of now, these alternatives cannot replace antibiotics used in treating many cattle diseases, and further research is required to develop novel therapeutic molecules.

III. CONCLUSION

Protection of animal health is necessary for human health. Infection reduction requires rapid diagnosis, epidemiological projections, safer and better vaccines, and hygiene. India lacks cold storage and transport infrastructure to deliver vaccines to rural areas. Advanced diagnostic tests speed up disease diagnosis and differentiation. Better farmer awareness and door-to-door veterinarian services might control dairy animal infections. Budget constraints, low vaccination rates, and poor infrastructure restrict herd immunity in emerging nations like India. This compilation discusses Indian ethnoveterinary medicinal plant dairy cow illness prevention and treatment without any antimicrobial resistance.

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Effect of Nitrogen Management on Microbial Population After Harvest of Maize (*Zea mays* L.) in typic haplustepts of Rajasthan

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***Abstract*— *The field experiment was conducted during the kharif season of 2018-19 at the Instructional Farm (Agronomy) of the Rajasthan College of Agriculture in Udaipur, situated at an altitude of 579.5 meters above sea level, with coordinates 24º34' latitude and 73º42' longitude. This region falls under agro-climatic zone IVa (Subhumid Southern Plain and Aravalli Hills) of Rajasthan. The results indicated that the highest populations of bacteria, fungi, and actinomycetes in the soil were observed under treatment T11, which involved 100% recommended dose of nitrogen from chemical fertilizers combined with 10 tons of FYM per hectare. This was followed by T3 (75% RDN from chemical fertilizers and 25% RDN from poultry manure), T2 (75% RDN from chemical fertilizers and 25% RDN from enriched compost), T4 (75% RDN from chemical fertilizers and 25% RDN from vermicompost), and T12 (100% RDN from chemical fertilizers), consistent across both years and in the pooled analysis.*

Keywords*— *Maize, Bactria, Fungi and Actinomycetes.

I. INTRODUCTION

Maize has high production potential crop when compared to any other cereal crop. The productivity of maize is mainly dependent on its nutrient management. It is well known that maize is a heavy feeder of nutrients and because of its C_4 nature; it is very efficient in converting solar energy into production of dry matter. The crop has high genetic yield potential. Hence, it is called Miracle crop and "Queen of Cereals" (Durani et al., 2018). It has a fibrous root system that anchors the plant and allows for efficient nutrient and moisture uptake. The tall, erect stem can reach heights of 3 to 12 feet and consists of nodes, where leaves emerge, and internodes in between. Leaves are long, narrow and arranged alternately along the stem, playing a crucial role in photosynthesis. These morphological traits enable maize to thrive in various environments, making it a vital crop globally.

Improper farming techniques, such as excessive application of chemical inputs and frequent changes in land use, contribute to variability in soil microbial communities, adversely affecting soil fertility and productivity (Onet *et al.,* 2016). Conversely, organic farming methods that utilize eco-friendly fertilizers, such as compost, manure and microbial amendments, can mitigate some of the harmful effects associated with synthetic fertilizers (Aurelia Onet *et al.,* 2019). Moreover, studies indicate that prolonged monocultures without the incorporation of organic fertilizers or crop rotation, combined with continuous mineral fertilizer application, lead to a significant decrease in soil organic matter (Luo *et al*., 2015). Mineral fertilization has also been linked to reduced soil porosity and nutrient availability (Song *et al.*, 2015). The use of synthetic fertilizers disrupts the biological interactions within the soil ecosystem, negatively impacting both soil microorganisms and the overall health of agricultural systems, thereby exacerbating the environmental consequences of farming (Lucian Constantin Dincă *et al.*, 2022).

Applying herbicides to soil microorganisms can inhibit, activate, or have no effect at all. Bezuglova *et al*. (2019) showed that foliar application of sulfonylurea herbicide decreased the abundance of bacteria, especially for the quickly growing ones on winter wheat soil. Jie chen *et al*. (2021) reported that sterane first decreased soil bacterial diversity and abundance in maize fields 10 days after sowing but increased them 60 days after application. Herbicides changed the population and diversity of the cultivatable soil bacteria, actinomycetes and fungi, according to research done by Borowik *et al*. (2017) after applying a mixture of herbicide consisting of terbuthylazine, S-metolachlor, and mesotrioneto pot culture maize soil (Bezug *et al*., 2017). According to Borowik (2017), the spray of sulfonylurea herbicide on winter wheat soil caused stress on the soil, which in turn affected the plants and soil bacteria.

Additionally, a study by Borowik *et al*. (2017) reported that a combination of herbicides—specifically terbuthylazine, S-metolachlor, and mesotrione altered the populations and diversity of cultivatable soil bacteria, actinomycetes, and fungi in maize pot cultures. Borowik (2017) also noted that the use of sulfonylurea herbicides imposed stress on the soil environment, which subsequently impacted both plant health and soil microbial communities. Herbicides may influence soil microbial diversity by affecting root growth and altering the secretion of root exudates, which are known to play a critical role in regulating microbial communities in the soil.

Majorly poor management of N fertilizer has key role to play in obtaining low yield productivity, so in order to achieve optimum crop productivity management of nutrients through judicious application of inorganic sources, organic sources, bio-fertilizers and micro-nutrients are required (Gu and Yang *et al*., 2022). Improving N management is required to understand the contribution of a farmer's behavior to current N application practical problems, such as N use efficiency (NUE) of the main cereal production system (McAllister *et al*., 2012).The use of appropriate and conjunctive use of application of suitable nutrients through organic and inorganic solely or in combination can provide the solutions to the problems such as increase in the price of inorganic fertilizers and deterioration effect of soil fertility and productivity.

II. MATERIAL AND METHODS

The field experiment was carried out during the kharif season of 2018-19 at the Instructional Farm (Agronomy) of the Rajasthan College of Agriculture in Udaipur, located at an altitude of 579.5 meters above mean sea level, with coordinates at 24º34' latitude and 73º42' longitude. This area is classified under agro-climatic zone IV-a (Subhumid Southern Plain and Aravalli Hills) of Rajasthan. In 2018, the mean maximum and minimum temperatures were 34.40°C and 13.70°C, while in 2019, they were 33.60°C and 13.20°C, respectively. The soil used for the experiment was clay loam in texture, exhibiting a bulk density of 1.55 and 1.56 Mg m^{-3}, a particle density of 2.65 and 2.66 Mg m^{-3}, porosity of 41.46% and 41.35%, and water holding capacity of 38.91% and 39.00% for the years 2018 and 2019. The soil's pH levels were 8.27 and 8.28, electrical conductivity (EC) was 0.85 and 0.86 dS m^{-1}, organic carbon content was 0.50% and 0.52%, and cation exchange capacity was 9.03 and 9.20 Cmol (P^+) kg^{-1}. The available nitrogen ranged from 265 to 278 kg ha^{-1}, while available phosphorus was 16.27 and 17.13 kg ha^{-1}, and available potassium was 430 and 442 kg ha^{-1} during 2018 and 2019, respectively.

Application of organic manure and nitrogen fertilization

The organic nutrient sources used in the experiment included farmyard manure, enriched compost, poultry manure, and vermicompost. These organic manures were applied to the field according to specific treatments and thoroughly mixed in one month prior to sowing, while chemical fertilizers were applied at the time of planting. The nutrient contents of the organic manures were as follows: farmyard manure (FYM) had 0.49% nitrogen, 0.25% P_2O_5, and 0.48% K_2O; enriched compost contained 1.2% nitrogen, 2.1% P_2O_5, and 0.9% K_2O; poultry manure had 1.4% nitrogen, 1.0% P_2O_5, and 1.1% K_2O; and vermicompost contained 1.6% nitrogen, 1.3% P_2O_5, and 1.2% K_2O. The recommended application rates for nitrogen, phosphorus, and potassium were 120:60:30 kg ha^{-1}. Nitrogen was supplied through urea in two equal applications: half as a basal dose and the remaining half as top dressing at the knee-high stage of growth.

Experimental design and treatments

The experiment was designed using a Randomized Block Design with three replications and thirteen treatments. These treatments included various combinations of organic manure and chemical nitrogen fertilizers viz., T_0 : Control T_1 : 75% Recommended N through CF + 25% Recommended N through FYM, T_2 : 75% Recommended N through CF + 25% Recommended N through Enriched Compost, T_3 : 75% Recommended N through CF + 25% Recommended N through Poultry Manure, T_4 : 75% Recommended N through CF + 25% Recommended N through Vermicompost; T_5 : 50% Recommended N through CF + 25% Recommended N through FYM + 25%

Recommended N through Enriched Compost, T_6 : 50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Poultry Manure, T_7 : 50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Vermicompost, T_8 : 50% Recommended N through CF + 25% Recommended N through Enriched Compost + 25% Recommended N through Poultry Manure, T_9 : 50% Re commended N through CF + 25% Recommended N through Enriched Compost + 25% Recommended N through Vermicompost, T_{10} : 50% Recommended N through CF + 25% Recommended N through Vermicompost + 25% Recommended N through Poultry Manure, T_{11} : 100% Recommended N through CF + FYM (10 t ha^{-1}) and T_{12} : 100% Recommended N through CF. Maize variety Pusa Early Hybrid Maize-2 (PEHM-2) was sown at the seed rate of 25 kg ha^{-1} at inter row of 60 and plant to plant spacing of 20 cm.

Statistical analysis

The data collected for various parameters were analyzed using the analysis of variance (ANOVA) technique as described by Panse and Sukhatme (1985) for a factorial randomized block design. The results are reported at a 5% significance level (P = 0.05).

III. RESULT AND DISCUSSION

An assessment of data shows that bacteria, fungi & actinomycetes population in post harvested soil increased due to integrated use of organic and inorganic nitrogen source during both the years and in pooled mean. The data shown in Table 1 and Figure 1 reveal that the highest bacterial population in the soil, measured at 41.25, 41.75, and 41.50 cfu $g^{-1,}$ was found under treatment T_{11} (100% RDN from chemical fertilizer + FYM at 10 t ha^{-1}). This was followed by T_3 (75% RDN from chemical fertilizer + 25% RDN from poultry manure), T_2 (75% RDN from chemical fertilizer + 25% RDN from enriched compost), T_4 (75% RDN from chemical fertilizer + 25% RDN from vermicompost), and T_{12} (100% RDN from chemical fertilizer), across both years and in the pooled mean. In contrast, the lowest bacterial population of 12.68, 13.11, and 12.89 cfu g^{-1} was observed under T_0 (control) during both years and in the pooled mean. The data presented in Table 2 and Figure 2 indicate that the highest fungal population in the soil was observed under treatment T_{11} (100% RDN from chemical fertilizer + FYM at 10 t ha^{-1}), with values of 18.27, 18.67, and 18.47 cfu g^{-1}. This was followed by T_3 (75% RDN from chemical fertilizer + 25% RDN from poultry manure), T_2 (75% RDN from chemical fertilizer + 25% RDN from enriched compost), T_4 (75% RDN from chemical fertilizer + 25% RDN from vermicompost), and T_{12} (100% RDN from chemical fertilizer) across both years and in the pooled mean. Conversely, the lowest fungal population was recorded under T_0 (control), with values of 6.88, 7.30, and 7.09 cfu g-1 during both years and in the pooled mean. The data presented (Table 3 and figure 3) shows that highest actinomycetes (26.00, 26.72 and 26.36 cfu g^{-1}) population in soil was recorded under T_{11} (100 % RDN through chemical fertilizer +FYM @10t ha^{-1}) followed by T_3 (75 % RDN through chemical fertilizer +25% RDN through poultry manure), T_2 (75 % RDN through chemical fertilizer + 25% RDN through enriched compost), T_4 (75 % RDN through chemical fertilizer + 25% RDN through vermicompost) and T_{12} (100 % RDN through chemical fertilizer) during both years and in pooled mean, respectively. The lowest actinomycetes (8.87, 9.27 and 9.07 cfu g^{-1}) population in soil was recorded under T_0 (control) during both years and in pooled mean, respectively and the increase in bacteria, fungi and actinomycetes population in soil was obtained to the extent of 221.83, 194.73, 192.40, 182.32 &165.26; 160.56, 148.99 , 137.71, 129.33 and 124.02 and 190.60, 165.26, 156.00, 153.58 & 142.55 per cent in pooled analysis with the application of T_{11}, T_3, T_2, T_4 & T_{12} as compared to control (T_0), respectively. All the treatments combination of organic and inorganic source of nitrogen significantly improved the soil microbial population (bacteria, fungi and actinomycetes) during 2018, 2019 and on pooled analysis. The application of 100% RDN through chemical fertilizer plus 10t ha^{-1} farmyard manure reported highest soil microbial population (bacteria, fungi and actinomycetes) in soil during during 2018, 2019 and on pooled analysis. The use of organic manure (FYM/ enriched compost/ and poultry manure) along with chemical fertilizer led to higher microbial population in soil and increase microbial respiration than use of chemical fertilizer alone. Organic manure is a rich source of organic matter and an important source of nutrients for plants and microorganisms in soil. The incorporation of organic manure in soil promoted microbial activities and improved chemical fertilizer use efficiency. The lowest microbial activity was noticed in control and the plots receiving nutrients through chemical fertilizers alone, which might be due to more acidification of soil and mining of the macronutrients. The cumulative effect of organic and inorganic fertilization in increasing organic carbon content of soil which acted as carbon and energy source for microbes and their quick build up in the soil (Sun *et al*., 2015). The present study showed higher microbial population in FYM treated plot along with chemical fertilizers because FYM is a source of nutrient and also as substrate for decomposition and mineralization of nutrients, thereby creating a favourable condition for the proliferation of the microbes in the soil. Among the microbes, bacterial population was maximum followed by actinomycetes and fungi, which may be due to their higher multiplication rates (Dincă *et al.*, 2022). The organic-inorganic fertilizers may improve nutrient cycling which increased the nutrients status of soil and higher nutrient status accelerated the microbial activity in soil and these results were supported by Zhang *et al.* (2021).

IV. CONCLUSION

On the basis of above experiment it is concluded that the highest bacteria, fungi and actinomycetes population in the soil was found under treatment T_{11} (100% RDN from chemical fertilizer + FYM at 10 t ha^{-1}). This was followed by T_3 (75% RDN from chemical fertilizer + 25% RDN from poultry manure), T_2 (75% RDN from chemical fertilizer + 25% RDN from enriched compost), T_4 (75% RDN from chemical fertilizer + 25% RDN from vermicompost), and T_{12} (100% RDN from chemical fertilizer), across both years and in the pooled mean.

Table 1: Effect of nitrogen management on bacteria population in soil after harvest of maize crop

Symbol	Treatments	Bacteria (10^7cfu g^{-1} of soil)		
		2018	**2019**	**Pooled**
T_0	Control	12.68	13.11	12.89
T_1	75% Recommended N through CF + 25% Recommended N through FYM	33.68	34.09	33.88
T_2	75% Recommended N through CF + 25% Recommended N through Enriched Compost	37.50	37.91	37.70
T_3	75% Recommended N through CF + 25% Recommended N through Poultry Manure	37.80	38.21	38.00
T_4	75% Recommended N through CF+ 25% Recommended N through Vermicompost	36.20	36.61	36.40
T_5	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Enriched Compost	32.00	32.41	32.20
T_6	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Poultry Manure	32.24	32.65	32.44
T_7	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Vermicompost	30.58	30.99	30.78
T_8	50% Recommended N through CF + 25% Recommended N through Enriched Compost + 25% Recommended N through Poultry Manure	33.36	33.77	33.56
T_9	50% Recommended N through CF + 25% Recommended N through Enriched Compost + 25% Recommended N through Vermicompost	32.45	32.86	32.65
T_{10}	50% Recommended N through CF + 25% Recommended N through Vermicompost + 25% Recommended N through Poultry Manure	32.68	33.09	32.88
T_{11}	100% Recommended N + FYM (10 t/ha)	41.25	41.75	41.50
T_{12}	100 % Recommended N through CF	34.00	34.41	34.20
	SEm±	0.56	0.71	0.45
	CD (P=0.05)	1.63	2.06	1.28

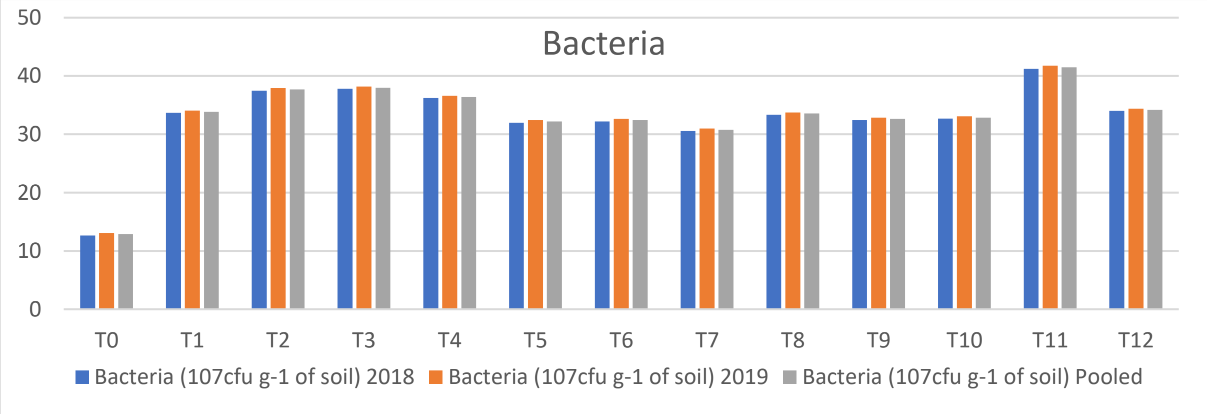

Fig.1: Effect of nitrogen management on bacteria population in soil after harvest of maize crop

Table 2: Effect of nitrogen management on Fungi population in soil after harvest of maize crop

Symbol	**Treatments**	**Fungi (10^5 cfu g^{-1} of soil)**		
		2018	**2019**	**Pooled**
T_0	Control	6.88	7.3	7.09
T_1	75% Recommended N through CF + 25% Recommended N through FYM	15.5	15.9	15.7
T_2	75% Recommended N through CF + 25% Recommended N through Enriched Compost	16.65	17.05	16.85
T_3	75% Recommended N through CF + 25% Recommended N through Poultry Manure	17.45	17.85	17.65
T_4	75% Recommended N through CF+ 25% Recommended N through Vermicompost	16.06	16.46	16.26
T_5	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Enriched Compost	14.01	14.41	14.21
T_6	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Poultry Manure	14.26	14.66	14.46
T_7	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Vermicompost	12.88	13.28	13.08
T_8	50% Recommended N through CF + 25% Recommended N through Enriched Compost + 25% Recommended N through Poultry Manure	15.32	15.72	15.52
T_9	50% Recommended N through CF + 25% Recommended N through Enriched Compost + 25% Recommended N through Vermicompost	14.68	15.08	14.88
T_{10}	50% Recommended N through CF + 25% Recommended N through Vermicompost + 25% Recommended N through Poultry Manure	15.02	15.42	15.22
T_{11}	100% Recommended N + FYM (10 t/ha)	18.27	18.67	18.47
T_{12}	100 % Recommended N through CF	15.68	16.08	15.88
	SEm±	0.27	0.27	0.19
	CD (P=0.05)	0.79	0.8	0.55

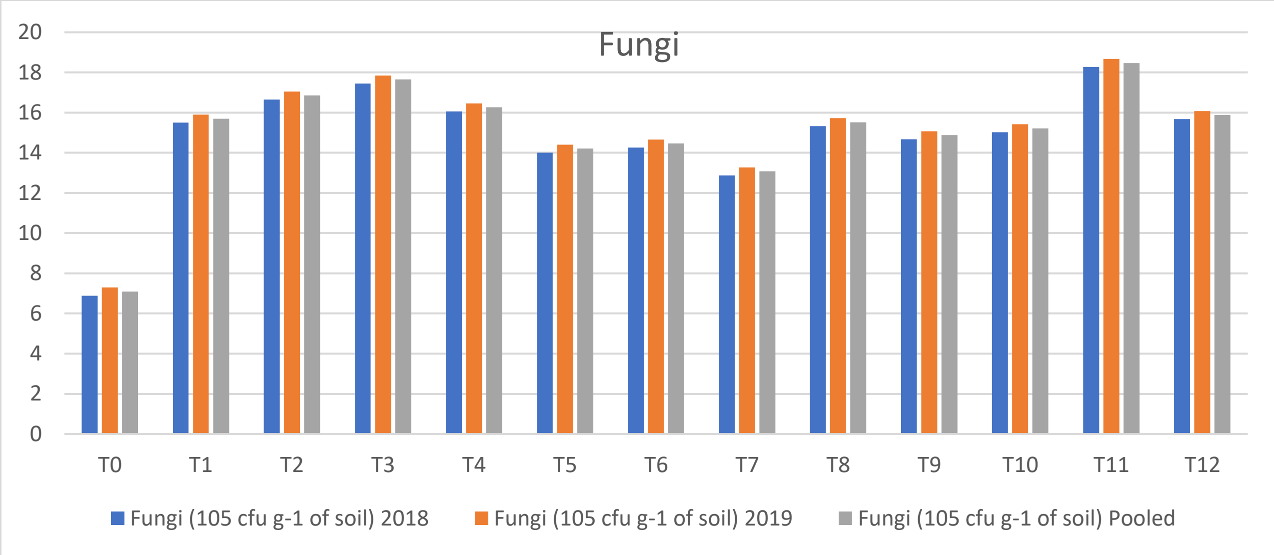

Fig.2: Effect of nitrogen management on fungi population in soil after harvest of maize crop

Table 3: Effect of nitrogen management on actinomycetes population in soil after harvest of maize crop

Symbol	Treatments	Actinomycetes (10^6 cfu g^{-1} of soil)		
		2018	**2019**	**Pooled**
T_0	Control	8.87	9.27	9.07
T_1	75% Recommended N through CF + 25% Recommended N through FYM	21.23	21.63	21.43
T_2	75% Recommended N through CF + 25% Recommended N through Enriched Compost	23.02	23.43	23.22
T_3	75% Recommended N through CF + 25% Recommended N through Poultry Manure	23.86	24.27	24.06
T_4	75% Recommended N through CF+ 25% Recommended N through Vermicompost	22.80	23.21	23.00
T_5	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Enriched Compost	18.02	18.42	18.22
T_6	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Poultry Manure	18.65	19.05	18.85
T_7	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Vermicompost	18.00	18.40	18.20
T_8	50% Recommended N through CF + 25% Recommended N through Enriched Compost + 25% Recommended N through Poultry Manure	21.12	21.52	21.32
T_9	50% Recommended N through CF + 25% Recommended N through Enriched Compost + 25% Recommended N through Vermicompost	19.20	19.60	19.40
T_{10}	50% Recommended N through CF + 25% Recommended N through Vermicompost + 25% Recommended N through Poultry Manure	19.88	20.28	20.08
T_{11}	100% Recommended N + FYM (10 t/ha)	26.00	26.72	26.36
T_{12}	100 % Recommended N through CF	21.80	22.21	22.00
	SEm±	0.43	0.42	0.30
	CD (P=0.05)	1.25	1.24	0.86

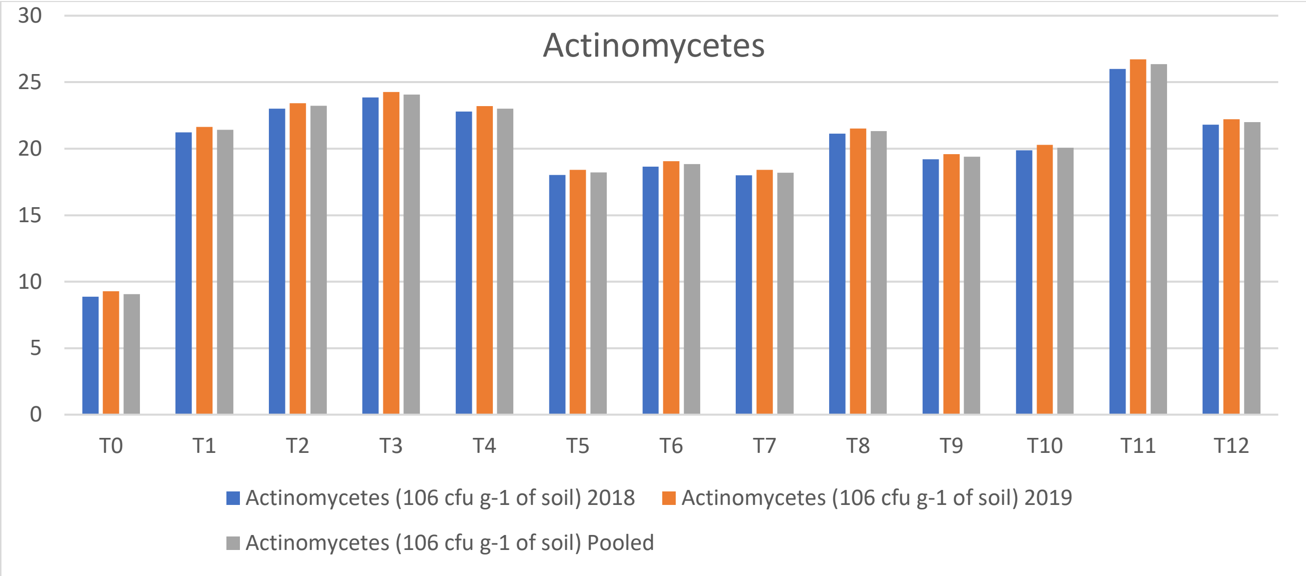

Fig.3: Effect of nitrogen management on actinomycetes population in soil after harvest of maize crop

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FT-IR and GC-MS characterization of bioactive compounds from the root extract of *Anacyclus pyrethrum* Linn

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***Abstract*— *Medicinal plants have long been considered for their ability to treat various human diseases owing to their potent phytochemical properties. However, isolating lead compounds from complex mixtures requires extensive knowledge, specialized equipment, and expertise. The emergence of novel diseases underscores the importance of accurately documenting the research on medicinal plants. This study focused on Anacyclus pyrethrum (L.) Lag, an ingredient in Kabasurakudineer. Although traditional and experimental evidence supports various claims regarding these plants, thorough evaluation and utilization of their potential are still necessary. Further research is required to elucidate the mode of action of these isolates. The primary objective of this study was to identify the bioactive compounds in the ethanolic root extract of Anacyclus pyrethrum using Fourier Transform-Infrared (FTIR) and Gas Chromatography-Mass Spectroscopy (GC-MS). FTIR analysis revealed the presence of hydroxyl groups, alcohols, carboxylic acids, aromatic compounds, nitro compounds, alkyl halides, and aryl halides with major peaks at 3740.03, 3281.04, 2903.30, 1612.69, 1402.96, 1242.33, 1023.12, 658.19, and 582.88, respectively, indicating phenols, flavonoids, tannins, and saponins. GC-MS analysis identified 60 compounds, with the major constituents being 4-Decadienamide, N-Isobutyl-, (E, E)-, and (2e,4e)-N-Isobutyldodeca-2,4-Dienamide, constituting 23.03% and 17.33% of the extract, respectively. This study confirmed that the roots of Anacyclus pyrethrum (L.) contain significant natural chemical compounds, validating its traditional use in various pharmacological activities.*

Keywords*— *Anacyclus pyrethrum, Bioactive compounds, Flavonoids, Gas chromatography, Hydroxyl compounds, Pharmacological activities

I. INTRODUCTION

Medicinal plants are a valuable resource for drug development and synthesis. These plants play a crucial role in human culture and in the development of natural resources. Phytochemicals are biologically active compounds of plant origin that provide health benefits to humans [1]. These non-nutritive plant chemicals exhibit protective or disease-preventive properties, and may play a significant role in plant growth. Medicinal plants contribute substantially to the treatment and cure of numerous human diseases owing to their potent phytochemical constituents [2]. At present, more than 4,000 phytochemicals have been identified and classified according to their protective functions, physical characteristics, and chemical characteristics, with approximately 150 of them being studied in detail [3]. The process of isolating and identifying lead compounds from complex mixtures requires several resources, including comprehensive knowledge, specialized equipment, and expertise. The urgency for the discovery of new agents arises from intractable factors including the emergence of novel pathogenic diseases. There is a significant need and ethical imperative to accurately document investigation findings regarding plants used for health purposes. Globally, the ongoing pursuit of an effective drug to combat the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) has not been successful. Indian traditional medicines, particularly polyherbal formulations such as Nilavembu Kudineer and Kaba Sura Kudineer of the Siddha system of medicine, have been employed as public health interventions for controlling viral epidemics such as dengue and chikungunya. Traditional therapies are safe, effective, and widely used. Kabasurakudineer is a compound formulation comprising fifteen ingredients [4]. In this study, we selected one of the ingredients of Kabasurakudineer *Anacyclus pyrethrum* (L.) Lag. roots, commonly known as pellitory roots or Akarkara in Indian trade. In traditional medicine, the roots of *A. pyrethrum* are recommended for the treatment of toothache, salivary secretion, angina, digestive problems, lethargy, female infertility, and paralysis of the tongue and limbs. They are utilized in the form of cream-based animal fats to treat gout and sciatica, and to prevent illness. Other pharmacological and biological properties of *A. pyrethrum* roots have been reported in the literature, including sialagogue aphrodisiac [5,6], immunostimulant [7,8], antidepressant[9], antimicrobial [10,11], anesthetic [12], anti-inflammatory [13,14], anticonvulsant1 [5,16], antioxidant [17], antidiabetic [18], reproductive [19], and memory enhancer [20] properties. Although there is traditional and experimental evidence to support the various claims and benefits of these plants, proper evaluation and exploitation are required. Further investigations are necessary to assess the mode of action of the isolates in various activities. Therefore, this plant was selected for this study. The aim of the present study was to analyze the phytochemicals present in the roots of *Anacyclus pyrethrum* using gas chromatography and mass spectroscopy.

II. MATERIALS & METHODS

2.1 Study species

In this study, we selected *Anacyclus pyrethrum* L., a medicinal plant belonging to the Asteraceae family. It is a perennial herb found in North Africa, India, and other Arabian countries. The medicinal application of this plant is utilized in Ayurvedic, Unani, and herbal medicines globally for the treatment of male disorders, common cold, toothache, and pyorrhea, and plays a crucial role in preventing and controlling epilepsy and seizures [9,15].

2.2 Study area

Anacyclus pyrethrum L. was collected from Kollimalai in February, 2022. Kollimalai is situated west of Pachaimalais in the Namakkal district of Tamil Nadu, India. It comprises a compact block of hills with a total area of 490 square kilometers and altitude ranging from 1000 to 1300 m. The average annual precipitation is approximately 1200 mm.

2.3 Sample preparation

The collected plant roots were washed with water to remove soil and debris. The plant material was subsequently dried in the shade for four–five days and subsequently reduced to small pieces. It was then pulverized into a coarse powder. The resultant powder was used for extraction of the active compounds. Plant roots were extracted using a previously described method. The dried powders were immersed separately in ethanol (1:4, w/v) at room temperature for 24 h. The extracts were suction-filtered through a Whatman No.1 filter paper. This process was repeated for two additional days, and similar extracts were pooled, concentrated, and vacuum-evaporated using a rotary evaporator at a temperature of 40°C [2,4].

2.4 Fourier-transform infrared spectroscopy (FTIR) analysis

FTIR is a chemical analytical method that measures infrared intensity versus the wavelength or wave number of light. It was employed to analyze potential biomolecules and bonding interactions between them. IR spectroscopy was used to determine the vibrational characteristics of the chemical functional groups in the samples. When infrared light interacts with matter, chemical bonds undergo stretching, contraction, and bending. This chemical functional group tends to adsorb infrared radiation in a specific wavenumber range within the structure of the rest of the molecule. The functional groups of the plant extracts were characterized by FTIR analysis, and the spectra were scanned in the range 4000–400 cm^{-1} [21] at a resolution of 4 cm^{-1}. FTIR analysis of *Anacyclus pyrethrum* L. powdered root samples was conducted using FTIR spectroscopy (PERKIN ELMER, IR) at the National College Instrumentation Facility, National College Trichy.

2.5 GC-MS analysis

Gas chromatography-mass spectrometry (GC-MS) is a technique used to analyze and quantify organic volatile and semi-volatile compounds. Gas Chromatography (GC) was used to separate the mixtures into individual components using temperature-controlled capillary columns. GC-MS (Shimadzu QP-2020) was performed using a DB-WAX column containing a polar stationary phase. A sample injection volume of 1µl with a split ratio of

10:1, was used. The initial injector temperature was 250°C. The linear velocity to control the flow was maintained at 39.7 cm/sec, Pressure: 68.1 k Pa, total flow: 16. 2 mL/min, Column flow: 1. Twenty mL/min, ion-source temperature: 200°C, and interface temperature: 250 °C. The oven temperature was varied from 50 °C to 280°C for 2 min. ACQ Mode range from 50m/z to 500m/z. Mass spectra were examined by electron impact ionization at 70 eV.The gas chromatography (GC) run time for each sample was 40 minutes. Mass spectral range interpretation in gas chromatography-mass spectrometry (GC-MS) was conducted using NIST and WILEY library databases [22]. GC-MS analysis of the ethanolic extracts of *A. pyrethrum* L. roots was performed using gas chromatography-mass spectrometry (Shimadzu QP-2020) at the Heber Analytical Instrumentation Facility (HAIF), Bishop Heber College, Trichy.

III. RESULTS AND DISCUSSION

3.1 FT-IR spectral data interpretation

Fourier transform infrared (FTIR) spectroscopy is a vibrational spectroscopic technique that employs infrared radiation to induce vibrations in molecular bonds within a sample [23]. The FTIR spectrum was utilized to identify the functional groups of the active components present in the extract based on the peak values in the IR region. The FTIR spectra of the plant extracts (prepared in ethanol) of *A. pyrethrum* are presented in Fig 1. The peak values and probable functional groups present in the root extracts are summarized in TABLE 1. FTIR analysis results demonstrated that the root extract of *A. pyrethrum* contained hydroxyl groups, alcohols, carboxylic acids, aromatic compounds, nitrocompounds, alkyl halides, and aryl halides, which exhibited major peaks at 3740.03, 3281.04, 2903.30, 1612.69, 1402.96, 1242.33, 1023.12, 658.19, and 582.88, respectively. These peaks indicate the presence of phytochemical compounds such as phenols, flavonoids, tannins, and saponins. *Clitoria ternatea* was investigated for bioactive compounds in the leaf and flower parts used in this study. Fourier-transform infrared spectroscopy of the leaf extract revealed eight bands, indicating the presence of alcohols, carboxylic acids, and aromatic compounds, whereas the flower extract showed eight bands, suggesting the presence of nitro compounds and alkanes. Upon analyzing the results of this study, it is evident that they partially corroborate the previously mentioned output [24]. FTIR analysis of the four types of *Wedelia trilobata* extracts revealed the presence of carboxylic acids, alkenes, and nitro compounds, which aligns with the aforementioned output [25]. The FTIR analysis of *Rivinia humilis* and *Diplazium esculentum* samples at 4000–500 cm-1 demonstrated the presence of alkanes and aromatic compounds, which is consistent with the previously discussed results [26]. A subsequent study was initiated on *Allium sativum* and Nymphaea lotus samples, wherein multiple peaks were identified in different extractions. Among these peaks, alcohols, carboxylic acids, nitro compounds, alkanes, and aromatic compounds were identified, which is consistent with the previously mentioned results [27].

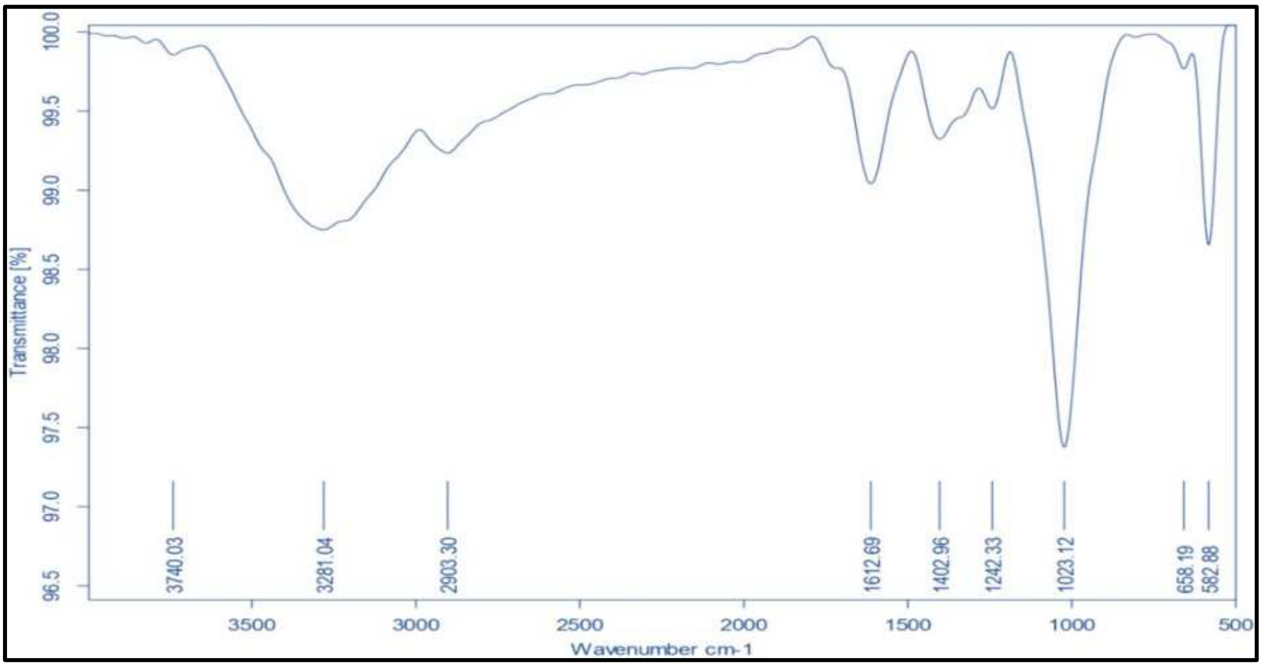


Fig 1. FTIR spectrum of A. pyrethrum

Table 1. FTIR functional groups of compounds in root extract of A. pyrethrum

Frequency range	Molecular motion	Intensity	Functional group
3740.03	O-H(Non-bonded)	W	Hydroxyl group
3281.04	O-H stretch	Br	Alcohol
2903.30	O-H stretch	Br	Carboxylic Acid
1612.69	C-H stretch	M-W	Aromatic compound
1402.96	NO_2 stretch	S	Nitro compound
1242.33	C-F stretch	M-W	Alkyl & Aryl Halides
1023.12	C-F stretch	S	Alkyl & Aryl Halides
658.19	C-l stretch	S	Alkyl & Aryl Halides
582.88	C-l stretch	S	Alkyl & Aryl Halides

3.2 Gas chromatography mass spectrometry

The ethanolic root extract of A. pyrethrum was subjected to gas chromatography-mass spectrometry (GC-MS) analysis, wherein the mass spectra of the compounds identified in the extract were compared with the National Institute of Standards and Technology (NIST) library[28]. Sixty compounds exhibiting various phytochemical activities were identified in the ethanolic root extracts of A. pyrethrum. The chromatogram is presented in Fig. 2, and the chemical constituents and their retention time (RT), molecular formula, molecular weight, and concentration (%) in the root extract of *A. pyrethrum* are presented in TABLE 2 and some structures are in TABLE 3. Fatty amides were the predominant chemical constituents. The major components were 2,4-Decadienamide, N-Isobutyl-,(E,E)- (23.03%) , (2E,4E)-N-Isobutyldodeca-2,4-dienamide (17.33%), Tetrapentacontane, and N-Hexadecanoic Acid (3.22%). A study was conducted to evaluate phytochemical screening and GC-MS analysis for the presence of secondary metabolites, including alkaloids, flavonoids, terpenoids, steroids, and tannins. Extracts of numerous plant species have gained popularity in recent years, and efforts to characterize their bioactive properties for various pharmaceutical applications [29]. *Erigeron canadensis* was subjected to infrared and mass spectroscopy analyses, yielding 20 peaks, among which alcohols, phenols, and carboxylic acids were the most prevalent. Mass spectroscopy was used to identify 23 bioactive compounds [30]. Subsequently, *Chenopodium album* was used to investigate its antifungal activity using mass spectroscopy, resulting in the identification of six compounds [31]. *Senna occidentalis* was analyzed via GC-MS and infrared spectroscopy, leading to the isolation of nine compounds, including fatty acids, using a separation technique [32]. The roots of *Cassia siberiana* produced eight strong and four weak peaks, and mass spectroscopy was used to isolate 18 compounds [33]. The root extract of *Asparagus racemosus* was subjected to FTIR, yielding the expected peaks along with carboxylic acids, whereas mass spectroscopy was utilized to isolate the methyl group [34]. The bioactive compounds present in *Solanum khasianum* were investigated using gas chromatography-mass spectrometry. A total of 48 compounds were identified, 13 in the leaves and 32 in the roots. These results demonstrated that similar compounds were observed in this study [35]. *Eichornia crassipes* leaves were used for phytochemical profiling, and FTIR analysis revealed 16 peaks, including those for aromatic, alcohol, phenol, and nitro compounds. GC-MS analysis revealed several peaks, the most prevalent of which were those of the five compounds [36]. *Senna tora* were subjected to phytochemical characterization and GC-MS, several major peaks were identified in the samples along with phenolic compounds [37]. The leaf extracts of *Tamarindus indica* were subjected to infrared and mass spectroscopy, which provided evidence to support these results. Infrared analysis revealed 26 peaks from the ethanol and water samples with alcohol, alkene, and carboxylic groups, whereas mass spectroscopy identified 60 compounds with hexadecanoic acid, which is consistent with the findings of the aforementioned study. These results provide crucial evidence to support the aforementioned findings [38]. The present study utilized *Mentha spicata* for phytochemical investigations. GCMS analysis revealed six peaks indicative of the presence of alcohol and phenol groups [39]. Phytochemical investigations were conducted on *Ruellia tuberosa*. Infrared analysis revealed 13 peaks corresponding to phenols and alkene compounds, whereas GC-MS identified 16 distinct compounds [40].

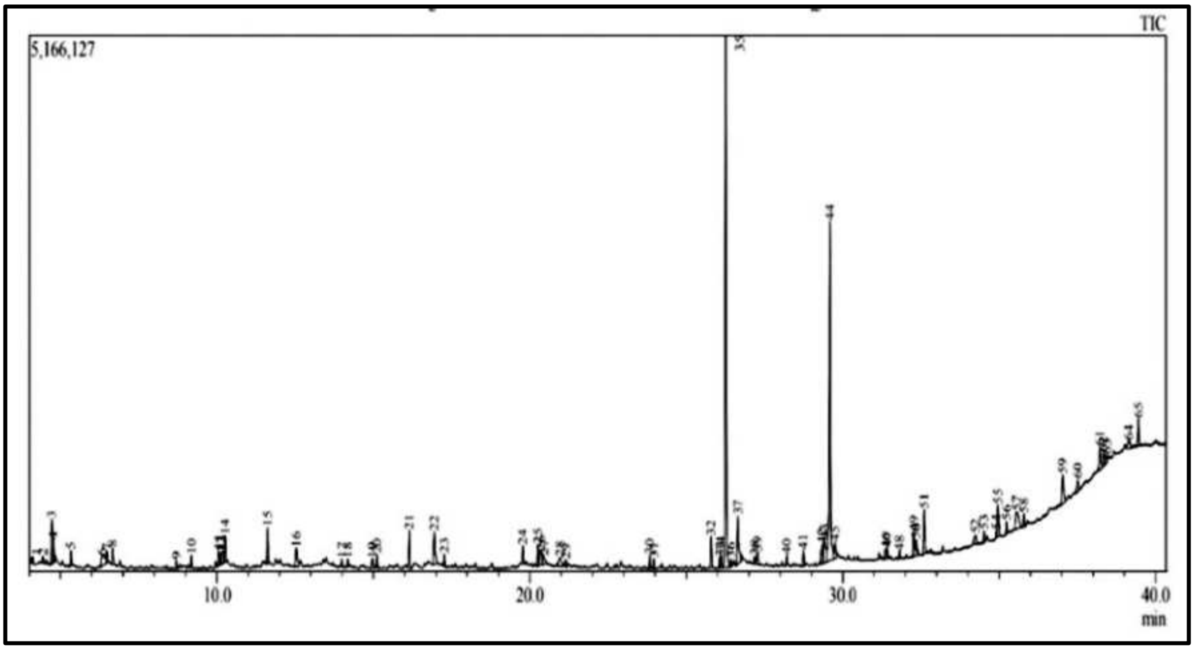


Fig 2: Chromatogram of A. pyrethrum

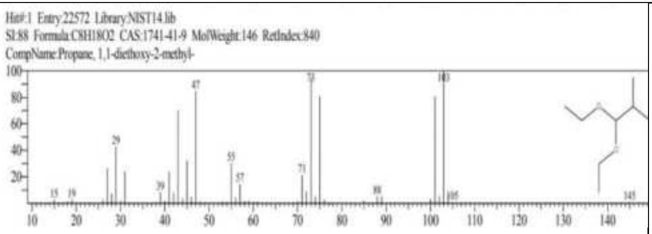
Table 2: Phytochemical Components in the root extract of A. pyrethrum by GC-MS

Peak	R.t (Min)	Area(%)	Compound name	Molecular weight	Molecular formula
1.	4.114	0.25	Propane, 1,1-Diethoxy-2-Methyl-	146	$C_8H_{18}O_2$
2.	4.438	0.33	1-Butanol, 3-Methyl-, Acetate	180	$C_7H_{14}O_2$
3.	4.718	2.79	1-Butanol, 2-Amino-3-Methyl- (+/-.)-	103	$C_5H_{13}NO$
4.	4.77	0.84	Acetic Acid, 1-Ethyl-2-Methylpropyl Ether	144	$C_8H_{16}O_2$
5.	5.33	0.55	1,2-Cyclooctanedione	98	$C_5H_6O_2$
6.	6.335	1.51	Glycerin	92	$C_3H_8O_3$
7.	6.475	0.49	2,4-Dihydroxy-2,5-Dimethyl-3(2h)-Furan-3-One	144	$C_6H_8O_4$
8.	6.662	0.68	Formic Acid, 2-Propenyl Ester	86	$C_4H_6O_2$
9.	8.706	0.35	Uracil, 1-methyl-	126	$C_5H_6N_2O_2$
10.	9.186	0.51	1,1,3-Triethoxybutane	190	$C_{10}H_{22}O_3$
11.	10.061	0.81	Cyclopentasiloxane, Decamethyl-	370	$C_{10}H_{30}O_5Si_5$
12.	10.13	0.67	N,N-Dimethyl-O-(1-Methyl-Butyl)-Hydroxylamine	131	$C_7H_{17}NO$
13.	10.165	1	2-[(Dimethylamino) Oxy]Pentane	131	$C_7H_{17}NO$
14.	10.265	1.32	4h-Pyran-4-One, 2,3-Dihydro-3,5-Dihydroxy-6-Methyl-	144	$C_6H_8O_4$
15.	11.617	1.55	Dodecane	170	$C_{12}H_{26}$
16.	12.529	1.25	3-Acetoxy-3-Hydroxypropionic Acid, Methyl Ester	162	$C_6H_{10}O_5$
17.	13.99	0.32	Cyclohexasiloxane, Dodecamethyl-	444	$C_{12}H_{36}O_6Si_6$
18.	14.18	0.45	2-Methoxy-4-Vinylphenol	150	$C_9H_{10}O_2$
19.	14.967	0.53	Phenol, 2,6-Dimethoxy-	154	$C_8H_{10}O_3$
20.	15.113	0.61	Eugenol	164	$C_{10}H_{12}O_2$

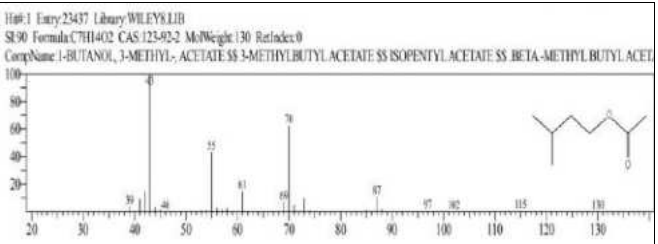
21.	16.157	1.55	Tetradecane	198	$C_{14}H_{30}$
22.	16.946	1.87	Benzaldehyde, 2-Hydroxy-4-Methyl-	136	$C_8H_8O_2$
23.	17.272	0.49	1,6,10-Dodecatriene, 7,11-Dimethyl-3-Methylene-, (E)-	204	$C_{15}H_{24}$
24.	19.777	0.8	Lavandulyl Propionate	210	$C_{13}H_{22}O_2$
25.	20.261	0.83	Hexadecane	226	$C_{16}H_{34}$
26.	20.37	1.23	1,3,4,5-Tetrahydroxy-Cyclohexanecarboxylic Acid	192	$C_7H_{12}O_6$
27.	20.455	0.97	4-Methylmannitol	196	$C_7H_{16}O_6$
28.	20.957	0.96	Beta.-D-Glucopyranose, 4-O-.Beta.-D-Galactopyranosyl-	342	$C_{12}H_{22}O_{11}$
29.	21.159	0.44	Acetic Acid, Trifluoro-, Octahydro-4-Hydroxy-1,5-Methano-1h-Inden-1-Yl Ester	264	$C_{12}H_{15}F_3O_3$
30.	23.826	0.58	9,11Dimethyltetracyclo[7.3.1.0(2.7).1(7.11)]Tetradecane	218	$C_{16}H_{26}$
31.	23.96	0.38	Tetradecane	198	$C_{14}H_{30}$
32.	25.793	1.27	1-(3-Phenyl-Bicyclo[1.1.1]Pent-1-Yl)-Propan-1-One	200	$C_{14}H_{16}O$
33.	26.075	0.38	Methyl 14-Methylpentadecanoate	270	$C_{17}H_{34}O_2$
34.	26.106	0.68	1h-Indene, 1-Ethylideneoctahydro-7a-Methyl-, Cis-	164	$C_{12}H_{20}$
35.	26.258	23.03	2,4-Decadienamide, N-Isobutyl-, (E,E)-	223	$C_{14}H_{25}NO$
36.	26.435	0.53	7-Hexadecyn-1-Ol	238	$C_{16}H_{30}O$
37.	26.652	3.22	N-Hexadecanoic Acid	256	$C_{16}H_{32}O_2$
38.	27.182	0.32	Hexadecanoic Acid, Ethyl Ester	284	$C_{18}H_{36}O_2$
39.	27.274	0.69	[1,1'-Biphenyl]-2-Ol	170	$C_{12}H_{10}O$
40.	28.207	0.46	Naphthalene, Decahydro-1,1-Dimethyl-	166	$C_{12}H_{22}$
41.	28.741	0.64	9,12-Octadecadienoic Acid (Z,Z)-, Methyl Ester	294	$C_{19}H_{34}O_2$
42.	29.341	1.23	9,12-Octadecadienoic Acid (Z,Z)-	280	$C_{18}H_{32}O_2$
43.	29.419	2.26	(Z,Z)-6,9-Cis-3,4-Epoxy-Nonadecadiene	278	C19H34O
44.	29.597	17.33	(2e,4e)-N-Isobutyldodeca-2,4-Dienamide	251	$C_{16}H_{29}NO$
45.	29.759	0.97	N-Propyl 9,12-Octadecadienoate	322	$C_{21}H_{38}$O2
46.	31.381	0.65	N-(2-Methylbutyl)Undeca-(2e,4z)-Diene-8,10-Diynamide	243	$C_{16}H_{21}NO$
47.	31.43	0.38	9-Tricosene, (Z)-	322	$C_{23}H_{46}$
48.	31.813	0.3	Eicosane	282	$C_{20}H_{42}$
49.	32.271	1.14	N-Isobutyl-(2e,4z,8z,10e)-Dodecatetraenamide	247	$C_{16}H_{25}NO$
50.	32.345	0.83	(2e,4e,10e)-N-Isobutylhexadeca-2,4,10-Trienamide	305	$C_{20}H_{35}NO$
51.	32.608	2.05	(2e,4e)-N-Isobutyltetradeca-2,4-Dienamide	279	$C_{18}H_{33}NO$
52.	34.246	0.81	Stigmasta-3,5-Diene	396	$C_{29}H_{48}$
53.	34.52	0.45	Octadecane	254	$C_{18}H_{38}$
54.	34.905	0.29	1,2-Benzenedicarboxylic Acid	390	$C_{24}H_{38}O_4$
55.	34.957	1.58	5,8,11-Eicosatriynoic Acid, Methyl Ester	314	$C_{21}H_{30}O_2$
56.	35.232	0.55	5,8,11,14-Icosatetraynoic Acid	296	$C_{20}H_{24}O_2$

57.	35.559	2.3	Tetrapentacontane	758	$C_{54}H_{110}$
58.	35.795	0.58	Tetrapentacontane	758	$C_{54}H_{110}$
59.	37.031	2.14	Tetrapentacontane	758	$C_{54}H_{110}$
60.	37.51	0.84	1,3-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester	390	$C_{24}H_{38}O_4$
61.	38.215	1.28	Tetrapentacontane	758	$C_{54}H_{110}$
62.	38.332	1.01	1-Methyl-1h-Imidazole-4,5-Dicarboxamide #	168	$C_6H_8N_4O_2$
63.	38.44	0.72	Silikonfett	9999	-
64.	39.141	0.79	Stigmasta-5,22-Dien-3-Ol	412	$C_{29}H_{48}O$
65.	39.448	1.37	Tetrapentacontane	758	$C_{54}H_{110}$

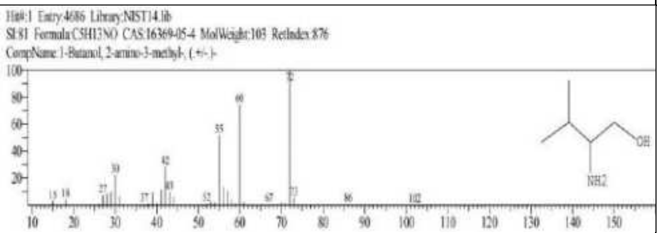
Table 3: The structure of some identified compounds



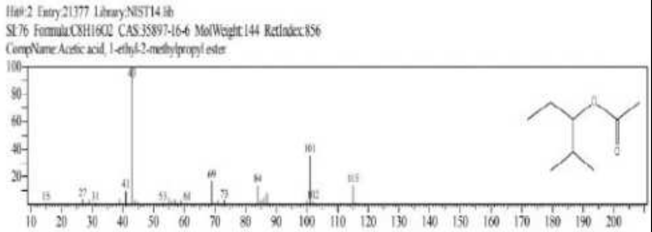
Peak 1: Propane, 1,1-Diethoxy-2-Methyl-



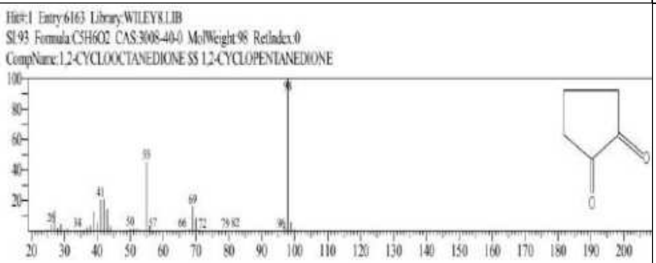
Peak 2: 1-Butanol, 3-Methyl-, Acetate



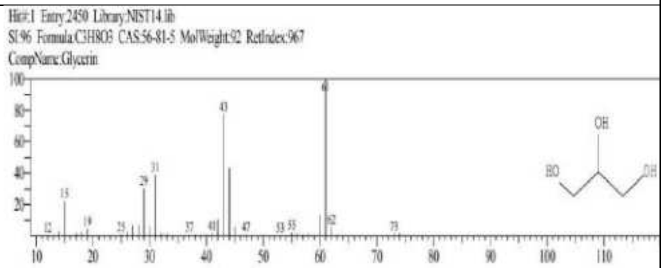
Peak 3:1-Butanol, 2-Amino-3-Methyl-



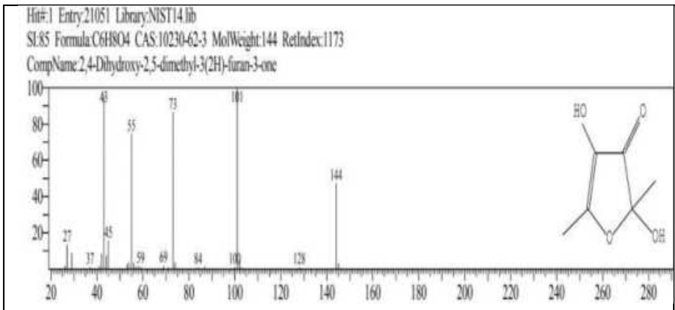
Peak 4:Acetic Acid, 1-Ethyl-2-Methylpropyl Ester



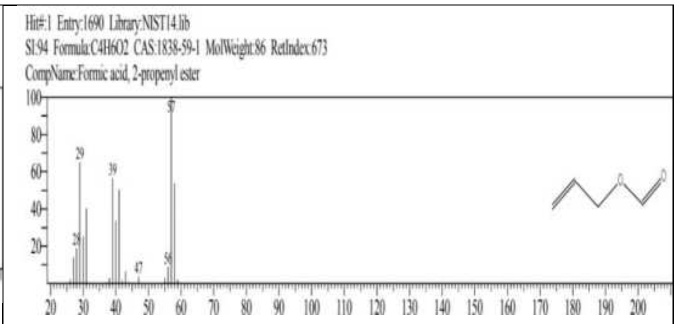
Peak 5:1,2-Cyclooctanedione



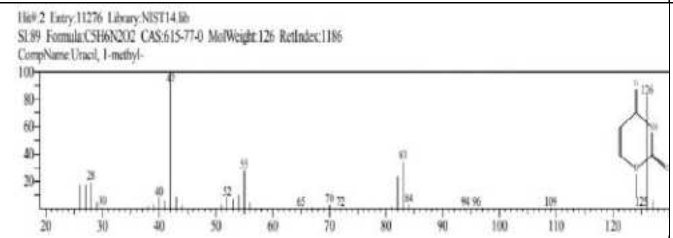
Peak 6:Glycerin



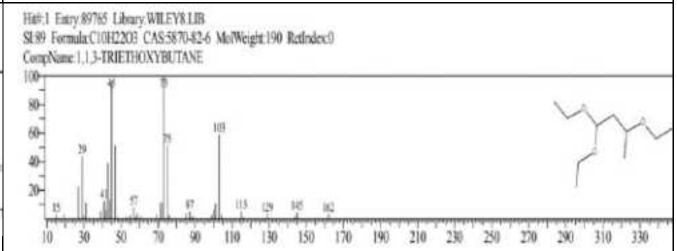
Peak 7:2,4-Dihydroxy-2,5-Dimethyl-3(2h)-Furan-3-One



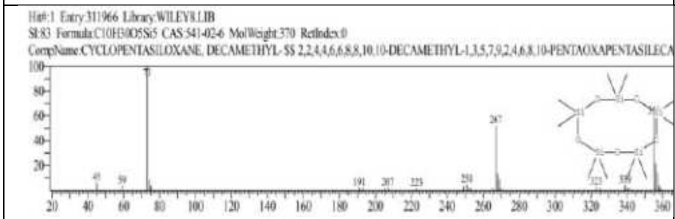
Peak 8:Formic Acid, 2-Propenyl Ester



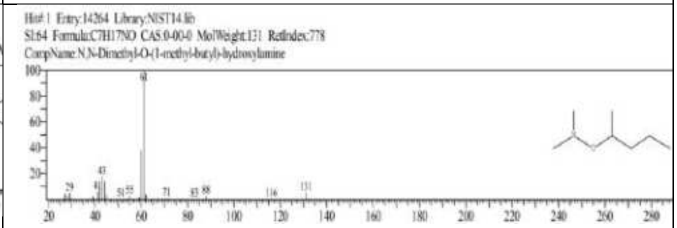
Peak 9:Uracil, 1-Methyl



Peak 10:1,1,3-Triethoxybutane



Peak 11:Cyclopentasiloxane, Decamethyl-



Peak 12:N,N-Dimethyl-O-(1-Methyl-Butyl)-Hydroxylamine

IV. CONCLUSIONS

In conclusion, this investigation offers significant insights into the phytochemical composition of *Anacyclus pyrethrum* (L.) Lag root extract, corroborating its traditional applications in various pharmacological contexts. Fourier-transform infrared spectroscopy (FTIR) analysis revealed the presence of essential functional groups, including hydroxyl groups, alcohols, carboxylic acids, and aromatic compounds, indicating the presence of phenols, flavonoids, tannins, and saponins. Gas chromatography-mass spectrometry (GC-MS) analysis identified 60 bioactive compounds, with 4-Decadienamide, N-Isobutyl-, (E, E)-, and (2e,4e)-N-Isobutyldodeca-2,4-Dienamide as the predominant constituents. These findings are consistent with those of previous studies on various medicinal plants, which demonstrated the presence of similar functional groups and bioactive compounds. The identification of these phytochemicals provides a scientific foundation for the traditional use of *A. pyrethrum* in the treatment of various ailments and supports its potential for pharmaceutical development. Additional research is necessary to elucidate the specific pharmacological activities of the identified compounds and their mechanisms of action. The isolation and individual testing of these bioactive constituents could potentially lead to the discovery of novel therapeutic agents. Furthermore, in vivo studies and clinical trials are required to fully understand the efficacy and safety of *A. pyrethrum* extracts in medical applications. This study contributes to the expanding body of knowledge on medicinal plants and underscores the importance of continued ethnopharmacological research. The results highlight the potential of *A. pyrethrum* as a valuable resource for phytopharmaceutical development and emphasize the need for the conservation and sustainable utilization of medicinal plants.

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5.1 Author contribution

All the authors contributed in the design of the study. All the authors contributed in the collection and fractionation of the plant extract. All the authors contributed in FT-IR evaluation of the plant sample, and in the interpretation of the results. All the authors contributed in preparing the manuscript. All the authors read and approved the manuscript

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Plant based mounting materials use for spinning during seed crop rearing by Adopted Seed Rearers (ASRs)

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***Abstract*— *Adopted Seed Rearers (ASRs) or P1 seed farmers use locally accessible plants as mounting materials for mounting the matured silkworms under the study they used viz., Dodonaea viscosa, Malotus philipansis,* Bambusa nutans, *Eucalyptus globulus. Based on the data analysis, significant difference was found when the matured silkworms were mounted on plastic collapsible mountages, which resulted in the highest cocoon yield per 100 dfls (85.45 Kg) and also number of cocoons per kg.*

Keywords*— *Mountages, plants, plastic collapsible mountage, Adopted seed Rearers.

I. INTRODUCTION

Sericulture can immensely support to reduce poverty while increasing income of seed farmers in Udhampur district especially when the seed cocoon prices was enhanced at par with that of southern seed farmers. The Adopted Seed Rearers (ASRs) in Udhampur district having small or marginal land holdings, bivoltine seed rearing provides employment and income opportunities for them. It is supplementary farming for Adopted Seed Rearers at present 213 active Adopted Seed Rearers (ASRs) are involved in P1 seed rearing in three different seed zones *viz.,* Suntha, Thill and Hartaryan and the P1 quality seed cocoons generated from ASRs are procured and utilized by SSPC, Udhampur for the production of double and single hybrid silkworm seed at SSPC, Udhampur. These seed farmers or ASRs seed cocoon productivity is highest in the north-western states. Although the seed farmers in Udhampur produce seed cocoons, their knowledge level on how to use mounting materials is insufficient, and it has been repeatedly observed despite better silkworm rearing seed farmers make mistake at the time of mounting their matured silkworms and lose their seed crop to some extent. Adoption of sericulture technology in the sericulture sector is very low in Udhampur despite being a very productive district where more than 5000 sericulture farmers are practising sericulture farming. Many studies have been conducted to find out reasons for this issue in the past, but still majority of the sericulture farmers in J&K do not adopt sericulture technology it may be due to they considered sericulture as subsidiary occupation . The majority of seed cocoons producers depend on resources and use different types of plant based materials available locally in their areas for making mountages during spinning to mount mature silkworms, yet this has many drawbacks, such uneven shape of seed cocoons, more numbers of defective cocoons, narrow space for ventilation, *etc.,* which effect the quality of seed cocoons. SSPC, Udhampur provides technical guidance to ASRs time to time and in last few years some selected ASRs were motivated to use plastic collapsible mountage for quality seed cocoon generations. In addition to support for spinning worms, the mountages should satisfy the requirements like, providing convenient and uniform space with suitable dimension for spinning good sized cocoons, discouraging formation of double cocoons and malformed cocoons, providing ventilation for drying up of the last excreta of the worm prior to spinning, enabling easy mounting and harvesting (Shinde *et al.,* 2012). Narrow space affects ventilation for spinning larvae and results in poor reelability of cocoons. The varied number of defective cocoons depends on the material and structure of the cocooning frame (Tazima, 1972). The number of defective cocoons was very less on self-mounting shindi branches than plastic mountages (Shinde *et al.,* 2012) and the absorbent nature of the natural substrate probably reduced the number of defective cocoons like urinated ones. The type of material used to design mounting structure played a significant role in determining cocoon and rawsilk quality (Naphade *et al.,* 2011; Datta *et al.,* 2007; Chikkanna *et al.,* 2009 and Pandey et al., 2007). A mountage is basically a device for providing convenient space for mature silkworms to spin cocoon and therefore mountage or mounting material is the most important component that supports the matured silkworm larvae for spinning of cocoons comfortably (Singh, 1995, Mathur and Qadri 2010., Singh *et al.,* 2012) and the process of transferring the mature larvae is called mounting (Rajan *et al.,* 1996., Shinde *et al.,* 2012). Thus the mountage or mounting material is the most important device that supports the silk worm larvae for spinning of cocoons comfortably (Singh, 1995, Mathur and Qadri 2010., Singh *et al.,* 2012) and the process of transferring the mature larvae is called mounting (Rajan *et al.,* 1996., Shinde *et al.,* 2012). In the past many researchers found that if the silkworm crop is healthy, wrong mounting methods, spinning conditions and bad type of mounting material can result in inferior or poor quality cocoons and silk yarn leading to lower income to farmers (Rajan *et al.,* 1996, Singh and Kambli 1997). It has also been observed when material and structure of the mountage are not proper, the reelibility of the cocoons is reduced and other features like double cocoons, deformed cocoons and soiled cocoons get increased (Mathur and Qadri, 2010). In different sericulture practising countries various types of mountages have been used such as rotary mountage in Japan (Kutsumata, 1975., Rajan *et al.,* 1996) bottle brush mountage in Brazil (Singh *et al.,* 1994).In China many types of mountages *viz.,* Umbrella type, centipede type, checkerboard type are being used at farmers level. All of them are fabricated from rice straw, Wheat/paddy stray and card board material which are economical and easily available (Sugun *et al.,* 2000). Nevertheless, despite the favorable climate for raising bivoltine seed crop, the Adopted Seed Rearers (ASRs) in Udhampur district are losing a significant amount of their seed cocoon crop during spinning due to production of defective or deformed cocoons by employing inappropriate or incorrect mounting materials. Keeping in view, the present study was undertaken to evaluate the comparative performance of locally available plant based materials use by Adopted Seed Rearers with improved mountage *i.e.,* plastic collapsible mountage.

II. MATERIALS AND METHODS

The present study was undertaken in the year 2022-23 during spring season at seed zones Suntha & Hartaryan of Udhampur district. For seriposition five different types of locally available plant materials *viz.,* Dodonaea viscosa, Malotus philipansis, Bambusa nutans, Eucalyptus globulus used by Adopted Seed Rearers (ASRs) along with ASRs who was motivated to use plastic collapsible mountages for mounting the matured silkworms their comparative performance on some important parameters were observed such as pupation percentage, cocoon yield per 100 Dfls, single cocoon weight (g), single shell weight (g), shell percentage, No. of melted seed cocoons, no. of good seed cocoons and number of seed cocoons per kg were recorded. Bivoltine pure race SH_6 & NB_4D_2 procured from P2- Basic Seed Stations, Sheeshambara, Dehradun chawki reared by feeding with improved mulberry variety S-1635 and supplied to Adopted Seed Rerarers (ASRs) in seed zone Suntha & Hartaryan.The optimal temperature and relative humidity of the mounting rooms was maintained throughout the period of mounting or seriposition (Jolly, 1987, Mathur and Qadri, 2010). Thus in total 20 seed farmers data were taken to evaluate the seed crop performance, with 04 seed farmers each with separate mounting materials. Harvesting of seed cocoons was done on 7^{th} day from mounting, only after complete pupation by testing the hardening of the pupal skin (Rajan *et al.,* 1996, Rahmathulla *et al.,* 2007). The above said parameters were subjected to statistical analysis to draw logical conclusion for presenting the results (Table 1-2).

Plants materials utilised as mountages by Adopted Seed Rearers (ASRs) under the study areas.

Local Name	Scientific Name	Family	Photos
Santha	*Dodonaea viscosa*	Sapindaceae	

Kaamla	*Malotus philipansis*	Euphorbiaceae	
Bans	*Bambusa nutans*	Poaceae	
Safeda	*Eucalyptus globulus*	Myrtaceae	

Demonstrations on use of plastic collapsible mountage at P1 seed zone

Use of plastic collapsible mountages by ASRs

Seed Cocoon spun on Santha leaves

Seed cocoons spun on Kamla leaves

Seed cocoons spun on Eucalyptus leaves

III. RESULTS AND DISCUSSION

From the data (Table-1) it could be seen that there was significant difference in yield per 100 Dfls (85.45 Kg) when the seed farmers use plastic collapsible mountage when compared to other locally accessible plant materials used for spinning. The pupation percentage was also recorded highest in plastic collapsible mountage & Bamboo shootlets (90%). The improvement noticed in the plastic collapsible mountage is may be to the design and material used for fabrication of mountage and it is well suited to the behaviour of spinning larvae. Reddy *et al.,* (2004) also advocated that plastic mountages are more durable, easily washable and can be thoroughly washed, dried and preserve safely. It occupies less space and is suitable for self-mounting and maintaining cocoon quality. Geetha Devi *et al.,* (2004) opined that an ideal mountage having many merits over conventional chandrike is the plastic collapsible mountage. According to Tazima (1972) increase or decrease in the defective and good cocoons varies depending upon the materials and structure of cocooning frame used for spinning. Wu Pangh-Chuan and Chen Da-Chuang (1988) suggested that a good mountage should be convenient for spinning cocoons with abundant space. Others parameters did not show any significant different except shell percentage which was recorded highest in Bamboo shootlets (19.69 %) Table-1. The silkworm *Bombyx mori L.* is the main source of quality silk. It requires specific atmosphere conditions and care in handling, during its various development stages. The quality and quantity of silk produced are highly related with the care taken during rearing and kind of mountages provided to them during spinning (Ullal and Narsimhanna, 1987) besides other factors. Among the many factors that contribute to produce the quality cocoons at the end of spinning, the mounting material provided to the matured larvae play a significant role (Yokohama, 1954; Tanaka, 1964; Alam *et al.,* 1977; Barah and Samson, 1990; Singh and Kamble 1997, Haroon and Khan, 2004). Statistical difference was observed among the different mounting materials tested as number of seed cocoons per kg was recorded highest in plastic collapsible mountage (665 No's) followed by Santha leaves (575 No's), Bamboo shootlets (569 No's), Kamla leaves (565 No's) and Eucalyptus dried leaves (560 No's) respectively. Number of melted cocoons were recorded highest in Kamla leaves (69 No's) and least were recorded in Bamboo shootlets (59

No's)). Numbers of good cocoons were recorded highest in plastic collapsible mountages (606 No's) (Table-2)

Table-1. Performance of seed crop rearing using different plants based materials/mountage during spinning by Adopted Seed Rearers (ASRs).

Mountage/ Mounting materials used	Pupation (%)	Cocoon Yield/100 Dfls	Single Cocoon Weigh (g)	Single Shell Weight (g)	Shell %
Santha leaves	89.40	81.74	1.73	0.340	19.70
Kamla leaves	88.20	66.98	1.77	0.343	19.39
Bamboo shootlets	90.00	71.37	1.78	0.346	19.69*
Plastic collapsible mountages	90.00	85.45*	1.77	0.338	19.23
Eucalyptus dried leaves	88.80	68.03	1.78	0.343	19.21
Mean	**89.28**	**74.72**	**1.77**	**0.342**	**19.44**
CD@5%	**0.427-NS**	**0.019***	**0.140-NS**	**0.747-NS**	**0.013***

*The result is significant at $p < .05$., NS-Non-Significant.

Table-2. Performance of seed crop rearing using different plants based materials/mountage during spinning on melted, good and numbers of cocoons per Kg.

Mountage/Mounting materials used	No. of melted cocoons	No. of good cocoons	No. of cocoons per Kg
Santha leaves	59	516	575
Kamla leaves	69	496	565
Bamboo shootlets	57	512	569
Plastic collapsible mountages	59	606	665*
Eucalyptus dried leaves	62	498	560
Mean	**61**	**506**	**587**
CD@5%	**0.1516-NS**	**0.2204-NS**	**0.001***

*The result is significant at $p < .05$., NS-Non-Significant.

IV. CONCLUSION

Locally available plant based materials is traditionally used by Adopted Seed Rearers (ASRs) in Udhampur district as mountage, which gives space for the formation of cocoons of different shape and size. But in seed crop the quality seed cocoons is indispensible for quality hybrid silkworm seed production and present findings has shown that plastic collapsible mountages performing better when compared to other locally available plant based mounting materials used by seed farmers under the study. However, seed farmers may not always have easy access to plastic collapsible mountages because of their expensive price; they prefer to mount the matured silkworms using locally accessible plant materials, but surely it has some negative impact on seed cocoon quality. The findings of the study recommended that the seed farmers need to be aware about usage of plastic collapsible mountage during the seed crop rearing to produce quality seed cocoons.

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Biological control of fall armyworm *Sopdoptera frugiperda* (Lepidoptera: Noctuidae) by using the pheromone Z7-dodecenyl acetate, Z11-hexadecenyl acetate, Z9-tetradecenyl acetate

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***Abstract*— *With an energy value of 86 kcal/100 g to 386 kcal/100 g, maize is a staple food for many people. In Côte d'Ivoire, maize is grown mainly in the north of the country, where it is an enormous source of income for the local population. However, maize cultivation is severely limited by parasitic constraints that affect the organoleptic quality and production of maize. These include the fall armyworm Spodoptera frugiperda, whose damage can cause up to 73% of yield losses. Today, in a sustainable agriculture and food security context, biological control constitutes an essential element. The aim of this study was to carry out biological control of the fall armyworm using the pheromones Z7-dodecenyl acetate, Z11-hexadecenyl acetate, Z9-tetradecenyl acetate. The study was carried out at the maize, millet and sorghum research station of the Centre National de Recherche Agronomique in Ferkessédougou in the north of the country. The experimental design was a total randomization, with four (4) plots containing the pheromone and one control plot. Three (3) vegetative stages of the EV 8728 maize variety sown, were monitored. The results showed a high average number of S. frugiperda adults caught (129 adults), with a low infestation rate (19.42%) and a high average number of other insects caught (162 insects caught) at phenological stage 2 of the maize. Maize yields in plots containing the pheromone ranged from 6.13 tons/ha to 6.27 tons/ha, around twice that of the control plot, which was 3.03 tons/ha. This pheromone can therefore be used to combat the fall armyworm.*

***Keywords*— Biological control, fall armyworm, Spodoptera frugiperda, pheromone, maize**

I. INTRODUCTION

Maize is a very important cereal crop in sub-Saharan Africa. With an energy value of 86 kcal/100 g to 386 kcal/100 g (Yapi and Kouassi, 2017), maize is a staple food for many people. It is grown mainly for its grains, which are an important source of nutrition for humans. In fact, these grains contain around 72 to 73% carbohydrates, 8 to 11% protein, 3 to 18% lipids, dietary fiber and many other minerals (P, K, Ca, Mg, Na, Fe, etc.) as well as vitamins A and E (Yapi and De Kouassi, 2017; Ranum et *al*., 2014). In Côte d'Ivoire, maize is grown mainly in the northern part of the country, with the Savannas region alone accounting for 60% of production (N'Da et *al*., 2022). Maize is an enormous source of revenue for the people of Côte d'Ivoire and Africa. Maize production from 2016 to 2018 grew exponentially from 967,196 to 1,054,960 tons per year (Ceresco, 2020). Despite this major nutritional and economic contribution to the population, maize growing is severely limited by a large number of parasitic constraints that affect the organoleptic quality and production of maize in Côte d'Ivoire. These include rodents, birds, diseases and insect pests. The latter include the fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae), which was first recorded in West Africa in 2016 (Goergen et *al*., 2016). It is a polyphagous insect, attacking crops such as cotton, rice, sugarcane, sorghum, millet, maize etc. (FAO, 2017; Prasanna et *al*., 2018). Damage caused by the fall armyworm can result in yield losses of between 15% and 73% (Bhusal and Chapagain, 2020). Several control methods have been used to reduce pest populations to acceptable levels. Chemical control using certain chemical insecticides such as cypermethrin and profenos, for example, has shown resistance phenomena (Koffi et *al*., 2021). Today, in order to protect plants and human health and for sustainable agriculture, new integrated pest management approaches exist. These include the use of biopesticides, biological agents and pheromones to control the fall armyworm (Duval *et* al., 2018; FAO, 2020; N'Guessan et *al*., 2022).

The aim of this work was to control *Spodoptera frugiperda* populations using pheromone. Specifically, it was to:

- assess the number of insects captured by pheromone traps;
- evaluate these insects in relation to the phenological stage of the maize;
- assess plot yields as a function of treatments.

II. MATERIALS AND METHODS

2.1. Study site

This study was carried out at the maize, millet and sorghum research station (MMS) of the National Center of Agronomic Research (CNRA) in Ferkessédougou (9°36′00″ Nord, 5°12′00″ Ouest). The town is the capital of the Tchologo region, which borders Mali and Burkina Faso. Ferkessédougou is located to 650 km from Abidjan, the country's economic capital and largest city, and to 360 km from Yamoussoukro, the political capital. The vegetation of the region is that of the treed savannah. The climate is very hot and very dry (similar to the Sudanese climate), with the harmattan, a powerful wind from the Sahara, considerably lowering the temperature in December and January. The long dry season (October-May) precedes the rainy season, marked by two rainfall maxima, one in June and the other in September (Figure 1).

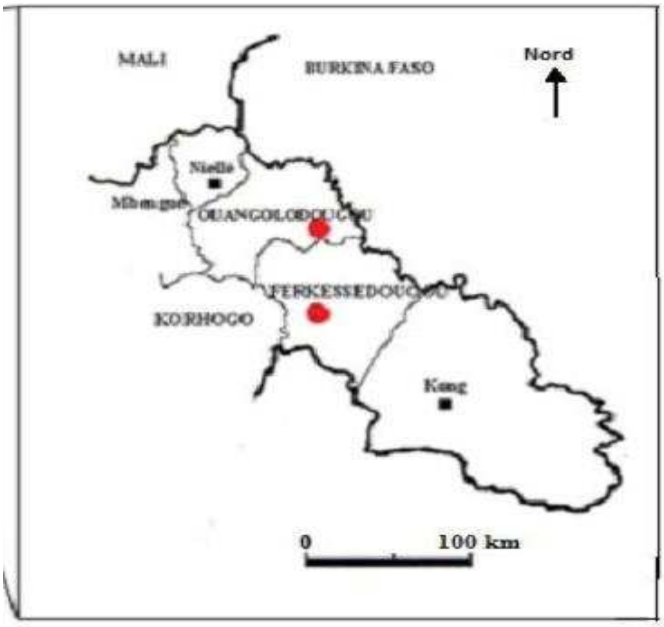


Fig. 1: Map of Ferkessédougou (Saraka, 2017)

2.2. Study device

The study design was based on total randomization. Five 0.5-hectare maize plots were replicated three times. The maize variety EV8728 was used for sowing. This is the most widely cultivated variety in Côte d'Ivoire. The pheromone Z7-dodecenyl acetate, Z11-hexadecenyl acetate, Z9-tetradecenyl acetate was placed in the middle of 4 plots and 1 plot without the pheromone was used as an untreated control. A total of 5 plots were set up for this study.

2.3. Monitoring of trial plots

The EV8728 variety is used for sowing. For the monitoring, 3 phenological stages of maize were chosen as followed:

- Stage 1: 2-3 leaves (approximately 15 cm in height).

- Stage 2: 6-8 leaves (70-90 cm high).
- Stage 3: flowering-heading.

A suitable location was chosen to place the trap. Indeed, the trap was placed in the middle of each plot using a piece of wood approximately 1.5 m long at the end of which it was suspended (Figure 2), at the rate of one trap per plot. The trap was equipped with a pheromone Z7-dodecenyl acetate, Z11-hexadecenyl acetate, Z9-tetradecenyl acetate (4.35 g/kg), and the water, when it is set up. The pheromone was replaced every 10 days, corresponding to it persistence duration.

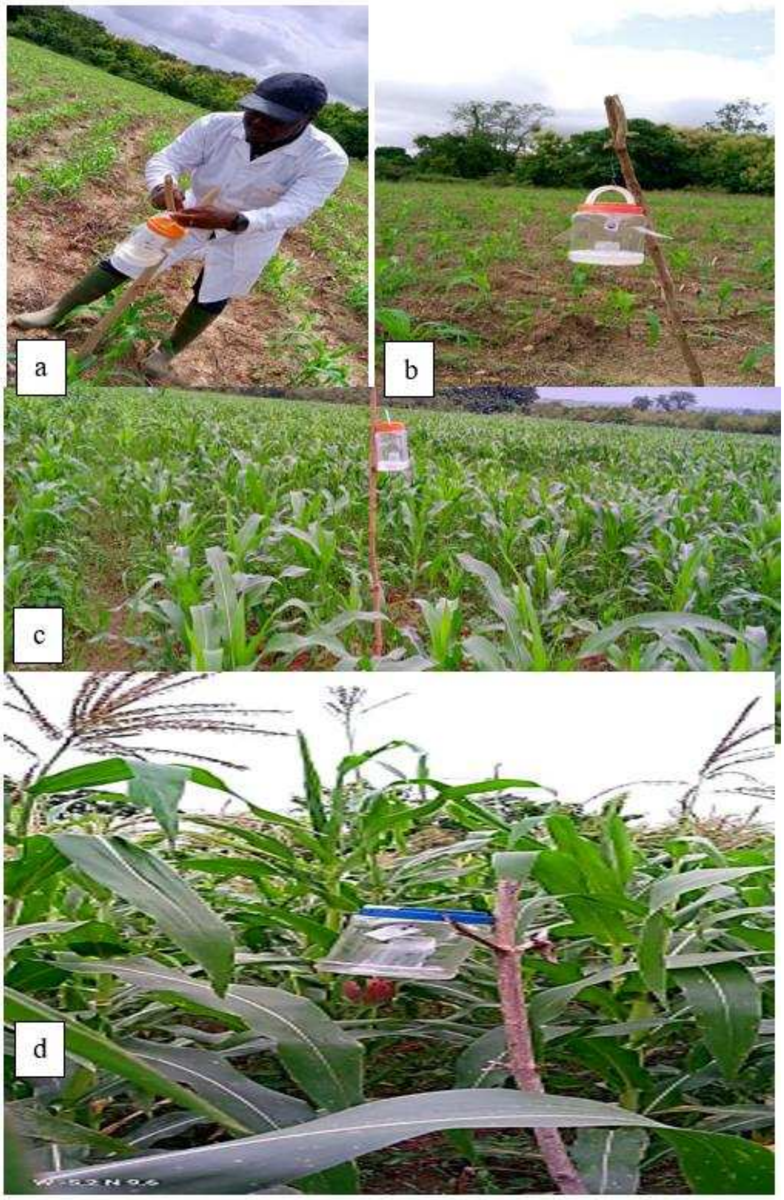


Fig. 2: Pheromone traps placed at different phenological stages of maize

A, b : Stage 1, c : Stage 2, d: Stage 3

2.4. Observations

Daily visits of the pheromone traps made it possible to collect the captured insects. To do this, the trap was opened by turning the transparent box located at the bottom of the trap counterclockwise, while firmly holding the closure above. The captured insects were collected and sorted every day. Adults of fall armyworm were counted separately from other captured species. It should be noted that perfect knowledge of fall armyworm adults is the basis for monitoring this pest.

2.5. Data analysis

Collected data during this study were submitted to Analysis of variance by SAS 9.4. software. Means comparison was realized with the LSD test at 0.05 threshold.

III. RESULT AND DISCUSSION

3.1. Number of insects trapped in the trial plots

Pheromone traps were used to capture several adults of *S. frugiperda* and many other insects. Other parameters such as the infestation rate and the number of live larvae were assessed to see how the pest was behaving in the plots. Table I shows the number of *S. frugiperda* adults caught at each phenological stage of maize.

At stage 1, corresponding to the 2 to 3 leaf stage, i.e. 10 to 24 days after germination, the pheromone traps captured 116 *S. frugiperda* adults. The infestation rate in the plots was lower (9.83% of plants infested) than in the control plot without pheromone, where an average of 27.33% of plants were infested. The number of live larvae collected in plots containing pheromone traps was 22 larvae compared with 53 larvae in the control plot. As for the other insects caught, there were 184 insects (Table I, Figure 3).

At stage 2, corresponding to the 6 to 8 leaf stage (25th to 39th day), the number of captured *S. frugiperda* adults was 129 with an average infestation rate of 19.42% of plants compared with 60.33% of infested plants in the control plot. The number of live *S. frugiperda* larvae was 26, which was lower than the control (48 larvae). One hundred and sixty-two (162) other insects were caught in the pheromone trap (Table I, Figure 3).

At stage 3, corresponding to heading (40 to 50 days after germination), the number of adults of *S. frugiperda* tended to fall, with 53 adults caught, an infestation rate of 23.25% compared with 73.67% in the control plot. Very few larvae were collected in both the plots containing pheromones and the control plot, with 3 and 4 larvae respectively. In addition, 143 other insects were caught in the pheromone trap (Table I, Figure 3).

The use of the pheromone Z7-dodecenyl acetate, Z11-hexadecenyl acetate, Z9-tetradecenyl acetate revealed the effectiveness of this semiochemical in controlling the armyworm. The results showed that at phenological stage 2 of maize, 129 adults of *S. frugiperda* were caught by pheromone traps, compared with 116 at stage 1 and 53 adults at stage 3. The high number of adults of *S. frugiperda* caught at the first two phenological stages of maize is thought to be due to the strong presence of the armyworm in the maize plots. At this stage, the maize plants, being younger, would have many succulent serves, thus attracting a large number of pests, including the armyworm. Kouamé *et al* (2014) and N'Guessan *et al* (2014) indicated that succulent plant parts are an important food source for certain pests. This could explain the high presence of *S. frugiperda* on maize plants during these first two phenological stages compared with phenological stage 3. Also, during these first two phenological stages of maize, the plants are thought to host numerous pests in the corncob. This was not the case at phenological stage 3, when the corncob disappeared and flowers appeared. Adeye *et al.* (2018) indicated that the drop in population levels of *S. frugiperda* larvae in untreated plots can be explained on one hand by their entry into chrysalidation and on the other hand by the disappearance of the cones where the larvae were lodged, which gave way to maize flowers, thus explaining the low number of individuals caught at phenological stage 3.

Table I: Some parameters observed as a function of the phenological stage of maize

Some parameters studied	Stade 1	Untreated control	Stade 2	Untreated control	Stade 3	Untreated control
S. frugiperda Adults	116	0	129	0	53	0
Infestation rate (%)	9.83	27.33	19.42	60.33	23.25	73.67
Live larvae	22	53	26	48	3	4
Other insects	184	0	162	0	143	0

Fig. 3: Spodoptera frugiperda larvae in the whorl of a maize plant

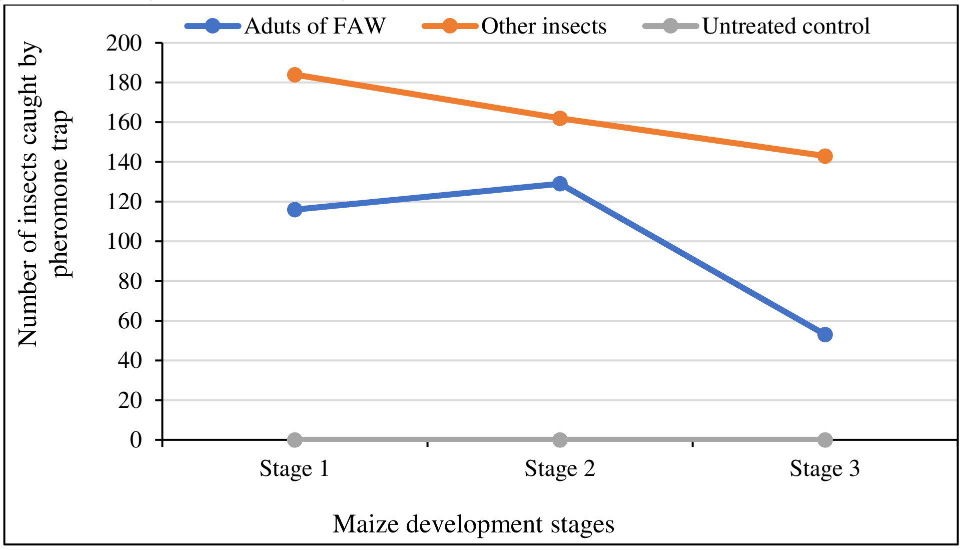
3.2. Evolution of insect population trapped as relation of phenological stages of maize

From the first phenological stage of maize (2-3 leaves), the number of *S. frugiperda* adults captured increased strongly at the second phenological stage corresponding to 6-8 leaves. Then this number fell drastically at phenological stage 3, i.e. flowering or ear-heading of the maize (Figure 3). The results obtained during this study showed that the number of *S. frugiperda* individuals trapped by the pheromone Z7-dodecenyl acetate, Z11-hexadecenyl acetate, Z9-tetradecenyl acetate increases from phenological stage 1, with a peak at phenological stage 2 and then decreases until phenological stage 3 of maize. The peak observed at phenological stage 2 of the maize could be due to the many leaves (6 to 8 leaves per plant) acquired by the maize plants, which could serve as a food source, breeding ground and oviposition site for *S. frugiperda*. According to Malausa and Marival (1981), maize is most susceptible to *S. frugiperda* at the 6-8 leaf stage. They state that it is at this stage that the largest number of larvae are collected. As a consequence, he indicates that the eggs are deposited on the very young plants (stage 1) and the most significant damage is caused at the following stage (2) by the older larvae that emerge from these eggs; these larvae then hang around in the maize corncob where they devour the young leaves.

As for the other insects caught, at phenological stage 1, a high number were captured by the pheromone trap. The number of other insects caught continued to fall until the 3rd phenological stage of the maize, i.e. flowering or heading (Figure 3). In the untreated control plot, no insects were caught throughout the maize cycle. This number remained static because no trap had been installed to capture insects (Figure 3). With regard to the other insects captured by the pheromone, a higher number of individuals were captured at phenological stage 1 of the maize. Beyond that, a decrease in the number of individuals trapped was observed up to phenological stage 3. This could be due to the fact that at phenological stage 1, the smaller maize plants (2 to 3 leaves) are very sensitive to several groups of insects. At the early season, a large number of pests can be found in maize crops (armyworms, black cutworms and other noctuidae, potato stemworms, white grubs (chafer sp.), wireworms, codling moths, corn flea beetles, seed maggots, prairie tent caterpillars, slugs, brown plant bugs, etc.) (Labrie *et al.*, 2020). In the control plot, no insects were caught because there was no treatment.

3.3. Yield assessment depending on the treatments

Control of the armyworm using the pheromone Z7-dodecenyl acetate, Z11-hexadecenyl acetate, Z9-tetradecenyl acetate (4.35 g/kg) placed in 4 different plots made it possible to give results on the yield of the experimental plots. These results are given in the table below (Table 2). Plots 1, 2, 3 and 4, in which the pheromone traps were placed, gave yields ranging from 6.13 tons per hectare to 6.27 tons per hectare. This is much higher than the yield from the untreated plot, which gave only 3.03 tons per hectare. These results are significantly different ($p = 0.0001$) at the 0.05 threshold (Table II). The use of the pheromone Z7-dodecenyl acetate, Z11-hexadecenyl acetate, Z9-tetradecenyl acetate revealed the efficacy of this biological control through the yield of the different plots of maize. Plots 1, 2, 3 and 4, in which pheromone traps were placed, gave a yield of between 6.13 ± 0.38 tons per hectare and 6.27 ± 0.58 tons per hectare of maize grain, compared with the control plot, which gave a lower yield of 3.03 ± 0.30 tons per hectare of maize grain. This difference in yield between these treated plots and the untreated control plot could be explained by the fact that the control plot without the pheromone would be virtually ravaged by insect pests, in particular the fall armyworm. N'Guessan et al (2023) indicated that this caterpillar attacks all phenological stages of maize. The only maize variety used in this study was EV 8728. However, CABI (2017) advised using a mixture of varieties in order to avoid numerous attacks by the armyworm. This led to an increase in numbers of caterpillars and attack rates in the control plot, resulting in a halving of the yield in this plot.



FAW: Fall Armyworm

Fig.3 : Evolution of the number of adults of S. frugiperda and other insects caught in the pheromone trap according to the phenological stages of the maize

Table II: Yield assessment of the applied treatments.

Parcels	**Yield (t/ha)**
Parcel 1	6.13 ± 0.38^{a}
Parcel 2	6.20 ± 0.34^{a}
Parcel 3	6.27 ± 0.50^{a}
Parcel 4	6.27 ± 0.58^{a}
Untreated parcel	3.03 ± 0.30^{b}
p	**0.0001**

Averages with the same letter in the same column are not statistically different (LSD test; 5%)

IV. CONCLUSION

The pheromone Z7-dodecenyl acetate, Z11-hexadecenyl acetate, Z9-tetradecenyl acetate allowed to trap a high number of *Sopodoptera frugiperda* larvae and other pests. It made it possible to reduce the number of live larvae of this pest as well as the rate of attack in the plots, and helped to increase maize grain yields by more than 50%. This pheromone is therefore an important element in the biological fight against the armyworm, and should be proposed to professionals in the maize sector.

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Effect of Plant Growth Regulators on the Growth and Yield of Capsicum (*Capsicum annuum* L.)

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***Abstract*— An experiment was conducted in the experimental Farm of DAV University, Jalandhar during kharif, 2023 to assess the combined effect of plant growth regulators and varieties on growth and yield of capsicum. The experiment comprised of four treatments of plant growth regulators, (G_0 = No growth regulator (control), G_1= GA_3 @ 50 ppm, G_2= SA @ 50 ppm, G_3= MeJa @ 2mM) and three varieties (V_1=PSM-1, V_2= F_1- hybrid, V_3= Orobelle) was replicated thrice and laid out in Randomized Block Design. Among plant growth regulators, maximum growth and yield parameters were observed in GA_3 @ 50 ppm. Among the varieties, V_1= PSM-1 were recorded to be the best regarding growth and yield parameters. For combined effect, G_1V_1 gave the highest growth and yield and G_0V_3 gave the lowest growth and yield. The highest gross return, net returns and cost benefit ratio was significantly observed in T1 (GA_3 @ 50ppm × PSM-1) following by in T5 (GA_3 × F1- hybrid). So, 50 ppm GA_3 may be used for capsicum cultivation.*

***Keywords*— Capsicum, Plant growth regulators, Gibberellic acid, Salicylic acid, Methyl jasmonate**

I. INTRODUCTION

Capsicum (*Capsicum annuum* L.) is an annual herbaceous plant that belongs to the Solanaceae family. It is commonly referred to as peppers, paprika, or capsicum (Shimla mirch) and has its origins in South and Central America. The genus Capsicum comprises over 30 species, with five of them (*C. annuum, C. frutescens, C. chinense, C. baccatum, and C. pubescens*) being domesticated and primarily cultivated for vegetable consumption. Capsicum is considered the world's second-most important vegetable after tomatoes [1]. In India, capsicum is cultivated across 24,000 hectares, with a total production of 3.21 lakh metric tons. West Bengal is the largest producer of capsicum in the country, accounting for 29.61 % of the total, followed by Karnataka (10.54 %), Haryana (10.49 %), Jharkhand (10.10 %), Himachal Pradesh (8.68 %), and Punjab (5.06 %) [2].

Plant growth regulators (PGRs) and natural biostimulants are used to enhance horticulture products, improving plant growth and increasing yield in various crops such as cucumber, tomato, pepper, potato, onion, pea, and melon [3, 4]. They help to reduce flower and fruit drops, improve production per unit area and time, and stimulate the translocation of photosynthates, leading to better retention of flowers and fruits [5, 6]. Sweet pepper's responses to PGRs vary [7]. PGRs are diverse substances that can modify plant physiological or morphological processes at very low concentrations.

Gibberellic acid (GA_3) is a plant hormone that regulates growth and development. It is produced by plants, fungi, and bacteria. GA_3 accelerates plant growth and development by enhancing plant height, shoot weight, and root length [8]. Salicylic acid has a wide range of biological activities, making it a valuable tool for optimizing plant growth, development, and stress management [9]. The application of salicylic acid can lead to increased fruit size and overall yield in capsicum plants. It can also improve the color, texture, and flavor of capsicum fruits, enhancing their marketability [10].

Methyl jasmonate is a plant hormone that plays a role in various stress responses, including defense against pathogens and herbivores. In *Capsicum* species (e.g., bell peppers and hot peppers), methyl jasmonate can influence several aspects of plant growth and development like enhance stress resistance, increase secondary metabolites and induce defense mechanisms [11].

II. MATERIALS AND METHODS

The research work was conducted at the experimental Farm, DAV University, Jalandhar during the period from March 2023 to August 2023. The location of the site was 31° 25' 18" N / 75° 37' 14" E, with an average elevation altitude of 238 meters above mean sea level. Plant growth regulators and varieties was used for present study. The experiment comprised four treatments of plant growth regulators, (G_1= GA_3 @ 50 ppm, G_2= SA @ 50 ppm, G_3= MeJa @ 2mM, G_0 = No growth regulator(control)) and three varieties (V_1=PSM-1, V_2= F_1- hybrid, V_3= Orobelle). The experiment was laid out in the Randomized Block Design (RBD) with three replications and twelve treatments. Plant growth regulators was done through foliar application of Gibberellic acid, salicylic acid and methyl jasmonate. The Plant growth regulators were applied at the 30, 60 and 90 days after transplanting. The treatments consisted of T_1 (GA_3 × PSM-1), T_2 (SA × PSM-1), T_3 (MeJa × PSM-1), T_4 (Control × PSM-1), T_5 (GA_3 × F_1- hybrid), T_6 (SA× F_1- hybrid), T_7 (MeJa × F_1- hybrid), T_8 (Control × F_1- hybrid), T_9 (GA_3 × Orobelle), T_{10} (SA × Orobelle), T_{11} (MeJa × Orobelle) and T_{12} (Control × Orobelle). Observations were recorded on randomly selected plants with different characters *i.e.,* plant height (cm), number of branches per plant, number of leaves per plant, leaf area index, days from transplanting to 1st flowering, days from transplanting to 50 % flowering, number of flowers per plant, days from transplanting to 1st harvest, number of fruits per plant, percent fruit setting, fruit length (cm), fruit diameter (cm), fruit weight (g), yield per plant (g), yield per plot (kg) and yield per hectare (tons) and economics. The data was analysed as per design of the experiment.

III. RESULTS

3.1 Growth parameters

The analysis of variance revealed significant differences among the treatments for all the plant growth attributes under study.

3.1.1 Plant height (cm)

The data recorded on the effect of plant growth regulators and varieties on various growth attributes of capsicum presented in Table 1. Maximum plant height was obtained when GA_3 was applied at the rate of 50 ppm in G_1. In case of varieties maximum plant height was obtained in V_1 (PSM-1).

3.1.2 Number of branches per plant

Maximum number of branches per plant was obtained when GA_3 was applied at the rate of 50 ppm. In case of varieties maximum number of branches per plant was recorded in F_1- hybrid variety. The interaction between plant growth regulators and varieties the maximum plant height was obtained in (GA_3 × F_1- hybrid) in treatment T_5.

3.1.3 Number of leaves per plant

Maximum number of leaves per plant was obtained when GA_3 was applied at the rate of 50 ppm. In case of varieties maximum number of leaves per plant was obtained in variety V_1 (PSM-1). The possible reason may be that application of Azotobacter improved nitrogen status of the soil because this is free nitrogen fixer. The variation in number of leaves per plant of capsicum varieties with different plant growth regulators observed in treatment T_1 (GA_3 × PSM-1).

3.1.4 Leaf area Index

Maximum leaf area Index was recorded in G_1 (GA_3 @ 50 ppm) which was significantly highest than all PGR's. Among varieties, maximum leaf area Index was recorded in V_1 (PSM-1). The maximum interaction effect on leaf area Index at the harvest time was recorded in (GA_3 × PSM-1) in treatment T_1.

3.2 Days to first flowering/50 % flowering/number of flowers per plant/days to first harvest/number of fruits per plant/percent fruit setting

With the plant growth regulator, they reduced days to first flowering and 50 % flowering, an increased number of flowers per plant, reduced days to first harvest, a greater number of fruits per plant, and improved fruit setting percentages by spray of GA_3 @ 50 ppm. In varieties maximum days to first flowering and 50 % flowering, an increased number of flowers per plant, maximum days to first harvest, a greater number of fruits per plant, and maximum fruit setting percentages was recorded in variety V_1 (PSM-1). In interaction between plant growth regulators and varieties maximum days to first flowering, 50 % flowering, number of flowers per plant, days to first flowering, number of fruits per plant, and percent fruit settings was obtained in T_1(GA_3 @ 50ppm × PSM-1).

3.3 Yield parameters

3.3.1 Fruit length/ fruit diameter/ fruit weight/ yield per plant/ yield per plot/ yield per hectare

The data recorded on the effect of plant growth regulators and biofertilizers on various yield attributes of capsicum presented in Table 2. In plant growth regulator application, the higher Fruit length/ fruit weight/ yield per plant/ yield per plot/ yield per hectare were noticed in G_1 (GA_3 @ 50 ppm). In varieties the fruit diameter/ fruit weight/ yield per plant/ yield per plot/ yield per hectare was noticed in V_1 (PSM-1) and maximum fruit diameter was recorded in V_2 (F_1- hybrid).Among the interaction, significantly higher fruit diameter/ fruit weight/ yield per plant/ yield per plot/ yield per hectare was observed in the interaction of plant growth regulator and varieties in G_1V_1 (GA_3 @ 50ppm × PSM-1) and in fruit length was observed in the interaction of plant growth regulator and varieties in G_1V_2 (GA_3 @ 50 ppm × F_1-hybrid).

4. Economics

The highest gross return, net returns and cost benefit ratio was significantly observed in T_1 (GA_3 @ 50ppm × PSM-1) following by in T_5 (GA_3 × F_1- hybrid). Based on the results obtained in this experiment, it is concluded that the treatment T_1 (GA_3 @50ppm × PSM-1) was found to be superior over all other treatments in relation to growth and yield parameters in capsicum under the agro-climatic conditions.

IV. DISCUSSION

For plant height similar outcomes have been reported by [12] in sweet pepper, [13] in brinjal, [14, 15, 16] in tomato, and [17] in tomato. [18] supported the results as increases in plant height may be due to GA_3 which increase the cell division and cell elongation in sub apical meristem. The variation was found due to combined effect of plant growth regulators and varieties on plant height at harvest (86.15cm) in (GA_3 × PSM-1) in treatment T_1. The possible reason for increase in the number of branches per plant due to impact of plant's overall growth and photosynthetic capacity [19]. The similar trend was also reported in sweet pepper [15], [16, 20] in tomato and [21] in potato. To encourage the formation of lateral buds and increase the number of adaptable branches [22]. [18] supported the results as increases in number of leaves may be due to activity of GA_3 at the apical meristem resulting in more nucleo-protein synthesis responsible for increasing leaf initiation. Application of efficient and healthy strain of Azotobacter in rhizosphere have resulted in greater fixation of atmospheric nitrogen for use by the plant resulting in vigorous growth of plant. Similar results have been reported by [23, 24, 25]. For leaf area index, similar results have been reported by [26-30]. The foliar application of plant growth regulators, including GA_3, leads to significantly improved growth parameters by [31]. Similar results have been reported by [26-30] in different vegetables crops. The increasing concentration of plant growth regulators mixture only up to GA_3 @ 50 ppm proved highly beneficial which enhanced the maximum yield of the capsicum varieties. Another probable reason for increasing yield attributes might be due to the increasing growth characters by cell division, cell elongation and cell expansion that might have ultimately increased in the yield. Similar trend was also observed by [32, 33, 34] in cabbage and [35] in sprouting broccoli. In addition, results obtained for economics od capsicum were found in close conformity with the findings of [36].

V. CONCLUSION

Based on the results experimentation it seems quite logical to conclude that application of plant growth regulator G_1 (GA_3 @ 50 ppm) observed maximum growth, yield and economics. Among the varieties V_1 (PSM-1) were recorded to be the best regarding the growth, yield and economics of capsicum. In case of interaction between plant growth regulators and varieties maximum growth, yield and economics was recorded in T_1 (GA_3 @ 50ppm × PSM-1). These results might be effective and efficient in further capsicum improvement programs.

Table 1. Effect of plant growth regulators on Plant height(cm), Number of branches per plant, Number of leaves per plant, Leaf area Index, days transplanting to 1st flowering, days to 50 % flowering, Number of flowers per plant, days from transplanting to 1st harvest, Number of fruits per plant and percent fruit setting on capsicum varieties

Treatments	Plant height(cm)	Number of branches per plant	Number of leaves per plant	Leaf area Index	Days from transplanting to 1st flowering	Days to 50 % flowering	Number of flowers per plant	Days from transplanting to 1st harvest	Number of fruits per plant	Percent fruit setting
Varieties										
V_1	83.43	10.66	108.14	0.73	42.87	90.02	12.20	56.91	10.01	82.00
V_2	74.64	14.57	91.25	0.68	53.55	96.70	8.07	64.02	6.05	74.97
V_3	67.96	10.14	100.14	0.55	45.98	93.30	9.34	58.32	7.22	77.28
S.E (m) ±	**0.649**	**0.057**	**0.050**	**0.011**	**0.640**	**0.668**	**0.059**	**0.681**	**0.053**	**0.656**
C.D(5 %)	**2.291**	**0.199**	**0.178**	**0.040**	**2.259**	**2.357**	**0.208**	**2.402**	**0.187**	**2.314**
Plant growth regulators										
G1	78.56	12.38	100.49	0.70	46.06	91.25	10.56	57.79	8.33	78.99
G2	76.46	12.07	100.07	0.65	46.62	93.35	10.02	58.66	7.94	78.39
G3	75.35	11.63	99.53	0.64	48.11	93.59	9.59	60.31	7.52	77.74
G0	73.67	11.09	99.29	0.62	49.08	95.18	9.31	62.25	7.25	77.20
S.E (m) ±	**0.749**	**0.065**	**0.058**	**0.013**	**0.736**	**0.772**	**0.068**	**0.786**	**0.061**	**0.758**
C.D(5 %)	**2.643**	**0.231**	**0.205**	**0.046**	**2.102**	**2.235**	**0.240**	**2.774**	**0.216**	**0.256**

Table 1(a). Interaction effect of plant growth regulators on Plant height(cm), Number of branches per plant, Number of leaves per plant, Leaf area Index, days transplanting to 1st flowering on capsicum varieties.

Varieties	**Plant height (cm) (At Harvest)**					**Number of branches per plant (At Harvest)**					**Number of leaves per plant (At Harvest)**					**Leaf area Index**					**Days from transplanting to 1st flowering**				
	Plant growth regulators																								
	G1	G2	G3	G0	Mean	G1	G2	G3	G0	Mean	G1	G2	G3	G0	Mean	G1	G2	G3	G0	Mean	G1	G2	G3	G0	Mean
V1	86.15	83.17	82.86	81.55	**83.43**	11.35	10.97	10.47	9.86	**10.67**	108.67	108.33	107.94	107.63	**108.14**	0.76	0.73	0.72	0.70	**0.73**	43.66	43.02	42.65	42.15	**42.87**
V2	78.68	75.86	73.25	70.79	**74.64**	15.05	14.85	14.54	13.85	**14.57**	91.98	91.54	90.83	90.65	**91.25**	0.70	0.68	0.67	0.66	**0.68**	56.92	54.85	51.55	50.86	**53.55**
V3	70.85	70.36	69.95	68.68	**69.96**	10.75	10.39	9.87	9.55	**10.14**	100.83	100.35	99.81	99.58	**100.14**	0.64	0.55	0.52	0.51	**0.55**	46.65	46.45	45.66	45.17	**45.98**
S.E (m) ±	**0.03**					**0.02**					**0.05**					**0.01**					**0.03**				
C.D at (5%)	**0.08**					**0.05**					**0.13**					**0.03**					**0.08**				

Table 1(b). Interaction effect of plant growth regulators on Days to 50% flowering, Number of flowers per plant, days from transplanting to 1st harvest, Number of fruits per plant and percent fruit setting on capsicum varieties.

Varieties	Days to 50% flowering					Number of flowers per plant					Days from transplanting to 1st harvest					Number of fruits per plant					Percent fruit setting				
	Plant growth regulators																								
	G1	G2	G3	G0	Mean	G1	G2	G3	G0	Mean	G1	G2	G3	G0	Mean	G1	G2	G3	G0	Mean	G1	G2	G3	G0	Mean
V1	92.65	90.55	88.64	88.24	**90.02**	12.85	12.35	11.95	11.65	**12.20**	58.75	58.33	53.30	57.27	**56.91**	10.58	10.06	9.84	9.54	**10.01**	82.34	81.46	82.29	81.89	**82.00**
V2	96.95	96.36	98.64	94.85	**96.70**	8.85	8.05	7.85	7.54	**8.08**	66.06	64.76	63.02	62.25	**64.02**	6.55	6.25	5.86	5.55	**6.05**	73.99	77.68	74.58	73.62	**74.97**
V3	95.94	93.85	92.77	90.65	**93.30**	9.97	9.66	8.98	8.75	**9.34**	61.95	57.83	57.06	56.45	**58.32**	7.86	7.52	6.86	6.66	**7.22**	78.83	77.84	76.36	76.08	**77.28**
S.E (m) ±	**0.02**					**0.02**					**0.67**					**0.01**					**0.21**				
C.D at (5%)	**0.06**					**0.06**					**1.98**					**0.03**					**0.62**				

Table 2. Effect of plant growth regulators on fruit length(cm), fruit diameter (cm), fruit weight(g), yield per plant (g), yield per plot (kg) and yield per hectare (tons) on capsicum varieties.

Treatments	Fruit length(cm)	Fruit diameter (cm)	Fruit weight(g)	Yield per plant (g)	Yield per plot (kg)	Yield per hectare (tons)
Varieties						
V_1	8.94±0.30	7.12±0.33	82.22±0.59	296.32±2.40	4.45±0.04	74.22±0.76
V_2	13.34±0.32	3.15±0.41	77.80±1.03	287.83±4.33	4.32±0.07	72.00±1.16
V_3	11.62±0.37	6.44±0.49	69.12±1.43	282.43±1.52	4.23±0.02	70.51±0.36
S.E (m) ±	**0.126**	**0.126**	**0.470**	**1.610**	**0.068**	**0.456**
C.D (5%)	**0.444**	**0.446**	**1.657**	**5.678**	**0.240**	**1.609**
Plant growth regulators						
G1	11.92±1.30	6.35±1.17	78.79±3.21	294.49±4.43	4.43±0.08	73.78±1.37
G_2	11.64±1.31	6.02±1.24	76.95±3.79	292.13±4.53	4.39±0.07	73.14±1.18
G_3	11.18±1.20	5.41±1.28	75.73±4.02	285.95±4.80	4.29±0.07	71.46±1.19
G_0	10.47±1.32	4.51±1.23	74.05±4.38	282.88±3.54	4.24±0.05	70.59±0.38
S.E (m) ±	**0.145**	**0.146**	**0.542**	**1.859**	**0.078**	**0.527**
C.D.	**0.513**	**0.515**	**1.913**	**6.557**	**0.277**	**1.858**

Table 2 (a). Interaction effect of plant growth regulators on fruit length(cm), fruit diameter (cm), fruit weight(g), yield per plant (g), yield per plot (kg) and yield per hectare (tons) on capsicum varieties.

Varieties	**Fruit length(cm)**					**Fruit diameter(cm)**					**Fruit Weight (g)**				
	Plant growth regulators														
	G1	G2	G3	G0	Mean	G1	G2	G3	G0	Mean	G1	G2	G3	G0	Mean
V1	9.54	9.24	8.85	8.15	**8.94**	7.84	7.43	6.85	6.35	**7.12**	83.55	82.83	81.45	81.04	**82.22**
V2	14.03	13.74	12.85	12.73	**13.34**	4.04	3.55	2.85	2.17	**3.15**	80.14	78.15	77.77	75.14	**77.80**
V3	12.18	11.95	11.83	10.53	**11.62**	7.16	7.06	6.53	5.02	**6.44**	72.68	69.86	67.97	65.98	**69.12**
S.E (m) ±	**0.01**					**0.01**					**0.02**				
C.D at (5%)	**0.03**					**0.03**					**0.07**				

Varieties	**Yield per plant (g)**					**Yield per plot (kg)**					**Yield per hectare (tons)**				
	Plant growth regulators														
	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3
V1	300.85	298.96	295.54	300.85	298.96	295.54	300.85	298.96	295.54	300.85	298.96	295.54	300.85	298.96	295.54
V2	296.65	293.87	280.95	296.65	293.87	280.95	296.65	293.87	280.95	296.65	293.87	280.95	296.65	293.87	280.95
V3	285.96	283.56	281.36	285.96	283.56	281.36	285.96	283.56	281.36	285.96	283.56	281.36	285.96	283.56	281.36
S.E (m) ±	**0.08**			**0.08**			**0.08**			**0.08**			**0.08**		
C.D at (5%)	**0.23**			**0.23**			**0.23**			**0.23**			**0.23**		

Table 3 . Cost and return of capsicum cultivation as influenced by variety and plant growth regulators

Treatment	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C Ratio
G1V1	59413.4	229200	169786.6	**2.86**
G2V1	58932.4	223990	165057.6	**2.80**
G3V1	59103.4	221500	162396.6	**2.75**
G0V1	53756.4	197160	143403.6	**2.67**
G1V2	60013.4	222170	162156.6	**2.70**
G2V2	59532.4	221810	162277.6	**2.73**
G3V2	59703.4	210650	150946.6	**2.53**
G0V2	54356.4	182840	127683.6	**2.35**
G1V3	60813.4	219980	159166.6	**2.62**
G2V3	60332.4	212500	152167.6	**2.52**
G3V3	60503.4	211000	150496.6	**2.49**
G0V3	**55156.4**	**181330**	**126973.6**	**2.30**

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Effect of Different Sources of Phosphorus on Nutrient Content and Uptake by Chickpea (*Cicer arietinum* L.)

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Abstract— *A field experiment entitled "Effect of Different Sources of Phosphorus on Productivity of Chickpea (Cicer arietinum L.) and Soil Properties" was conducted during Rabi season of 2023-24 at Instructional Farm, Rajasthan College of Agriculture, Udaipur (Rajasthan). The experiment included nine phosphorus sources treatments (SSP, RP with and without PSB). The experiment was set up in a randomized block design with three replications. Application of 75% RDP through SSP +25% RDP through RP + PSB (T_7) significantly increased nutrient content and uptake (N, P and K) by chickpea (Cicer arietinum L.) and recorded highest nutrient content and uptake over control.*

Keywords— ***Single Super Phosphate, Rock Phosphate, Phosphorus Solubilizing Bacteria, Nutrient Content, Nutrient Uptake, Chickpea***

I. INTRODUCTION

Pulses play an important role in developing countries to provide nutritional security as a major source of protein in vegetarian diets. In India, the pulses have been called as "poor man's meat and rich man's vegetable". In addition to protein, pulses contain a good amount of essential amino acids, vitamins, dietary fibers and minerals required by human beings. It also has unique property of maintaining and restoring the soil fertility through biological nitrogen fixation as well as conserving and improving the physical properties of soil by virtue of their nodulated root system and leaf fall. hickpea is a good source of carbohydrates and proteins, which together constitute about 80% of the total dry seed mass. The starch content of chickpea cultivars has been reported to vary from 41% to 50% and kabuli type contains more soluble sugars (Jambunathan and Singh, 1980). The unavailable carbohydrate content is higher in chickpea than other legumes (Kamath and Belavady, 1980) and chickpea carbohydrate has a lower digestibility than that of other pulses (Rao, 1969). The crude protein content of chickpea varies from 12.4 to 31.5%. PSB is capable to solubilize the fixed soil phosphorus (Singh et al, 2008). The use of organic and inorganic amendments with microbial inoculation is considered to be the best possible eco-friendly option (Shahzad, et al., 2017). In general increase in uptake of total potassium due to addition of rock phosphate along with PSB might be due to increased availability of nutrients from rock phosphate blend with manures especially phosphorus would have enhanced root proliferation which helped in more uptake of potassium. The higher K uptake in wheat by the application of Phosphate solubilizers and organic amendments with rock phosphate was also reported by Saurabh, (2012).

Chemical fertilizers are highly expensive these days, therefore effective nutrient management not only helps to increase current agricultural output levels, but also to sustain production and protect the environment from all types of risks caused by improper fertilizer management. Chemical fertilizers combined with organic sources resulted in higher N, P, and K concentrations as well as chickpea uptake (Deshpande et al., 2015). Organic Manures are an excellent source of nutrients for microorganism growth and development.

Table-1: Effect of different sources of phosphorus on nutrient (N, P, K) content (%) by chickpea

Treatments			**Nitrogen Content**		**Phosphorus Content**		**Potassium content**	
			Grain	Haulm	Grain	Haulm	Grain	**Haulm**
T_1	:	Control	2.110	0.500	0.310	0.120	0.480	**1.400**
T_2	:	100% RDP through SSP	2.840	0.590	0.440	0.197	0.560	**1.800**
T_3	:	75% RDP through SSP+PSB	2.757	0.588	0.430	0.187	0.560	**1.767**
T_4	:	50% RDP through SSP+PSB	2.440	0.533	0.360	0.160	0.500	**1.570**
T_5	:	100% RDP through SSP+PSB	3.600	0.770	0.460	0.240	0.730	**2.493**
T_6	:	75% RDP through SSP+25% RDP through RP	3.410	0.660	0.450	0.223	0.630	**2.330**
T_7	:	75% RDP through SSP +25%RDP through RP + PSB	3.670	0.800	0.490	0.253	0.763	**2.580**
T_8	:	50% RDP through SSP+50% RDP through RP	3.377	0.650	0.450	0.206	0.620	**2.210**
T_9	:	50% RDP through SSP + 50% RDP through RP + PSB	3.610	0.783	0.477	0.240	0.733	**2.503**
SEm±			0.046	0.013	0.015	0.005	0.015	**0.046**
CD (at 5 %)								

II. MATERIALS AND METHODS

The field experiment conducted during rabi season of 2023-24 at the Instructional Farm, Rajasthan College of Agriculture, Udaipur. which is located at an elevation of 579.5 m above mean sea level at 24o 35' latitude and 74o 42' longitude. The region is a part of Rajasthan's agro-climatic zone IV-a (Sub-Humid Southern Plain and Arawali Hills).

Table 2: Effect of different sources of phosphorus on nutrient uptake (kg ha^{-1}) by chickpea

Treatments			**Nitrogen uptake**		**Phosphorus uptake**		**Potassium uptake**	
			Grain	Haulm	Grain	Haulm	Grain	**Haulm**
T_1	:	Control	2.110	0.500	0.310	0.120	0.480	**1.400**
T_2	:	100% RDP through SSP	2.840	0.590	0.440	0.197	0.560	**1.800**
T_3	:	75% RDP through SSP+PSB	2.757	0.588	0.430	0.187	0.560	**1.767**
T_4	:	50% RDP through SSP+PSB	2.440	0.533	0.360	0.160	0.500	**1.570**
T_5	:	100% RDP through SSP+PSB	3.600	0.770	0.460	0.240	0.730	**2.493**
T_6	:	75% RDP through SSP+25% RDP through RP	3.410	0.660	0.450	0.223	0.630	**2.330**
T_7	:	75% RDP through SSP +25%RDP through RP + PSB	3.670	0.800	0.490	0.253	0.763	**2.580**
T_8	:	50% RDP through SSP+50% RDP through RP	3.377	0.650	0.450	0.206	0.620	**2.210**
T_9	:	50% RDP through SSP + 50% RDP through RP + PSB	3.610	0.783	0.477	0.240	0.733	**2.503**
SEm±			0.046	0.013	0.015	0.005	0.015	**0.046**
CD (at 5 %)			**0.138**	**0.040**	**0.044**	**0.014**	**0.044**	**0.137**

The soil of site was slightly alkaline, loamy structure, medium in available nitrogen, phosphorus and potassium. The experiment comprised 9 treatments to find out the effect of various sources of phosphorus on productivity of chickpea and the experiment was laid out in a RBD with three replications. GNG-2144 var. was used for the experiment as a test crop. Single super phosphate, Rock phosphate and PSB was used as various sources of phosphorus. The concentration of nutrient was determined by the following methods, N colorimetric method for nitrogen (Snell and Snell, 1949), P by vanodomolybdo phosphoric acid yellow colour method for phosphorus (Jackson, 1973) and potassium determined by Flame photometer method (Jackson, 1973). The nutrient uptake calculated by multiplying the concentration of nutrients to the yield of field crop.

III. RESULTS AND DISCUSSION

The results of this experiment showed that application of 75% RDP through SSP +25%RDP through RP + PSB (T_7) significantly enhanced the nutrient content and uptake by chickpea over control. Nutrient content and uptake are the most important parameters to increase the capacity of soil to provide nutrients to plant and increase the yield parameters. The maximum total nitrogen, phosphorus and potassium uptake were noted in the with application of 75% RDP through SSP + 25% RDP through RP + PSB (T_7). This might be due to increased microbial activity in rock that has led to increase in the total N uptake by chick pea. Beneficial microbes like P solubilizers and N fixers in the organic matter as well as added PSB induced solubilization of rock phosphate in presence of organic matter and helped in N fixation. The higher N uptake in wheat by the application of PSB and organic amendments with rock phosphate was also reported by Saurabh, (2012).

The results showed that application of rock phosphate amendment along with seed inoculations with PSB had promising positive effects on the seed and haulm yield of chickpea crop as compared with to control treatment. Rhizosphere colonization by microbial inoculants has been described as a crucial factor for plant growth promotion was observed by Lugtenberg, (2001).

The increased nitrogen, phosphorus and potassium content in seed and haulm might be due to improving available nutrients particularly within the rhizosphere. The use of organic and inorganic amendments with microbial inoculation is considered to be the best possible eco-friendly option (Shahzad, et al., 2017). PSB biofertilizer also increase water uptake capacity. PSB inoculation convert the insoluble phosphorus in to soluble form by secreting organic acids (lactic, lectiolic, acetic and formic acid) (Gangwar and Dubey, 2012).

IV. CONCLUSION

On the basis of experimental results, it was concluded that application of 75% RDP through SSP +25% RDP through RP + PSB had significant effect with respect to N, P, K content and uptake. It means the combination of SSP, RP and PSB improves the nutrient concentration and uptake by plants (N, P, K). Seed treatment by PSB increase the solubility of rock phosphate and help the plant to absorb phosphorus and other macronutrients. This experiment also reveals that the combine application of SSP, RP and PSB enhanced the overall availability of macronutrients to the plant.

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Assessment of Carbon Reserves in Nanchang City, Jiangxi Province, Using the InVEST Model

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Abstract— *This study depends on the dynamic index of land use change and land transfer matrix, as well as the carbon module in the InVEST model. The features of land use change and carbon reserve change in Nanchang city from 2001 to 2021 were investigated, and the influence of land use change on carbon reserve was identified. The results show that, from 2001 to 2021, the area of cultivated land, water area, grassland, and bare land in Nanchang City decreased while the area of construction land and forest land increased. Under the influence of land use changes, the high-value areas of carbon reserves are mostly distributed in forest areas, including the northwest and southeast parts of Nanchang, whereas the low-value areas are mostly distributed in urban construction areas, including the central part of Nanchang, which is consistent with the current situation of urban land types. Overall, the carbon reserves of Nanchang City decreased from 2001 to 2021, primarily due to the decrease of cultivated land and the increase of construction land.*

Keywords— ***land use change, carbon reserves, InVEST model, Nanchang City.***

I. INTRODUCTION

The growth and collapse of ecology corresponds to the rise and fall of civilization. Since the CPC's 19th National Congress, the whole country has earnestly implemented the Party's vision for ecological civilization construction and promoted sustainable development to the pinnacle of green development (Cai, 2000). According to studies has a significant impact on ecosystem carbon storage capacity because it affects both vegetation and soil carbon stocks. Land use change is an essential indicator of human activities and directly affects the terrestrial ecosystem carbon reserves(Zhu et al., 2022). It is an important factor influencing the change of carbon stocks in the whole region (Fang et al., 2015). The study of land use change is of great significance to the sustainable development of regional economy (Zong and Cao, 2020), the coordinated development of ecological economy (Liu et al., 2021), and the sustainable use of land (Xu et al., 2009). Regional carbon emissions have attracted significant attention in the context of sustainable development.

As the core area of the construction of Jiangxi Province and Poyang Lake ecological economic zone, Nanchang city has a large demand for construction land, coupled with the frequent extensive use of land, resulting in the shortage of available arable land resources and great pressure on the urban ecological environment. Therefore, this study, from the perspective of land use change, as the research area of Nanchang, Jiangxi province, applying the InVEST model, combined with the dynamic degree index of land use change and land transfer matrix, discusses the spatial and temporal change of carbon reserves in 2001-2021 and aims to reveal the influence of land use change on carbon reserves, for regional land use planning and carbon management, which has important reference value, in order to provide theoretical support for urban practice of green development concept.

II. STUDY AREA

Nanchang city is located in the north central part of Jiangxi Province, China, between east longitude 115 27 '-116 35' and north latitude 28 10 '-29 11', which belongs to the subtropical monsoon humid climate (Figure 1). The terrain of the territory is "three rivers with five lakes, control Manjing and lead ouyue," that is, the southeast terrain is flat, northwest hills, ups and downs; Ganjiang River, Fuhe River downstream, the southwest bank of Poyang Lake, abundant rainfall.

Nanchang is the capital of Jiangxi Province, the earliest aviation industry base, an important comprehensive transportation hub and photovoltaic industry base in China, and a world-class photovoltaic industry base. It is one of the important members of the Yangtze River economic belt, urban agglomeration in the middle reaches of the Yangtze River, and in the "Belt and Road" initiative node, is the link between the Midwest and the southeast coast important traffic corridor, and with the nine integrations, urban agglomeration in the middle reaches of the Yangtze River, the implementation of the river district policy, urban construction land expansion, and land use changed significantly.

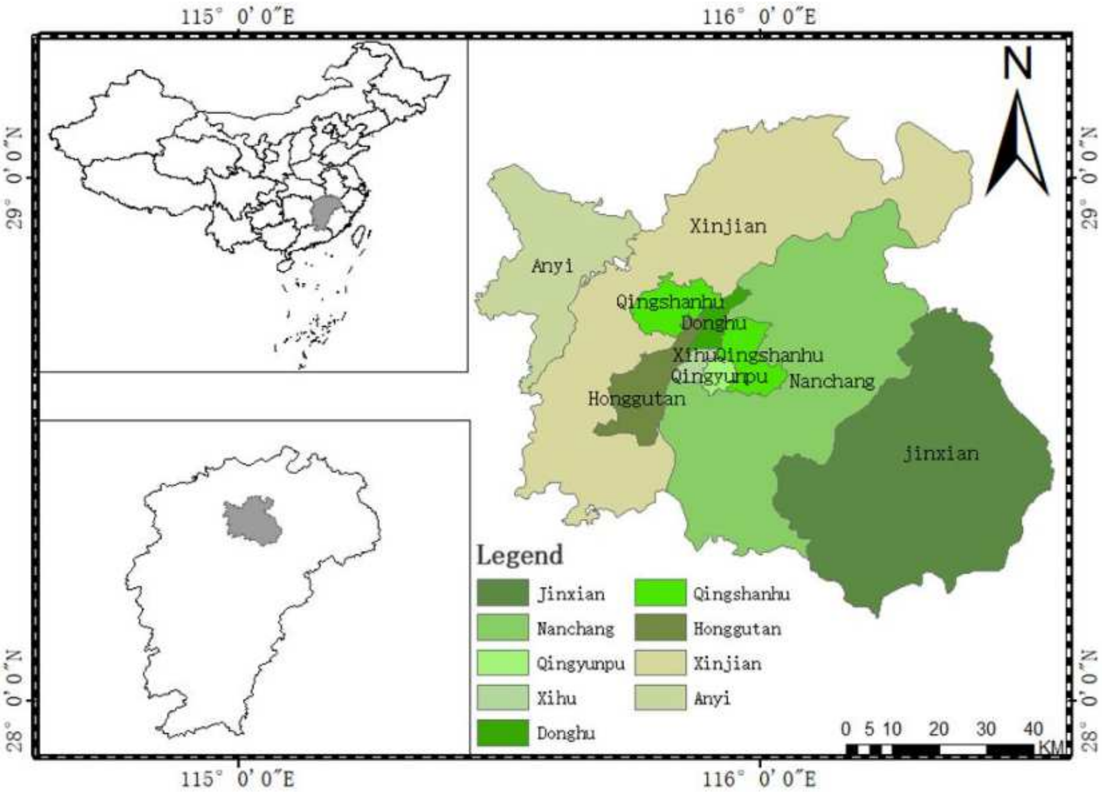


Fig.1 Map of administrative division of Nanchang City

III. METHODOLOGY

3.1 Data Collection

This study's data sources are as follows:

1. The land use data of Nanchang city in 2001 and 2021 are derived from Yang & Huang (2022), that is, the 30 m annual land cover datasets and its dynamics in China from 1990 to 2021 (1.0.0), (Zenodo, https://doi.org/10.5281/zenodo.5816591).
2. The spatial resolution of land cover data is 30 m, including nine types of land for cropland, forest, shrubs, water area, grassland, bare land, and buildings.
3. Carbon bank data: consult the literature and sort out the carbon density data of above-ground and

underground roots, soil, and dead organic matter of various urban land types.

4. Administrative boundary data originated from the Resource and Environment Data Center of the Chinese Academy of Sciences, and extracted vector data from the study area.

3.2 Methods

3.2.1 Land Use Change

Land use dynamic degree: describe the intensity of land use change in a certain area, reflecting the difference in the change rate of different land use types in the region (Zhu and Wang, 2013; Lai and Wen, 2022). Formula for calculating a single land-use dynamic degree:

$$D=\frac{Ub-Ua}{Ua}\times\frac{1}{T}\times100\% \quad (1)$$

Where D is the dynamic degree of a land use type during the analysis period; Ua and U_b represent the area of a land use type at the beginning and end of the analysis period; T is the long analysis period.

Land use transfer matrix: using the matrix form to represent the interconversion area between different land classes effectively analyzes the internal transfer characteristics and pattern changes of land use classification in the research area and reflects the transformation between various land categories, including the direction, area, and development trend of transfer.

In Table 1, two time points T_1 and T_2 are located in rows and columns, respectively, and they indicate the current land cover in the study area at time points T_1 and T_2. P_{ij} represents the area converted from i land use type to land use type j during T_1-T_2, and P_{ii} indicates the area where land of type I was not converted to other types of land during the study period. P_{i+} represents the total area of land of type i at the study start time T_1, and P_{+j} represents the total area of land of type j at the end of the study time T_2. P_{i+} -P_{ii} refers to the area or area percentage of type I land decrease during the study period T_1-T_2; similarly, P_{+j}- P_{jj} refers to the area or percentage area of type j land increase during the study period T_1-T_2 (Liu and Zhu, 2010).

Table 1 Land use transfer matrix

		T_2				P_{i+}	Decrease
		A_1	A_2	...	A_n		
T_1	A_1	P_{11}	P_{12}	...	P_{1n}	P_{1+}	P_{1+}-P_{11}
	A_2	P_{21}	P_{22}	...	P_{2n}	P_{2+}	P_{2+}-P_{22}
	...	...	...	...	...	...	...
	A_n	P_{n1}	P_{n2}	...	P_{nn}	P_{n+}	P_{n+}-P_{nn}
P_{+j}		P_{+1}	P_{+2}	...	P_{+n}	1	
Newly increased		P_{+1}-P_{11}	P_{+2}-P_{22}	...	P_{+n}-P_{nn}		

3.2.2 Carbon Reserves

InVEST The carbon module in the model divides the ecosystem carbon reserves into four basic carbon pools, namely, aboveground biological carbon, underground biological carbon, soil carbon, and dead organic carbon. The module uses socio-economic and natural data under current or future scenarios as inputs to output the spatial distribution and evolution trend of carbon stocks under certain scenarios (zhang, 2016). Above ground biomass includes all surviving plant materials above soil, such as tree trunks, branches, leaves, bark, etc. with the average value of carbon reserves per unit area around 0 to 20 cm above the surface; underground biomass includes the living root system of the plants with average carbon reserves per unit area around 0 to 20 cm below the surface; soil carbon reservoirs are usually limited to organic carbon from mineral soil but also organic soil, which is the average value of carbon reserves per unit area around 20 to 100 cm below the surface; dead organic matter includes litter, inverted or standing dead trees. The formula is as follows:

$$C = C_{above}+C_{below}+C_{soil}+C_{dead} \quad (2)$$

Where C is the total carbon storage of the terrestrial ecosystem, C_{above} is the aboveground carbon storage, C_{below} is the underground carbon storage, C_{soil} is the soil carbon storage, and C_{dead} is the carbon storage of dead organic matter.

The data required for model operation mainly includes land use/cover type data and carbon storage in each carbon bank to calculate the total amount of carbon storage in the ecosystem. Carbon density data is an important factor for the InVEST model to calculate the carbon storage in the ecosystem, and the carbon density is the carbon storage per unit area. In this paper, the research results obtained in the same or adjacent regions are integrated (Table 2). The average carbon storage per unit area is expressed by Mg/hm^2.

Table 2 Carbon density of different land use types in Nanchang city (Mg / hm^2)

Type	Above-ground carbon density	Underground carbon density	Soil carbon carbon density	Litter carbon carbon density
Cropland	4.7	0	54.5	0
Forest land	60.17	12.64	68.79	4.4
Grassland	1.52	3.11	9.99	1.99
Waters	2.93	0.81	0.5	0
Bare ground	0	0	0	0
Building	0	0	0	0

IV. RESULTS AND ANALYSIS

4.1 Characteristics of Land Use Change

This paper, based on 30 m× 30 m resolution of Nanchang land use grid data, used the ArcGIS 10.1 spatial analysis method to extract the area of the six land use types in 2001, 2011, and 2021, namely cropland, forestland, grassland, water area, bare land, and building land (Figure 3), establish the land use transfer matrix, analyze the scale of the Nanchang land type and transfer direction, and form an intuitive comparison.

In terms of spatial distribution, between 2001 and 2021, the general land use distribution pattern in Nanchang city has not changed greatly. The land use type is mainly cropland and building land, with a broad water area and numerous water systems and rivers in the territory. The cropland land is distributed in most areas outside the water area, and the building land is increasing, concentrated in the city center and rivers along the Ganjiang River. The water is mainly distributed in the east and north, namely Poyang Lake; in the middle, the Ganjiang River passes into cropland land in 20 years. Most of the forestland is concentrated in the northwest and southeast, consistent with the northwest hilly terrain; the grassland is distributed in the forestland, and most of the secondary vegetation formed after the destruction of forest resources. Overall, the change range of forestland and grassland area is small. Most of the bare land is distributed near the water, indicating that the bare land originates from the periodic fluctuation of the water area.

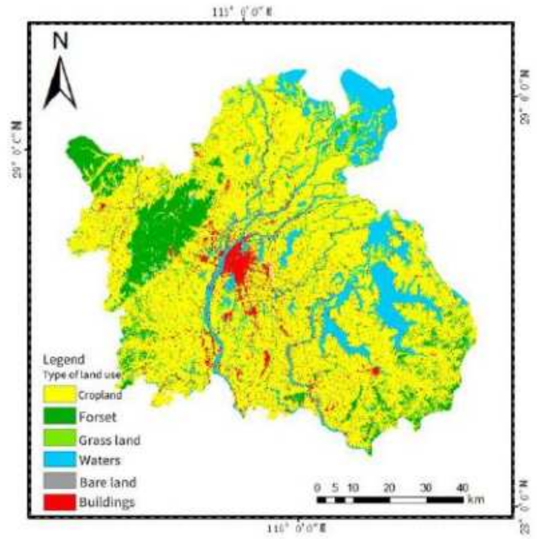
According to Table 3, the area changes of cropland, grassland, water area, and bare land were consistent, and the four types of land use decreased; the area of the two land use types of forest land and buildings land increased.

The area of cropland decreased the most in 2001 and 2021, with 4864.8771 km^2 and 4818.2337 km^2 respectively. In the past 20 years, the cropland area was less than 364.829 km^2, and the area decreased by 7.49%, making it the largest land type in Nanchang.

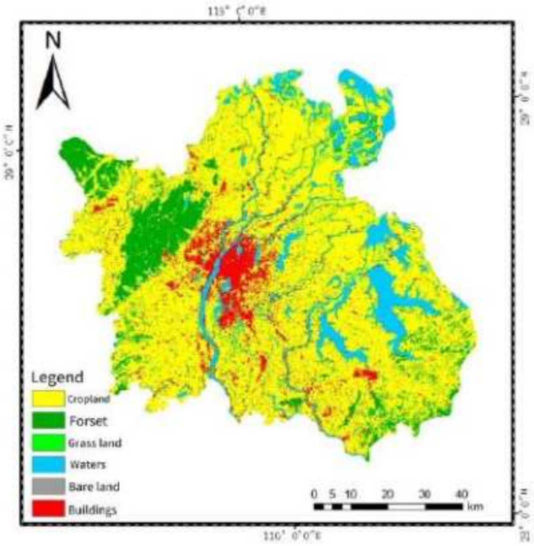
The area of forest land was first reduced and then increased. In 2001 and 2021, the area was 806.7087 km^2 and 891.9414 km^2 respectively, and the overall increase was 85.233 km^2 in the past 20 years, an increase of 11.03% compared with 2011, indicating that Nanchang pays attention to the protection of the ecological environment in the later development process.

The area of building land has increased the most in the past 20 years. In 2021, the area of buildings land is 749.1285 km^2, with an average annual rate of 4.454%, an increase of 90.48% compared with 2001. Building land has become a major advantage of land types in Nanchang.

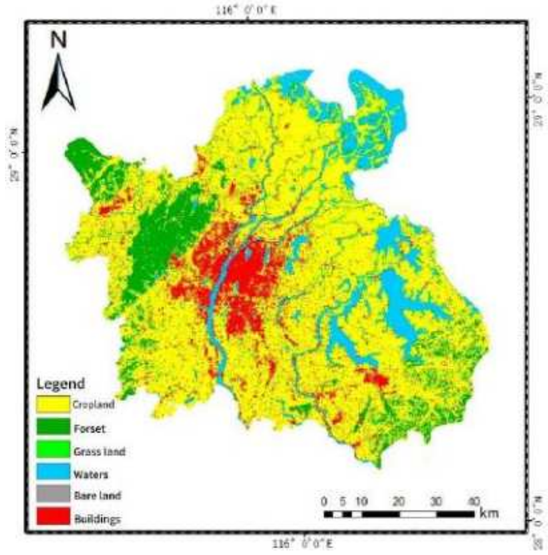
The water area has decreased in the past 20 years; in 2001 and 2021, 1106.1765 km^2 and 1044.748 km^2 respectively, only reducing 61.4286 km^2, 5.55% less than that in 2001. If it continues to decrease, it will be difficult to meet the needs of human production and life, causing bad effects.



(a) Land use distribution in 2001



(b) Land use distribution in 2011



(c) Land use distribution in 2021

Fig.3 Land use distribution map

.The area of grassland in 2001 and 2021 was 9.9414km^2 and 8.7381km^2 respectively, and the grassland area decreased by 7.6104km^2 in the past 20 years. Meanwhile, the bare land has changed greatly, with the area in 2001 being 10.4787km^2 and 3.2787km^2 in 2021, and the area decreased by 7.2km^2. In comparison, grass changes more dynamic attitudes than bare land.

The four types of land use with reduced area decreased from large to small: cropland>water>grassland>bare land, and the two types of land use with increased area increased from large to small: Building land>forest land, building land increased at an average annual rate of 4.524%.

The land use data of Nanchang was analyzed using ArcGIS 10.1, and the land use transfer matrix was extracted after Excel treatment. According to Table 4 and Table 5, between 2001 and 2021, the building land increased rapidly, mainly derived from the transformation of cropland land, indicating the accelerated process of urbanization. Between 20 years, the building land area has increased from 393.2937km^2 in 2001 to 749.1285km^2 in 2021, increasing at an annual average 17.79km^2 rates. Through calculation, a total of 322.8453km^2 cropland has been converted into building land, accounting for 90.73%

of the newly added building land. It can be seen that cropland land is the main source of building land expansion, and Nanchang city has developed remarkable urban expansion in recent years. The change in water area is small; in 20 years, the area decreased by 61.4285km^2, mainly transformed into crop land and building land, indicating that urban expansion accelerates land development and utilization. The bare land is distributed near the water area. With the transformation of the water area, the bare land area decreases continuously, and the area drops from 10.4787km^2 to 3.2787km^2. On the whole, the decrease of the area of cropland, grassland, water area, and bare land is structurally related to the increase of the area of forest land and building land.

Table 3 Land use area and attitude in Nanchang during 2001-2021 (%)

Year Land type	2001 area/km^2	2011 area/km^2	2021 area/km^2	2001-2021 area/km^2	Dynamics degree (%)
Cropland	4864.8771	4818.2337	4500.049	-364.829	-0.375
Forest	806.7087	803.3562	891.9414	85.233	0.528
Grassland	9.9414	8.7381	2.331	-7.6104	-3.828
Waters	1106.1765	979.3674	1044.748	-61.4286	-0.278
Bare land	10.4787	5.8095	3.2787	-7.2	-3.436
Buildings	393.2937	575.9712	749.1285	355.835	4.524

Table 4 Land Use Transfer Matrix of Nanchang City from 2001 to 2011 (unit: km^2)

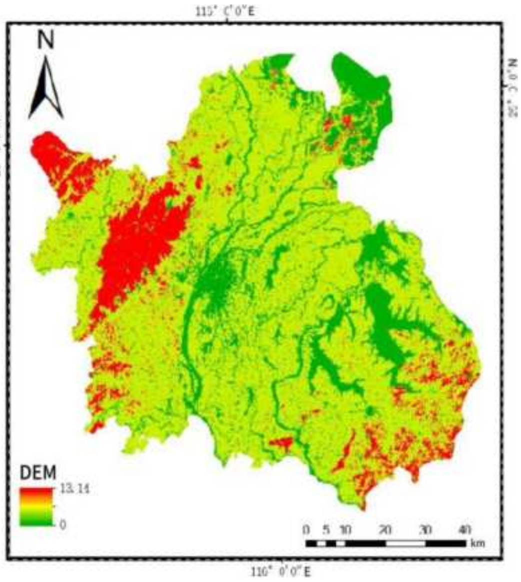
Type	Cropland	Forest	Grassland	Waters	Bare land	Buildings	Total
Cropland	4516.8408	95.8914	2.016	86.5395	0.1215	163.4679	4864.8771
Forest	111.5739	688.4982	0.3978	2.0727	0	4.1661	806.7087
Grassland	1.3986	0.0864	3.0195	2.6307	0.774	2.0619	9.9414
Waters	187.6212	18.8784	1.5147	876.5028	1.5282	20.1312	1106.1765
Bare land	0.4158	0	1.7865	3.4965	3.4056	1.3743	10.4787
Buildings	0.3834	0.0018	0.0036	8.1252	0.0099	384.7698	393.2937
Total	4818.234	803.3562	8.7381	979.3674	5.8095	575.9712	

Table 5 Land Use Transfer Matrix of Nanchang City from 2011 to 2021 (unit: km^2)

Type	Cropland	Forest	Grassland	Waters	Bare land	Buildings	Total
Cropland	4334.9454	163.7856	0.2079	157.8771	0.036	161.3817	4818.234
Forest	64.7244	727.6842	0.0017	8.0118	0	2.9241	803.3562
Grassland	2.7324	0.2448	1.0791	1.746	0.504	2.4318	8.7381
Waters	96.6348	0.225	0.3357	866.3859	0.8379	14.9481	979.3674
Bare land	0.5112	0.0018	0.6795	1.6326	1.8594	1.125	5.8095
Buildings	0.5004	0	0.0171	9.0945	0.0414	566.3178	575.9712
Total	4500.0486	891.9414	2.331	1044.7479	3.2787	749.1285	

4.2 Changes in Carbon Reserves

Analysis indicated that the spatial distribution of carbon reserves in Nanchang city changes little from 2001 to 2021, and the carbon density in different regions has obvious spatial differences, and its range is 0-13.14t/hm^2. The main manifestations are: in 2001, 2011, and 2021, the carbon reserves in the northwest and the southeast were the highest, and the central ones were the lowest, forming a pattern of "high and low weeks" (Figure 4). In northwest and southeast regions, late development, good forest vegetation, and strong carbon fixation capacity; the central area of building land is increasing, dense population, high urbanization level, large water area, cropland area, and large carbon emissions, resulting in low carbon reserves.



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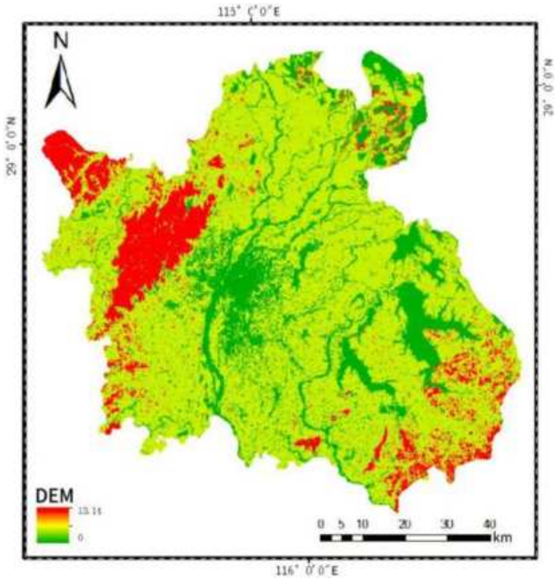
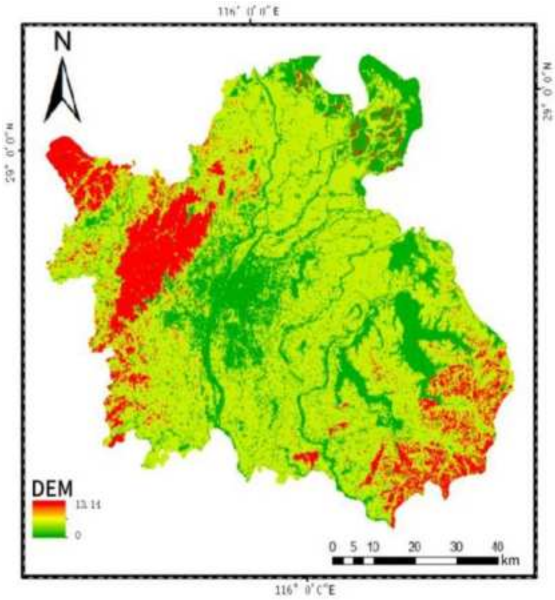
(a) Distribution of carbon reserves in 2001



(b) Distribution of carbon reserves in 2011



(c) Distribution of carbon reserves in 2021

Fig.4: Distribution diagram of carbon reserves

Through calculation, the total carbon reserves of Nanchang in 2001, 2011, and 2021 are 4.12107 t, 4.06107 t, and 4.01107 t, respectively. Consequently, in the two stages of 2001-2011 and 2011-2021, the carbon reserves of Nanchang city decreased continuously, but the decline in 2011-2021 was smaller than that in 2001-2011. Due to the good carbon fixation capacity of plant leaves and roots, the increase in forestland area after 2011 can increase the regional carbon reserves to a certain extent. With the continuous increase in urbanization rate, the sharp increase in building land area will also lead to the reduction of carbon reserves in terrestrial ecosystems. In recent years, the urban management department of Nanchang city has strengthened the management of landscaping construction (Chen and Wei, 2023). In 2020, the park area will be increased by 1 million square meters, and the green space and park site will be expanded through demolition and construction measures, forming a network system of "four horizontal, seven vertical, and six ring" urban greenways, which is of great significance to the improvement of regional carbon reserves.

In general, the distribution characteristics of urban carbon reserves are similar to those of urban vegetation, with a large vegetation area, high vegetation coverage, and higher regional carbon reserves.

V. CONCLUSION

This paper primary uses the land use type data of Nanchang city to analyze the land use change and applies the InVEST model to integrate the carbon density data to analyze the change of its carbon reserve.

From 2001 to 2021, the land use in Nanchang showed obvious spatial and temporal changes, and the overall change of cultivated land area showed a downward trend, especially in the central region, which is mainly the result of urban development and construction in the central region.

Under the influence of the change in land use type, the urban carbon reserves show a downward trend of continuous decrease. The high-value areas are mostly distributed in the northwest and southeast forest areas; the low-value areas are mostly distributed in the central urban construction areas; and other land types are between the two ranges. It shows that the decrease of cropland and the increase of building land are the main reasons for the decrease of carbon reserves.

To sum up, the government should take timely measures such as adjusting land use structure, strengthening land use management, and increasing ecological engineering construction; coordinate ecological environment protection; achieve scientific planning and reasonable development so as to coexist well with nature; promote carbon balance; and realize high-quality and low-carbon urban development.

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Effect of Paclobutrazol and α-naphthaleneacetic acid on Growth and Yield of Zucchini (*Cucurbita pepo* L.) In Tropical Regions

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Abstract— *Zucchini is one of Cucurbitaceae family with a lot of vitamins and benefical for boosting immune system, preventing cancer risk and preventing inflammation. In Indonesia cultivation zucchini less than optimal so that it is necessary to apply cultivation techniques that can increase production zucchini. This Research to study effect of α-naphthaleneacetic acid (NAA) and various concentrations of paclobutrazol (PBZ) on growth and yield zucchini. The Experiments was a factorial experiment using split plot design with two factor, first factor was NAA with 2 treatment levels (with and without apply NAA) and the second factor was the concentration with 5 treatment levels (0, 50, 100, 150, and 200 ppm). The observation data results were analysis of variance (ANOVA) and continued least significant difference (LSD) at 5% error level. The results showed that significant effect of NAA and PBZ on growth and yield of zucchini. There was can inhibit the vegetative organs like plant length, leaf area and stem length. Beside that, there were increasing the generative organs in the parameters number of fruits, fruit length, diameter fruit, fresh fruit weight and fruit weight per plant, harvest index and partition biomass. Effect of PBZ especially at higher concentrations can inhibited plant growth while enhancing fruit quality, where was NAA demonstrated potential in optimizing fruit development through hormonal regulation. In conclusion, the interaction of PBZ and NAA was found to influence not only zucchini fruit morphology but providing into the regulation of growth and quality in horticultural crops.*

Keywords— ***Paclobutrazol, A-Naphthaleneacetic acid, Zucchini, Quality of fruit, Biomassa partition and Harvest index***

I. INTRODUCTION

Zucchini (*Cucurbita pepo* L.) contain B-complex vitamins (B1, B2, B3, B6, folate, and choline) and dietary fiber, which are beneficial in regulating blood sugar levels and preventing cancer risk, as well as helping to reduce the risk of heart problems and stroke (Rizky et al. 2021). Zucchini is very high in vitamin C, which is important for preventing premature aging, boosting the immune system and preventing inflammation. In addition, zucchini are also high in zinc, protein, iron, calcium, vitamin K, vitamin A and lutein important for eye problems (Bannayan et al. 2017).

The domestic demand for zucchini continues to grow due to the increase in Japanese and Korean restaurants. In addition, the need for vegetable imports in Japan from Indonesia rose significantly from 2014 to 2019 by 11.5% year^{-1} and in 2020 it increased by 24.2%, so zucchini farmers have a great opportunity to export zucchini (Tokoro et al. 2020). Data on zucchini production from 2015 to 2018 experienced a fairly low increase in production of 10,253 t ha^{-1}, 10,190 t ha^{-1},10,673 t ha^{-1} and 10,961 t ha^{-1} (BPS, 2018). So that zucchini production in Indonesia has not met the needs of local and international markets. Indonesia only meets international market demand of less than 2,000 t year^{-1}. Meanwhile, the average Japanese market demand for zucchini is more than 50,000 t year^{-1} (Binardi et al. 2017).

Various factors can affect plant growth which causes plant growth and yield to be less than optimal so that it is necessary to apply cultivation techniques that can increase production of zucchini fruit, one of which is the use of growth regulators such as paclobutrazol (PBZ) and α-naphthaleneacetic acid (NAA). PBZ inhibits gibberellin biosynthesis so that stem and leaf growth is inhibited, but stimulates flower induction and increases fruit production (Syahputra et al. 2021). PBZ also increases leaf chlorophyll content, to supports photosynthesis and flowering (Franca et al. 2017).

Increasing the production yield and quality of zucchini fruit can be done by cultivation techniques, one of which is by applying growth regulators. Based on the nature of growth regulators is divided into two, namely there are those that spur and inhibit growth (Asgarian et al. 2013). Paclobutrazol (PBZ) functions to inhibit gibberellin biosynthesis, thereby inhibiting stem and leaf elongation and stimulating flower induction, causing plants to become shorter as photosynthetic activity is allocated to increase fruit production (Franca et al. 2017) in their experiments. Optimization of photosynthetic products into generative organs can also be done with NAA which includes auxins so that it can stimulate fruit formation. The hormone auxin has an important role in fruit formation in plants. this study was done. The objectives of this study were therefore to evaluate the effects interaction relationship between NAA and PBZ concentrations in controlling growth, increased fruit formation and quality of fruit zucchini. The objective of our study was to evaluate the effects interaction relationship between NAA and PBZ concentrations in controlling growth, increased fruit formation and quality of fruit zucchini.

II. MATERIALS AND METHODS

2.1. Research Site

The research was conducted from Mei to June 2024 in Dresel, Oro-Oro Ombo, Batu, East Java. Located at 7°54'-37 "S 122°31'34 "E with an altitude between 1010 meters above sea level with a minimum temperature of 18-24°C and a maximum temperature of 28-32°C (BPS, 2021).

2.2. Experimental Design and Treatments

The experimental design used was Split Plots Design with 3 replications. The first factor as the main plot is the provision of NAA consisting of 2 levels, without and with applying NAA. The second factor as a subplot with PBZ concentration consists of 5 levels, concentrations PBZ 0, 50, 100, 150 and 200 ppm.

Growth regulator was applied at 06.30-08.00 AM, apply PBZ with the concentration according to the treatment by spraying on all parts of the plant at the age of 14 DAT before the flowers bloom, and consentration NAA 100 ppm at the age of 26 DAT by spraying on flowers and fruits The preparation of growth regulator solution is done by making a 1 liter water stock solution with growth regulator concentration according to calculation on the basis of (Flores et al., 2018).

$$M1 \times V1 = M2 \times V2$$

Legend: M1 – Pure growth regulator concentration before dilution (ppm), V1 – Volume of growth regulator stock solution before dilution (ml), M2 – Treatment growth regulator concentration after dilution (ppm), and V2 – Volume of treatment stock solution after dilution (ml)

Fig. 1: PBZ and NAA application

Growth observations at 14, 21, 28, and 35 DAT by observed plant length, number of leave, leaf area, stem length, female flower bloming, number of male flowers, number of female flowers, and flower ratio. Yield Observations by Fruit length, fruit diameter, fruit number, fruit set, fruit weight, fruit weight per plant, harvest index and biomassa partition,

Leaf area observations were using the ALA method (Average Leaf Area). Calculation of plant leaf area with the ALA method using the formula showed below Widaryanto et al. (2019):

$$LA\ (cm^2\ plant^{-1}) = ALA\ (cm^2\ leaf^{-1}) \times \sum \text{Number of leaf}\ (leaf\ plant^{-1})$$

The Harvest Index (HI) observations is a measure of the efficiency of a plant in converting its biomass into economically valuable parts, usually grains or fruits. The formula is as follows (Donald, 2962):

$$HI = \frac{\text{Economic Yield}}{\text{Total Aboveground Biomass}}$$

Legend: Economic Yield: The yield of the portion of the plant that is harvested for economic purposes and Total Aboveground Biomass: The total biomass produced by the plant

Biomass Partitioning observation describes how the total biomass of a plant is distributed among different plant organs (roots, stems, leaves, fruits, etc.). It is calculated as a ratio (Poorter and Nagel, 2000):

$$\text{Biomass Partitioning} = \frac{\text{Biomass of Specific Organ}}{\text{Total Biomass of the Plant}}$$

Legend: Biomass of Specific Organ: Biomass of a particular organ like roots, stems, or fruits. And Total Biomass of the Plant: Total mass (dry or fresh weight) of the plant, including all aboveground and underground organs.

2.3. Data Collection and Analysis

The observation results were analyzed using ANOVA test at the 5% level. If the test results show a real effect, then the Least Significant Difference (LSD) test is continued at the 5% level and polynomial regression test to determine relationship between the two variable

III. RESULTS

3.1. Effect of NAA and Various Concentrations of PBZ on Zucchini Plant Growth

The results of the analysis of variance of plant length observations. There is no interaction between the provision of NAA and PBZ concentration. The provision of NAA showed no significant difference at 7, 14, 21, 28 and 35 DAT on the increase in plant length. Meanwhile, the provision of PBZ concentration was able to give a significant difference to plant length of zucchini at 21, 28 and 35 DAT (Table 1).

Table 1: The Effect of NAA and Various Concentrations of PBZ on the Plant Length of Zucchini

NAA	Plant Length (cm) at DAT				
	7	14	21	28	35
Without NAA	17,64	29,36	43,94	49,47	51,32
With NAA	16,67	29,00	44,86	50,79	52,72
LSD-N (5%)	ns	ns	ns	ns	ns
CoV-N(%)	10,07	12,00	14,98	13,55	13,24
Consentration of PBZ (ppm)	Plant Length (cm) at DAT				
	7	14	21	28	35
0	17,47	29,64	54,11 b	60,65 c	64,22 c
50	16,70	28,78	44,04 a	52,13 b	53,57 b
100	17,40	28,95	43,56 a	48,74 ab	50,50 ab
150	17,10	29,42	40,69 a	45,43 a	46,73 ab
200	17,11	29,13	39,60 a	43,71 a	45,06 a
LSD- P (5%)	ns	ns	4,638	5,650	6,936
CoV-P (%)	11,15	8,29	8,53	9,21	10,89

Legend: means followed by different letters are significantly different by a LSD test at $\alpha = 0.05$, ns = not significantly different, CoV= Coefisien of Varians

NAA application had no significant effect on zucchini plant length growth at all observation times. Beside that, PBZ application especially at high concentrations have significantly inhibited plant length growth. The decrease in plant length was increasingly evident with increasing plant age with a noticeable effect occurring at the highest PBZ concentration which consistently caused plant shortening compared to treatments without PBZ and lower concentrations.

The results of the analysis of variance of the observation number of leaves in there is no interaction between the provision of NAA and PBZ concentration. The provision of NAA showed no significant difference at 7, 14, 21, 28 and 35 DAT on the addition of the number of leaves. Meanwhile, the provision of PBZ concentration was able to give a significant difference to the number of zucchini leaves at 21, 28 and 35 DAT (Table 2).

Table 2: The of NAA and Various Concentrations of PBZ on the Number of Leaves

NAA	Number of Leave (leaf plant^{-1}) at DAT				
	7	14	21	28	35
Without NAA	1,86	6,35	12,27	15,28	18,44
With NAA	1,88	6,41	12,34	14,50	17,44
LSD-N (5%)	ns	ns	ns	ns	ns
CoV-N(%)	10,46	11,73	12,91	12,86	14,73
Consentration of PBZ (ppm)	Number of Leave (leaf plant^{-1}) at DAT				
	7	14	21	28	35
0	1,85	6,53	11,07 a	13,38 a	15,09 a
50	1,88	6,20	11,73 ab	13,71 ab	16,38 a
100	1,86	6,36	12,37 ab	15,07 abc	16,51 a
150	1,89	6,43	13,08 b	15,55 bc	19,87 b
200	1,86	6,38	13,27 b	16,73 c	21,85 b
LSD- P (5%)	ns	ns	1,552	1,944	3,221
CoV-P (%)	12,43	12,61	10,31	10,67	14,67

Legend: means followed by different letters are significantly different by a LSD test at α = 0.05, ns = not significantly different, CoV= Coefisien of Varians

The results showed that the application of NAA showed no significant effect on the number of leaves of zucchini plants at all observation times. Beside that, PBZ application at higher concentrations consistently increased the number of leaves significantly, especially at the highest concentration. The increase in leaf number was most prominent at older plant ages, with a more pronounced effect at higher PBZ concentrations compared with other treatments.

The results of the analysis of variance the leaf area observations in there is no interaction between the provision of NAA and PBZ concentration. The provision of NAA showed no significant difference at 7, 14, 21, 28 and 35 DAT on the addition of leaf area. Meanwhile, the provision of PBZ concentration was able to give a significant difference to the area of zucchini leaves at of 21, 28 and 35 DAT (Table 3).

Table 3: The Effect of NAA and Various Concentrations of PBZ on Leaf Area of Zukini NAA Leaf area (cm^2 plant^{-1}) at DAT

NAA	Leaf Area (cm^2 plant^{-1}) at DAT				
	7	14	21	28	35
Without NAA	51,56	363	1034	1556	2198
With NAA	51,78	362	1091	1758	2480
LSD-N (5%)	ns	ns	ns	ns	ns
CoV-N(%)	10,45	12,50	11,16	11,32	9,671
Consentration of PBZ (ppm)	Leaf Area (cm^2 plant^{-1}) at DAT				
	7	14	21	28	35
0	50,12	365,9	1217 c	2192 d	2823 c
50	52,55	363,0	1153 bc	1650 c	2567 bc
100	51,55	364,5	1044 ab	1608 bc	2299 ab
150	52,62	359,6	1003 ab	1448 ab	2024 a
200	51,53	357,6	894,7 a	1388 a	1983 a

LSD- P (5%)	ns	ns	171,9	183,2	373,1
CoV-P (%)	13,47	9,210	13,22	9,040	13,03

Legend: means followed by different letters are significantly different by a LSD test at α = 0.05, ns = not significantly different, CoV= Coefisien of Varians

The result NAA application showed no significant impact on the leaf area of zucchini plants at all observation times. Beside that, PBZ application especially at high concentrations had significantly reduced leaf area. This reduction in leaf area became more pronounced at higher PBZ concentrations especially at older plant ages, compared to treatments without PBZ or with lower PBZ concentrations. The leaf area reduction effect was most pronounced at the highest PBZ concentration.

Table 4: The Effect of NAA and Various Concentrations of PBZ on Flowering, Number of Female and Male Flowers, Female Flower Ratio, Number of Fruits and Fruit Set in zucchini Plants

NAA	Flower Blooming (DAT)	Number of Male Flower (flower plant^{-1})	Number of Female Flower (flower plant^{-1})	Flower Ratio	Number of Fruits (fruit plant^{-1})	Fruit Set (%)
Without NAA	23,24	14,00 A	13,70	1,061	8,730	65,17
With NAA	23,28	16,33 B	14,50	1,169	9,510	58,25
LSD-N (5%)	ns	2,254	ns	ns	ns	ns
CoV-N(%)	4,041	9,460	10,70	9,222	9,980	9,440
Consentration of PBZ (ppm)	Flower Blooming (DAT)	Number of Male Flower (flower plant^{-1})	Number of Female Flower (flower plant^{-1})	Flower Ratio	Number of Fruits (fruit plant^{-1})	Fruit Set (%)
0	22,76	11,50 a	16,17 c	0,705 a	7,001 a	65,50
50	23,42	14,25 b	15,08 c	0,952 b	8,120 ab	58,58
100	23,45	15,67 bc	14,58 bc	1,082 bc	9,330 bc	61,53
150	23,34	17,08 c	13,25 b	1,304 cd	10,25 cd	59,84
200	23,36	17,33 c	11,42 a	1,533 d	10,91 d	62,92
LSD- P (5%)	ns	2,443	1,782	0,236	1,495	ns
CoV-P (%)	1,750	13,16	10,32	17,32	13,39	19,77

Legend: means followed by different letters are significantly different by a LSD test at α = 0.05, ns = not significantly different, CoV= Coefisien of Varians

There is no interaction between the provision of NAA and PBZ concentration. On Table 4 in the provision of NAA showed significantly different in the observation of the number of female flowers, but not significantly different in the observation of flowering age, number of male flowers, female flower ratio, number of fruits and fruit set. Meanwhile, the provision of PBZ concentration is able to provide significantly different on the observation of flowering age, the number of female and male flowers, the ratio of female flowers, the number of fruits but not significantly different on the observation of fruit set NAA did not accelerate flowering age but significantly increased the number of female flowers.

PBZ application, especially at concentrations of 150 and 200 ppm, also increased the number of female flowers, while the number of male flowers was reduced at the highest PBZ concentration. PBZ application at 200 ppm increased the ratio of female flowers, and NAA application had no significant effect on the ratio. In addition, PBZ at high concentrations increased fruit set, although NAA had no significant effect on fruit set.

3.2. Effect of NAA and Various Concentrations of PBZ on Zucchini Harvest

The results of analysis of variance of fruit length observations in there is an interaction between the provision of NAA and PBZ concentration. Separately, the administration of NAA showed significantly different on fruit length. In addition, the concentration of PNZ showed significantly different on fruit length (Table 5).

Table 5: Interaction between NAA and Various Concentrations of PBZ on Zucchini Fruit Length

NAA	Fruit Length (cm)				
	Consentration of PBZ (ppm)				
	0	50	100	150	200
Without NAA	25,33 a	26,89 ab	28,78 ab	30,22 b	26,67 ab
	A	A	A	A	A
With NAA	21,67 a	28,42 b	29,18 b	30,71 b	31,69 b
	A	A	A	A	B
LSD (%)	3,659				
CoV-N (%)	9,161				
CoV-P (%)	7,560				

Legend: Numbers accompanied by the same uppercase letter in the same column and the same lowercase letter in the same row show no significant difference based on 5% LSD test, ns = not significantly different

The application of PBZ at a high concentration (200 ppm) without NAA significantly reduced the length of zucchinifruit, while the application of NAA at the same PBZ concentration reduced the impact of the reduction. An increase in PBZ concentration generally affected fruit length, whether in treatments with or without NAA. At a concentration of 150 ppm without NAA, fruits showed a significant increase in length compared to the treatment without PBZ. In addition, application of PBZ at various concentrations with NAA resulted in longer fruits, with the highest increase in length at 200 ppm PBZ concentration.

The results of the analysis of variance of fruit diameter observations in there is no interaction between the administration of NAA and PBZ concentration. Separately, the provision of NAA showed significantly different on the addition of fruit diameter. Meanwhile, the provision of PBZ concentration is able to give a significant difference to the diameter of zucchini fruit (Table 6).

Table 6: The Effect of NAA and Various Concentrations of PBZ on fruit diameter of zucchini

NAA	Fruit Diameter (mm)
Without NAA	61,60 A
With NAA	69,58 B
LSD-N (5%)	ns
CoV-N(%)	7,600
Consentration of PBZ (ppm)	Fruit Diameter (mm)
0	61,63 a
50	63,63 ab
100	66,51 abc
150	69,07 bc
200	67,20 c
LSD- P (5%)	4,886
CoV-P (%)	6,090

Legend: Means followed by different letters are significantly different by a LSD test at α = 0.05, ns = not significantly different, CoV= Coefisien of Varians

Fruit diameter was significantly different between NAA and PBZ concentrations. NAA increased fruit diameter more, while PBZ at 200 ppm concentration also showed a significant increase compared to several treatments, but there was no significant difference at 100 and 150 ppm concentrations.

The results of analysis of variance of observations of fresh fruit weight and fruit weight per plant in there is an interaction between the provision of NAA and PBZ concentration. Separately, the provision of NAA showed significantly different to the weight of fresh fruit and large fruit per plant. In addition, the application of PBZ concentration showed significantly different on fresh fruit weight and fruit wight per plant (Table 7).

Table 7: Interaction between NAA and Various Concentrations of PBZ on Zucchini Fresh fruit weight and fruit weight per plant

NAA	Fresh fruit weight (g fruit^{-1})				
	Consentration of PBZ (ppm)				
	0	50	100	150	200
Without NAA	430,4 a A	570,2 b A	572,8 b A	735,7 c A	543,0 b A
With NAA	740,4 bc B	684,3 a B	721,0 ab B	749,0 bc A	778,6 c B
LSD (%)	77,24				
CoV-N (%)	6,34				
CoV-P (%)	6,84				
	Fruit Weight (g plant^{-1})				
NAA	Consentration of PBZ (ppm)				
	0	50	100	150	200
Without NAA	3013 a A	4656 b A	4964 bc A	6989 d A	5610 c A
With NAA	5182 a B	5520 a B	7210 b B	8239 c B	8953 d B
LSD (%)	673,9				
CoV-N (%)	6,060				
CoV-P (%)	6,450				

Legend: Numbers accompanied by the same uppercase letter in the same column and the same lowercase letter in the same row show no significant difference based on 5% LSD test, ns = not significantly different

Fresh fruit weight and fruit weight per plant are significantly different between the treatment without NAA and with NAA application at various PBZ concentrations. The treatment without NAA showed heavier weight than the treatment with NAA at most PBZ concentrations. PBZ concentrations of 150 ppm in the treatment without NAA and 200 ppm in the treatment with NAA also showed a significant increase in weight compared to other treatments, while there were no significant differences at certain concentrations.

Table 8: Interaction between NAA and Various Concentrations of PBZ on Zucchini harvest index

NAA	Harvest Index (%)				
	Consentration of PBZ (ppm)				
	0	50	100	150	200

Without NAA	0,966 a A	0,972 b A	0,979 c A	0,987 e A	0,983 d A
With NAA	0,976 a B	0,979 a B	0,983 b B	0,988 c A	0,989 c B
LSD (%)			0,003		
CoV-N (%)			0,166		
CoV-P (%)			0,158		

Legend: Numbers accompanied by the same uppercase letter in the same column and the same lowercase letter in the same row show no significant difference based on 5% LSD test, ns = not significantly different

The results of the analysis of variance of harvest index observations in there is an interaction between the provision of NAA and PBZ concentration. Separately, the application of NAA showed significantly different to the harvest index of zucchini. In addition, the PBZ concentration showed significantly different on the harvest index of zucchini (Table 8).

Application of NAA and PBZ at various concentrations significantly affected the harvest index of zucchini. Increasing PBZ concentration showed significant differences in harvest index both with and without NAA. In the treatment without NAA, 150 ppm PBZ concentration produced the highest harvest index with a significant increase compared to other concentrations. Meanwhile, when NAA was applied, PBZ concentrations of 150 and 200 ppm showed a higher harvest index and were significantly different from PBZ concentrations of 0, 50, and 100 ppm.

IV. DISCUSSION

The results showed that the application of NAA and various concentrations of PBZ had a significant effect on the growth and yield of zucchini plants. There was a significant effect on plant length, number and area of leaves, stem length, number of female and male flowers, female flower ratio, and number of fruits. Meanwhile, the application of NAA with 100 ppm PBZ affected the age of female flowering, although it did not have a significant impact on fruit set. In the weight.

The study showed that the application of NAA had no significant effect on the length of zucchini plants at the age of 35 DAT, with the average length without NAA (51.32 cm) and with NAA (52.72 cm). In contrast, the application of PBZ with a concentration of 200 ppm showed a significant decrease in plant length compared to the control without PBZ, from 64.22 cm to 45.06 cm, which means a decrease of 42.52%. Paclobutrazol (PBZ) inhibits the biosynthesis of gibberellin, a hormone responsible for cell elongation and division, thus slowing the growth of zucchini plants (Degarajan, 2014). PBZ increases the activity of cellulase and pectinase enzymes, which break down cell walls and stems to become shorter but fuller. Pectinase enzymes hydrolyze pectin, making the cell wall more flexible, while cellulase decomposes cellulose, improving nutrient access and accelerating nutrient translocation to other organs, as well as producing carbohydrates as an energy source. As a result, plants grow fuller with more flexible but shorter stems (Seleim et al., 2015).

The decrease in plant length is also caused the absorption of PBZ which affects the plant canopy, so that the growth of new shoots is inhibited, The effect of PBZ in inhibiting similar growth was found in the research on potato plants with a concentration of 150 ppm. which recorded a 23.4% decrease in zucchini plant height upon PBZ application.) also found that PBZ can inhibit gibberellin biosynthesis in rice plants, resulting in significantly inhibited growth (Zhang et al., 2020)

The study also showed that the application of NAA had no significant effect on the number of zucchini leaves at the age of 35 DAT, with the average number of leaves without NAA (18.44) and with NAA (17.44). However, the application of PBZ at concentrations 200 ppm and 150 ppm showed a significant effect, with the number of leaves 21.85 and 19.87 respectively, while the control without PBZ had 64.22 leaves. This decrease in the number of leaves amounted to 24.06% and 30.94%. PBZ works by inhibiting the production of gibberellin, a hormone responsible for cell elongation, thus slowing stem growth and directing energy to leaf formation (Yuliadi et al., 2012). This mechanism is also supported an increase in the activity of cellulase and pectinase enzymes, which break down cell walls and improve nutrient translocation, and convert cellulose into carbohydrates that become a source of energy for plants, helping to increase the number of leaves (Putri et al., 2023; Gusmawan et al., 2018). PBZ inhibits gibberellin biosynthesis by suppressing the enzyme kaurene synthase, which prevents the formation of kaurenoate, thus inhibiting cell elongation and stem internodes. This diverts plant resources to increase the number of leaves, as also found in the research of Anggraeni et al. (2015), which reported a significant increase in leaf number at various PBZ concentrations, including 2.71 additional leaves at 20 ppm PBZ. However, the increase in leaf number decreased at PBZ concentrations higher than 500 ppm (Yuliadi et al., 2012).

The application of NAA has no significant effect on the leaf area of zucchini plants at the age of 35 DAT with an average leaf area without NAA (2198 cm²) and with NAA (1983 cm²). However, the application of PBZ at a concentration of 200 ppm showed a significant effect, with a leaf area reaching 2823 cm², which decreased by 42.38% compared to the control without PBZ. PBZ works by inhibiting gibberellin biosynthesis through inhibition of the enzyme ent-kaurene oxidase, which reduces active gibberellin levels in plants. This reduction in gibberellin impacts growth patterns, including a decrease in leaf area and an increase in leaf thickness (Hedden et al., 2021). Smaller and thicker leaves reduce total photosynthetic capacity, although water use efficiency increases due to thicker leaf morphology (Al-Munqedhi et al., 2021).

The reduction in leaf area is mainly due to a decrease in cell size, not cell number. This results in a decrease in light penetration and overall photosynthetic capacity, although leaf thickness increases with more chloroplasts per unit area. Research by Kumar et al. (2021) also showed that PBZ significantly reduced leaf area in tomato and chili plants, with changes in leaf morphology to become thicker and darker green.

Zucchini stem length have decreased significantly due to PBZ application, especially at concentrations of 100 and 150 ppm. At 28 DAT, the stem length decreased by 25.97% and 51.93% without NAA. However, NAA application can reduce this decrease, especially at 100 and 150 ppm PBZ. At 35 DAT, a decrease in stem length was also seen at PBZ concentrations of 0 and 50 ppm, with a decrease of 18.66% and 6.22%, but the effect of NAA helped maintain stem length. NAA increases amino acid and protein synthesis, and stimulates cell division, while also working with cytokinin hormones for stem growth. Activation of signal transduction pathways by NAA induces the expression of cell growth-related genes, facilitating plant stem elongation through expansin and hydrolytic enzymes (Rademacher, 2020). PBZ at concentration of 200 ppm showed a significant effect in inhibiting stem elongation, both the treatment with and without applying NAA, with a reduction of 100.7% and 130.3% at 28 DAT, and 118.32% and 111.1% at 35 DAT, respectively. This study shows that PBZ, as an inhibitor of gibberellin synthesis, slows down and inhibit stem growth, while this effect can be slightly reduced by NAA application .

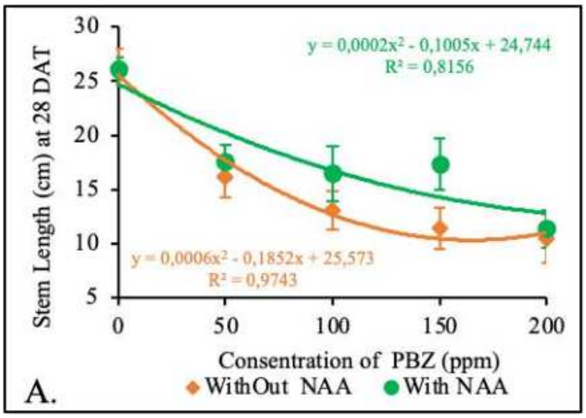
PBZ inhibits the biosynthesis of gibberellin, an important hormone in stem elongation and flowering. Through the inhibition of key enzymes such as Copalyl Diphosphate Synthase (CDS), Kaurene Synthase (KS), and Kaurene Oxidase (KO), PBZ prevents the conversion of isoprenoid precursors to active gibberellins, inhibiting vegetative growth (Al-Munqedhi et al., 2021).

Fig 2 Relationship between the Application of NAA and Various Concentrations of PBZ on the Stem Length of Zucchini at A. 28 DAT and B. 35 DAT. The higher the concentration of PBZ with combination to the treatment without NAA and the application NAA then showed a significant decreased in the value of the stem length of zucchini plants. However, the treatment without NAA showed a shorter stem length value than the treatment with application NAA.

Based on the results of the regression test showed that the treatment had a significant effect on the stem length of zucchini plants. The following below is the relationship between the application of NAA with various concentrations of PBZ on the stem length of zucchini plants.

NAA and PBZ have an antagonistic relationship, NAA functions as a growth stimulator, while PBZ functions as a growth inhibitor. NAA can increased zucchini stem length by affecting protein synthesis and root development. This hormone also plays a role in activating enzymes that play a role in the synthesis of important compounds such as amino acids. Meanwhile, increased the concentration of PBZ can decrese the zucchini stem length by inhibiting protein synthesis and reducing enzyme activity. This hormone also plays a role in inhibiting root and stem development, and reduces the production of other hormones such as NAA (Hedden, 2021).

The study showed that the application of NAA did not significantly affect the flowering age of zucchini plants, either without NAA (23.24 DAT) or with NAA (23.28 DAT). However, the application of PBZ at a concentration of 200 ppm showed a longer flowering age (23.36 DAT) than without PBZ (22.76 DAT). PBZ inhibits the biosynthesis of gibberellin, a hormone that plays a role in the transition from the vegetative phase to the generative phase, thus extending the flowering time (Flores et al., 2018). The higher the concentration of PBZ, the greater the effect on delaying flowering age, as lower gibberellins cause a delay in the transition to flower formation.



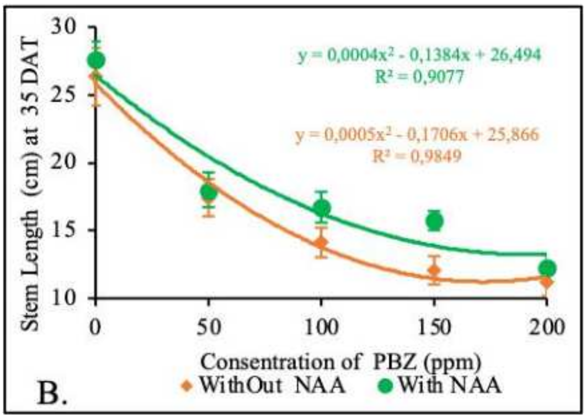


Fig. 2 Relationship between the Application of NAA and Various Concentrations of PBZ on the Stem Length of Zucchini at A. 28 DAT and B. 35 DAT

The results showed that the application of NAA increased the number of female flowers from 14.00 flowers plant^{-1} without NAA to 16.33 flowers plant^{-1} with NAA, with an increase of 14.27%. Synthetic auxins, such as NAA to stimulate female flower formation by modulating the expression of genes involved in flower development and cell differentiation (Singh et al., 2021). In addition, the interaction of NAA with ethylene accelerates the development of female flowers and inhibits the formation of male flowers (Rahmawati et al., 2020). The application of PBZ at a concentration of 200 ppm also significantly increased the number of female flowers (17.33 flowers plant^{-1}), which showed an increase of 33.64%. PBZ reduces gibberellin levels that usually promote male flowers, so more female flowers are formed (Zhang et al., 2021).

NAA application showed no significant effect on the number of male flowers at Table 4 either without NAA (13.70 flowers plant^{-1}) or with NAA (14.50 flowers plant^{-1}). However, PBZ had a significant effect, reducing the number of male flowers from 16.17 flowers plant^{-1} (without PBZ) to 11.42 flowers plant^{-1} (with PBZ), showing a decrease of 41.52%. PBZ works as a gibberellin inhibitor that usually stimulates male flower formation. By reducing gibberellin levels, PBZ inhibits the formation of male flowers and increases the number of female flowers (Wang et al., 2021). This study found that the ratio of female flowers was not significantly different in the treatments without NAA (1.061) and with NAA (1.169). Although NAA has the potential to increase auxins that stimulate the formation of female flowers, in this case, the administration of NAA did not have a significant effect, possibly due to the inappropriate timing of NAA administration (Lee et al., 2020). In contrast, the administration of PBZ at a concentration of 200 ppm increased the ratio of female flowers to 1.533 compared to the treatment without PBZ (0.705), with an increase of 54.02%. This is because PBZ suppresses gibberellin levels, which encourage the formation of male flowers, thus increasing the proportion of female flowers (Aghaalikhani et al., 2012).

NAA application did not have a significant effect on the number of fruits at Table 4, with an average without NAA (8.73 fruits plant^{-1}) and with NAA (9.51 fruits plant^{-1}). In theory, NAA can extend the life span of female flowers, increasing the chances of pollination success (Li et al., 2019), but in this study, environmental factors such as suboptimal temperature or humidity might limit the effect of NAA on fruit set (Zhang et al., 2021). On the other hand, PBZ showed a more pronounced effect on fruit number. PBZ application is able to inhibit gibberellins so that more resources are allocated to fruit formation, increasing the number of fruits formed (Rahimi et al., 2018). PBZ inhibits the enzymes ent-kaurene oxidase and Gibberellin 20-oxidase in the gibberellin biosynthesis pathway, which decreases the production of active gibberellin. With reduced gibberellin levels, PBZ not only slows vegetative growth but also promotes the differentiation of female flowers over male flowers (Chen et al., 2020). This gibberellin inhibition also affects the transition from vegetative to generative phase, making zucchini plants more efficient in using energy for fruit production rather than excessive vegetative growth. Auxins, such as NAA, interact with ethylene to stimulate the formation of female flowers and inhibit male flowers. Ethylene is known to accelerate the maturation of female flowers, while auxin regulates hormonal balance by increasing the expression of genes involved in female flower differentiation (Singh et al., 2021).

The increase in ethylene after NAA application leads to a decrease in male flowers, thus increasing the proportion of female flowers. Research shows that too high a dose of PBZ can cause phytotoxic effects, which reduce plant productivity and damage plant physiology (Kim et al., 2022). Therefore, it is necessary to select the right dose and application time to obtain optimal benefits from PBZ without harming plant productivity. PBZ increases carbohydrate accumulation in leaves and reduces vegetative growth, which allows zucchini plants to allocate more resources to female flower formation and development (Rahimi et al., 2018). PBZ helps improve the efficiency of nutrient transportation through the vessel network, supporting increased production of fruits and female flowers, which may ultimately increase the economic potential of zucchini plants (Zhang et al., 2021).

Based on the results in Table 6, it was found that the interaction between NAA and PBZ affected the fruit length of zucchini. Application of 200 ppm PBZ without NAA produced fruit length of 26.67 cm, while the addition of NAA at the same PBZ concentration increased the fruit length to 31.69 cm, with an increase of 18.82%. PBZ inhibits the biosynthesis of gibberellin, an important hormone in cell elongation, while NAA stimulates growth by increase cell division and elongation (Kurepin et al., 2019). This study also showed that in the treatment without NAA, PBZ 150 ppm produced the longest fruit length (30.22 cm), an increase of 23.38% compared to the control (25.33 cm). In contrast, in the treatment with NAA, the highest fruit length was achieved at 200 ppm PBZ, with an increase of 31.62% compared to the control. These results suggest that NAA can compensate for the inhibition of gibberellin by PBZ, resulting in optimal fruit length at higher PBZ concentrations (Thomas et al., 2018). NAA and PBZ also affect enzymatic activity, PBZ inhibits enzymes involved in gibberellin synthesis, while NAA increases the activity of enzymes that trigger cell elongation (Taiz et al., 2018). This interaction creates balanced hormonal conditions, favoring optimal fruit growth. At 200 ppm PBZ, NAA is able to neutralize the inhibitory effect of PBZ, so that the fruit can grow longer. addition, the effect of PBZ and NAA on fruit length is related to the increase in secondary metabolites, such as flavonoids and phenolics, which play a role in plant resistance and fruit quality (Abebie et al., 2020). The optimal interaction of PBZ and NAA produces the best fruit length, with 150 ppm PBZ concentration without NAA and 200 ppm PBZ with NAA showing maximum results. Adjustment of PBZ and NAA dosage is important to optimize agricultural yield and quality of zucchini fruit.

Based on the results in Table 6, the diameter of zucchini fruit did not show a significant interaction, but the application of NAA increased the diameter to 69.58 mm, an increase of 11.47% compared to without NAA (61.60 mm). NAA, as an auxin, stimulates cell division and expansion in the pericarp, allowing cells to absorb more water and nutrients, thus increasing cell size. NAA application also increases the efficiency of nutrient transportation to the fruit (Hasanuzzaman et al., 2020) and contributes to fruit quality by strengthening cell walls (Wang et al., 2019). NAA interacts with other hormones, such as gibberellins and cytokinins, to create synergistic effects in fruit growth, Application of PBZ at a concentration of 200 ppm resulted in a diameter of 67.20 mm, an increase of 8.29% compared to 61.63 mm in the absence of PBZ. PBZ also increases water use efficiency and nutrient distribution to the fruit and affects cytokinin levels that support cell division (Smith et al., 2020). Overall, PBZ directs nutrient distribution to the fruit, increasing their size and quality, with a 16% increase in diameter in Rademacher's (2020) study. Further research is needed to understand the interaction between PBZ and environmental factors and optimize PBZ concentration.

Based on Fig. 3, the treatment of naphthalenacetic acid (NAA) and paclobutrazol (PBZ) on the harvest index of zucchinis, the results showed that this combination had a significant effect in increasing yield.

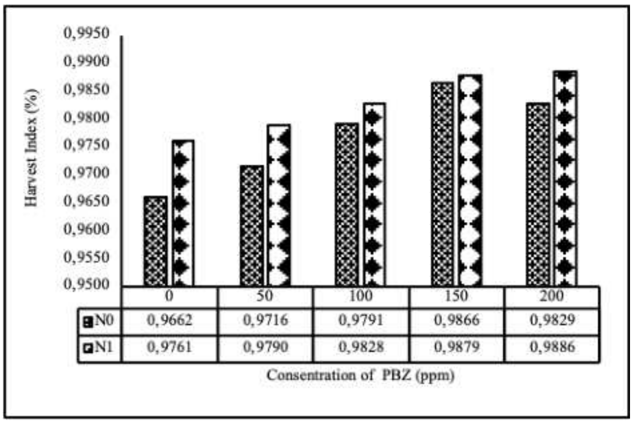


Fig 3. Relationship between the Application of NAA and Various Concentrations of PBZ on the fruit fresh weight and fruit weight per plant of Zucchini

The application of PBZ without NAA resulted in significant variations in harvest index at different PBZ concentrations. Without NAA, the harvest index increased from 0.966 at 0 ppm PBZ to 0.987 at 150 ppm, indicating an increase in photosynthetic efficiency with increasing PBZ concentration. However, at 200 ppm, there was a slight decrease in harvest index to 0.983. This suggests that too high a concentration of PBZ might have a saturating effect or inhibit some aspects of plant metabolism, resulting in a slight decrease in photosynthetic efficiency at the highest level. Beside that, the treatment with NAA, the harvest index at 0 ppm PBZ concentration reached 0.976 and continued to increase to 0.989 at 200 ppm concentration. These results indicate that the combination of NAA and PBZ at various concentrations has a synergistic effect that increases the efficiency of photosynthetic yield utilization by plants, resulting in a higher harvest index than without NAA.

The application of NAA and PBZ had a significant impact on harvest index in zucchini plants. A higher harvest index in PBZ and NAA treatments indicates a better efficiency of photosynthesis yield utilization for fruit formation. an increase in harvest index is generally caused a change in the allocation of assimilate from vegetative growth to generative organs, which in this case are zucchini fruits. This effect was apparent at 150 ppm PBZ concentration without NAA and 200 ppm PBZ concentration with NAA, which produced the highest harvest index. PBZ as an inhibitor of gibberellin biosynthesis, inhibits plant vegetative growth by reducing stem elongation and increasing stress resistance (Fletcher et al., 2015). In this study, the application of PBZ without NAA resulted in an increased harvest index at a concentration of 150 ppm, indicating that at this concentration, vegetative growth was optimally reduced, so that more energy was used for fruit formation. However, at 200 ppm PBZ concentration, the harvest index slightly decreased. Sharma et al. (2017) noted that too high a dose of PBZ can excessively inhibit plant metabolism, causing a reduction in photosynthetic efficiency and assimilate distribution, thereby lowering the harvest index.

A higher harvest index indicates that zucchini plants are more efficient in utilizing photosynthetic products for fruit production, which in turn increases the economic value of the plants. Based on the table, the combination of NAA and PBZ, especially at higher concentrations of PBZ, significantly increased plant efficiency. This means that in cultivation practices, the application of growth regulators such as NAA and PBZ can be an effective strategy to economically increase zucchini yield. The results of this study are in line with previous findings stating that PBZ is able to reduce plant height, increase harvest index, and stimulate fruit formation through regulating assimilate distribution (Rademacher, 2015). In addition, the use of NAA has been shown to play an important role in increasing photosynthetic efficiency through regulating cell division and fruit elongation, which also increases yield (Taiz & Zeiger, 2018). From the results shown in Table 8, it is clear that the interaction between NAA and PBZ significantly affected the harvest index of zucchini plants. Application of NAA together with PBZ resulted in a higher harvest index, which means that the plants were able to utilize photosynthetic products more efficiently for fruit production. This increase in harvest index indicates that the combination of NAA and PBZ can significantly increase the yield of zucchini plants, improve photosynthetic efficiency, and ultimately contribute to an increase in the economic value of the plants.

The application of NAA and PBZ with various concentrations affects biomass partitioning in zucchini plants, especially in the dry weight of roots, stems, and leaves. In this study, it was found that the treatment without NAA with 50 ppm. PBZ produced dry weight of roots, stems, and leaves of 26.6 g, 50.2 g, and 59.2 g, respectively. Meanwhile, at 100 ppm PBZ concentration, the root dry weight remained 26.6 g, but the stem and leaf weight decreased to 26.4 g and 52.5 g, respectively. A more significant decrease in stem and leaf dry weight occurred at 200 ppm PBZ concentration, where root dry weight dropped to 22.4 g, while at 150 ppm PBZ, stem and leaf weight dropped to 30.9 g and 39.6 g, respectively.

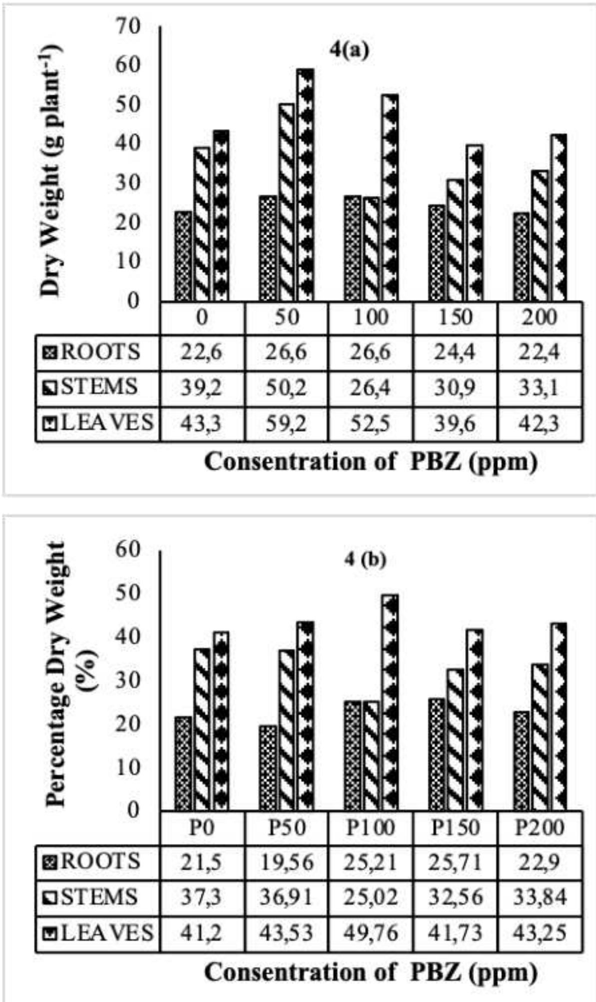
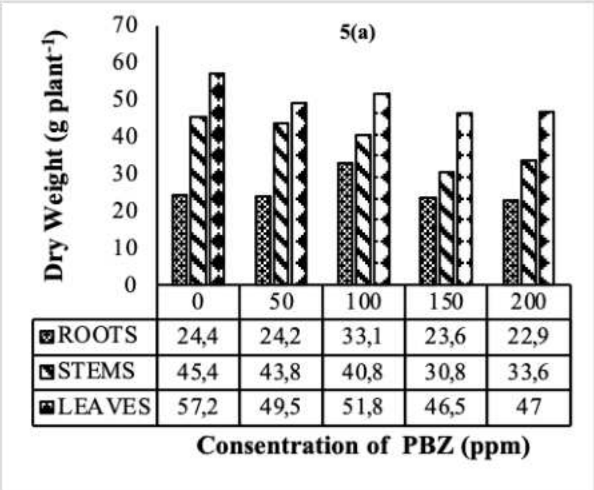


Fig 4. Dry weight (4a), percentage dry weight (4b) of roots, stems, and leaves treated with out NAA and applying various concentrations of PBZ

Consentration PBZ of 50 ppm have the highest dry weight of roots, stems, and leaves, while the lowest dry weight for all plant parts (roots, stems and leaves) is obtained in plants given 150 ppm PBZ concentration. However, the percentage of biomass between plant parts or organs (4b), the partition of biomass obtained is not always in line with the quantity of dry weight. The results showed that the percentage of root dry weight in plants treated with 150 ppm PBZ concentration was higher than that treated with 50 ppm PBZ concentration.



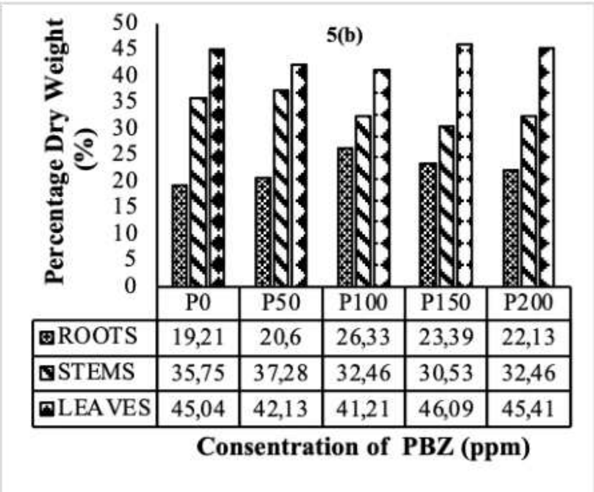


Fig 5. Dry weight (5a), percentage dry weight (5b) of roots, stems, and leaves treated with applying NAA and various concentrations of PBZ

The provision of NAA and PBZ concentration of 0 ppm gave the highest dry weight of roots, stems, and leaves, while the lowest dry weight for all parts of the plant (roots, stems and leaves) was obtained in plants given at the provision of NAA and PBZ concentration of 150 ppm. Fig. 5(a) shows the effect of NAA application at various concentrations of PBZ on plant dry weight. At 0 ppm PBZ, the dry weight of roots, stems, and leaves were 24.4 g, 45.4 g, and 57.2 g, respectively. However, at 200 ppm PBZ, stem and leaf dry weight decreased to 33.6 g and 47 g, while root weight increased at 100 ppm PBZ before decreasing again at 150 and 200 ppm PBZ.

However, when analyzed based on the percentage of biomass between plant parts or organs (5b), the partition of biomass obtained is not always in line with the quantity of dry weight. The results showed that the percentage of root dry weight in plants given NAA and 100 ppm PBZ concentration was actually higher than those given NAA and 0 ppm PBZ concentration.

The decrease in stem weight was caused by the inhibition of gibberellin biosynthesis by PBZ, a hormone important in plant cell elongation. This resulted in shorter and more compact plants. At 100 ppm PBZ, the percentage of leaf weight increased to 49.76%, which was due to a greater allocation of resources to the leaves than the stems, resulting in the leaves having a greater proportion in the biomass. Recent studies have also confirmed that PBZ not only inhibits the vertical growth of plants, but also helps plants adapt to environmental stress. According to Zhang et al. (2023), PBZ increases water use efficiency and plant resistance to abiotic stress. In addition, PBZ reduced gibberellin (GA) levels and increased abscisic acid (ABA) levels, which enhanced root biomass stability and plant resistance to unfavorable environmental conditions.

V. CONCLUSION

Applying NAA had no significant impact on zucchini growth, but increased the number of female flowers and fruit size, while PBZ effectively inhibited vegetative growth by reducing stem length and leaf area, and increased fruit production by diverting resources to female flower formation. The combination of NAA and PBZ exerted a synergistic effect, NAA helped mitigate PBZ inhibition of stem growth. In addition, this study also showed PBZ affected biomass partitioning by directing more resources to the roots and leaves, while NAA helped improve nutrient distribution to the stem and fruit. In addition, the combination of NAA and PBZ was shown to increase harvest index, with PBZ concentration the 150 ppm providing a significant increase in plant yield. Further research is needed to understand the interaction of these hormones and their impact on plant resilience and long-term productivity and to optimize combination of these two hormones to achieve maximum yield without compromising long-term productivity.

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Survey and Effects of Weather Parameters on Powdery Mildew of Black Gram Caused by *Erysiphe Polygoni* DC

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***Abstract*— *Surveys were conducted during kharif 2018 in ten villages viz., Gandholi, Noorda, Joonawas, Odwariya, Banora, Malpur, Panarwa, Oda, Khandiovri and Sundara of four tehsil's (Mavli, Salumbar, Jhadol and Kherwara) of Udaipur district. The maximum (54.67%) disease incidence was recorded in Joonawas village (Mavli tehsil) with 43.22% disease severity while, minimum incidence 25.40% with 19.54% severity from Malpur village (Salumber tehsil). Study of weather parameters in relation to powdery mildew development revealed that, the maximum disease severity (8.67-58%) was found during July 30- Sept 2, 2018. During this period the maximum temperature (29.1-30.5˚c), minimum temperature (22-22.9˚c), maximum relative humidity (82.6-85.1%), minimum relative humidity (58.6-78.3%), sunshine (1.2-3.6 hours) and rainfall (17.4-67.6 mm) was favoured for powdery mildew development.*

***Keywords*— Survey, Weather, Powdery Mildew, Black Gram, Erysiphe Polygoni.**

I. INTRODUCTION

Black gram [*Vigna mungo* (L.) Hepper] is the most important grain legumes. It is from *Fabaceae* family with 2n=22 Chromosomes and it is believed to have originated in India (Chatterjee and Bhattacharya, 1986). Black gram cultivation is suitable for hot and moist weather condition. Black gram is well known protein rich *kharif* pulse crop in India, which is approximately three times richer than cereals (Kanade, 2006). It is the most important pulse crop in India as it is produced about 2.83 million tonnes annually from about 44.78 lakh hectares of area and an average productivity is 632 kg per hectare (Anon., 2017a).

Black gram is attacked by several diseases like- Anthracnose- *Colletotrichum lindemuthianum* (Sacc. and Magnus) Briosi and Cavara, Bacterial leaf blight- *Xanthomonas phaseoli* (Dowson), *Cercospora* leaf spot- *Cercospora canescens* (Ellis and Martin), Powdery mildew- *Erysiphe polygoni* (De Candolle), Root rot- *Rhizoctonia solani* (Kuhn), Rust- *Uromyces phaseoli* (Winter), *Macrophomina* blight- *Macrophomina phaseolina* (Tassi) Goid., Yellow mosaic disease- *Mungbean yellow mosaic virus* and Leaf crinkle disease - *Leaf crinkle virus* (Anon., 2014). Powdery mildew of black gram incited by *Erysiphe polygoni* (De Candolle) is the major problem in black gram production, it causes both quantitative and qualitative losses of grains. This disease has been observed severe mainly in late sown *kharif* crop and remains active throughout the year. The powdery mildew disease interferes in photosynthetic activity and causes significant physiological changes in plants, which causes reduction in yield (20-40 per cent) depending on the stage and time at which the disease appears (Legapsi *et al*., 1978; Singh, 1995).

II. MATERIALS AND METHODS

The investigations on "Epidemiology of Powdery Mildew of Black Gram Caused by *Erysiphe polygoni* DC" was conducted during *Kharif* 2018. The laboratory studies were carried out in the Plant Pathology Department and the field experiments were conducted at agronomy farm of RCA, MPUAT, Udaipur. The detailed information of experimental techniques and materials used for these studies are described below.

Surveys were carried out to know the occurrence and incidence of powdery mildew of black gram disease at farmers' fields of Udaipur district during *kharif* season

2018. In Udaipur district randomly ten black gram growing villages *viz*., Gandholi, Noorda, Joonawas, Odwariya, Banora, Malpur, Panarwa, Oda, Khandiovri and Sundara from four tehsils (Mavli, Salumber, Jadhol and Kherwara) were surveyed to record the incidence and severity of powdery mildew disease. In each field, four plots of 1 m×1 m area were randomly selected and the powdery mildew incidence was recorded by counting the total number of plants and the infected plants in the selected area. The per cent disease incidence was calculated by the following formula:

$$\text{Per cent disease incidence} = \frac{\text{Total number of diseased plants}}{\text{Total number of plants observed}} \times 100$$

Powdery mildew severity was recorded by observing leaf area covered by the pathogen on the plants in selected areas. Powdery mildew disease severity was recorded by 0 to 5 rating scale of Gawande and Patil (2003). Where, 0 = No infection; 1= 0.1-10.0 % leaf area infection, 2 = 10.1-25 % leaf area infection, 3 = 25.1-50 % leaf area infection, 4 = 50.1-75 % leaf area infection, 5 = >75.1-100 % leaf area infection.

The recorded values were transformed into per cent disease index (PDI) by following formula given by wheeler (1969).

$$\text{Percent disease index} = \frac{\text{Sum of the individual disease ratings}}{\text{No. of leaves observed x Maximum disease grade}} \times 100$$

Identification of the pathogen

Black gram leaves infected with powdery mildew showing the fresh white powdery patches symptoms were collected from field and brought in laboratory to identify the pathogen. With the help of Camel brush, the powdery mass was mounted in the lactophenol on the glass slide. For the identification of the pathogen these mounted slides were examined under low and high-power objective lens of a compound microscope and the pathogen was identified by morphological characters of conidia and mycelium described by (Hans and Boeswinkel, 1980; Basu *et al*., 2006 and Patil *et al*., 2017a).

Effect of environment factors on black gram powdery mildew disease development under field conditions.

Field experiment was conducted in *kharif* 2018 during July to Sept 2018 at Agronomy Farm, Rajasthan college of Agriculture, MPUAT, Udaipur. The experiment was conducted in Randomized block design (RBD) in three replications. The moderately susceptible black gram cultivar "PU 31" was sown at 30 cm × 10 cm distance in four rows of 1.2 m × 3 m (3.6 m^2) size plots. All the agriculture activities were followed as per package and practices. After the initiation of powdery mildew disease symptoms, the observations were started to recorded at seven days interval and continued until disease severity reached maximum up to physiological maturity of the crop on 0-5 rating grade in terms of per cent disease severity (Gawande and Patil, 2003).

The observations for powdery mildew development in relation to effect of weather elements was recorded up to eleven weeks after sowing. Minimum ten plants were randomly selected and tagged in each replication. For observations these tagged plants were assessed for disease progress in each replication. In each plant two upper, two middle and two lower leaves were assessed for powdery mildew development. The weather data *viz.,* maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, sunshine and rainfall were collected from Meteorological observatory unit of Agronomy department, RCA, Udaipur. The statistical analysis [multiple linear regression (Panse and Sukhatme, 1985)] was done based on average weekly data of per cent disease index and average weekly meteorological data using MS Excel Software.

(R^2) $Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6$

Where: -

R^2 = multiple correlation coefficients

Y = per cent disease index (dependent variable)

a = constant (intercept)

b_1, b_2, b_3, b_4, b_5 and b_6 = partial regression coefficients

X_1 = maximum temperature

X_2 = minimum temperature

X_3 = maximum relative humidity

X_4 = minimum relative humidity

X_5 = Sunshine

X_6 = Rainfall

Statistical Analysis

The data from all the experiment were statistically analyzed. For laboratory experiment Completely randomized design (CRD) was followed, while for field experiment the Randomized block design (RBD) was followed. For the epidemiological studies the correlation and regression analysis were calculated between weather parameters and PDI (Per cent disease index).

III. RESULT & DISCUSSION

1. Survey for powdery mildew (*Erysiphe polygoni*) incidence in different black gram growing areas of udaipur district

Surveys were conducted to know the occurrence and incidence of black gram powdery mildew at farmers's fields of Udaipur district during *kharif* season 2018. Ten black gram growing villages (Gandholi, Noorda, Joonawas, Odwariya, Banora, Malpur, Panarwa, Oda, Khandi ovri and Sundara) belongs to four different tehsils (Mavli, Salumber, Jadhol and Kherwara) of Udaipur were selected randemly to record the incidence and severity of powdery mildew disease. In these villages farmers were mostly growing local land race and hybrid varieties *i.e*., PU 31, PU 1 and Azad-3 of black gram (Table-1). In the surveyed villages average per cent disease severity and incidence ranged from 19.54% to 43.22% and 25.40% to 54.67%, respectively. The highest (54.67%) disease incidence was observed in Joonawas village of Mavli tehsil with 43.22 per cent disease severity on "local variety" of black gram followed by Odwariya village (Mavli tehsil) had 50.89% disease incidence with 38.56 per cent disease severity on black gram variety "Pratap urd 1", Sundara village (Kherwara tehsil) (49.23% disease incidence) with 41.90 per cent disease severity on local variety of black gram and Khandi ovri village (Kherwara tehsil) (47.20 % disease incidence) with 39.84 per cent disease severity on local variety, Gandholi village (Mavli tehsil) (45.20% disease incidence) with 39.73 per cent disease severity on black gram variety "Pratap urd 1", Noorda village (Mavli tehsil) (43.40% disease incidence) with 35.91 per cent disease severity on black gram variety "PU 1", Banora village (Salumbar tehsil) (38.45% disease incidence) with 30.25 per cent disease severity on black gram variety "PU 31", Panarwa village (Jadhol tehsil) (34.30% disease incidence) with 27.82 per cent disease severity on black gram variety "PU 31", Oda village (Jadhol tehsil) (33.16% disease incidence) with 25.98 per cent disease severity on black gram variety "PU 31" and lowest disease incidence (25.40%) is recorded in Malpur village of Salumber tehsil with 19.54 per cent disease severity on black gram variety "Azad 3" (Table-2).

Table- 1. Effect of environmental factors on black gram powdery Mildew (Erysiphe polygoni) development under field condition

Week No.	*SMW	Period	Temperature (°C)		R. H. (%)		Sunshine	Rainfall	PDI** (%)
			Max.	Min.	Max.	Min.	(Hrs)	(mm)	
1	29	July 16-22 ,2018	30.1	23	90.9	81	1.2	98.2	0
2	30	July 23-29, 2018	28.2	22.9	82.1	74.6	0.9	2.4	0
3	31	July 30-Aug 5 , 2018	30.5	22.7	75.6	58.6	3.6	0	8.67
4	32	Aug 6-12, 2018	29.6	22.4	85.1	73.9	1.6	27.2	20.67
5	33	Aug 13-19, 2018	30.8	22.9	82.7	72.1	2.8	67.6	36.67
6	34	Aug 20-26, 2018	28.6	22.5	82.6	78.3	1.2	33.6	42.67
7	35	Aug 27-Sept 2, 2018	29.1	22	83.7	74.1	1.7	17.4	58.00
8	36	Sept 3-9, 2018	28.3	21	81.7	69.1	4.1	11	64.00
9	37	Sept 10-16, 2018	27.9	21	83.7	64.7	3.3	8.8	68.00
10	38	Sept 17-23, 2018	32.3	19.6	81.3	52.4	6.5	28.8	81.34

*Standard meteorological week **Per cent disease index; Mean of three replications

Table–2. Survey for powdery mildew (Erysiphe polygoni) incidence in different black gram growing area of Udaipur district

S. No.	Name of Tehsils	Name of village	Black gram cultivar	*Mean Incidence (%)	*Severity (%)
1.	Mavli	Gandholi	Pratap urd 1	45.20 (44.23)	39.73 (39.06)
		Noorda	Pratap urd 1	43.40 (41.19)	35.91 (36.80)

		Joonawas	Local variety	54.67 (47.66)	43.22 (41.09)
		Odwariya	Pratap urd 1	50.89 (45.49)	38.56 (38.37)
2.	Salumbar	Banora	PU 31	38.45 (38.31)	30.25 (33.35)
		Malpur	Azad 3	25.40 (30.25)	19.54 (26.22)
3.	Jhadol	Panarwa	PU 31	34.30 (35.84)	27.82 (31.82)
		Oda	PU 31	33.16 (35.15)	25.98 (30.63)
4.	Kherwara	Khandi ovri	Local variety	47.20 (43.38)	39.84 (39.12)
		Sundara	Local variety	49.23 (44.54)	41.90 (40.32)
SEm±				0.02	0.03
CD *(P=0.05)*				0.06	0.09

*Mean of three replications: Figures given in Parentheses are arcsine √ Per cent angular transformed values

Disease symptoms on black gram plant

The powdery mildew (*E. polygoni*) symptoms on black gram were first appeared as small, white powdery colonies on upper surface of infected leaves. When the disease progressed, these white powdery patches enlarge and joined together and covers both the surface of infected leaves. This white powdery mass consists of mycelium, conidiophores, and conidia. The lower leaves of infected plants turn yellow, later yellow-brown, and finally cover all parts of the plant. In the later stages the white patches turn in dirty grayish and dry.

characteristics of *Erysiphe polygoni*

Morphological characters of black gram powdery mildew pathogen *E. polygoni* were examined in the laboratory. The leaves showing white powdery mass of fungus was scraped with the help of brush and the slide was prepared in lacto phenol and cotton blue than examined under the compound microscope at 40X. The external mycelium was white in colour, hyphae was hyaline, branched and septate. The conidiophores were simple, erect, hyaline in colour and cylindrical at base, bearing conidia singly or in chain at apex. The conidia were unicellular, oval to roundish or barrel shaped and hyaline in colour.

2. Effect of weather elements on black gram powdery mildew (*e. Polygoni*) development under field condition-

To study the relationship between weather parameters (maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, sunshine, rainfall) and powdery mildew development a field experiment was laid out at the agronomy farm of Rajasthan College of Agriculture, Udaipur during *kharif* season July to Sept. 2018. The black gram variety PU 31 was sown in 1.2 m × 3 m size plots at 30 cm × 10 cm in three replications. The relationship between the black gram powdery mildew disease progress and six weather parameters was studied for ten standard meteorological weeks. The data of weather parameters and disease development revealed that the disease was first appeared in first week of august. The observation was recorded after the initiation of disease at seven days interval up to third week of September. The observations of average weekly data of six weather parameters *i.e.* maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, sunshine, rainfall, and average Per cent disease index (PDI) were recorded and then correlated.

Data depicted from (Table-1) revealed that for the development of powdery mildew, the favorable weather elements *viz;* maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, sunshine, and rainfall have in ranged from 27.9 to 32.3˚C, 19.6 to 22.9˚C, 75.6 to 85.1 per cent, 52.4 to 78.3 per cent, 1.2 to 6.5 hrs and 8.8 to 67.6 mm respectively. The disease severity in these data ranged from 8.67 to 81.34 per cent. The maximum disease development in increasing order was observed during standard week 31 to 33 with mean PDI 8.67 to 36.67 per cent. In 34th week the PDI (42.67) was increased with slowly increased rate and again in 35th week, the trend got fluctuated and the PDI (58.0) again increased with increasing rate and after that in 36th week the PDI was 64.0% and in 37th it was 68.0%, again the PDI increased but slowly and in the 38th week PDI was 81.34 with increasing trend.

The results revealed that the correlation between powdery mildew disease severity and maximum temperature (r = +0.064) was found non-significant and positive, Minimum temperature (r = -0.865) was found significant and negative, where as the sunshine (r = +0.664) was found significant and positive correlated with powdery mildew disease severity and the maximum relative humidity (r = -0.158), minimum relative humidity (r = -0.484) and the rainfall (r = -0.250) were found negative and non-significantly correlated with powdery mildew disease severity (Table-1).

The multiple linear regression analysis was done to find out the relationship between six independent variables (maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, sunshine, rainfall) and dependent variable (per cent disease index- PDI). By fitting this equation, the contribution of independent variables in the powdery mildew development was observed.

R^2 $Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6$

$R^2 = 0.8733$ $a = 1859.24$

$b_1 = -5.13$ $b_2 = -48.33$

$b_3 = -7.85$ $b_4 = +0.80$

$b_5 = -13.10$ $b_6 = +0.82$

$(0.87) = 1859.24 - 5.13\ X_1 - 48.33\ X_2 - 7.85\ X_3 + 0.80\ X_4 - 13.10\ X_5 + 0.82\ X_6$

The equation showed that the effect on PDI, if maximum temperature, minimum temperature, morning relative humidity and sunshine increased 1 unit the PDI decreased by 5.13, 48.33, 7.85 and 13.10, respectively. In case of evening relative humidity and rainfall increase in 1 unit the PDI will be increased by 0.80 and 0.82.

The coefficients of determination (R^2) were 0.8733. It indicated that there was 87.33% effect of these six weather elements on powdery mildew of black gram and the remaining 12.67% variations were unexplained. The results revealed that the higher temperature and low humidity favours the disease development.

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Estimation of rice area in KWD region using geospatial tools

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Abstract**—** *The estimation of crop areas was recognized as crucial for assessing agricultural production, supporting food security, and guiding policy decisions. In India, rice cultivation was particularly significant, especially in Andhra Pradesh, where remote sensing technologies like Landsat 9 improved the accuracy of mapping and monitoring crop areas compared to traditional field survey methods. These advancements helped optimize resource allocation, enhance market forecasting, and detect shifts in cropping patterns. The study aimed to estimate rice area in the KWD region during the kharif season of 2023 using geospatial tools. A combination of satellite imagery and ground truth data was employed. Landsat 9 data were utilized to estimate rice areas during the kharif season, and this data was processed using ENVI software. The Random Forest classification method was applied to distinguish rice areas, achieving an overall accuracy of 94.3% with a Kappa coefficient of 0.81, indicating almost perfect agreement. The total rice area in the study region was estimated at 127,565 ha, with the largest area recorded in Bapatla (12,299 ha) and the smallest in Pedanandipadu (3 ha). A 4.4% underestimation was observed when compared to the Department of Agriculture (DoA) statistics, which reported 133,402 ha.*

Keywords**— *Geospatial tools, Remote sensing, Landsat 9, ENVI software, Random Forest classification***

I. INTRODUCTION

Accurate estimation of crop area is essential for assessing agricultural productivity, supporting food security planning, and enhancing market forecasts. Reliable crop area data allows governments and organizations to track production trends, optimize resource allocation, and anticipate future demands (Raman *et al.*, 2017). Additionally, this data plays a significant role in managing agricultural subsidies, insurance schemes, and disaster relief efforts. Early detection of changes in cropping patterns, often influenced by climate factors, is made possible through accurate estimates. It also informs decisions related to imports, exports, and maintaining food supply balance, while helping capitalize on market opportunities when surplus production occurs (Husak *et al.*, 2007; Karydas *et al.*, 2015).

In India, rice is the most widely cultivated crop, serving as a staple food for the population, providing livestock fodder, and creating employment opportunities in rural areas. Andhra Pradesh is a major rice-growing region, with paddy cultivation extending over 2.2 million ha during the *kharif* and *rabi* seasons. The districts of West Godavari, East Godavari, and Krishna are key contributors to rice production, not only within the state but also at the national level (apseeds.ap.gov.in). Accurate estimation of rice cultivation areas helps inform decisions related to water management, fertilizer distribution, and market trends, which are crucial for policy-making on trade, resource allocation, and disaster preparedness (Wang *et al.*, 2015; Dong *et al.*, 2016; Zhu *et al.*, 2021).

Traditionally, crop area estimation in India has been based on field surveys carried out by local authorities, who gather data through direct observation (www.mospi.gov.in). While periodic inspections aim to ensure accuracy, these manual methods often result in errors due to the subjective nature of observations and limited data coverage (Li *et al.*, 2014).

Recent advances in remote sensing (RS) technologies offer a more efficient alternative. RS uses satellite imagery to monitor large areas, enabling real-time data collection while reducing the time and labor required (Mosleh *et al*., 2015). The integration of RS with Geographic Information Systems (GIS) allows for precise mapping of crop areas and seasonal variations. This approach reduces human error, improves insights into crop health, and enhances the accuracy of area estimations at both regional and global levels (Tian *et al*., 2017).

In this context, the present study focuses on mapping rice cultivation areas using medium-to-high-resolution optical satellite data. The free Landsat 9 time series, provided by the United States Geological Survey (USGS), was utilized to investigate the effectiveness of remote sensing technologies in this task. The study hypothesizes that the Landsat 9 time series will provide highly accurate identification of rice crops (Zhao *et al*., 2015).

II. MATERIALS AND METHODS

Study Area

The Krishna Western Delta (KWD) of Andhra Pradesh spreads from longitude 80° 10'E to 80° 39'E and latitude 15° 50'N to 16° 30'N. It has an area of 1895 square kilometres and a perimeter of approximately 226.48 km. The elevation ranges from 3.5 meters to 15 meters above sea level. The study area is located in the Guntur district of Andhra Pradesh. It includes mandals such as Bapatla, Kakumanu, Pedanandipadu, Prathipadu, Guntur, Pedakakani, Duggirala, Mangalagiri, Tadepalle, Chebrolu, Vatticherukuru, Ponnur, Tsundur, Tenali, Kollipara, Kollur, Vemuru, Amruthalur, Bhattiprolu, Nagaram, Pittalavanipalem, Karlapalem, Repalle, and Nizampatnam. The KWD experiences a semi-arid climate with an annual rainfall range from 960 mm to 1100 mm. Most of the rainfall is received during the southwest monsoon period. Summers are hot and dry. The predominant soil composition consists of clay and loamy sandy soils, which account for around 85% of the total area.

The total rice area in the study area *i.e*., Krishna Western Delta of Guntur was derived with the use of optical data that is Landsat 9 OLI/TIRS satellite data. Since rice cultivation in KWD takes place between August and December of every year, we focus our analysis of Landsat 9 satellite data only on this period. For this reason, Landsat 9 data were downloaded for the period on 12 November 2023. The processing procedures included layer stacking, subsetting, training data creation, Random Forest supervised classification, cloudy pixel removal and accuracy assessment all of which were implemented using the QGIS and ENVI Softwares.

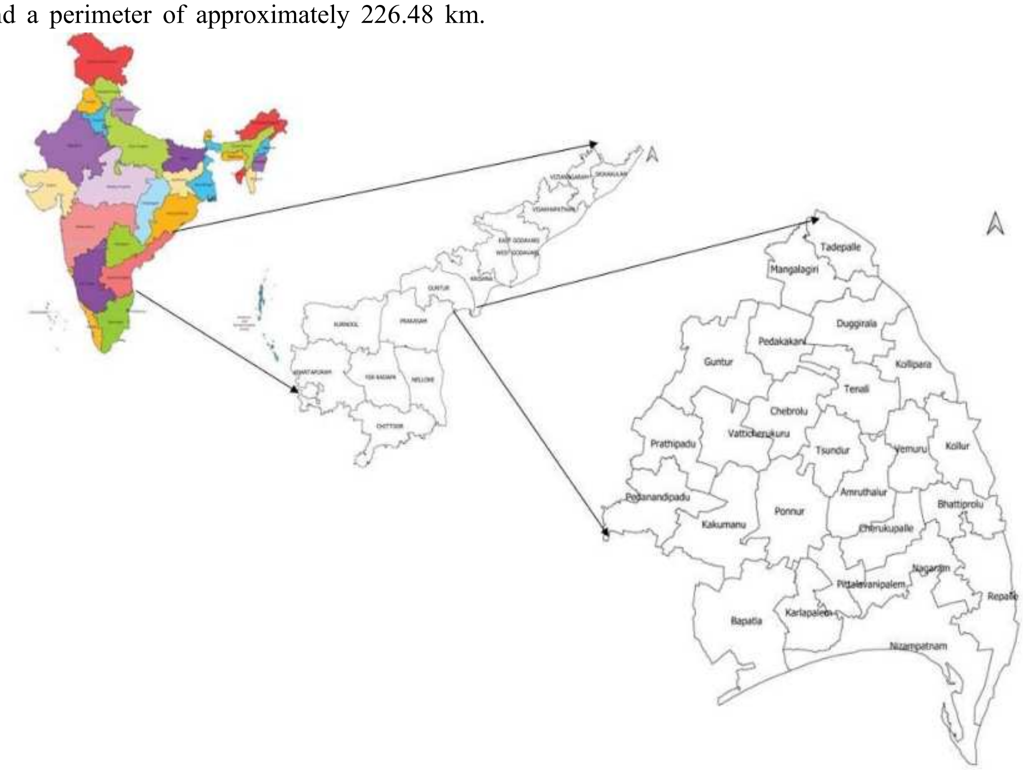

Fig. 1 Location of the Krishna Western Delta of Guntur district

Ground truthing (GT) is a process that validates remote sensing image characteristics by comparing them to real-world observations (Bolun *et al.,* 2017). GT was conducted during the rice crop's peak vegetative stage on 29th August 2023, to assess the seeded area during the *kharif* season. Total 88 ground truth samples were collected out these 73 rice and remaining 15 were non rice samples.

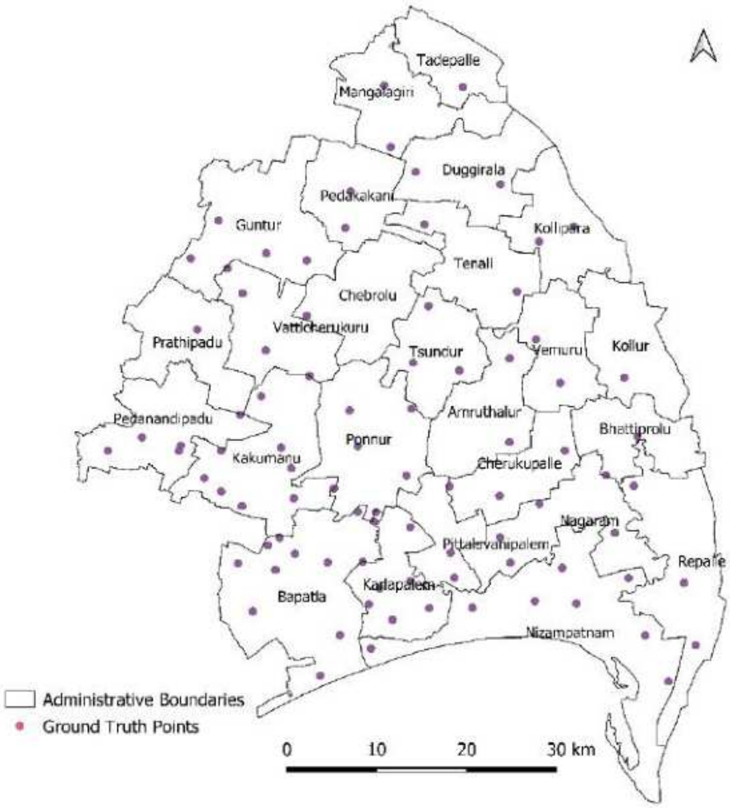

Fig. 2 Distribution of ground truth points across the KWD region

Methodology

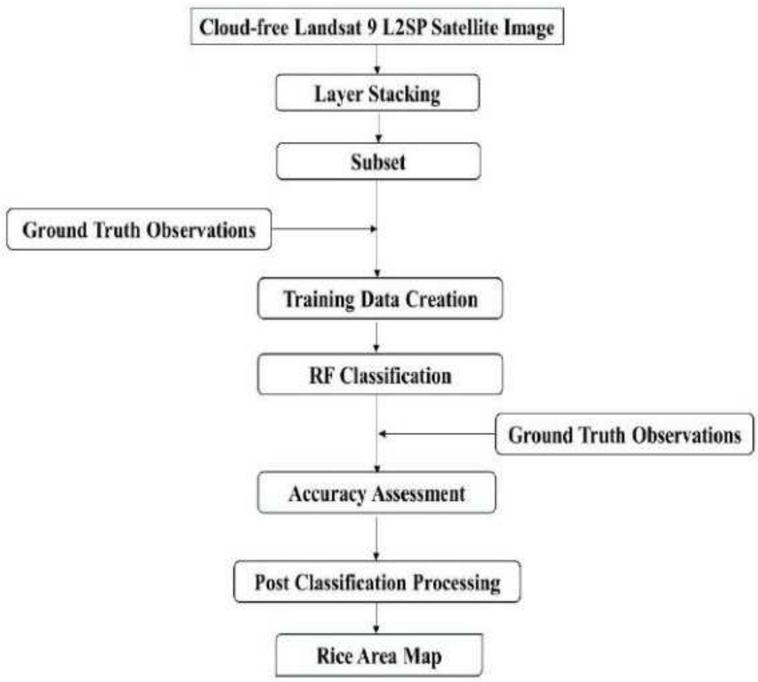

Fig 3 Flow chart of methodology to estimate rice area

Landsat 9 Level 2 data was downloaded from USGS Earth Explorer and pre-processed for atmospheric correction and surface reflectance. The data was then extracted and imported into ENVI software, where bands 6, 5, 4, and 3 were stacked into a single multi-band image using the collocation tool, preserving individual band details.

For supervised classification, distinct spectral signatures were developed by gathering training samples from known locations. In this study, 60% of the signatures were for rice crops, with the remaining 40% representing other land uses such as water bodies, horticulture, and settlements. These signatures were recorded as ESRI shapefiles using QGIS software and validated through comparison with ground truth photos and satellite imagery.

The Random Forest algorithm was used for classification, where multiple decision trees built from training data provided robust results. Each tree voted, and the majority class was assigned to each pixel, producing an accurate land cover map based on spectral data. This approach effectively reduced errors and improved classification outcomes.

The accuracy of the rice area map was evaluated by comparing the classified land cover with spatially and temporally consistent reference data, and the results were summarized using an error matrix. Cohen's kappa coefficient was employed to measure classification reliability, accounting for the possibility of agreement by chance, making it more robust than simple percent agreement (Sharma *et al*., 2022).

Post-classification refinement is crucial for correcting misclassifications and enhancing map accuracy. Techniques such as filtering remove isolated pixels and small clusters to improve coherence, while manual expert edits address errors that automated processes may overlook. The inclusion of ancillary data, such as topographic and land use maps, adds context that spectral data alone cannot provide, improving the distinction between features like forests and agricultural fields on varying terrains.

The refined map is then masked with a land use map to exclude irrelevant areas, reducing misclassifications and aligning the output with the study's objectives. This ensures a more accurate and reliable tool for decision-making.

The final map, after refinement and validation, represents rice fields with distinct symbols for easy interpretation. It helps stakeholders make informed decisions by clearly delineating rice cultivation areas. The cultivated area in ha was calculated in QGIS software by multiplying pixel counts with the pixel size, using the equation proposed by Siddiquee *et al*. (2021).

Area (ha) = pixel number × pixel size,

Where **pixel size = 30×30 = 900m² = 0.09 ha**

III. RESULTS AND DISCUSSION

The classified raster image of rice cultivation in the Krishna Western Delta (KWD) of Guntur district (Fig. 1) showed that rice is the primary crop during the Kharif season across the study area. Rice cultivation was observed in all mandals, with Pedanandipadu, Prathipadu, Tadepalli, Mangalagiri, and Guntur focusing primarily on the lower southeastern regions, where canal water was accessible. In Nizampatnam mandal, factors such as water-borne salts, aquaculture, the inland influx of brackish water during tidal events, and freshwater aquifer contamination caused salt accumulation on approximately 40% of the land. This accumulation rendered the soil unsuitable for rice cultivation until the salts were flushed out, resulting in delayed sowing, further impacted by the late arrival of canal water in this tail-end area of the KWD. In Bapatla, Amruthalur, Vemuru, Cherukupalli, Nagaram, Pittalavanipalem, and Ponnuru mandals, over 85% of the net cultivable area was estimated to be under rice cultivation.

In the southern part of the study area, the land slope was unsuitable for rice farming. To manage this, farmers constructed extensive bunds to conserve water, leading to a landscape where rice fields were interspersed with non-rice areas. In the western part of Kakumanu mandal, located within the Nagarjuna Sagar right canal command area, irrigation water was provided in late September, supplemented by water from the Prakasam barrage. Terrain changes in this region caused delays in sowing, extending the rice cultivation period until the end of the Kharif season.

The rice area, as depicted in the raster image, was analyzed using the zonal histogram module of QGIS, applying administrative boundaries. The total estimated rice area in the Krishna Western Delta of Guntur district for the *kharif* 2023 season was 1,27,565 ha (Table 4.2). The estimated rice area, obtained using the Random Forest supervised classification technique, was compared with the mandal-wise rice area figures provided by the Department of Agriculture, Government of Andhra Pradesh, for the same season. Bapatla recorded the largest estimated rice cultivation area (12,299 ha), followed by Ponnuru (12,077 ha) and Nagaram (10,184 ha), while Pedanandipadu (3 ha), Prathipadu (57 ha), and Tadepalli (169 ha) had the smallest areas.

The comparison between the estimated and reported rice areas revealed an underestimation of 5,837 ha, a deviation of 4.4%. Karlapalem mandal had the smallest deviation at 0.2%, while Bhattiprolu showed a 3.1% variance. The largest deviation occurred in Pedanandipadu mandal, with a 97.5% difference, likely due to rice cultivation on narrow strips adjacent to streams using borewell irrigation, with most of the sowing occurring in September. Additionally, narrow strips of land (less than 150 m) bordered by vegetation near drains complicated the precise identification of rice cultivation areas. Bapatla mandal showed the largest overestimation of rice area, exceeding 4,037 ha, followed by Ponnuru with an overestimation of 1,517 ha. The most significant misclassifications occurred in Repalle (2,505 ha) and Kakumanu (2,214 ha) mandals, likely due to water accumulation in seasonal fallows and the misidentification of annual grasses in waterlogged areas as rice fields, leading to the misclassification of non-rice areas.

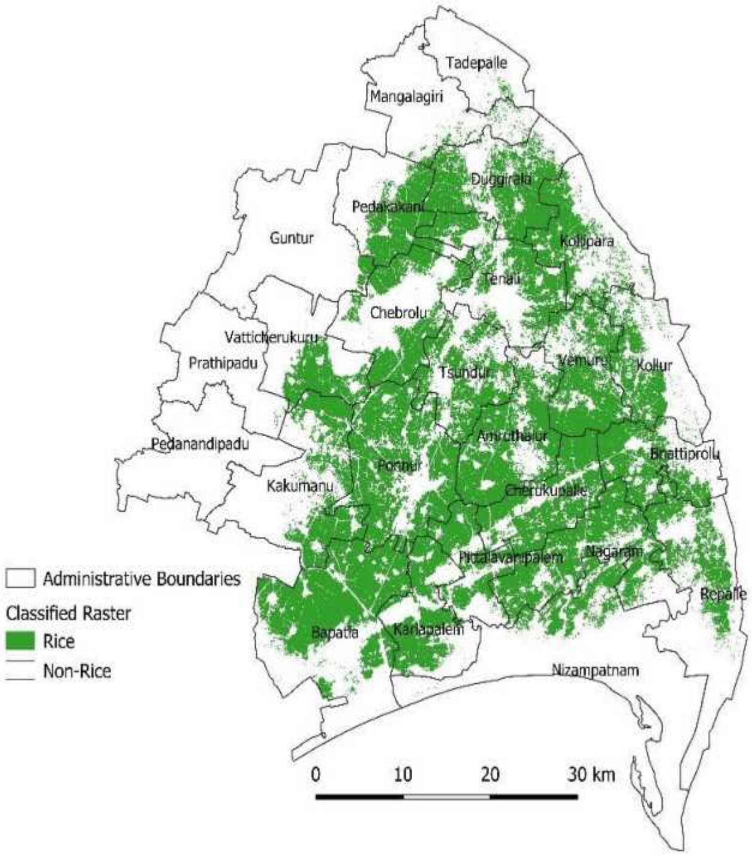

Fig. 4 Estimated rice area map of the KWD region kharif 2023

Table 1 Comparison of estimated and reported Department of Agriculture rice cultivated area in KWD region during kharif 2023

S.No	Mandal Name	Normal Area(ha)	DoA reported area(ha)	Estimated area (ha)	Difference (ha)	Deviation (%)
1	Amruthalur	10402	9910	8402	-1508	-15.2
2	Bapatla	13206	8733	12770	4037	46.2
3	Bhattiprolu	5942	5536	5362	-174	-3.1
4	Chebrolu	6025	4389	5497	1108	25.2
5	Cherukupalle	7402	6721	7086	365	5.4
6	Duggirala	8665	8078	7534	-544	-6.7
7	Guntur	679	543	458	-85	-15.7
8	Kakumanu	10089	8254	6040	-2214	-26.8

9	Karlapalem	6427	5140	5152	12	0.2
10	Kollipara	6252	5872	4806	-1066	-18.2
11	Kollur	4976	4286	3929	-357	-8.3
12	Mangalagiri	2427	1979	632	-1347	-68.1
13	Nagaram	10720	8218	8854	636	7.7
14	Nizampatnam	5260	3996	3288	-708	-17.7
15	Pedakakani	5303	4531	4918	381	8.4
16	Pedanandipadu	112	119	3	-116	-97.5
17	Pittalavanipalem	4921	4407	3952	-455	-10.3
18	Ponnur	13073	10560	12077	1517	14.4
19	Prathipadu	357	264	57	-207	-78.4
20	Repalle	10373	7500	4995	-2505	-33.4
21	Tadepalle	674	579	169	-410	-70.8
22	Tenali	7958	6500	6017	-483	-7.4
23	Tsundur	8058	7231	5442	-1789	-24.7
24	Vatticherukuru	3330	2802	3241	439	15.7
25	Vemuru	8032	7254	6884	-370	-5.1
	Total	160663	133402	127565	-5837	-4.4

Accuracy assessment of rice area map

The rice area map generated using supervised classification was confirmed with ground truth data, and the findings are described in Table 4.

Table 2. Error matrix for validation of estimated rice area

Actual Class from Survey	Predicted Class from Map				UsersAccuracy (%)
	Class	Rice	Non-Rice	Total	
	Rice	69	4	73	**94.5**
	Non-Rice	1	14	15	**93.3**
	Total	70	18	88	**0**
	Producers Accuracy (%)	**98.6**	**77.8**		**94.3**

Kappa coefficient

Kappa Index = $\frac{(Observed\ Accuracy - Expected\ Accuracy)}{(1 - Expected\ Accuracy)}$

$= \frac{(Po-Pe)}{(1-Pe)} = \frac{(0.94-0.67)}{(1-0.67)} = \frac{0.27}{0.33} = 0.81$

A classification error matrix was generated using 88 ground truth observations, of which 73 were classified as rice and 15 as non-rice. Of the 73 rice observations, 69 were correctly identified, while 4 were misclassified as non-rice. Similarly, 14 of the 15 non-rice observations were accurately classified, with 1 misclassified as rice.

The user accuracy for the rice class was 94.5%, indicating a high level of accuracy in identifying rice areas. For the non-rice class, the user accuracy was 93.3%. The producer accuracy, reflecting the model's ability to correctly identify actual rice areas, was 98.6% for rice and 77.8% for non-rice.

The overall classification accuracy reached 94.3%, supported by a kappa coefficient of 0.81, indicating strong agreement between the classification results and the ground truth data. These results align with previous studies: Bhatt and Nain (2018) reported an overall accuracy of 92.88% and a kappa coefficient of 0.89, Chen *et al*. (2016) achieved 86.2% accuracy with a 0.72 kappa coefficient, and Chang *et al*. (2020) noted 91.9% accuracy and a 0.83 kappa coefficient, all demonstrating a high degree of classification reliability.

IV. CONCLUSION

Accurate estimation of rice areas in the Krishna Western Delta (KWD) is critical for agricultural planning, resource management, and policy formulation, particularly in rice-dominated regions like Andhra Pradesh. Traditional field survey methods for area estimation are often subject to inaccuracies and inefficiencies. However, with the advent of geospatial technologies, remote sensing (RS) and Geographic Information Systems (GIS) offer more precise and efficient methods for crop area estimation. In this study, Landsat 9 satellite data from November 2023 was utilized to estimate the rice area in KWD during the Kharif season. The analysis was performed using ENVI and QGIS software, applying Random Forest supervised classification to distinguish between rice and non-rice areas. Ground truthing, conducted in August 2023, validated the satellite data. The classification accuracy was evaluated using an error matrix, which included user and producer accuracies, as well as commission and omission errors. Additionally, the overall accuracy and Cohen's Kappa coefficient were calculated to assess the reliability of the results. This method significantly reduces errors and provides a reliable framework for accurate rice area estimation, supporting better decision-making in agricultural planning and resource allocation.

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Assessing the Introduction of Genetically Modified Organisms (GMOs) into Ghana: The Perspectives of Agriculture Professionals in Northern Region

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Abstract— *The role of agriculture officers is essential and cannot be ignored when introducing technology such as Genetically Modified Organisms (GMOs). However, there is no known study presently that examines agriculture officers' perspectives of GMOs emergence in Ghana. Our study assesses agriculture officers' perceptions on the introduction of GMOs into Ghana and its impact on food and seed security as well as officer's level of involvement in GMOs related activities and willingness to promote it. We further solicited their views on GMOs as a successful solution to tackle farming challenges and assessed what influenced their views. Our findings revealed that 53% of agriculture officers agreed that GMOs will have positive impact on food/ seed security/sovereignty. Also, 56% said they will champion GMOs, however, 67% said there is limited information on GMOs and 74% of the respondents indicated that they have never attended or participated in GMOs related activity. We highlighted officers' divergent views around the introduction of GMOs as a successful solution to tackle farming challenges and the key influencers include: GMOs is unsafe for human consumption, gene escape into wild relatives, and possibility of creating insect resistant and limited capacity to genetically engineered crops locally. The study recommended that there is the need for pro and anti-GMO groups to involve officers in GMO activities for effective dissemination of information on GMO to farmers or citizens.*

Keywords— ***Agriculture Officers, GMOs, Perception, Seed/food security, Successful solution.***

I. INTRODUCTION

Biotechnology is a novel technique of the 21st era that is considered as a tool for enhancing agriculture output that could lead to agriculture and economic growth while saving labour (Essen 2022). Yet, there are still ongoing controversies over agrobiotechnology (Shanahan et al., 2001). In line with this, some authors are of the view that there are prospects in exploring solutions that are adoptable, adaptable, and exchangeable; they are worried that if too much attention is paid to biotechnology, this could limit the research capacity of nation states (WHO 2005). Among the present biotechnology of significance to food security and food safety is genetic modification (Gbashi et al., 2021). Although across the globe, crop genetic modification is highly contested (FOE, 2022). According to Edwards (2017), one contentious issue in agriculture is employing genetic engineering[1] to produce Genetically Modified Organism (GMO)[2]. Therefore,

[1] Kloppenburg (2010) notes that genetic engineering presently employs a technic known as 'Genetic Use Restriction Technologies' that only permit the seed to germinate upon application of branded chemicals.
[2] GMO involves altering any living thing excluding human beings, through genetic manipulation ensuing from recombination technology rather than natural mating to produce a 'new product'. These include foods, feeds, medicines and vaccines (Ghana Public Health Association 2014).

genetically modified organisms (GMOs) have been a controversial topic in the agricultural sector for years.

It is claimed that genetically engineered crops will feed the world, as these crops are assumed to provide a solution to anxiety over possible starvation emanating from increasing population. These crops could be engineered to be more nutritious, resist to disease/pest, drought tolerant, and have a higher yield (Ewens, 2000). Lamichhane (2014), Ampadu-Ameyaw et al. (2021), and Gbashi et al. (2021) are in favour of this argument. Debatably, some questions remain unanswered as to whether to (dis)continue the cultivation of GM crops. Such decisions should engage a larger society since research findings on GM crop safety are limited, sometimes contradictory, not conclusive and open more debate around biosafety, especially in relation to risk acceptability and socioeconomic considerations (Hilbeck et al., 2015).

However, as indicated by Lang and Heasman (2015), Genetically Modified Organisms are being introduced into global food systems at a rate that cannot be reversed, yet the long-term consequences for agrarian environments and the power relations in the food chain, are unknown. Following this, opponents of GMOs largely premise their arguments on the fears of possible side effects on human health as well as on the ecology following GMOs introduction. Likewise, arguments in favour of GMO's introduction in Africa are situated within the context of the continent's food and nutrition insecurity status as proponents for GM crops' introduction in Africa argue that this is likely to address food and nutrition challenges in the global south (Arvidsson, 2015). Despite these developmental functions being played by GMOs, there are nonetheless concerns in relation to safety issues. Muzhinji and Ntuli (2021) note that (not) introducing GMOs on safety concerns will not hurt the policy maker/scientist or the politician but rather the small-scale farmers who exert so much energy yearly cultivating unproductive soil with little fertility hoping for a higher yield.

Globally, to address food insecurity, some steps have been initiated with potential positive outcomes. Specifically, advances in genetic engineering have shown some level of success in tackling some farming challenges such as low crop yield, diseases and pests, as in the case of GM insect resistant maize (Gbashi et al. 2021). Whereas in Africa a promising agrarian intervention such as GMO techniques could play a role in addressing food insecurity on the continent, there are divided opinions among actors with respect to its merits relative to its hazards (Gbashi et al. 2021). Hence, controversies around GMO have not only highlighted the divided opinions within and among the stakeholders, but also the debate and struggle on GMO has different perspectives, which include economic and legal issues, biological concerns, farmers rights as well as ethical issues (Ewens 2000).

The Northern region of Ghana is one of the food hubs of the country due to the abundant land and agricultural intensification. The introduction of GMOs in the region is envisaged to improve productivity and increase farmers' resilience to climate change. Involving and engaging farmers is a core task of agriculture officers at various levels of the agrarian sector throughout the country. A study of agriculture professionals' perspectives and opinions about the issues surrounding GMOs will provide opportunities for rich discussion on the technology. In line with agriculture technology, agriculture officers should be actively involved in the discussions regarding the kind of technology, such as GMOs and how it will impact the seed/food security. So, what do agriculture officers think about introducing GMOs into Ghana? In the context of introducing GMOs in the agriculture sector in Ghana, there exist multiple perspectives depending on the school of thought or paradigm to which one is aligned. It's important to note that these opinions may vary, and it is crucial to survey a wide range of professionals to get a comprehensive understanding of their viewpoints on GMOs. Therefore, this research seeks to examine the perception of agriculture officers in Ghana with a focus on Northern Region. Significantly, there exist different narratives of GMOs depending on the person's profession or interest or how one understands the GMO technology. But there is the need to keenly look at agriculture officers' views and the role they play at various levels in relation to GMOs as their roles could shape farmers use, understanding and uptake or rejection of these products. This study explores agriculture officers' views because they could shape farmers' ideologies and their sense of hope or otherwise in GMOs.

According to a study conducted in Northern Ghana with respect to the source of information on GMOs, only 10% of the study participants indicated extension officers as their primary source of information (Zakaria et al., 2022). It is important for farmers to obtain the right information with respect to GMOs as this will guide them so they can make informed decisions and offer them the opportunity to decide about what to grow and what they will eventually offer to consumers.

To unpack the introduction of GMO, the current study seeks to bring to the fore perceptions of agriculture officers' as well as their perspectives on GMO in the light of the underlying assumption of what it offers for their clients. The African Centre for Biodiversity (ACB) notes that the Ministry of Food and Agriculture is responsible for information dissemination through extension to farmers as well as offering training to farmers (ACB, 2015). To this end, it is the agriculture officers at various districts, zonal, and operational levels who are responsible for disseminating messages and information with respect to GMO at their respective levels of operations. Amid growing focus and agenda on the pathway towards successful solutions to agriculture challenges, it is the agriculture officers who will be faced with the task of convincing the farmers that GM crops and by extension their cultivation is beneficial to farmers and their livelihood. Even though Agriculture officers play an important role in dissemination of information, they are an understudied group whose perceptions on GMOs could shape debate and farmers understanding or possible adoption or other wise of the GMO. However, there is no known study presently that examines agriculture officers' perspective of GMO; this study will explore their understanding, experience, and willingness to promote the GMO among their farmers.

II. METHODOLOGY

This paper adopted the use of Google Form and purposefully gathered data from the agriculture officers. We reached out to 297 participants on the agriculture platform to gather their opinions and thoughts about GMOs, as we wanted to understand how they perceive the GMOs.

Data collection started from 20 October to December 2023. The Google Form was shared on the agriculture platform and through a known person in each district, especially the Management Information System officer or the District Director of Agriculture. In all, 74 responses were received. One challenge was security concern; thus, how secure the form was a major concern by some participants who were not comfortable because of their past experiences with data breaches.

The survey was designed using a Google Form to assess agricultural officers' views, involvement, and experiences related to GMOs, amongst the platform participants of Northern Agriculture Information Ghana.

Data was analyzed using tables to categorise responses into percentages and power BI employed to determine key influencers. The survey examined their views on GMOs and willingness to promote them. Combining the successful solution framework and agriculture officers' perspectives with the insights from the literature review, this paper highlights officers' views around the introduction of GMOs into Ghana. The study further assessed their views on GMO contribution as a successful solution to tackle farmers' challenges.

III. BRIEF DESCRIPTION OF THE STUDY PARTICIPANTS AND FRAMEWORK

The platform was created on 26 February 2016 by a group of agriculture officers in the then Northern Region, now Northern, North East, and Savanna Regions. The platform is made up of all classes of agriculture professionals and technical officers.

In recent months, anytime the issue of GMOs is up on the agriculture platform, it attracts debate and attention among the platform participants. This attention and debate are borne out of the contentious nature of the technology, which has progressively come to be seen as a central reference point for participants with divergent interests and views who take seriously the role of GMOs in agriculture.

Framework for Analysis

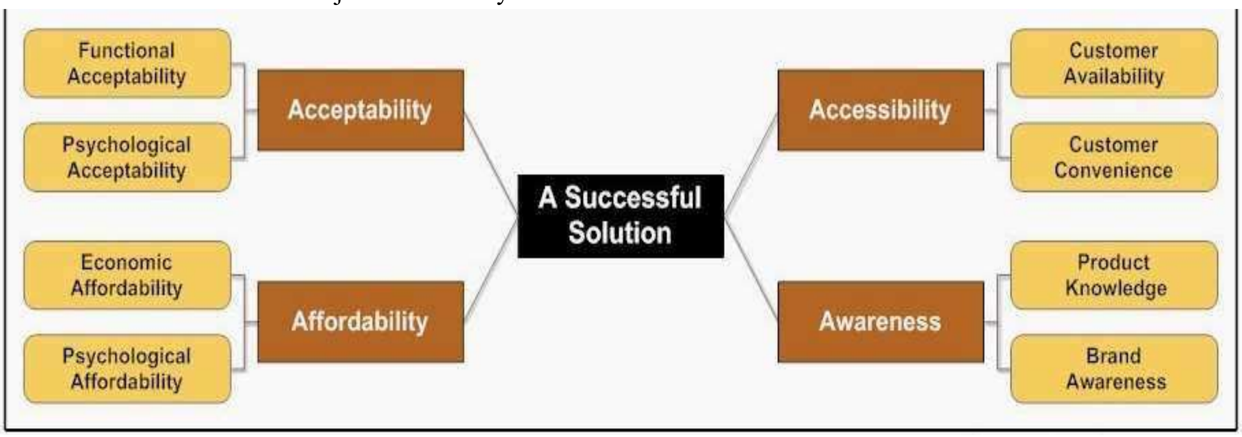

Fig.1: Framework for assessing a successful solution (Adapted from Badmus 2022 on analysis of food waste reduction)

From the Figure 1 above, there are four (4As) features of successful solutions, namely: Acceptability, Accessibility, Affordability and Awareness. Raising awareness about GMOs is a key factor that can influence people's acceptance and attitude with respect to GMOs and subsequent adoption. As farmers become aware of GMOs, there is a likelihood of acceptance among farmers (Gbashi et al., 2021). However, more effort is required to raise awareness among actors often through discussion, especially in Africa (ibid.). Accordingly, organization such as Friends of the Earth (FOE) 2022 note that organizing awareness campaigns will help citizens appreciate the consequences of GMOs on health, food security and sovereignty to resist prevalent of GMO introduction into Ghana (FOE, 2022).

Whereas, in relation to acceptability of GM technology, Gbashi et al. (2021) report that there is old age hesitancy in many African states in accepting GMOs though upon recognizing their merits, they relax their stands and opinions on GMOs. Even though, some authors were of the view that there is high acceptability of genetic modification when employed in improving food safety as opposed to food quality among citizens (Shanahan et al. 2001). However, if farmers do not accept technology as being suitable within the perspectives of their community, traditional, and economic settings, the technology could be ignored (Badmus, 2022 as cited in Affognon et al., 2015). On the other hand, it was opined that age and gender among other factors, can influence the acceptance of GMOs (Ampadu-Ameyaw et al., 2021). Juxtaposing this to education, according to Ampadu-Ameyaw et al. (2021), the level of education attained by individual influences the level of consciousness of the individuals because information on GMOs at higher levels of schooling exposes individuals to a lot more knowledge on the subject.

Also, Ampadu-Ameyaw et al. (2021) observed that accessibility of GMOs in relation to access to information is challenging as the initial time individuals access information on GMOs affects awareness. In terms of affordability, according to the Africa Center for Biodiversity (ACB), smallholder farmers can barely afford the price of GM seeds and other agro chemical inputs needed when cultivating GMO seeds. So, the high cost of inputs, which is the feature of GM hi-tech package, will contribute to endangering delicate socio-economic systems (ACB, 2015).

IV. RESULTS AND DISCUSSIONS

Characteristics of the Study Respondents

From table 1, a total of 74 responded to this question; this implies that out of 74, 62 (84%) of respondents were male while the remaining 12 (16%) were female. According to Ampadu-Ameyaw et al. (2021), age and gender, among others can impact the acceptance of GMOs.

The majority (55%) of the respondents was between the ages of 31-40 years, followed by those within the ages of 41-50 years (24); whilst 18% indicated that they were below 30 years and 3 (3%) said they were above 50 years. Also, the study shows that the majority (50%) of the study participants indicated that they have a BSc/BTech whilst 28.4% said they have a masters whereas, 10.8% stated they have a Diploma or certificate and none had a PhD. Indeed, the higher the level of education of individuals, the more aware and conscious they become of GMOs, Ampadu-Ameyaw et al. (2021). Also, Zakaria et al. 2021 identified low level of education is as a challenge that faces the introduction of GM technology among smallholder farmers in Ghana and Nigeria.

With respect to years of work experience 32% of the study participants have between 3-5 years of work experience, 27% indicate they have worked between 6-10 years, 15% have worked between 11-15 years, while 10% said they had worked 16-20 years, and 8% have less than two years of work experience. Others stated 21-25 as the number of years they had on the job, and the least years of work experience was 30 years and above.

Agriculture Professionals Perspectives

Agriculture officers' views on GMOs and environment

Analysis of the data from the study indicates that 37% of the respondents agreed and 27% strongly agreed with the statement that GMOs could reduce chemical use in the ecosystem. This implies that the majority of the study group perceives GMOs as a possible solution that may reduce chemical usage because GMOs can breed variety that could resist insects or variety tolerant to disease, which will decrease use of pesticides. Although some study participants, thus, 11% disagreed and the 5% strongly disagreed with the statement that GMOs could decrease environmental chemicals on the ecosystem. Possibly, this group could have reservation about the long-term impacts of GMOs in the environment, including damage to non-target plants, or this could result in resistant pests within the environment. On the other hand, about 19% of respondents indicate their stands as neutral; this shows they are not certain about the effect of GMOs in the environment and their relationship with reducing chemicals in ecology.

On GMOs to contaminate the food chain and wider environment, some 32% of respondents disagreed and 7% strongly disagreed with the statement. On the other hand, 26% of the study participants agreed and 12% strongly agreed with the statement that GMOs could contaminate the food chain and wider environment. This implies that these respondents believe that GMOs do pose a risk of polluting the food chain and broader environs. These individuals may be concerned about the potential for allergenic or toxic effects from genetically modified organisms, as well as the impact on soil health and beneficial insect populations. Yet, 23% of the respondents were neutral, which reflects their weak opinion concerning the issue of GMO contamination of the food chain and broader environs. According to Stephen and Mannion (2008), genetically modified crops have the ability to both aid in the protection of natural ecosystems and contribute to their continued decline. Therefore, GM crops elicit a wide range of opinions although there is no proof that they will have the same negative effects on the environment with respect to pesticide usage, hence, opinions on the use of genetically modified agriculture have been divided between fierce resistance and enthusiastic approval (ibid.).

Whereas, with GMOs benefit linked to environment, farmers, and society, data gathered suggests that 46% of respondents agreed and 11% strongly agreed with the statement. Thus, the majority perceives GMOs as having positive impacts. Although, 19% of respondents were neutral, as they seem to be uncertain about the benefits of GMOs to society, the environment and farmers. However, from the data, opinions of other respondents showed that 17% disagree and the rest (7%) strongly disagree. It is important to note that although 23% (disagree and strongly disagree) is lower than that of the 57% (agree and strongly agree), a lot of education of officers with regards to the benefits of GMOs will be required to aid in information dissemination.

Officers views on GMOs and sustainable food and nutrition security/safety

Results of the data analyzed indicate that 45% of participants disagreed with the impression that GMOs will worsen food security. Likewise, 7% strongly disagreed when they expressed opinions in relation to GMOs and food security deteriorating. However, 19% expressed their opinions by strongly agreeing that GMOs will worsen food security. Similarly, 8% agreed that introducing GMOs could worsen our food security. Of the respondents who took part in the study, 22% were neutral without a clear position on the role of GMOs in worsening food security. Agreeably, 44% believe GMOs will improve food security, whilst 27% strongly agreed. On the other hand 14% took a neutral position. Whereas 10% disagreed and the remaining respondent (5%) said they strongly disagreed.

According to the data gathered, 44% of participants agreed that GMOs can enhance nutrition but 20% remained neutral. It's worth noting that 15% of the respondents both disagreed and strongly agreed with this statement, indicating a split in opinions within this group. Additionally, 6% of the participants opted to strongly disagree with the idea of GMOs improving household nutrition. Again, majority of the study participants, thus, (43%), representing 32% disagree and 11% strongly disagree that GMOs are unsafe for consumption. About 28% of the study participants were neutral with the statement that GMOs are unsafe for consumption. Though 19% agreed that GMOs are unsafe for consumption and 10% strongly agreed that GMOs are unsafe for consumption. The majority opinions are in line with the finding from Gbashi et al. (2021), which suggest that the GMO cassava variety was developed with features such as a low cyanide level, which is considered safe at the same time being tolerant to virus and having a better shelf life.

Officers views on GMOs and agribusiness

Respondents' views on GMOs contributing to the success of agribusiness were also solicited. Results indicate that about 51% and 26% agreed and strongly agreed, respectively that GMOs contribute to the success of agribusinesses. This suggests that the majority believe GMOs play a role in enhancing agribusiness. However, 14% of the respondents to the study were neutral or uncertain about the possibility of GMOs playing a role in enhancing agribusiness. On the other hand, 6% simply disagreed with the idea of GMOs contributing to agribusiness, while 4% strongly disagreed. When the question of whether GMOs are geared towards agribusiness was asked, the majority (60%) representing 34% agreed and 27% strongly agreed that GMOs are geared towards agribusiness. Though 24% said they were neutral as they express uncertainty on their position. On the other hand, 10% disagreed and 5% strongly disagreed with the assertion that GMOs are geared towards agribusiness. With reference to BT cowpea, ACB 2015 reports that there is a lucrative market along the seed production value chain, especially for foundation and certified seeds. This therefore will ultimately enhance the agribusiness narrative for farmers awareness and adoption.

Most of the respondents, thus, 49% (30% strongly agreed and 19% agreed) with the notion that GMOs will lead to monopolies. However, 31% were neutral and uncertain about how GMOs introduction will lead to monopolies. Other respondents differed in their opinions, with 16% disagreeing and 4% strongly disagreeing. On the matter of employing GMOs in making seed sterile, officers' views were as follows: Out of the total study respondents, 38% were neutral, as they did not have a clear opinion on this statement. Whereas 28% agreed, 5% strongly agreed, with the same percentage of 15% disagreeing with this assertion. Only 4% disagreed with GMOs seed sterility.

GMOs promotion, benefit and impact on food security/sovereignty

From the data presented in Table 2, the majority (40% likely and 16% very likely) representing 56% of respondents said they will champion GMOs. While 28% are not sure of whether they will promote GMOs and 10% are unlikely to promote GMOs. The remaining (6%) of respondents said they are not very likely to promote. Also, from the same table, 44% said GMO is helpful, while 23% agreed that it is very helpful. However, 19% and 14% mentioned that it is not very helpful and unhelpful, respectively. According to 67% of the study group, GMO technology is considered to be beneficial to farmers, whereas 33% stated that it will not be beneficial to farmers. A significant proportion of the respondents, 67% think that there is no available information on GMO technology, whilst 33% said there is available information on GMO technology. This suggests that, to make use of the officers as a link to the farmers, more information on the GMO needs to be available to change agents.

Ampadu-Ameyaw et al. (2021) argued that there is the need to find a middle point amid differing opinions; therefore, appreciating GMOs will depend on the level of participation as well as individuals' attitudes towards GMOs in Ghana. From the data analyzed, the majority 54 (74%) of the respondents indicated that they have never attended or participated in any GMOs related program, whereas 26%, representing 19 participants, stated that they have been involved in GMOs related activity or program. One respondent did not respond to this question.

Sources of information on GMOs

From the data analyzed, 28% representing 20 respondents indicated that an article or a journal/newspaper, thus print or online media, is their source of information or how they got to know about GMOs. While 21% (15) of the study participants said television is their source of information. About 20% responded that word of mouth is how they got to know about GMOs. Accordingly, 14% (10) of respondents specified that they got to know about GMOs through conferences. Also, 9 respondents, representing 13%, said social media (Facebook, Twitter, Instagram, WhatsApp) was where they got to know about GMOs; 3 (4%), stated radio as a medium through which they found out about GMOs.

Assessing GMOs through successful solution lens

From the data presented in Table 3, 32% of the respondents indicated that GMOs would have average acceptance among their clients. While 30% were of the view that its acceptance will be very low among farmers. On the other hand, 22% of the respondents said its acceptability will be high, whereas 15%, stated that its acceptance will be low among farmers. Therefore, acceptability among farmers will be low, as 45% indicated low and very low acceptance of GMOs among farmers.

Again, from the analyzed responses in the table it was indicated that 30% of the study group thinks GMOs will be average in terms of how affordable they will be. While, 29 linked very low to its affordability. About 23% of the study participants said its affordability will be low whereas, 10% are of the view that its affordability will be high, and 8% contemplate that its affordability is very high. Generally, the affordability of GMOs, as indicated by 52% of the study participants said, it will not be affordable by farmers.

According to the study group, in terms of accessibility, 36% believe that there will be low access to GMOs among their clients as indicated in Table 3, while (33%) of the respondents associated low access to GMOs. On the other hand, 24% indicated that its access will be average and whilst 5% said its accessibility will be high. Similarly, 2% say its accessibility is very high. From the analysis above, 69% (36% low and 33% very low) claimed there is a likelihood of farmers' low accessibility to GMO.

Table 3 shows that 40% and 30% claimed that GMO awareness among the farmers is very low and low awareness, respectively. While 19% and 11% said awareness is average and high respectively. Hence, the majority (70%) believed there is low awareness of GMOs among farmers.

V. CONCLUSION

This study assessed agriculture officers' perceptions on the introduction of GMOs into Ghana and its impact on food and seed security, as well as their level of participation in GMO-related events and readiness to promote them. The study sought their views on GMOs as a successful solution to tackle farming challenges and also assessed what influenced their views.

The responses gathered were analyzed using Power BI. While descriptive statistics such as percentages were employed to show how their opinions differ from a wide range of perspectives based on factors such as environmental, sustainable food and nutrition security/safety, and agribusiness viewpoints on GMOs emergence in Ghana.

The study revealed that 53% of agriculture officers agreed that GMOs will have a positive impact on food, seed security, and sovereignty. Also, 56% said they will champion GMOs; however, 67 % said there is limited information on GMOs and 74% of the respondents indicated that they have never participated in GMOs related programs or activities.

The paper highlighted officers' views around the introduction of GMOs into Ghana, although there were divergent views on GMOs as a successful solution to tackle farming challenges. From the officers' point of view, 45% of the study respondents suggest that GMO acceptability among farmers will be low. Also, more than half of the studied group (52%) said it will not be affordable by farmers. Again, most respondents (69%) claimed that there will be low access to GMOs by the farmers and 70% claimed there is low awareness of GMOs among farmers. The study further seeks to understand what influenced their opinion and the key influencers include: GMOs is unsafe for human consumption, genes escape into wild relatives; GMOs will create insect resistance and genetically engineered crops will have limited capacity locally.

It is important to note that agriculture officers' opinions are not exhaustive and that there is a wide range of perspectives within the agriculture community. There exist varied views, as some agriculture professionals have a more nuanced view, acknowledging that GMOs can have both helpful and adverse effects. Some are of the view that specific traits, potential risks, and benefits of GMOs should be assessed on a case-by-case basis.

The study recommended that there is a need for pro- and anti-GMO groups to involve officers in GMO activities for effective dissemination of information on GMOs to farmers and citizens.

Table 1 Demographic or Socio-Economic Characteristic of Respondents

VARIABLES	FREQUENCY	PERCENTAGE
GENDER		
Male	(63)	84%
Female	(12)	16%
AGE (YEARS)		
Below 30	(13)	18%
31 – 40	(40)	55%
41 – 50	(18)	24%
Above 50	(3)	3%
EDUCATIONAL LEVEL		
PHD		0%
Masters	(21)	28%
BSc. B/Tech	(37)	50%
Diploma	(8)	11%
Certificate	(8)	11%
YEARS OF EXPERIENCE		
Less than 2 years	(6)	8%
3 -5 years	(24)	32%
6 – 10 years	(20)	27%
11 – 15 years	(11)	15%
16 – 20 years	(7)	10%
21 – 25 years	(5)	7%
30 years and above	(1)	1%

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Table 2 Impacts of GMO on Farming, Food Security, Promotion of GMO and Benefits

VARIABLES	PERCENTAGE	PERCENTAGE
GMO IMPACTS ON FARMING		
Very Positive	(5)	7%
Positive	(26)	35%
Neutral	(15)	20%
Negative	(11)	15%
Very Negative	(10)	14%
Not Sure	(7)	9%
GMO IMPACTS ON FOOD SECURITY		
Very Positive	(10)	14%
Positive	(29)	39%
Neutral	(11)	14%
Negative	(9)	12%
Very Negative	(8)	11%
Not Sure	(7)	10%
PROMOTION OF GMO		
Very Likely	(12)	16%
Likely	(30)	40%
Not Sure	(21)	28%
Not Very Likely	(4)	6%
Unlikely	(7)	10%
Very Helpful	(17)	23%
Helpful	(33)	44%
Not Very Helpful	(14)	19%
Unhelpful	(10)	14%

Table 3 Ranking of GMO Technology via Sustainable Solution Lens

FACTORS	RANKING				
	Very Low	Low	Medium	High	Very High
Acceptability	(22)30%	(11)15%	(24)32%	(16)22%	0%
Accessibility	(24)33%	(27)36%	(18)24%	(4)6%	(1)1%
Affordability	(21)29%	(17)23%	(22)30%	(7)10%	(6)8%
Awareness	(30)40%	(22)30%	(14)19%	(8)11%	0%

Table 4 Agriculture officers' views on GMOs

Statement: GMO ….	**Responses** **Strongly agree (S.A), Agree (A), Neutral (N), Disagree (D), Strongly disagree (S.D)**				
	S.A	**A**	**N**	**D**	**S.D**
Will contribute to sustainable agriculture	26%	51%	14%	5%	4%
Will enhance productivity per unit area	31%	49%	8%	6%	6%
Will reduce environmental chemical on the ecosystem	27%	37%	19%	11%	6%
Could contaminate the wider environment	12%	26%	23%	32%	7%
Genes may escape from a crop into wild relatives	11%	33%	27%	26%	3%
Will Create insect resistant	14%	42%	30%	7%	7%
Have potential contamination of the food chain	18%	25%	25%	27%	5%
Is unsafe for consumption	10%	19%	28%	32%	11%
Will lead to diversity of features been engineered in plants	14%	51%	24%	8%	3%
Will improve the situation in our food security	27%	44%	14%	10%	5%
Will worsen our food security	19%	8%	22%	44%	7%
Could lead to monopoly via patents	14%	51%	24%	8%	4%
Will reduce the need for potentially environmentally damaging, expensive pesticides	26%	36%	22%	6%	10%
Will be better for the farmer, the environment and society	11%	46%	19%	17%	7%
Is geared towards agri-business	27%	34%	24%	10%	5%
Will benefits resource-poor subsistence farmers	18%	42%	20%	11%	8%
Limited capacity to genetically engineered crops locally	19%	32%	28%	17%	4%
GMO seeds are or could be sterile	15%	28%	38%	15%	4%
Will lead to decline in chemical pesticide use	26%	36%	22%	6%	10%
Will reduce contamination of soils and water	22%	36%	23%	8%	11%
Will improve nutrition	15%	44%	20%	15%	6%
Will increase yield and increase income of farmers	38%	45%	9%	4%	4%
Will protect the environment	15%	29%	33%	12%	11%
Could reduce poverty	30%	34%	19%	10%	7%

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Analysis of Spatiotemporal Changes and Driving Forces of Vegetation Coverage in Foshan City, Guangdong Province

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***Abstract*— *Quantitative analysis of the spatiotemporal distribution characteristics and driving forces of regional fractional vegetation coverage (FVC) is of great significance for promoting urban ecological protection and high-quality development. This study utilized the GEE platform and Landsat series remote sensing data to invert the FVC of Foshan City from 2001 to 2020 based on a pixel binary model. The spatial pattern and spatiotemporal variation characteristics were analyzed, and combined with meteorological, topographic, and land use data of the same period in the region, Sen +Mann Kendall trend analysis and parameter optimal geographic detector model were used to analyze its driving factors. The results showed that: 1. From 2001 to 2020, the overall vegetation coverage showed a slight downward trend (with a reduction rate of 2.87%), and the average vegetation coverage over the years was 51.53%, indicating that the vegetation coverage in the study area was generally at a moderate level. In terms of spatial distribution, the overall vegetation coverage shows a pattern of "high in the northwest and low in the southeast," with significant regional differences, and the types are mainly moderate and low vegetation coverage. 2. The proportion of vegetation improvement areas in the research area is 49.53%, which is larger than the area of degraded areas. 3. In the detection of driving factors, land use type is the main driving factor with an average explanatory power of 61.25%, while vegetation, topography, precipitation, and altitude are secondary driving factors; The explanatory power (Q value) of the interaction between each factor is higher than that of a single factor, showing a synergistic and nonlinear enhancement relationship between two factors.*

Keywords*— *Fractional vegetation coverage (FVC), Trend analysis, Spatiotemporal differentiation, Optimal Parameters-based Geographic Detector (OPGD) model, Driving factors.

I. INTRODUCTION

Land cover change is one of the core contents of global change research, and vegetation is the most important part of land cover. Its changes have significant impacts on global energy cycling and material biochemical cycling 0[2]. Fractional vegetation cover (FVC) is not only an important control factor for soil erosion but also an effective indicator for evaluating land degradation, salinization, and desertification. It is also an indispensable parameter in models such as evapotranspiration and climate change and is of great significance for measuring the surface coverage and ecosystem status of plant communities [3]. Mastering the spatiotemporal changes in vegetation coverage, analyzing and predicting its development trends, and exploring the driving effects of factors such as terrain and climate has important theoretical and practical significance for evaluating ecosystem environmental quality and regulating ecological processes[3].

With the development of remote sensing technology, many scholars at home and abroad have used satellite remote sensing images to extract and analyze vegetation coverage. In terms of data, domestic and foreign scholars have achieved fruitful results in the extraction and spatiotemporal changes of vegetation coverage based on MODIS, SPOT, GIMMS, and Landsat series satellite image data [6]. The research on the driving factors of vegetation coverage has also made significant progress [7]. Although different resolutions of data have been applied to vegetation monitoring in different regions, research that simultaneously considers higher spatial resolution and longer time series is still one of the development trends on larger spatial scales. Previous studies have lacked accurate quantitative evaluation of the driving factors behind long-term changes in vegetation coverage. The Optimal Parameters-based Geographic Detector (OPGD) model can improve the overall ability of spatial heterogeneity analysis [8]. Therefore, it is of great significance to combine the Google Earth Engine (GEE) platform and OPGD model to analyze the long-term spatiotemporal changes and influencing factors of vegetation coverage.

Foshan is located in the central part of Guangdong Province and the hinterland of the Pearl River Delta. Quantitative analysis of temporal and spatial variation characteristics and driving factors of vegetation coverage in Foshan City is of great significance for understanding the changes in regional ecological environment quality and promoting the construction of ecological protection and high-quality development pilot areas in the Pearl River Basin.

This study uses the Landsat series of satellite remote sensing data from 2001 to 2020, combined with meteorological, topographic, vegetation, and geomorphic data of the same period in the region and comprehensively uses the pixel dichotomy model, Sen+Mann Kendall trend analysis, and OPGD model to conduct qualitative and quantitative analysis of regional vegetation coverage changes and driving factors. By mastering the distribution and evolution characteristics of vegetation in the region, we deepen our understanding of the driving mechanism of vegetation change in Foshan City, with a view to providing data support and a scientific basis for the sustainable development of Foshan City and the implementation of the Pearl River Basin protection strategy [2].

II. STUDY AREA

Foshan is located in the central and southern part of Guangdong Province, in the hinterland of the Pearl River Delta (PRD), east of Guangzhou, and adjacent to Hong Kong and Macao. Located at 113° 06 'E and 23° 02' N, with an administrative area of 3797.72 square kilometers. The terrain of Foshan City is generally high in the north and low in the south, high in the west and low in the east. Most areas are relatively flat, with little topographic relief. It is dominated by plains. The climate is mild, the rainfall is abundant, and the four seasons are like spring. It is a subtropical monsoon humid climate, with an annual average temperature of 23.2°C. The Xijiang River, Beijiang River, and their tributaries in the Pearl River water system run through Foshan City, which is a typical delta river network area. The main rivers are the Pearl River, Xijiang River, and Beijiang River, which provide Foshan with rich water resources. The rainfall is 1490.6 millimeters, and the annual sunshine hours are around 1800 hours. The soil is mainly red soil and yellow soil, and the surface vegetation types are mainly subtropical evergreen broad-leaved forests and shrub grasslands.

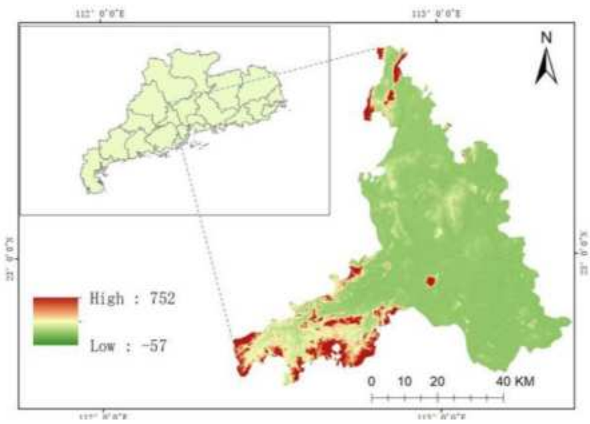


Fig.1 Geographical Location of the Study Region

III. MATERIALS AND METHODS

3.1 Data Sources

3.1.1 Remote Sensing Data

The remote sensing image data used in this study was sourced from the United States Geological Survey (https://www.usgs.gov/). The data production provider is the Land Use and Global Change Remote Sensing Team of the Institute of Geographic Sciences and Resources, Chinese Academy of Sciences. Through the GEE cloud platform, we selected the Level-2 surface reflectance product of Landsat 5 (2001-2012) and Landsat 8 (2013-2020) satellites, with a spatial resolution of 30 m, which has been atmospheric corrected [9].

The maximum Normalized Difference Vegetation Index (NDVI) dataset in China from 2000 to 2022 is based on the GEE cloud computing platform. Using all Landsat 5/7/8/9 remote sensing data throughout the year, all Landsat effective observation data are obtained by removing clouds and shadows. Then, the NDVI index of each Landsat effective observation is calculated, and combined with linear interpolation and S-G smoothing methods; the maximum NDVI value of each pixel location in a year is finally obtained. The spatial resolution of this dataset is 30 m, and the temporal resolution is annual. [10]

3.1.2 Factor Data

The terrain data adopts geospatial data cloud (http://www.gscloud.cn/). The downloaded ASTER Global Digital Elevation Model (GDEM) digital elevation data product [11] has a spatial resolution of 30 m. Using ArcGIS to extract slope and aspect data from DEM data, obtain data for the study area.

The temperature, precipitation, and humidity data are sourced from the National Science and Technology Infrastructure Platform—National Earth System Science Data Center (http://www.geodata.cn/). The temperature data and precipitation data are respectively sourced from the monthly average temperature dataset at 1 km resolution in China from 1901 to 2021 and the annual precipitation data at 1 km resolution in China from 2001 to 2020. The data on sunshine hours is sourced from the National Bureau of Statistics (http://www.stats.gov.cn/).

The land use data is sourced from the annual land cover data of 30 m in China from 1990 to 2021 (http://irsip.whu.edu.cn/resources/CLCD.php). This product includes 9 types of land use, namely: farmland, forest, shrub, grassland, water area, ice and snow, unused land, construction land, and wetland [12].

The vegetation type data and landform types are sourced from the resource and environmental science data of the Chinese Academy of Sciences (http://www.resdc.cn). The spatial resolution is 1 km. Based on the 1:1 million Chinese Vegetation Atlas and the 1:1 million Topographic Atlas of the People's Republic of China, combined with the actual situation of the research area, the vegetation types are divided into 8 types: coniferous forest, broad-leaved forest, shrub, desert, grassland, cultivated vegetation, and others. The landform types are divided into 5 categories: plain, plateau, hill, small undulating mountain, and medium undulating mountain.

All factor data were extracted using ArcGIS software according to the vector boundaries of the study area and resampled to match the resolution of NDVI data. Using ArcGIS to create a fishing net tool randomly generate a 1 km × 1 km grid within the study area with a total of 4151 center points as sampling points and input them into the geographic detector for processing.

3.2 Research Methods

3.2.1 Vegetation Coverage Estimation

Using the pixel binary model for vegetation coverage inversion [13], the FVC calculation formula is shown in (1).

$$\mathrm{FVC} = \frac{NDVI-NDVI_{soil}}{NDVI_{veg}-NDVI_{soil}} \#(1)$$

In the formula, FVC is the vegetation coverage of a certain pixel; NDVI is the value of the pixel; NDV_{Soil} is the NDVI value of pure soil pixels in the image; $NDVI_{Veg}$ is the value of pure vegetation pixels in the image. Considering the issues of image outliers and noise, combined with the actual situation of vegetation coverage in the study area and relevant research experience [14], this paper adopts the NDVI value when the cumulative histogram of NDVI results reaches 5% as the NDV_{Soil} value and the NDVI value when the cumulative histogram of NDVI results reaches 95% as the $NDVI_{Veg}$ value.

Referring to relevant research and expert experience [15], combined with the actual situation of the study area, the vegetation coverage in the study area is divided into 5 levels (Table 1).

Table 1 Classification of FVC Level

FVC Level	FVC value
Extremely low	0～0.2
Low	0.2～0.4
Medium	0.4～0.6
High	0.6～0.8
Extremely high	0.8～1

3.2.2 FVC Trend Analysis

The Sen+Mann Kendall method was used to analyze the long-term trend of vegetation coverage changes [16]. Sen's slope is a non-parametric statistical method for calculating stable trends, which can be used to represent the degree and trend of FVC changes [17-18]. The calculation formula is as follows:

$$S_{FVC} = \text{median}\left(\frac{FVC_j - FVC_i}{j-1}\right), \forall j > i \quad \#(2)$$

In the formula, FVC_i and FVC_j represent the vegetation coverage in the i-th and j-th year, respectively; S_{FVC} is the slope, $S_{FVC}>0$ indicates an upward trend in regional vegetation coverage, while $S_{FVC}<0$ indicates a downward trend in regional vegetation coverage.

Mann-Kendall trend analysis does not require data to follow a certain distribution and is not easily affected by outliers. It has a solid statistical theoretical basis for testing significance levels [19-20] and is suitable for non-normally distributed data. It is currently a widely used nonparametric testing method. The calculation formula is as follows:

$$S = \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} s\,gn(x_j - x_i)$$

$$\text{sgn}(x_j - x_i) = \begin{cases} 1, & x_j - x_i > 0, \\ 0, & x_j - x_i = 0, \\ -1, & x_j - x_i < 0. \end{cases}$$

$$\text{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)-(2t_i-5)}{18} \quad \#(3)$$

$$U = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, & S > 0, \\ 0, & S = 0, \\ \frac{S+1}{\sqrt{Var(S)}}, & S < 0. \end{cases}$$

In the formula, S is a normal distribution; the mean is 0: Var (5) is the variance, "is the number of time series, and when it is greater than 10, U tends to follow a normal distribution; m is the number of repeated data sets in the time series; t is the number of duplicate data in the i-th duplicate data group. S is x and x; the size relationship. The range of U values (- ∞, +∞), if | U |> $U_{1-\alpha/2}$, it is considered that there is a significant trend of change at the confidence level of a. U>0 indicates an increasing trend, and U<0 indicates a decreasing trend.

3.2.3 Geographic Detector Model Based on Optimal Parameters

The traditional geographic detector model suffers from subjective interference when discretizing continuous factors [21]. Therefore, this study chooses the OPGD model to analyze the driving factors of vegetation coverage changes in the research area. Meanwhile, we applied vegetation coverage as the dependent variable and tertiary indicators as explanatory factors for geographic detector analysis. Use the "gdm" function in the geographic detector R language package "GD" to select the optimal discretization method and quantity combination [22]. On this basis, differentiation and factor detection, interaction detection, and risk detection were selected to analyze the influencing factors of vegetation coverage in the study area. The types and indicators of detection factors are shown in Table 2.

Table 2 Probe Factors

Type	Probe factors	Index	Unit
Terrain	X_1	Aspect	°
	X_2	Slope	°
	X_3	Elevation	m
Climate	X_4	Annual cumulative sunshine hours	h
	X_5	Annual temperature	℃
	X_6	Annual precipitation	mm

Landform	X_7	Landform type	—
Vegetation	X_8	Vegetation type	—
Human activity	X_9	Land-use type	—

Notes: "—" indicates no unit

(1) Factor detection is used to calculate the degree of impact Q of each factor on vegetation coverage. The calculation formula is as follows:

$$Q = 1 - \frac{\sum_{h=1}^{l} N_h \sigma_h^2}{N\sigma^2} = 1 - \frac{SSW}{SST}$$
$$\mathrm{SSW} = \sum_{h=1}^{l} N_h\, \sigma_h^2 \quad \#(4)$$
$$\mathrm{SST} = N\sigma^2$$

In the formula, Q is the spatial differentiation index; l is the stratification of FVC attributes or natural and human factors; Nh and N are the number of units in a specific layer and the entire region, respectively; The variances of FVC values in the h layer and the entire region are represented by σ_h^2 and σ^2, respectively; SSW and SST are the sum of intralayer variances and the total variance of the entire region, respectively. The range of Q values is [0, 1], and the larger the Q value, the greater the spatial difference of FVC. In extreme cases, a Q value of 1 indicates that factor X completely controls the spatial distribution of Y, while a Q value of 0 indicates that factor X is independent of Y.

(2) Interaction detection is mainly used to identify the combined effect of two evaluation indicators on vegetation coverage [23], that is, to evaluate the combined effect (enhancement or weakening) and the impact of individual effects on FVC. The steps are as follows: Firstly, calculate the Q values [Q (Xi)] and [(Xj)] of the two factors relative to FVC, and then calculate the Q value [Q (Xi ∩ Xj)] regarding the interaction between the factors, and compare it with Q (Xi) and Q (Xj).

IV. ANALYSIS AND RESULTS

4.1 FVC Temporal Variation Characteristics

Analysis shows that the average vegetation coverage in the study area has decreased from 53.9% in 2001 to 52.4% in 2020 over a 20-year period, showing a slight decrease overall ($P<0.01$) at a rate of 2.87%. The average vegetation coverage over the years is 51.53%, and the overall vegetation coverage is at a moderate level (Figure 2). The vegetation coverage in the study area showed irregular fluctuations within the range of 47.89%–54.5%, with peaks in 2003, 2013, and 2016, and valleys in 2005, 2009, 2012, and 2014. Among them, the highest value was reached in 2003 at 53.9%, and the lowest value appeared in 2012 at 47.89% [24].

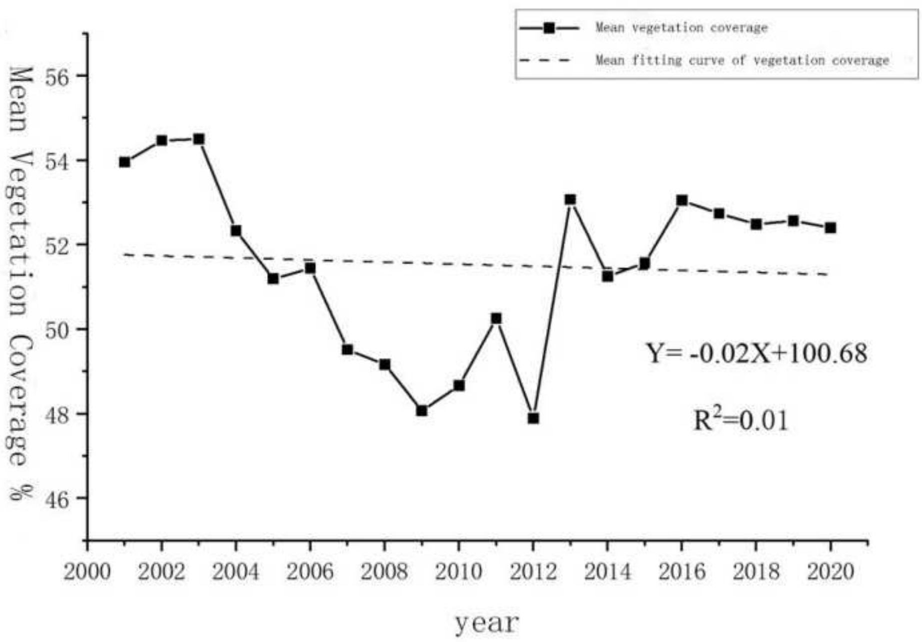


Fig.2 Changes and Trends of FVC from 2001 to 2020

4.2 FVC Spatial Distribution Pattern

Analysis shows that there are significant regional differences in vegetation coverage in the study area, with an overall trend of "high in the west and low in the east" and "high in the north and low in the south." The types are mainly moderate and low vegetation coverage (Figure 3, Figure 4). The area with moderate vegetation coverage accounts for the largest proportion, reaching 22.8%, mainly distributed in the central and western parts of the South China Sea and the southern part of the Sanshui District. The area with low vegetation coverage is distributed, accounting for 22.5% of the total area; the area with extremely low vegetation coverage accounts for the smallest proportion, at 15.8%, distributed in the northern part of Chancheng District and Shunde District; the high vegetation coverage and extremely high vegetation coverage account for 17.2% and 21.7% of the total area, respectively, distributed in Gaoming District and the northern part of Sanshui District. The above results are consistent with previous research findings [25].

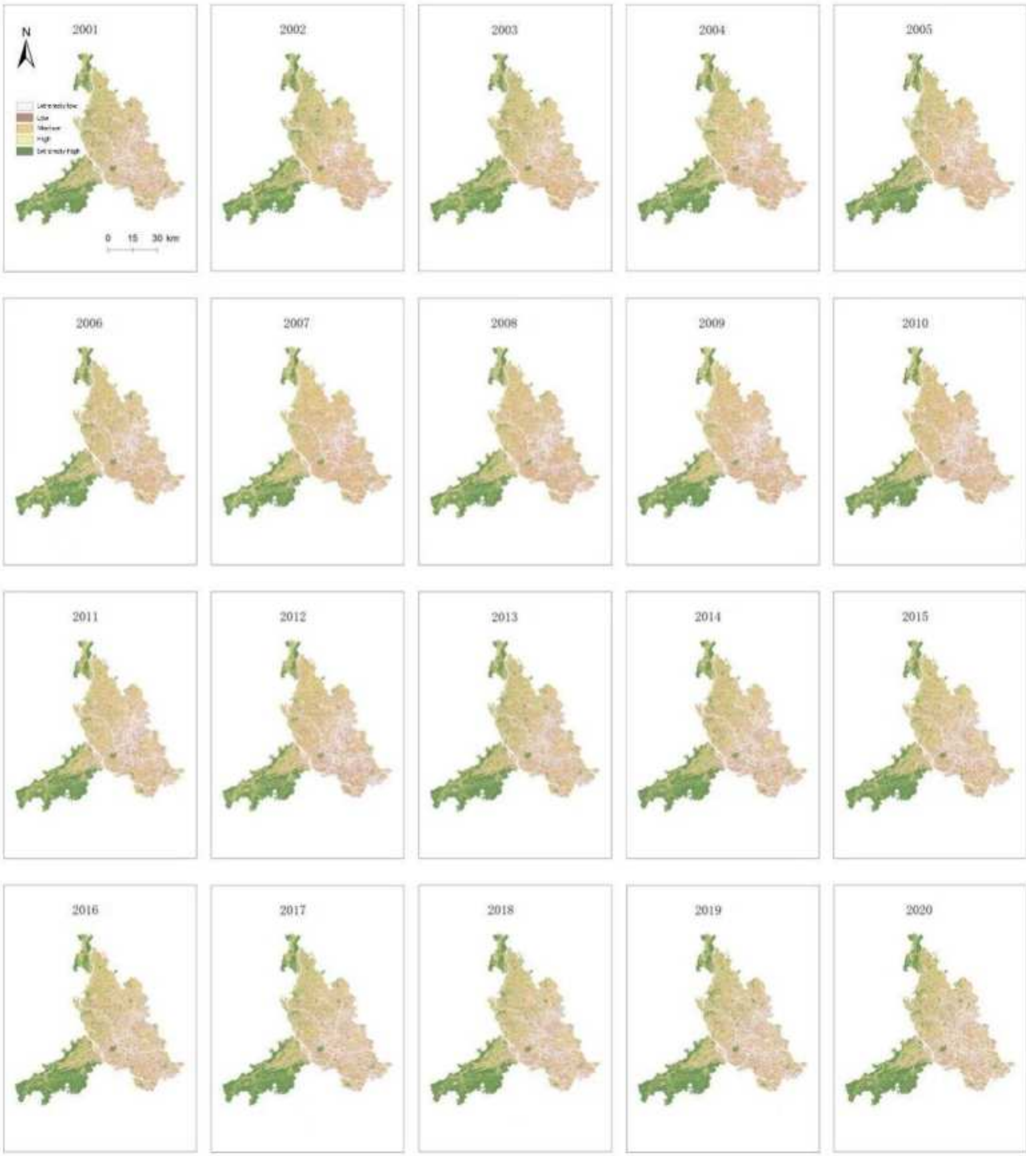


Fig.3 Annual Changes in the Distribution of Vegetation Coverage from 2000 to 2020

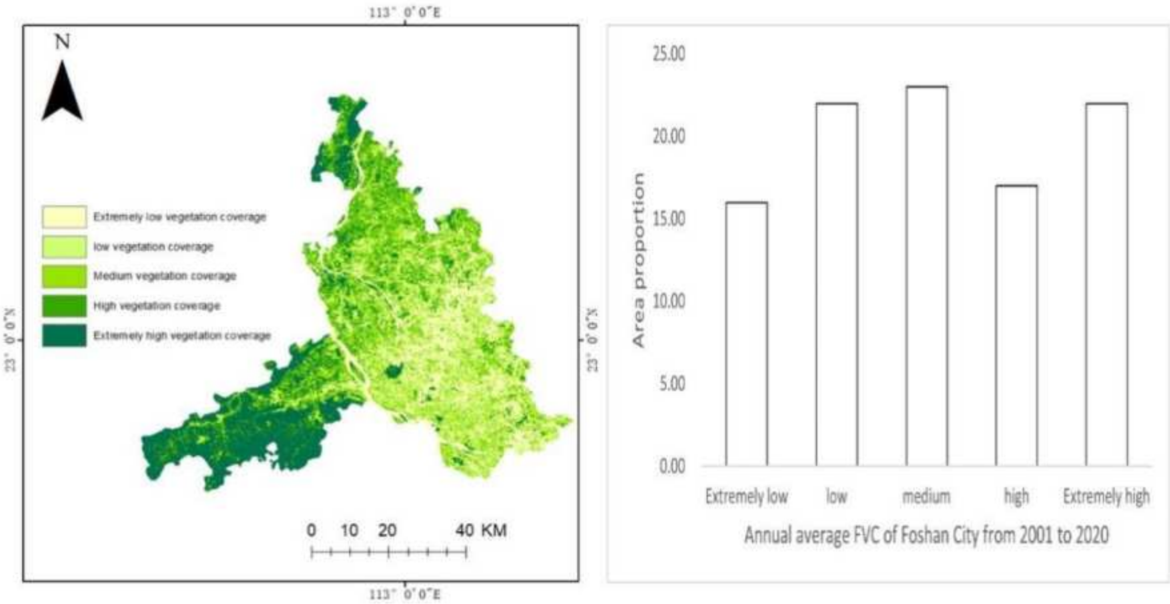


Fig.4 Average FVC Spatial Distribution and Area Ratio of Each Class from 2001 to 2020

4.3 FVC Spatial Variation Characteristics

Based on Sen+Mann Kendall trend analysis, the spatial distribution of vegetation change trends in the study area from 2001 to 2020 was obtained (Figure 5). According to the actual situation of SFVC and U values in the study area [26], the trend of vegetation coverage changes in the study area is divided into five categories: significant improvement, slight improvement, stable and unchanged, slight degradation, and significant degradation. From Table 3, it can be seen that from 2001 to 2020, the area with changes in vegetation coverage in the study area accounted for 87.3% of the total area, with improved areas accounting for 49.53% of the total vegetation coverage, degraded areas accounting for 37.77%, and stable areas without significant changes accounting for 12.70%. Overall, the area of vegetation coverage improvement in the study area is nearly half of the total area, showing an overall trend of improvement. From a spatial distribution perspective, the regional spatial characteristics of vegetation coverage improvement and degradation are not significant. Compared to Lingshan, the overall trend is improvement in the eastern, southeastern, and southwestern parts, while some areas in the southern, northern, and central parts show a degradation trend.

Table 3: Statistical Trends of FVC Changes from 2001 to 2020

S_{FVC}	|U| value	FVC trend	Area/km^2	Ratio/%
≥0.0005	≥1.96	Significant improvement	1121.24	27.21
≥0.0005	|U|<1.96	Slight improvement	920.04	22.32
-0.0005~0.0005	|U|<1.96	Stable and unchanging	523.32	12.70
<-0.0005	|U|<1.96	Slight degradation	795.47	19.30
<-0.0005	≥1.96	Significant degradation	761.13	18.47

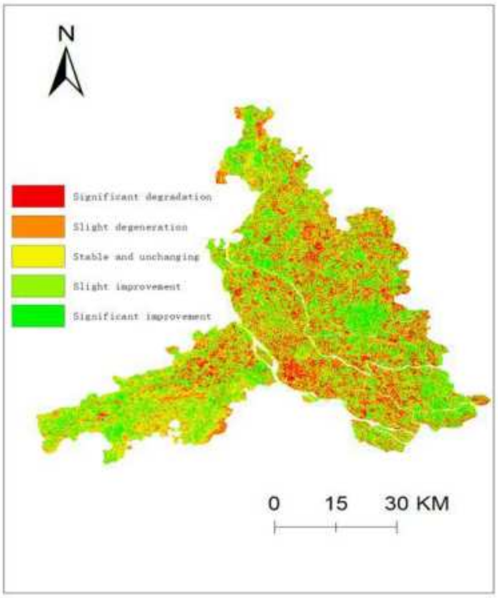


Fig.5 Changes Trend of the FVC from 2001 to 2020

4.4 FVC Driving Force Analysis

4.4.1 Continuous Factor Discretization

Referring to relevant research and the actual situation of the research area [22], the initial interval of interruption is set as 4-8 categories, and the letters A~H are used to represent different categories. Through model calculations, select the scheme with the highest Q value for each continuous dependent variable under different classification methods and hierarchical levels for spatial discretization [27]. Taking 2001 as an example, the optimal spatial data discretization parameters were set as follows: natural spacing classification was used to classify sunshine into 10 categories, and quantile spacing classification was used to classify terrain, slope, altitude, precipitation, and temperature into 9, 10, 10, 10, and 10 categories, respectively.

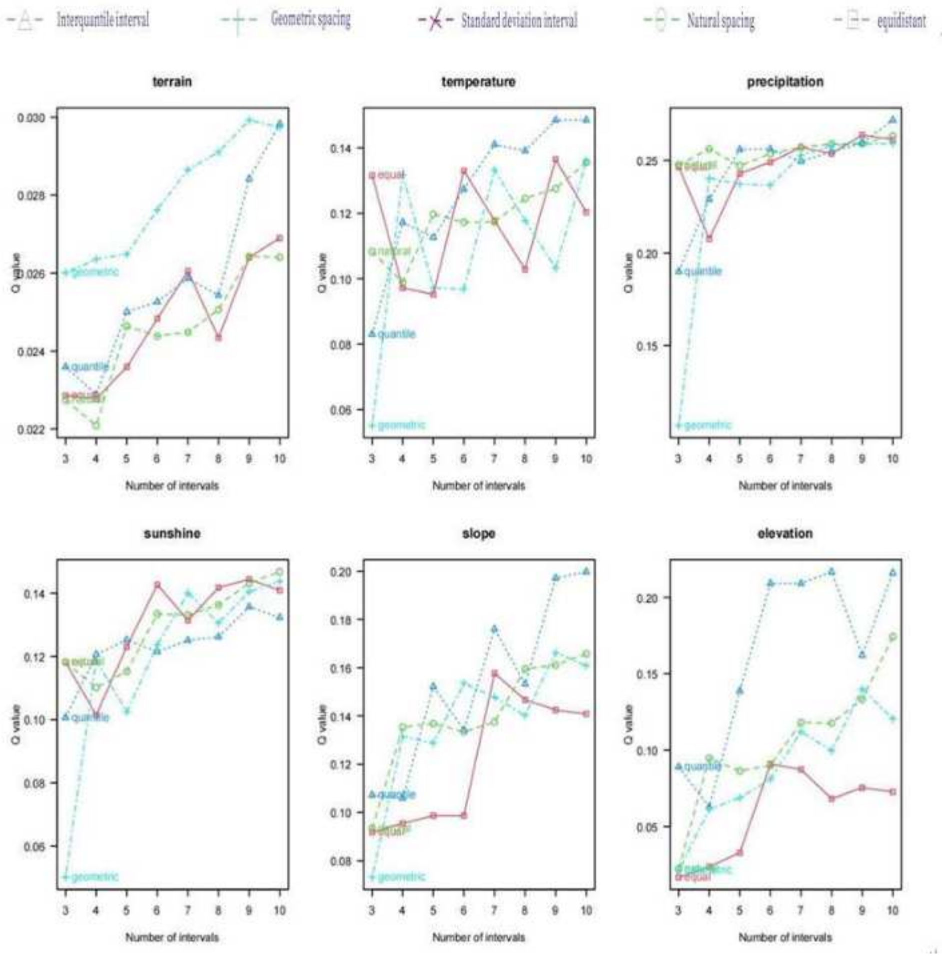


Fig.6 Continuous Factor Discretization Processes

4.4.2 Factor Detection

The explanatory power of each factor in the research area from 2001 to 2020 is shown in Figure 7. The average explanatory power of each factor from 2001 to 2020 is ranked as follows: land use (0.6125)>vegetation type (0.3662)>landform (0.2893)>precipitation (0.2717)>altitude (0.2167)>humidity (0.1997)>temperature (0.1485)>sunshine (0.1467)>terrain (0.0299). The Q values of each factor have passed the significance test. Among them, the average explanatory power of land use types is 61.25%, which is much greater than the explanatory power of other factors and is the main driving factor affecting changes in vegetation coverage in the study area; Vegetation, topography, precipitation, and altitude all have explanatory power of over 20% and are secondary driving factors; The explanatory power of slope, temperature, and sunshine hours all exceed 10%; The explanatory power of terrain is less than 10%, and its impact on vegetation coverage changes in the study area is minimal [24].

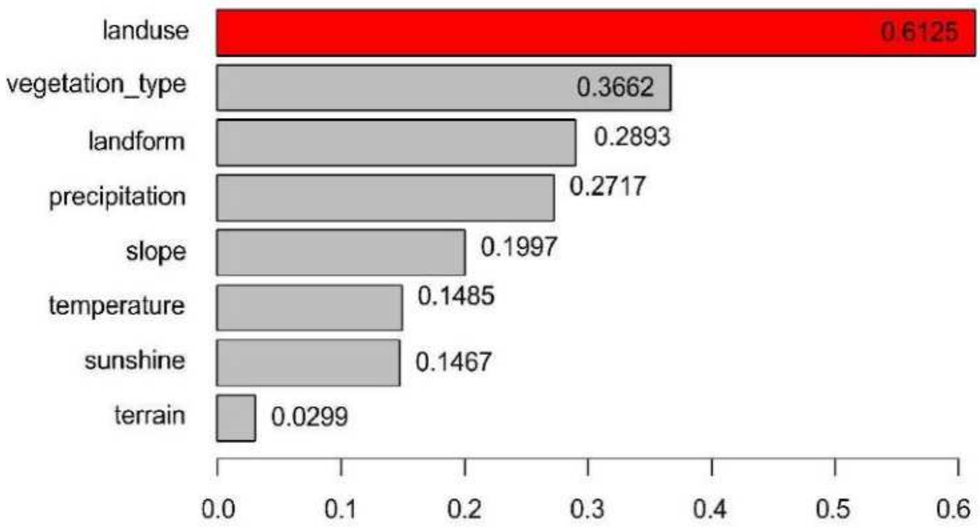


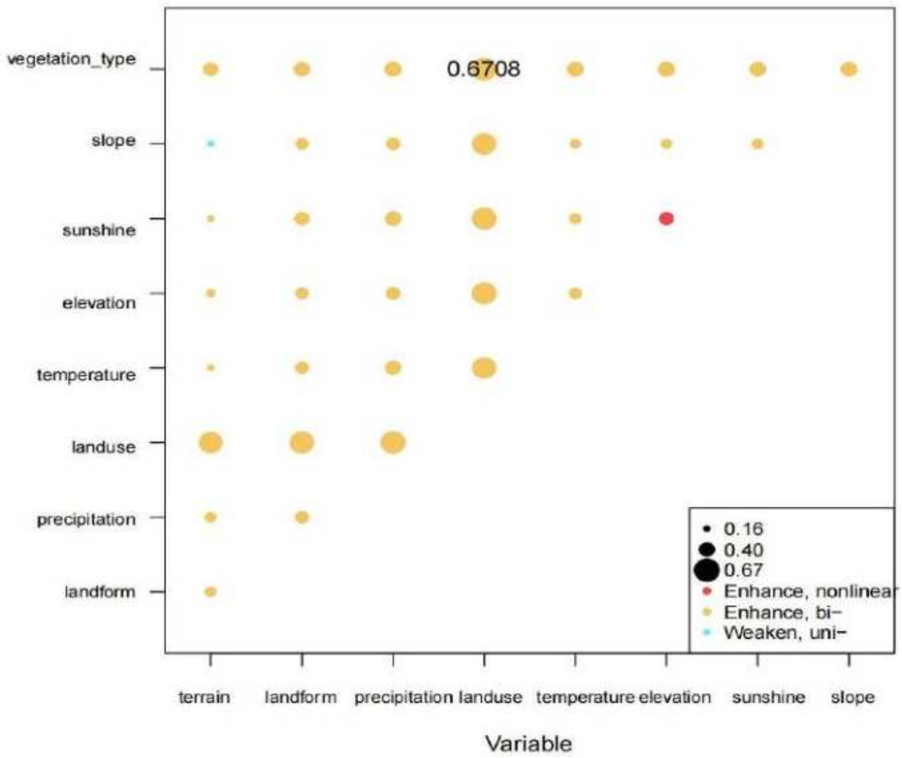
Fig.7 Result of the FVC Factor Detector from 2001 to 2020

4.4.3 Interaction Detection

Analyze the interaction between various factors of vegetation coverage through interactive detection (Figure 8). From a temporal perspective, the Q values of the interactions between various factors showed an overall trend of increasing from 2001 to 2010 and decreasing from 2011 to 2020. From a factor perspective, the interaction between two factors shows an enhancing effect, and over 75% of factor combinations exhibit a dual factor enhancing effect, while the remaining factors show non-linear enhancement, meaning that the superposition of two factors greatly enhances the impact of a single factor on vegetation coverage.

Among them, the Q value of the interaction between land use and terrain, slope, altitude, precipitation, sunshine, temperature, and vegetation type is the highest (all>0.64), indicating that the influence of spatial superposition on vegetation coverage is dominant. This suggests that the interaction between land use and other natural factors significantly enhances the influence of natural factors on vegetation coverage, indicating a clear dual factor synergistic enhancement relationship, demonstrating the dominant role of land use.

The interaction between sunshine and terrain, slope, altitude, temperature, and annual precipitation, as well as the interaction between terrain, temperature, vegetation, and precipitation, shows a non-linear enhancement. The interaction between vegetation type and topography and other factors is significant, while the interaction between sunlight, topography and other factors is relatively weak. Overall, the interaction and influence of human factors and natural factors have shown an increasing trend, indicating that changes in vegetation coverage are influenced by both natural factors and human activities [28].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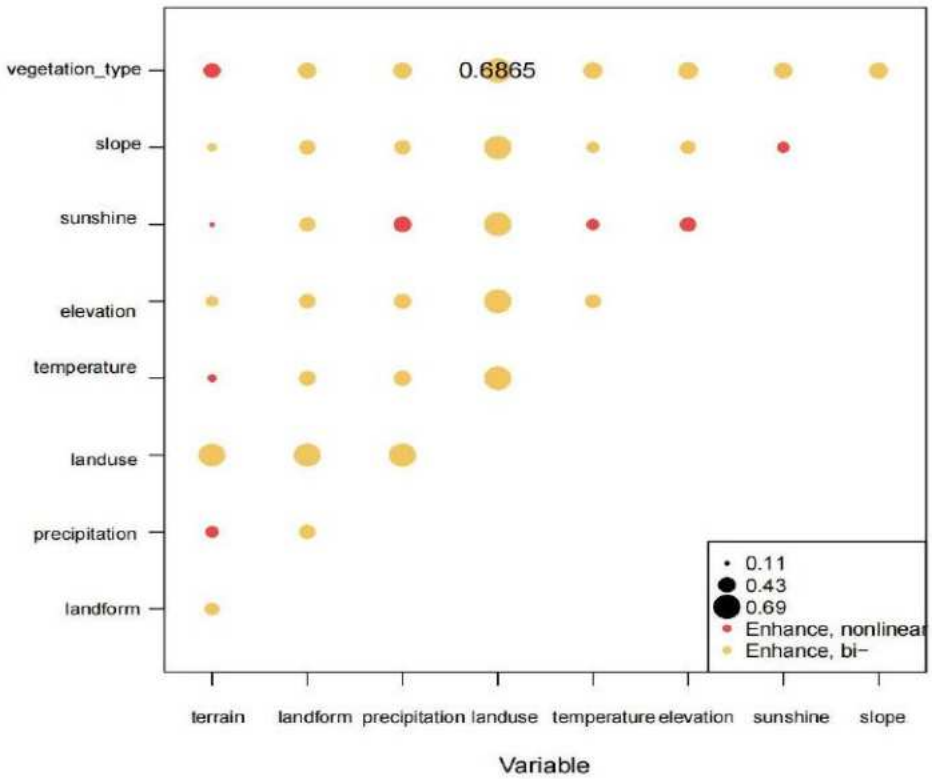
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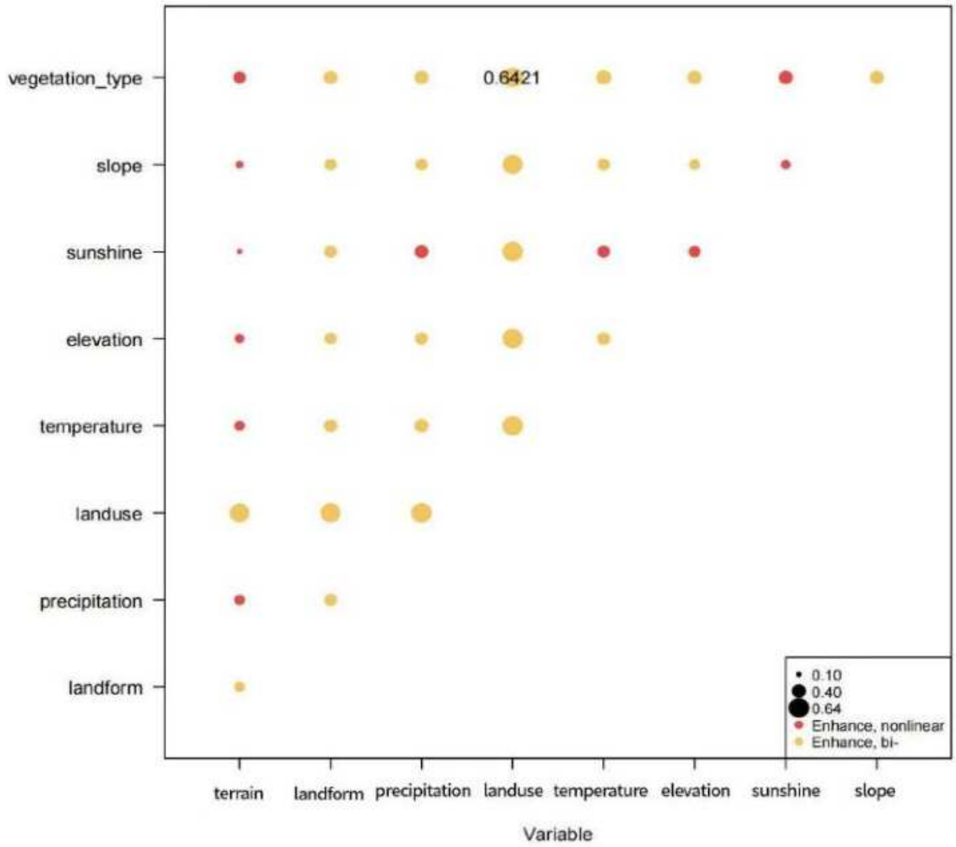

Fig.8 The Q Value of FVC Interaction Detector in 2001, 2010, and 2020

V. DISCUSSION

5.1 Spatiotemporal Evolution Characteristics of FVC in Foshan City

Vegetation changes can directly reflect the changes in the local ecological environment [29]. From a temporal perspective, the vegetation coverage in the study area showed an overall downward trend from 2001 to 2020. Over the past 20 years, the vegetation coverage in the study area has shown irregular fluctuations within the range of 47.89%–54.5%. Analyzing the reasons: 1. Over the past 20 years, Foshan's economy has been continuously developing, and land use changes have led to the loss of vegetation. Many green spaces have been converted into buildings, transportation, industrial parks, commercial squares, etc. 2. From 2002 to 2012, the industrial land in Foshan City continued to increase, and reclamation of arable land. 3. The new round of returning farmland to forests project in 2015 has just been implemented, resulting in a decrease in arable land area and a lower coverage of newly planted vegetation. By 2016, FVC had increased. From 2013 to 2020, Foshan City relocated some factories, reclaimed and green some land, and restricted the development of some land.

From a spatial perspective, the vegetation coverage in the study area has obvious spatial differentiation, and the typical terrain in the region lays the foundation for its distribution pattern of "high in the west and low in the east" and "high in the north and low in the south" vegetation coverage. The high-value coverage areas are distributed in the Gaoming District in the west and the Sanshui District in the north, with continuous mountains, steep terrain, and large relative height differences. The Beijiang and Xijiang rivers provide abundant irrigation water for the areas they pass through. The low-value areas are distributed in the eastern region, which is located in non-river flowing areas and has a high urbanization rate. The overall vegetation coverage is relatively low.

In terms of spatial change trend, the area of vegetation coverage improvement is greater than the area of degradation. This may be due to Foshan City's emphasis on land reclamation and greening, which restricts the development of some land, resulting in a certain area of vegetation coverage improvement.

5.2 Driving Factors Affecting Vegetation Changes

Vegetation cover change is the result of the combined effects of natural and human factors. Quantifying the impact of natural and human factors on vegetation change and identifying dominant factors can provide valuable references for decision-makers. The research results indicate that both natural and human factors have a significant impact on vegetation changes. Overall, the changes in vegetation coverage in the study area are highly correlated with five driving factors (land use, vegetation, topography, precipitation, and altitude) (Q value > 0.2), with land use type having the greatest impact.

5.2.1 The Impact of Human Factors on Vegetation Changes

Land use type, as the most direct reflection of human activities, plays an important role in vegetation change. Compared to climate factors, the overall impact of human factors on FVC is relatively high. As the only human factor, the explanatory power of land use types remains at a high level, indicating that human habitation and activities significantly affect the trend of vegetation cover change. The analyzed data shows that from 2004 to 2012, the continuous expansion of economic construction and the conversion from arable land to other land use types in Foshan City led to a significant decrease in vegetation coverage. After 2013, Foshan City took measures to improve the ecological environment, relocating some factories, reclaiming and greening some land, and restricting the development of some land, resulting in the gradual restoration of vegetation coverage.

5.2.2 The Impact of Natural Factors on Vegetation Changes

Terrain mainly affects vegetation distribution by altering the water and heat conditions in the environment [31]. As an important terrain factor, altitude has a significant impact on the growth process of surface vegetation and is the main factor affecting the distribution of water and heat conditions in mountainous areas, with a certain degree of complexity. As the altitude increases, the temperature decreases, solar radiation and wind speed increase, and local precipitation and relative humidity first increase and then decrease. Soil types show significant differences, forming changes in environmental gradients, resulting in different plant types and growth characteristics at different altitudes. In this study, vegetation types can explain approximately 36.62% of vegetation changes in the study area, and the impact of vegetation types on vegetation coverage is greater than other natural factors. The vegetation type in the research area is mainly cultivated vegetation, mainly distributed in towns and their edges in plain areas, and the natural environmental conditions are suitable for vegetation growth.

Different types of landforms have distinct topographical features, soils, and land use patterns, which can significantly affect the distribution of vegetation. The landform type can explain 28.93% of the vegetation changes in the study area and has a significant impact on the vegetation changes in the study area. The landform types in the research area are mainly plains and hills, with high vegetation coverage mainly distributed in the western and northern hilly areas. The Beijiang and Xijiang rivers flow through, and the water and heat conditions are sufficient. The altitude is relatively suitable and is conducive to vegetation growth.

The explanatory power of precipitation on vegetation changes in the study area is 27.17%. From the perspective of urban green vegetation in Foshan City, most of the vegetation on both sides of parks, green belts, and streets in the city relies on precipitation to maintain growth. Adequate precipitation contributes to the healthy growth of various trees, shrubs, and herbaceous plants, improving the coverage of urban greenery. From the perspective of natural vegetation in suburban areas, forests, shrubs, and grasslands in the natural ecosystems of suburban areas are also directly affected by precipitation. Adequate precipitation is beneficial for the flourishing of forests and shrubs, increasing vegetation coverage in these areas and maintaining ecological balance. From the perspective of water vegetation, rivers and lakes and river system vegetation in Foshan City also rely on appropriate rainfall to maintain the stability of the wetland environment. Adequate precipitation contributes to the richness and diversity of aquatic vegetation, increasing the coverage and biodiversity of aquatic ecosystems.

Previous studies on the impact of natural factors on vegetation cover have shown that in most subtropical monsoon regions, temperature and precipitation are considered the most important climate factors affecting vegetation distribution and change [32]. In this study, compared with other factors, the Q values of temperature and precipitation were relatively low. The reason is that the long-term development and trend of vegetation cover are more directly affected by human activity factors [5], which leads to the insensitivity of vegetation in the region to changes in temperature and precipitation.

6. CONCLUSIONS

(1) In terms of time, the overall vegetation coverage showed a slight downward trend from 2001 to 2020 (with a reduction rate of 2.87%). Except for the period from 2004 to 2012, when Foshan City experienced a significant and drastic decline due to continuous economic development, the average vegetation coverage for the rest of the years was 51.53%, indicating that the vegetation coverage in the study area was generally at a moderate level. The overall distribution pattern of vegetation coverage in space shows a pattern of "high in the northwest and low in the southeast," with significant regional differences. The types are mainly moderate and low vegetation coverage.

(2) From 2001 to 2020, the proportion of vegetation improvement areas in the study area was 49.53%, which is larger than the area of degraded areas. (It is mainly manifested in the restoration of vegetation coverage after 2012, which is related to the improvement of policies and human activity factors).

(3) The detection results of driving factors indicate that the average explanatory power of land use types is 61.25%, which is the main driving factor affecting the changes in vegetation coverage in the study area, with vegetation, topography, precipitation, and altitude as secondary driving factors; the explanatory power (Q value) of the interaction between each factor is higher than that of a single factor, showing a synergistic and nonlinear enhancement relationship between two factors; and the impact of each driving factor on vegetation growth in the study area has its appropriate range.

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Evaluation of Botanical - Insecticide modules against stem borer, brown planthopper and natural enemies in rice

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***Abstract*— *Field experiment was conducted at Regional Agricultural Research Station, Maruteru, West Godavari (A.P.) during fourrabi seasons of 2019-20to 2022-23 to evaluate botanical-insecticide modules against stem borer and brown planthopper. Significantly superior results were recorded in insecticides alone module, T4 (Chlorantraniliprole 0.4 G @ 1.0 g m^{-2}, Cartap hydrochloride 50% SC @ 2.0 g l^{-1}, Triflumezopyrim 10% SC @ 0.48 ml l^{-1} applied at 25, 45 and 60 DAT respectively) with 50% ROC, 33% ROC in dead hearts and white ears, respectively in case of stem borer and 94% ROC in brown planthopper population and registered the highest grain yield.Among botanical – insecticide modules, treatment, T_2 (Azadirachtin 10000 ppm @ 2.0 ml l^{-1}, Neem oil @ 10.0 ml l^{-1} and Triflumezopyrim 10% SC @ 0.48 ml l^{-1} applied at 25, 45 and 60 DAT respectively) is the best against stem borer (26% ROC in dead heart damage & 13% ROC in white ear damage) and brown planthopper (91% ROC in brown planthopper population). Further, T_2 is at par with insecticides alone module (T4) in managing stem borer and BPH and recorded the grain yield (6718 kg ha^{-1}) on par with the insecticides alone module (6824 kg ha^{-1}).*

***Keywords*— botanicals, brown planthopper, insecticides, rice, yellow stem borer**

I. INTRODUCTION

Rice (*Oryza sativa* L.) is an important staple food crop for more than half of the world population. It alone provides 20% of the global dietary energy supply. Insect pests and diseases remain as the key biotic stresses limiting the rice production significantly. Rice is infested by more than 100 species of insects and mites and about 20 of them are considered to be major economic significancewhich includes stem borers, gall midges, leaf folders, defoliators, and vectors like leafhoppers and plant hoppers that cause serious damage and spread many diseases. The Yellow stem borer attacks the crop from nursery stage till harvesting of the rice crop. It causes dead hearts during vegetative stage and white ears during reproductive stage. The yield losses to rice due to yellow stem borer are estimated 1-19% in early planted and 38-80% in late planted conditions (Catinding and Heong, 2003). Besides yellow stem borer, brown planthopper (BPH), *Nilaparvata lugens* (Stal) considered as the major yield limiting factor in all rice growing countries both in tropics and temperate regions (Krishnaiah, 2014). Both nymphs and adults of the BPH suckplant sap from phloem cells resulting in "hopper burn" symptoms and causes almost 10 to 90 per cent yield losses in rice (Seni and Naik, 2017).

Farmers rely solely on insecticides for management of insect pests and diseases and almost 50% of the insecticides used in rice are targeted against brown planthopper alone (Venkatreddy*et al.* 2012) but their repeated applications often result in problems such as development of resistance, induction of resurgence and residues on farm produce besides environmental concern.Because of this, interest in botanical pesticides has increased. Botanicals are effective in very small concentrations, only affect the targeted pest and closely related organisms, degrade quickly, and offer residue-free food and safe to environment. When used in integrated pest management programmes, rotational applications, or in combination with other insecticides, botanical pesticides can significantly reduce the use of conventional pesticides. This may result not only inreduction in the total amount of pesticide load used in a crop ecosystembut also preventing or delaying the emergence of pest populations with resistance (Khater, 2012). Keeping this in view, the present study was carried out to evaluate the efficacy of botanical– insecticide modules against stem borer and brown planthopper in rice eco-system.

II. MATERIALS AND METHODS

The experiments were conducted in the experimental farm of Regional Agricultural Research Station (RARS), Maruteru (16.38^{0}N, 81.44^{0}E), Andhra Pradesh, India to evaluate Botanical - Insecticide modules against stem borer and brown planthopper in ricefor four seasons from *rabi* 2019-20to *rabi*2022-23 in a randomized block design (RBD) with five treatments and four replications.Rice variety, MTU 3626wasused for the present investigation during rabi season (*rabi* 2019-20 to *rabi* 2022-23). One to two seedlings per hill were planted with a spacing of 15 cm x 15 cm during *rabi*seasonwith a help of a marked rope. The crop husbandry operations as recommended in the package of practices of Acharya N. G. Ranga Agricultural University, Andhra Pradesh were adopted.The details of treatments along with spray schedule are given in Table1.The treatments were imposed thrice at 25, 45 and 60 days after transplanting (DAT) in all the four *rabi* seasons (*rabi* 2019-20 to *rabi* 2022-23).A spray fluid of 500 l ha^{-1} was used to ensure thorough coverage of the crop canopy with battery operated hand sprayer.

Observations on dead heart by stem borer were recorded on 20 plants selected at random at 15 days after each application along with total tillers. Also record the data on white ears prior to harvest along with total productive tillers.Data on nymphs and adults of BPH were taken directly from twenty randomly selected hills per plot at one day before spray (Pre-treatment count) and ten days after third spray (Post-treatment count).

Grain yield was recorded per plot leaving two border rows on all sides and expressed in terms of kg ha^{-1}.

Data on per cent dead hearts and white ears caused by stem borer and BPH population were first converted in toangular transformations and square root transformations, respectively and subjected to analysis of variance technique (ANOVA) (Gomez and Gomez, 1984). The treatment means were compared by least significant difference (LSD) method.

III. RESULTS AND DISCUSSION

3.1 Efficacy of botanical –insecticide modules against yellow stem borer (*Scirpophagaincertulas* Walker)

The pooled data on per cent dead hearts and white ears caused by stem borer and population of brown planthopper per hill of four *rabi* seasons (*rabi* 2019-20 to *rabi* 2022-23) was analysed statistically and presented in Tables 2.

From the data presented in Table 2, the treatment, T_4comprising all insecticides (Chlorantraniliprole 0.4 G @ 1.0 g m^{-2}, Cartap hydrochloride 50% SC @ 2.0 g l^{-1}, Triflumezopyrim 10% SC @ 0.48 ml l^{-1} applied at 25, 45 and 60 DAT, respectively) recorded significantly the lowest per cent dead hearts with 1.60%DH followed by T_2 (Azadirachtin 10000 ppm @ 2.0 ml l^{-1}, Neem oil @ 10.0 ml l^{-1} and Triflumezopyrim 10% SC @ 0.48 ml l^{-1} applied at 25, 45 and 60 DAT, respectively) with 2.37% DH, which were at par with each other and superior over untreated control (3.21%DH). Rest of the treatments,T_1(Azadirachtin 10000 ppm @ 2.0 ml l^{-1}, Eucalyptus oil @ 2.0 ml l^{-1} and Cartap hydrochloride 50% SC @ 2.0 g l^{-1} applied at 25, 45 and 60 DAT respectively)and T_3(Azadirachtin 10000 ppm @ 2.0 ml l^{-1}, Eucalyptus oil @ 2.0 ml l^{-1} and Neem oil @ 10.0 ml l^{-1} applied at 25, 45 and 60 DAT respectively) registered 2.53% DH and 2.64%DH, respectively.

In terms of per cent reduction over control, T_4, T_2 T_1 and T_3 registered 50%, 26%, 21% and 18% reduction in dead hearts, respectively.

With regard to white ear damage, T_4 (Chlorantraniliprole 0.4 G @ 1.0 g m^{-2}, Cartap hydrochloride 50% SC @ 2.0 g l^{-1}, Triflumezopyrim 10% SC @ 0.48 ml l^{-1} applied at 25, 45 and 60 DAT, respectively) recorded significantly the lowest per cent white ears (7.26% WE) and superior over other treatments including untreated control (10.89% WE) with 33% reduction in white ears over untreated control.

Among the botanical – insecticide modules, T_1 (Azadirachtin 10000 ppm @ 2 ml l^{-1}, Eucalyptus oil @ 2 ml l^{-1} and Cartap hydrochloride 50% SC @ 2 g l^{-1}applied at 25, 45 and 60 DAT respectively), T_2 (Azadirachtin 10000 ppm @ 2.0 ml l^{-1}, Neem oil @ 10.0 ml l^{-1} and Triflumezopyrim 10% SC @ 0.48 ml l^{-1} applied at 25, 45 and 60 DAT, respectively) and T_3 (Azadirachtin 10000 ppm @ 2 ml l^{-1}, Eucalyptus oil @ 2 ml l^{-1} and Neem oil @

10 ml l^{-1} applied at 25, 45 and 60 DAT respectively) registered 9.40% WE, 9.47%WE and 9.80% WE, respectively and on par with untreated control (10.89%WE) (Table 2).

The present findings are in agreement with observations made by earlier workers. Neem Oil @ 1% offers protection against yellow stem borer (YSB) and gall midge (GM) by affecting the oviposition of YSB and GM (Krishnaiah and Kalode, 1991).Dhaliwal *et al.* (2002) evaluated four Azadirachtin-based neem formulations (Rakshak 1%, NeemAzal 1% and 5% and Nimbecidine 0.03%) against rice leaffolder and yellow stem borer and reported that the incidence of YSB was minimum in Monocrotophos and was at par with NeemAzal 5% @ 0.50 ml 1^{-1}. Among botanicals tested Eucalyptus oil @ 1000 ml/ha was found effective against stem borer and planthoppers in rice (Seni, 2019). Azadirachtin1%EC @ 750 ml/ha was significantly superior to other biopesticides tested (*B. bassiana* and Bt) against leaf folder and stem borer (Kaur*et al*. 2021).

3.2 Efficacy of botanical -insecticide modules against brown planthopper (*Nilaparvata lugens* Stal)

From the data evident from Table 2, the insecticide alone module, T_4 (Chlorantraniliprole0.4 G @ 1.0 g m^{-2}, Cartap hydrochloride50% SC @ 2.0 g l^{-1}, Triflumezopyrim10% SC @ 0.48 ml l^{-1}applied at 25, 45 and 60 DAT respectively) recorded significantly the lowest population of BPH (4.00 hoppers/hill) followed by T_2 (Azadirachtin 10000 ppm @ 2.0 ml l^{-1}, Neemoil @ 10.0 ml l^{-1} and Triflumezopyrim 10% SC@ 0.48 ml l^{-1} applied at 25, 45 and 60 DAT respectively) with 5.87 hoppers/hill, which were at par with each other and superior over other treatments including untreated control (64.77hoppers/hill). Other treatments, T_1 (Azadirachtin 10000 ppm @ 2.0 ml l^{-1}, Eucalyptus oil @ 2.0 ml l^{-1} and Cartap hydrochloride 50% SC @ 2.0 g l^{-1} applied at 25, 45 and 60 DAT respectively) and T_3 (Azadirachtin 10000 ppm @ 2.0 ml l^{-1}, Eucalyptus oil @ 2.0 ml l^{-1} and Neemoil @ 10.0 ml l^{-1} applied at 25, 45 and 60 DAT respectively) registered 45.42 hoppers/hill and 55.56 hoppers/hill, respectively. In terms of per cent reduction over control, $T_{4,}$ T_2 and T_1modulesregistered 94%, 91% and 30% reduction in BPH population, respectively.

The observations noticed in the present study are supported by the findings made by earlier workers who reported that NSKE at 7.5% recorded higher efficacy against planthoppers in rice (Venkatreddy et al. 2012) and biopesticides that were tested (azadirachtin 1%EC, *Bacillus thuringiensis*, *Beauveriabassiana*) were found significantly effective against planthoppers in rice (Kaur et al., 2022). Pymetrozine and Triflumezopyrim as sole treatments were highly effective against brown planthopper (BPH) by registering over 90% reduction in BPH population(Anand Kumar et al., 2022).

3.3 Effectof botanical – insecticide modules on natural enemies

The pooled data on population of spiders and green mirid bug per hill of four *rabi* seasons (*rabi* 2019-20 to *rabi* 2022-23) was analysed statistically and presented in Tables 3 and 4.

3.3.1Spiders

The results on the population of spiders in different botanical - insecticide modules revealed that there was no significant difference in the population of spiders among the treatments including untreated control during all the four seasons of testing indicating their safety to natural enemies (Table 3).

3.3.2 Green Mirid Bug

At 70 days after transplanting, mirid bug population was significantly more in untreated control (T_5) followed by T_1 (Azadirachtin 10000 ppm @ 2.0 ml l^{-1}, Eucalyptus oil @ 2.0 ml l^{-1} and Cartap hydrochloride 50% SC @ 2.0 g l^{-1} applied at 25, 45 and 60 DAT respectively) and T_3 (Azadirachtin 10000 ppm @ 2.0 ml l^{-1}, Eucalyptus oil @ 2.0 ml l^{-1} and Neem oil @ 10.0 ml l^{-1} applied at 25, 45 and 60 DAT respectively) and on par with each other. Insecticide alone module, T_4 (Chlorantraniliprole 0.4 G @ 1.0 g m^{-2}, Cartap hydrochloride 50% SC @ 2.0 g l^{-1}, Triflumezopyrim 10% SC @ 0.48 ml l^{-1} applied at 25, 45 and 60 DAT respectively) recorded significantly the lowest population of mirid bug followed by T_2 (Azadirachtin 10000 ppm @ 2.0 ml l^{-1}, Neem oil @ 10.0 ml l^{-1} and Triflumezopyrim 10% SC @ 0.48 ml l^{-1} applied at 25, 45 and 60 DAT respectively), which were at par with each other and superior over untreated control during four consecutive *rabi* seasons from 2019-20 to 2022-23. This indicates the density dependence nature of the mirid bug, specific predator of the planthopper (the population of the natural enemy are in direct proportion to the numbers of its prey). Thus, T_2 and T_4 modules did not showany adverse effect on mirid bug population (Table 4).

3.4 Effect of botanical – insecticide modules on grain yield

The results (Table 5) indicated that there was significant yield difference among the treatments after imposition of treatments. Insecticides alone module,T_4 (Chlorantraniliprole 0.4 G @ 1.0 g m^{-2}, Cartap hydrochloride 50% SC @ 2.0 g l^{-1}, Triflumezopyrim 10% SC @ 0.48 ml l^{-1} applied at 25, 45 and 60 DAT respectively) recorded the highest grain yield of 6824 kg ha^{-1} with 26.00% increase over control followed by T_2

(Azadirachtin 10000 ppm @ 2.0 ml l^{-1}, Neem oil @ 10.0 ml l^{-1} and Triflumezopyrim 10% SC @ 0.48 ml l^{-1} applied at 25, 45 and 60 DAT respectively) with grain yield of 6718 kg ha^{-1} with 24.00% increase over control which were at par with each other and superior over untreated control (5421kg ha^{-1}).

3.5 Economics of the treatments

Cost Benefit ratios were calculated for all the treatments (Table 5). Incremental Cost Benefit Ratio (ICBR) was the highest (1:2.72) in insecticides alone module (T4). It was followed by Botanical - Insecticide module (T_2) with cost benefit ratio of 1: 2.23.

Table1. Details of the treatments and spray schedule

Treatment	Treatment number	Particulars	Time of application	Dose (ml/l or g/m²)
Botanicals - Insecticide	T_1	Azadirachtin 10000 ppm	25 DAT	2.0 ml/l
		Eucalyptus oil	45 DAT	2.0 ml/l
		Cartap hydrochloride 50% SC	60 DAT	2.0 g/l
Botanicals - Insecticide	T_2	Azadirachtin 10000 ppm	25 DAT	2.0 ml/l
		Neemoil	45 DAT	10.0 ml/l
		Triflumezopyrim 10% SC	60 DAT	0.48 ml/l
All botanicals	T_3	Azadirachtin 10000 ppm	25 DAT	2.0 ml/l
		Eucalyptus oil	45 DAT	2.0 ml/l
		Neem oil	60 DAT	10.0 ml/l
All insecticides	T_4	Chlorantraniliprole 0.4G	25 DAT	1.0 g/m2
		Cartap hydrochloride 50% SC	45 DAT	2.0 g/l
		Triflumezopyrim 10% SC	60 DAT	0.48 ml/l
Untreated control	T_5	Untreated control (Water Spray)	-	-

Table 2. Effect of botanical- insecticide modules on stem borer and BPH during rabi season (Pooled analysis of four seasons, Rabi 2019-20, 2020-21, 2021-22 & 2022-23)

Treatment		Stem borer				BPH	
		DH% (60 DAT)	ROC (%)	WE%	ROC (%)	(No./ hill) (70 DAT)	ROC (%)
T_1	Azadirachtin 10000 ppm (25 DAT)	2.53 (9.14)^{bc}	21	9.40 (17.83)^{b}	14	45.42 (6.69)^{b}	30
	Eucalyptus oil (45 DAT)						
	Cartap hydrochloride 50% SC (60 DAT)						
T_2	Azadirachtin 10000 ppm (25 DAT)	2.37 (8.84)^{b}	26	9.47 (17.91)^{b}	13	5.87 (2.39)^{a}	91
	Neem oil (45 DAT)						
	Triflumezopyrim 10% SC (60 DAT)						
T_3	Azadirachtin 10000 ppm (25 DAT)	2.64 (9.31)^{bc}	18	9.80 (18.20)^{b}	10	55.56 (7.44)^{bc}	14
	Eucalyptus oil (45 DAT)						
	Neem oil (60 DAT)						
T_4	Chlorantraniliprole 0.4G (25 DAT)	1.60 (7.19)^{a}	50	7.26 (15.60)^{a}	33	4.00 (2.00)^{a}	94
	Cartap hydrochloride 50% SC (45 DAT)						

	Triflumezopyrim 10% SC (60 DAT)						
T5	Untreated control (Water Spray)	3.21 (10.29)[c]		10.89 (19.19)[b]		64.77 (7.44)[c]	
	CV (%)	**10.38**		**7.75**		**11.80**	
	CD (0.05)	**1.43**		**2.12**		**0.94**	
	F test	**Sig.**		**Sig.**		**Sig.**	

DAT- Days after transplanting; DH% - Per cent dead hearts; WE% - Per cent white ears

ROC (%) – Per cent reduction over control; Means followed by common letters are not significantly different by LSD (0.05%)

Table 3. Effect of botanical- insecticide modules on spiders during rabi season

(Pooled analysis of 4 seasons, 2019-20 to 2022-23)

Treatment		**Spiders (No./hill) (At 70 DAT)**				
		Rabi 2019-20	**Rabi 2020-21**	**Rabi 2021-22**	**Rabi 2022-23**	**Pooled**
T1	Azadirachtin 10000 ppm (25 DAT) Eucalyptus oil (45 DAT) Cartap hydrochloride 50% SC (60 DAT)	0.93 (0.94)	1.60 (1.26)	1.86 (1.36)	1.46 (1.21)	1.46 (1.21)
T2	Azadirachtin 10000 ppm (25 DAT) Neem oil (45 DAT) Triflumezopyrim 10% SC (60 DAT)	1.08 (1.03)	1.18 (1.08)	1.68 (1.29)	1.43 (1.19)	1.34 (1.16)
T3	Azadirachtin 10000 ppm (25 DAT) Eucalyptus oil (45 DAT) Neem oil (60 DAT)	1.15 (1.07)	1.71 (1.29)	2.15 (1.47)	1.65 (1.28)	1.54 (1.24)
T4	Chlorantraniliprole 0.4G (25 DAT) Cartap hydrochloride 50% SC (45 DAT) Triflumezopyrim 10% SC (60 DAT)	0.98 (0.98)	1.24 (1.11)	1.66 (1.29)	1.76 (1.31)	1.41 (1.19)
T5	Untreated control (Water Spray)	1.30 (1.11)	1.71 (1.31)	1.88 (1.36)	1.48 (1.21)	1.55 (1.25)
	CV (%)	17.14	11.67	6.33	11.57	4.82
	CD (0.05)	-	-	-	-	-
	F test	NS	NS	NS	NS	NS

DAT- Days after transplanting; The figures in parenthesis are square root transformed values

Table 4.Effect of botanical- insecticide modules on green mirid bug during rabi season (Pooled analysis of 4 seasons, 2019-20 to 2022-23)

Treatment		Green Mirid bug (No./hill) (At 70 DAT)				
		Rabi 2019-20	**Rabi 2020-21**	**Rabi 2021-22**	**Rabi 2022-23**	**Pooled**
T1	Azadirachtin 10000 ppm (25 DAT) Eucalyptus oil (45 DAT) Cartap hydrochloride 50% SC (60 DAT)	5.55 (2.35)[b]	6.09 (2.46)[b]	8.88 (2.97)[b]	2.18 (1.47)[b]	5.71 (2.39)[b]
T2	Azadirachtin 10000 ppm (25 DAT) Neem oil (45 DAT) Triflumezopyrim 10% SC (60 DAT)	1.58 (1.25)[a]	0.74 (0.80)[a]	1.64 (1.28)[a]	0.64 (0.80)[a]	1.15 (1.07)[a]
T3	Azadirachtin 10000 ppm (25 DAT) Eucalyptus oil (45 DAT) Neem oil (60 DAT)	5.40 (2.31)[b]	5.95 (2.43)[b]	10.68 (3.27)[c]	2.08 (1.43)[b]	6.17 (2.48)[bc]
T4	Chlorantraniliprole 0.4G (25 DAT) Cartap hydrochloride 50% SC (45 DAT) Triflumezopyrim 10% SC (60 DAT)	1.58 (1.25)[a]	0.94 (0.97)[a]	1.49 (1.22)[a]	0.56 (0.75)[a]	1.14 (1.07)[a]
T5	Untreated control (Water Spray)	6.20 (2.48)[b]	6.81 (2.61)[b]	11.26 (3.36)[c]	2.34 (1.52)[b]	6.47 (2.54)[c]
	CV (%)	11.27	11.45	4.96	12.50	4.52
	CD (0.05)	0.33	0.33	0.18	0.23	0.13
	F test	Sig.	Sig.	Sig.	Sig.	Sig.

DAT- Days after transplanting; The figures in parenthesis are square root transformed values

Means followed by common letters are not significantly different by LSD (0.05%)

Table 5. Effect of botanical – insecticide modules on grain yield and economics of treatments during rabi season (Pooled analysis of Rabi 2019-20, 2020-21, 2021-22 & 2022-23)

Treatment		Grain yield (kg/ha)	Increase over control (%)	Excess yield (kg)	Excess yield (qtl)	Additional income (Rs.)	Cost of inputs (Rs.)	ICBR
T_1	Azadirachtin 10000 ppm (25 DAT) Eucalyptus oil (45 DAT) Cartap hydrochloride 50% SC (60 DAT)	5473[b]	1.00	52	0.52	988	8700	0.11
T_2	Azadirachtin 10000 ppm(25 DAT) Neem oil (45 DAT) Triflumezopyrim 10% SC (60 DAT)	6718[a]	24.00	1298	12.98	24662	11075	**2.23**
T_3	Azadirachtin 10000 ppm(25 DAT)	5768[b]	6.00	347	3.47	6593	10375	0.64

	Eucalyptus oil (45 DAT)							
	Neem oil (60 DAT)							
T$_4$	Chlorantraniliprole 0.4G (25 DAT) Cartap hydrochloride 50% SC (45 DAT) Triflumezopyrim 10% SC (60 DAT)	6824^{a}	26.00	1404	14.04	26676	9825	2.72
T$_5$	Untreated control (Water Spray)	5421^{b}	-	-	-	-	-	-
	CV (%)	**7.04**						
	CD (0.05)	**655.0**						
	F test	**Sig.**	Paddy price per qtl:1900/-					

ICBR – Incremental cost benefit ratio; Means followed by common letters are not significantly different by LSD (0.05%)

Table 6. Information on cost of inputs and spraying cost and total cost incurred during rabi season

Treatments	**Name of the Botanical/insecticide**	**Quantity required (kg/l)**	**Unit Cost**	**Cost /ha (Rs.)**	**Cost of spraying operation (Rs.)**	**Total cost incurred (Rs.)**
T$_1$(Botanicals – Insecticide)	Azadirachtin 10000 ppm	1.0 litre	Rs. 1700/litre	1700	875	2575
	Eucalyptus oil	1.0 litre	Rs. 2800/litre	2800	875	3675
	Cartaphydrochloride 50% SC	1.0 kg	Rs. 1575/kg	1575	875	2450
				6075	**2625**	**8700**
T$_2$ (Botanicals – Insecticide)	Azadirachtin 10000 ppm	1.0 litre	Rs. 1700/litre	1700	875	2575
	Neemoil	5.0 litre	Rs. 650/litre	3250	875	4125
	Triflumezopyrim 10% SC	235 ml	1400/94 ml	3500	875	4375
				8450	**2625**	**11075**
T$_3$ (All botanicals)	Azadirachtin 10000 ppm	1.0 litre	Rs.1700/litre	1700	875	2575
	Eucalyptus oil	1.0 litre	Rs.2800/litre	2800	875	3675
	Neem oil	5.0 litre	Rs. 650/litre	3250	875	4125
				7750	**2625**	**10375**
T$_4$ (All insecticides)	Chlorantraniliprole 0.4G	10.0 kg	Rs. 850/4 kg	2125	875	3000
	Cartaphydrochloride 50% SC	1.0 kg	Rs. 1575/kg	1575	875	2450
	Triflumezopyrim 10% SC	235 ml	Rs. 1400/94 ml	3500	875	4375
				7200	**2625**	**9825**

IV. CONCLUSION

Among the different botanical insecticide modules tested against stem borer and BPH,insecticides alone module, T_4 (Chlorantraniliprole 0.4 G @ 1.0 g m^{-2}, Cartap hydrochloride 50% SC @ 2.0 g l^{-1}, Triflumezopyrim 10% SC @ 0.48 ml l^{-1} applied at 25, 45 and 60 DAT respectively) is the best module with 50% reduction over control (ROC), 33% ROC in dead hearts and white ears, respectively with regard to stem borer and 94% ROC in brown planthopper population and registered the highest grain yield (6824 kg ha^{-1}).

Among botanical – insecticide modules, treatment, T_2 (Azadirachtin 10000 ppm @ 2.0 ml l^{-1}, Neem oil @ 10.0 ml l^{-1} and Triflumezopyrim 10% SC @ 0.48 ml l^{-1} applied at 25, 45 and 60 DAT respectively) is the best against stem borer (26% ROC in dead heart damage & 13% ROC in white ear damage) and brown planthopper(91% ROC in brown planthopper population). Further, $T_2$is at par with insecticides alone module (T4) in managing stem borer and BPH and recorded the grain yield (6718 kg ha^{-1}) on par with the insecticides alone module. Hence, botanicals can be used in Integrated Pest Management programmes and in rotations with insecticides against insect pests of rice so as to reduce the pesticide load in the rice crop which in turn lessen the environmental concern.

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Impact of plant parasitic nematodes & its management in Mulberry (Morus sp.) cultivation in India— A Review

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***Abstract*— Mulberry (Morus sp.), a vital crop for India's silk industry, faces significant yield reductions (10-30%) due to plant parasitic nematodes. Root-knot nematodes (Meloidogyne incognita) are primary pests, compromising plant health and leaf quality. This review provides a comprehensive analysis of nematode diversity, damage, and management strategies in Indian mulberry cultivation. The review elucidates the impact of nematode infestations on mulberry growth, yield, and quality, highlighting the need for effective management. Chemical, biological, and cultural methods are evaluated for their efficacy and sustainability. Chemical treatments, while effective, pose environmental and health risks, emphasizing the need for alternative approaches. Biological control agents, such as Trichoderma viride and Pseudomonas fluorescens, show promise in managing nematode populations. Cultural practices like crop rotation, soil solarization, and resistant cultivars are also discussed. Integrated management strategies, combining multiple approaches, are recommended for optimal results.*
Keywords*— Plant parasitic nematodes, mulberry, silk production, sustainable nematode management, ecological sustainability.

I. INTRODUCTION

Mulberry (*Morus alba*) is a deciduous woody perennial plant which has a deep rooting system along with simple, stipulate, petiolate leaves arranged alternately. It is cultivated in many different types of soil ranging from loamy to clayey, deep fertile to flat, with high drainage and exceptional water retention capacity. It thrives under varied climatic conditions ranging from tropical to temperate. Most of the species of the genus *Morus* and its cultivated varieties are diploid, however, triploids are also extensively used for their vigorous growth and quality of leaves. The main commercial part of mulberry is the foliage which is used as a primary food source of silkworm (*Bombyx mori*) in the silk industry.

India is the second major silk producing country after China. The mulberry is cultivated in most of the silk producing states of the country including Andhra Pradesh, Karnataka, Assam, Kerala and many more(Table 1). The total area of cultivation in the country is around 2,82,244 ha (Source: Central Silk Board). The majorly cultivated species of mulberry are *Morus alba, M. indica, M. serrata* and *M. laevigata.* Although this plant is grown in a variety of climates, the tropical zone is where it is most commonly found covering Karnataka, Andhra Pradesh and Tamil Nadu. The cultivation of mulberry and leaf production are impeded by many pests and diseases, such as plant parasitic nematodes.(1) It is estimated that 10–30% of the leaf yield in mulberry is lost due to various diseases.(2) The rhizosphere soil of mulberry was observed with a significantly greater number of nematodes.(3) The nematodes spread easily and result in wilting, yellowing of the leaves, stunted growth, or a general decline in growth. Plant-parasitic nematodes, particularly root-knot nematode (RKN), *Meloidogyne incognita* (Kofoid and White), pose a major risk to mulberry productivity that shortens plant lifespan and significantly reduces herbage yield and leaf quality.(4) The incidence of nematode disease was found to be greater in irrigated mulberry gardens and lower in rainfed gardens.(5)

II. DIVERSITY OF NEMATODES IN MULBERRY SOIL ECOSYSTEM

The soil ecosystem of mulberry is inhabited by a wide range of microorganisms including nematodes. These includes plant parasitic nematodes and free-living nematodes which accounts about 42 species belonging to 24 genera(6). Of these 24, the nematodes belonging to five genera viz. , *Meloidogyne* , *Rotylenchulus* , *Helicotylenchus* , *Hoplolaimus* and *Xiphinema* were reported from India.(4) About 89 species of nematodes under 34 genera, 21 subfamilies, 17 families, 12 superfamilies and 6 suborders belonging to 4 orders, were described and reported so far from India(7). The plant parasitic nematodes which are most frequently associated with mulberry are *Meloidogyne incognita* (Swamy and Govindu, 1965), *M. javanica* (Mathur *et al.*, 1969), *M. arenaria* (Wang and Chen,1989), *Xiphinema index* (Martelli and Raski, 1963), *Helicotylenchus digitiformis* (Kiryanova and Shangalina, 1976) *Rotylenchulus reniformis* (Swarup *et al.* 1964), *Hoplolaimus seinhorsti* (Keereewan and Leeprasert, 1975), *Longidorus marini* (Ohishima *et al.*, 1971) and *Pratylenchus* sp. (Edward *et al.*, 1963). In India, Narayanan (1966) for the first time reported about the association of root knot nematode with mulberry(8). In a survey conducted by Bina Chanu in the some mulberry cultivations of Manipur, about four species of Aphelenchoides were found out of which two species namely *Aphelenchoides dhanachandi* sp. n. and *A. neoechinocaudatus* sp.n. were newly discovered from there(16).

III. ECONOMIC DAMAGE CAUSED BY SOME MAJOR NEMATODES

Root Knot Nematode (*Meloidogyne* spp.)

It is estimated that the nutritional value of mulberry leaves is reduced by up to 10% as a result of the root-knot nematode infestation.(9 & 10) The specific symptoms in mulberry caused by root knot nematode are sick with thrifty look as if due to water and nutrient deficiency, since the vascular tissue and cortex in the roots are highly disorganized. Therefore, the water and nutrient absorption in infected roots is highly affected resulting in disruption of the plant physiology. Symptoms like stunted growth, leaf chlorosis and necrosis along leaf margins can be seen in infected plants. In the root systems, extensive root gall formations are seen as separate beads unlike merged galls and flattened root seen in other crops.(6) In some studies, it has been observed that *M. incognita* provides a good site for easy entry of developing hyphae of some soil-borne fungal pathogens like *Botryodiplodia theobromae* and *Fusarium solani.*(11)

In Karnataka, studies were carried out to check the predominance of *M. incognita* in different farming systems and soil types and it showed that red sandy soil had the highest disease incidence (66.3%), with 31 to more than 100 galls containing egg masses per root system followed by red loamy soil (42.55%) with moderate to severe intensity having more than 11 to less than 100 galls with egg mass. Very poor incidence was noticed in black cotton soil (6.06%) with mild intensity having less than 10 galls and egg mass. Under irrigation gardens, there was a greater occurrence and seriousness as compared to other different cropping methods. The disease incidence was not at all noticed under rainfed conditions (5) .

Spiral Nematode (*Helicotylenchus indicus*)

In mulberry habitats, spiral nematodes are typically observed with their heads entrenched and feeding on roots. They are also known to spread secondary infections in the general vicinity of their feeding sites. The distinctive symptoms are reduced length and weight of shoot, lower number of leaves and leaf weight as well as reduced number of leaf buds (12).

Dagger Nematode (*Xiphinema basiri*)

The dagger nematode is dominant in 10-15 cm depth of soil (13) and feeds with long stylet deeply at near the root tips even up to vascular elements of young roots, but up to cortical parenchyma in older roots. Duration of feeding is long. Reduced growth and stunting are frequent. Common signs include reduced root system, lesion formation, discoloration, disintegration, and degradation of cortical tissue, terminal and sub-terminal swelling, and the formation of a fishhook or curling tip. The root tips exhibit profuse root development and significant forking.(14)

IV. FACTORS RESPONSIBLE FOR PATHOGENICITY

The nematode populations fluctuate in response to pressure and obstacles from external factors. As a result, they acquire a structure and exhibit growth characteristics in response to variables like temperature, rainfall, host plant type, and soil type, demonstrating the precise ways in which each of these variables influence biological processes. Factors like soil temperature and pH are inversely proportional to nematode population. Soil moisture is directly proportional to the population of nematodes belonging to different genera. In some studies, populations of all orders of nematodes were observed to be highest during rainy season(June-October) but remained comparatively lower in summer and winter seasons.(15)

V. PROSPECTS OF NEMATODE MANAGEMENT IN MULBERRY

Mulberries were treated with a variety of management techniques, including chemical, biological, physical, and cultural treatments(18), in order to reduce the infestation of root-knot nematodes. Among them, it was found that chemical techniques using nematicides applied in the field were more effective.(20 & 22) However, it has been noted that the nematicides and soil fumigants used to control plant-parasitic nematodes may be hazardous to silkworms and have an adverse effect on human health, groundwater contamination, and soil health.(19 and 21) Therefore, due to the serious risks associated with nematicides and pesticides, there has been a surge in interest in biological management in its widest sense as a means of reducing nematode damage in an eco-friendly manner. Hence, some studies has been done in this aspect with a view towards sustainable management strategies.

a. Cultural Approaches

Crop rotation is a sustainable method of using inadequate hosts, resistant or tolerant cultivars, plants hostile to nematodes, trap crops, or cover crops in conjunction with seasonal main crop rotation has produced noteworthy outcomes.(25) A technique known as soil solarization which involves the covering of soil with a plastic film during the summer season. This technique effectively increases soil temperature which causes destruction of nematode egg masses and their populations.(26) Trap crop is a way to develop susceptible plants that parasitic nematodes quickly infect, then destroy the plants at the right moment to prevent nematode reproduction. A crop that supports nematode hatching and heavy invasion but not support reproduction is the perfect trap crop. Some studies have revealed that crops such as sunhemp (*Crotalaria juncea*) can be used because of its dual benefits. In addition to eliminating soil nematodes, it also causes nitrogen fixation, which raises the amount of nitrogen in the soil.(18) Kafle (2013) conducted a pot experiment at Tsukuba, Japan on marigold, crotolaria and oat in rotation with tomato to determine their antagonistic effect on southern root knot nematode. It was observed that marigold and crotalaria followed by oat were proved to be the best antagonist plants to control southern root knot nematode.(27) Mulching with neem leaves have been found to reduce root-knot disease and prevent leaf yield loss. (28)

b. Host Resistance

Natural resistance (R) genes have been demonstrated as good alternative in effectively limiting nematode damage in crops under field conditions. Even though root-knot and cyst nematodes have been resisted by some cultivars for decades, recent evidence suggests that growing populations of resistance breaking nematode pathotypes are starting to appear. (31) Host Plant Resistance (HPR) against nematodes have been discovered in many major crops as well as their related wild relatives. This is because nematicides application are increasing with times. Thus, molecular biological methods will facilitate more straightforward ways of selecting and transferring resistance genes. Hence, the status of HPR for nematode control will improve in the near future. (29)

Kumari and Sujathamma (2016) studied the different degrees of tolerance by mulberry varieties toward nematode from which we can select the appropriate variety for cultivation depending on the climatic conditions and available inputs. The varieties Tr10, V1 can be selected for the regions with good irrigation or rainfall conditions. Also, the variety RFS175 can be used for rainfed cultivation. (2)

RNA interference (RNAi) has become one of the most promising strategies for nematode management in recent times. The most promising method for developing nematode resistance in plants is the host-mediated RNA interference (RNAi) strategy, which targets nematode genes and incorporates both plants and nematode RNA interference machinery. As of right now, the greatest rate of nematode infection decrease has been observed through the suppression of effector or secretory class of proteins. Hence, these genes represent the most promising targets for an RNA interference (RNAi) method.(30)

c. Biological Approaches

Using bio-pesticides on a sustainable farm for parasite and infection management is certainly a sustainable practice. The effectiveness of these products is usually affected by external factors such as rains, temperature variations, soil chemistry or it may be that they selectively disintegrate in either chemical or physical terms. Nevertheless, despite this sometimes they perform equally as synthetic pesticides; even in those instances agricultural products containing these bio-pesticides are anticipated to be highly sought after for ecological as well as health reasons.(32)

Under field conditions, the effectiveness of commercial formulations of the antagonistic fungus *Trichoderma viride* and the plant growth-promoting rhizobacterium *Pseudomonas fluorescens* on the root-knot nematode *Meloidogyne incognita* that infecting mulberry was assessed. When mixed together in a ratio of six grams per plot (6 g/plot), it was observed that both *P. fluorescens* and

T. viride were effective against *M. incognita* in soil as well as roots and inhibited the occurrence of root-galling on mulberry.(33)

In some field experiments, the bio-control agents *Pseudomonas fluorescens* and *Trichoderma viride*, were evaluated against *Meloidogyne incognita* in mulberry (V1 variety). The results showed that application of *P. fluorescens* and *T. viride* to the soil, either separately or in combination, was able to control the nematode population and enhance mulberry leaf yield and nutritional standards.(24)

VI. CONCLUSION

With the concerning issues regarding nematodes impact on the production of mulberry, there have been utmost attempts made by researchers for finding more and more effective as well sustainable management strategies for lessening the intensity of economic damage of plant parasitic nematodes. The lesser-known nematodes associated with mulberry plants might have been uncovered by exhaustive studies undertaken in the past, and their potential effects on the productivity of these plants may be analyzed. Most of the biocontrol studies on nematodes have been concentrated on sedentary endoparasitic nematodes. There are significant reductions in root knot and cyst nematodes of the genera *Meloidogyne* and *Heterodera* respectively. On the other hand, little is known about migratory parasitic nematodes that feed outside roots as well as those present in aerial part of plants. Therefore, more research and experimental assessment is required in order to support the biological methods for the management of these type of nematodes.

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Effect of Cooking Treatments on Drying Kinetics, Polyphenols Content and Antioxidant Activity of Orange-Fleshed Sweet Potato

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Abstract*— This study examines the effects of boiling, steaming, and microwaving on the drying kinetics, total polyphenol content (TPC), antioxidant activity, and total carotenoid content (TCC) of orange-fleshed sweet potatoes (OFSP), a vital source of beta-carotene for combating vitamin A deficiency. Results indicate that steaming preserved the highest TPC at 4.28 mg GAE/g DW, while microwaving yielded the highest TCC at 527.35 µg BCE/g DW. Antioxidant activity, measured via DPPH radical scavenging, was significantly enhanced by steaming (3.48 µmol TE/g DW) and microwaving (3.29 µmol TE/g DW) compared to boiling (1.40 µmol TE/g DW). The drying kinetics followed the Page model, demonstrating a strong fit ($R^2 > 0.9988$) across treatments, highlighting the complex moisture loss behaviors influenced by cooking methods. Boiling resulted in a 51% reduction in TPC due to leaching, while both steaming and microwaving significantly increased antioxidant activity despite some degradation of phenolic compounds during microwaving. These findings underscore the importance of cooking methods in optimizing the nutritional value of OFSP, providing practical recommendations for food preparation to enhance health benefits and address vitamin A deficiency in vulnerable populations.

***Keywords*— Drying kinetics, Microwave cooking, Page model, Steam cooking, Sweet potatoes**

I. INTRODUCTION

Orange-fleshed sweet potato (OFSP) is a biofortified root crop that has gained significant attention due to its high beta-carotene content, which is converted to vitamin A in the body. OFSP has been recognized as an effective food-based approach to combat vitamin A deficiency, particularly in sub-Saharan Africa [1]. Beyond its vitamin A content, OFSP is also a good source of dietary fiber, complex carbohydrates, proteins, vitamins C and B, iron, and calcium [2]. Polyphenols and antioxidants in OFSP have become an emerging field of interest in nutrition research. These compounds contribute to the distinctive flesh color and are associated with numerous health benefits, including antioxidant and anti-inflammatory properties that could have preventive and therapeutic effects for various chronic diseases [1]. Recent scientific reports have concluded that the phenolic acid components in OFSP exhibit antioxidative and free radical scavenging activities with beneficial health-promoting effects [1].

Carotenoids, particularly β-carotene, are the primary bioactive compounds responsible for the distinctive orange color of OFSP and its potential to address vitamin A deficiency. OFSP varieties have been reported to contain significantly higher levels of carotenoids compared to other commonly consumed vegetables and fruits. [3] found that OFSP from Korea contained up to 570 µg/g (dry basis) of total carotenoids. The β-carotene content in OFSP can range from 100 to 1,600 µg/g (fresh weight), which is substantially higher than that found in carrots (43.5-88.4 µg/g), mangoes (10.9-12.1 µg/g), and tomatoes (2.17-2.83 µg/g) [1]. In addition to β-carotene, OFSP also contains other carotenoids such as α-carotene, β-cryptoxanthin, lutein, and zeaxanthin, albeit in lower concentrations [4]. The carotenoid content in OFSP can vary significantly among cultivars, with some varieties like BARI SP-2 (Kamalasundari) showing exceptionally high levels in both raw and cooked forms. It's worth noting that cooking methods can affect carotenoid composition, with boiling associated with an increase in cis-β-carotene and a decrease in the trans isomer[5].

The rationale for studying cooking treatments such as boiling, steaming, and microwaving, as well as drying kinetics using models like the Page model, stems from the need to understand how these processes affect the nutritional and functional properties of OFSP. Cooking methods can significantly impact the bioavailability and retention of nutrients, including polyphenols and antioxidants [1]. Similarly, drying is an important preservation technique for OFSP, but the kinetics of moisture loss and its effects on nutrient content need to be carefully examined. By investigating these aspects, researchers can optimize processing methods to maintain or enhance the nutritional value of OFSP while improving its shelf life and versatility in various food applications.

The investigation aims to evaluate the effects of boiling, steaming, and microwaving on the drying kinetics, TPC, antioxidant activity, total carotenoid content, and color attributes of OFSP. This study will assess how these cooking methods influence the retention and bioavailability of nutrients and bioactive compounds in OFSP, which is recognized for its high beta-carotene content. Additionally, the research will analyze moisture loss kinetics using models such as the Page model to identify optimal processing techniques that enhance nutritional value and shelf life. The study will also explore the impact of cooking methods on color attributes, which are important for visual appeal and nutrient presence. Ultimately, the findings aim to provide practical recommendations for food preparation practices that maximize the health benefits of OFSP while addressing vitamin A deficiency.

II. MATERIALS AND METHODS

2.1 Materials

The OFSP (*Ipomoea batatas* L.) used in this study were sourced from a local market (With a moisture content of 74.29±2.20%). Analytical-grade solvents and chemicals, including ethanol, methanol, *n*-hexane, acetone, glacial acetic acid, sodium carbonate, Folin-Ciocalteu reagent, 2,2-diphenyl-1-picrylhydrazyl (DPPH), and 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), were obtained from Sinopharm Chemical Reagent Co., Ltd. in Shanghai, China. Standard β-carotene (purity ≥ 99%) and gallic acid (purity ≥ 99%) were procured from Sigma (St. Louis, MO, USA). All reagents utilized in this study were of analytical grade or the highest available purity.

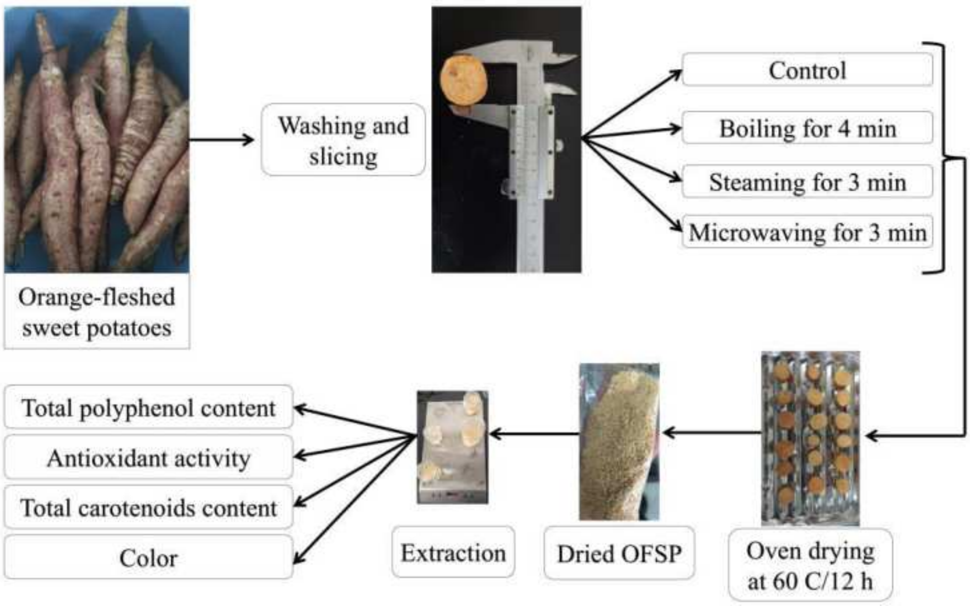

Fig. 1: Flow diagram of OFSP treatments, drying, and bioactivity evaluation.

2.2 Cooking Treatments

Prior to the application of cooking treatments, OFSP samples were thoroughly washed and uniformly sliced into pieces with diameters ranging from 2.3 to 2.8 cm and thicknesses of 1.0 to 1.2 cm (Fig. 1). This standardization ensured consistency across all treatments. For the boiling method, OFSP slices were immersed in boiling water for 4 min until thoroughly cooked. In the steaming treatment, OFSP slices were steam-cooked for 3 min in a covered steamer. The microwave treatment involved cooking the OFSP slices for 3 min with a small amount of added water in a covered microwave-safe container using a Galanz microwave oven (Model MND-16, 550W, 220V, 50Hz). Following each cooking method, all samples were immediately transferred to perforated lightweight aluminum trays to enhance air circulation during the subsequent drying process. This preparation ensured uniform cooking and facilitated consistent drying conditions across all samples.

2.3 Drying process and kinetics

All samples were weighed initially (t=0) and subsequently at 1-hour intervals for a total duration of 12 h using an analytical balance with a precision of ±0.01 g. The drying process for all treatments was conducted at a constant temperature of 60 ± 1°C in a Binder ED 56 oven equipped with a forced convection system. This setup ensured uniform heat distribution and efficient moisture removal throughout the drying period. The continuous 12-hour drying regime was implemented to comprehensively track moisture loss kinetics across all treatment groups under standardized conditions.

Moisture ratio is calculated as the ratio of the mass of water in a substance to the mass of dry matter, allowing for standardized comparisons between different samples. For OFSP, the moisture ratio at any given time can be expressed using the following equation.

$$MR = \frac{W_t - W_d}{W_0 - W_d} \text{ eq. (1)}$$

where W_t represents the mass of water in the OFSP sample at time (t), W_d is the mass of dry matter in the OFSP sample (constant throughout the drying process), and W_0 denotes the initial mass of water in the raw OFSP sample (at t=0).

The Page model was employed to analyze the drying kinetics of OFSP under various treatment conditions [6]. This empirical model is particularly useful for describing the moisture loss during drying processes and is mathematically defined as follows.

$$MR = \exp(-k.t^n) \text{ eq. (2)}$$

where MR represents the moisture ratio, k and n are constants; k reflects the rate of moisture loss, while n indicates the curvature of the drying curve, and t denotes time. To fit the model to the experimental data, non-linear regression techniques were utilized aimed at minimizing the difference between predicted and observed moisture ratio values.

2.4 Total polyphenol content analysis (TPC)

The Folin-Ciocalteu method was employed to determine the total phenolic content (TPC) of dried OFSP samples as described by Golshany, Yu and Fan [7]. For sample preparation, 5 g of powdered OFSP was extracted in 100 mL of 50% (v/v) aqueous ethanol. This mixture underwent sonication for 10 min using a 1200-watt probe sonicator at half intensity, followed by a 1-hour stirring period. Subsequently, the extract was centrifuged (8000 rpm, 10 min), filtered, and stored. Gallic acid solutions (0.1 – 1 mg/mL) were used as standards. The assay involved combining 0.5 mL of prepared sample or standard with 2.5 mL of 10% (v/v) Folin-Ciocalteu reagent, then adding 2 mL of 7.5% Na_2CO_3 solution. After mixing thoroughly, samples were incubated in darkness at 40°C for 15 min. A spectrophotometer (Model L8, INESA Co., Ltd., Shanghai, China) was used to measure absorbance at 765 nm. TPC was quantified using the standard curve equation ($y = 0.9766x + 0.0695$, $R^2 = 0.997$) and expressed as mg gallic acid equivalent per gram dry weight (mg GAE/g DW).

2.5 Antioxidant activity assays

The antiradical activity of dried OFSP samples was evaluated using the DPPH assay, following the protocol outlined by Golshany, Kamal, Yu and Fan [8]. OFSP dried samples were prepared as described in section 2.4. A calibration curve was established using Trolox standards ranging from 0 to 200 µg/mL. The assay procedure involved combining 200 µL of sample extract or Trolox standard with 2.8 mL of 0.2 mM DPPH solution in methanol, followed by thorough agitation. The reaction mixture was then incubated in darkness for 30 min at room temperature (25 ± 2°C). Absorbance was measured spectrophotometrically at 517 nm using a UV-visible spectrophotometer. Antiradical activity was quantified using the standard curve equation ($y = 156.02x + 6.7187$, $R^2 = 0.9953$) and expressed as micromoles of Trolox equivalent per gram of dry weight (µmol TE/g DW).

2.6 Total carotenoid content analysis (TCC)

Total carotenoid content of dried samples was determined according to the method described by Morsi, Morsy and Golshany [9], with modification. Approximately 0.5 g of finely ground dried sample was extracted with 10 mL of a hexane:acetone:ethanol mixture (50:25:25, v/v/v). The mixture was vortexed for 1 min and then sonicated for 15 min. Following centrifugation at 4000 rpm for 10 min, the supernatant was collected, and the extraction process was repeated twice with fresh solvent. The combined supernatants were then diluted to 25 mL with hexane. A standard curve was prepared using β-carotene (≥0.99 purity) dissolved in hexane at concentrations ranging from 0.5 to 10 µg/mL. Absorbance of both samples and standards was measured at 450 nm using a UV-visible spectrophotometer. Total carotenoid content was calculated using the β-carotene standard curve equation (y = 0.1207x

+ 0.1803, $R^2 = 0.9902$) and expressed as micrograms of β-carotene equivalent per gram of dry weight (μg BCE/g DW). All extractions and measurements were performed in triplicate under subdued light conditions to minimize carotenoid degradation.

2.7 Color analysis

The color of treated samples, before and after drying, was determined using a Minolta colorimeter. Color measurements were taken based on the CIELAB color space, which includes L* (luminosity), a* (red to green intensity), and b* (yellow to blue intensity). This method enabled precise quantification of color changes in OFSP samples due to different drying treatments, ensuring accurate and repeatable results for further analysis.

2.8 Statistical analysis

All experiments were performed in triplicate, and results are presented as mean ± standard deviation (SD). Statistical analysis was conducted using SPSS Statistics 27 (IBM Corp., Armonk, NY, USA) and OriginPro 2022 (OriginLab Corporation, Northampton, MA, USA). One-way analysis of variance (ANOVA) was employed to assess statistical significance among groups, followed by Tukey's post-hoc test for multiple comparisons. Differences were considered statistically significant at $P < 0.05$.

III. RESULTS AND DISCUSSION

3.1 Effects on Drying Kinetics

The analysis of MR data reveals distinct drying behaviors across different treatments and phases, aligning findings from other research while also presenting unique observations as shown in figure 2. The observed rapid initial moisture loss followed by slower drying rates is consistent with findings from other studies on sweet potato drying. Singh, Raina, Bawa and Saxena [10] reported that drying of sweet potato slices occurs entirely in the falling-rate period, indicating that diffusion is the dominant physical mechanism governing moisture movement. This aligns with our observations across all treatments. The phased approach (initial, middle, and final) provides a more detailed analysis compared to some other studies, allowing for a nuanced understanding of moisture loss patterns throughout the drying process. This approach could be valuable for optimizing drying protocols, as suggested by Kocabiyik and Tezer [11] for carrot slices. The effect of pre-treatments on drying rates presents a notable contrast to findings from previous research. While Falade, Olurin, Ike and Aworh [12] found that pre-treatments generally enhance drying rates, the results indicate that steam and boiling pre-treatments actually slowed the drying process compared to the control. This observation suggests that these pre-treatments may induce structural changes in the sweet potato tissue, leading to an increased water-holding capacity, which could ultimately benefit product quality. These findings underscore the necessity for further investigation into the impact of pre-treatments on the tissue structure of sweet potatoes. The behavior of microwave-treated samples in this study, which maintained the highest moist MR despite having lower initial moisture content, contrasts with typical observations reported in microwave drying studies. For instance, Rashid, Liu, Jatoi, Safdar, Lv and Li [13] found that microwave power significantly decreased drying time for sweet potato cubes. Our results suggest that microwave treatment may alter the sweet potato structure in ways that enhance moisture retention, warranting further investigation.

The Page model's exceptional performance in describing drying kinetics across all treatments is consistent with findings from other studies. Studies also found the Page model to be suitable for describing sweet potato drying kinetics [14, 15]. However, our study demonstrates even higher R-squared values (above 0.9988) compared to some previous studies, indicating particularly good model fit. These findings underscore the complex nature of the drying process and the importance of considering multiple factors when optimizing drying protocols for sweet potatoes. As suggested by recent research, future studies should focus on investigating the effects of these drying methods on product quality attributes [13], exploring the reasons behind the higher moisture retention in microwave-treated samples through microscopic analysis of tissue structure, and conducting sensory evaluations to determine consumer preferences for products dried using different methods [16].

3.2 Effect of cooking methods on TPC:

The data shows that steaming resulted in the highest TPC (4.28 mg GAE/g DW), followed by the control (3.92 mg GAE/g DW), microwaving (3.23 mg GAE/g DW), and boiling (1.92 mg GAE/g DW). This trend aligns with some recent studies but also presents some unique observations. Demirel Ozbek, Saral and Turker [17] found that microwave cooking, stir-frying, and sous vide increased TPC in *Trachystemon orientalis*, while steaming decreased it. In contrast, our results show steaming to be the most effective method for preserving and even increasing TPC in sweet potatoes. This difference could be attributed to the unique composition and structure of sweet potatoes compared to other vegetables. The significant decrease in TPC observed with boiling (51% reduction) is consistent with findings from Seal, Pillai and Chaudhuri [18], who reported that boiling caused the greatest reduction in TPC across various plants, with decreases ranging from 10.90%

to 25.66%. This reduction is likely due to the leaching of water-soluble phenolic compounds into the cooking water.

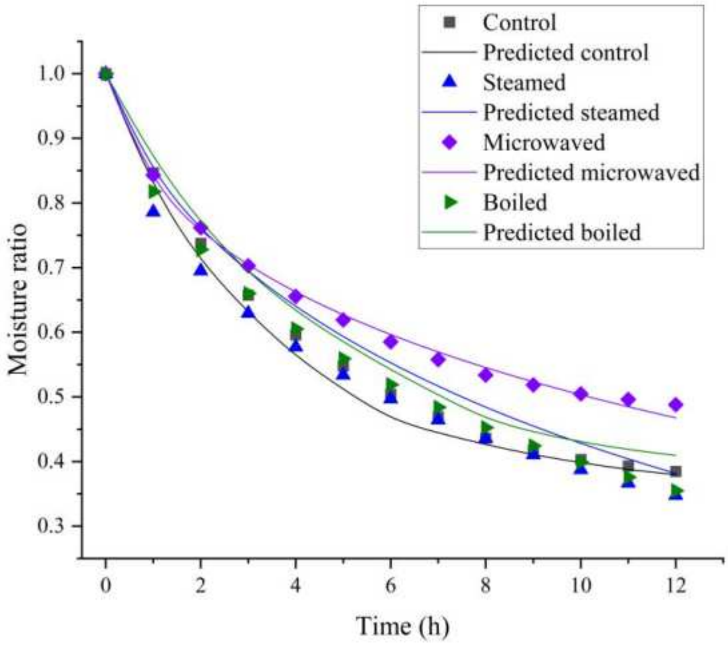

Fig. 2: Experimental and predicted MR values for drying of OFSP samples.

Table 1: Total polyphenol content, antioxidant activity, and total carotenoids content in OFSP samples.

Samples	TPC (mg GAE/g DW)	DPPH (μmol TE/g DW)	TCC (μg BCE/g DW)
Control	3.92 ± 0.04 [b]	0.65 ± 0.23 [c]	330.72 ± 12.08 [c]
Boiled	1.92 ± 0.07 [d]	1.40 ± 0.04 [b]	429.04 ± 23.93 [b]
Steamed	4.28 ± 0.08 [a]	3.48 ± 0.29 [a]	478.20 ± 30.07 [ab]
Microwaved	3.23 ± 0.08 [c]	3.29 ± 0.07 [a]	527.35 ± 36.26 [a]

All values are expressed as mean ± SD. Different superscripted letters within a column indicate significant differences ($P<0.05$).

3.3 Effect of cooking methods on antioxidant activity (DPPH):

The DPPH radical scavenging activity results show that both steaming (3.48 μmol TE/g DW) and microwaving (3.29 μmol TE/g DW) significantly increased antioxidant activity compared to the control (0.65 μmol TE/g DW). Boiling also increased antioxidant activity (1.40 μmol TE/g DW) but to a lesser extent. These findings partially align with Seal, Pillai and Chaudhuri [18], who found that microwave cooking led to an increase in DPPH radical scavenging activities by 9.39% to 46.32% across various plants. However, our results show a much more dramatic increase in antioxidant activity for both steaming and microwaving (over 400% increase). The increase in antioxidant activity despite the decrease in TPC for microwaved samples is particularly interesting. This suggests that while some phenolic compounds may be degraded during microwaving, the process might be enhancing the antioxidant capacity of the remaining compounds or generating new antioxidant compounds through chemical reactions. It's noteworthy that while steaming resulted in the highest TPC, it did not significantly differ from microwaving in terms of DPPH radical scavenging activity. This suggests that the relationship between TPC and antioxidant activity is not always linear, and different cooking methods may affect these parameters in complex ways. This observation is supported by a study by Zhang, Qu, Xie, Shi, Shi and Yu [19], which found that different cooking methods had varying effects on phenol content and antioxidant activity in peanut sprouts. They reported that microwaving retained the highest levels of both TPC and antioxidant activity, which partially aligns with our findings for antioxidant activity but differs for TPC.

3.4 Effect of cooking methods on total carotenoids content

The results of total carotenoids content in OFSP reveal significant differences across various cooking methods, with microwave treatment yielding the highest carotenoid levels (527.35 µg BCE/g DW), followed by steaming (478.20 µg BCE/g DW), boiling (429.04 µg BCE/g DW), and control (330.72 µg BCE/g DW). These findings align with previous research indicating that microwave cooking effectively retains carotenoids compared to boiling and steaming. For example, a study by Buratti, Cappa, Benedetti and Giovanelli [20] demonstrated that microwaving preserved carotenoids in vegetables due to shorter cooking times and reduced exposure to heat, which minimizes degradation. Similarly, Vimala, Nambisan and Hariprakash [21] found that thermal processing can disrupt the food matrix, facilitating carotenoid extraction; however, prolonged exposure to heat can degrade these sensitive compounds. The superior retention of carotenoids observed in microwaved samples may be attributed to rapid cooking times that prevent excessive thermal damage, thus preserving nutrient integrity. In contrast, while boiling showed an increase in carotenoid content compared to control, it was less effective than microwaving and steaming. This observation is consistent with findings from Demirel Ozbek, Saral and Turker [17], who reported that boiling can enhance carotenoid levels in certain vegetables but cautioned about nutrient loss through leaching. Overall, these results underscore the importance of selecting appropriate cooking methods to maximize the nutritional benefits of sweet potatoes and other vegetables, suggesting that microwaving is particularly effective for enhancing carotenoid retention while minimizing nutrient loss during preparation.

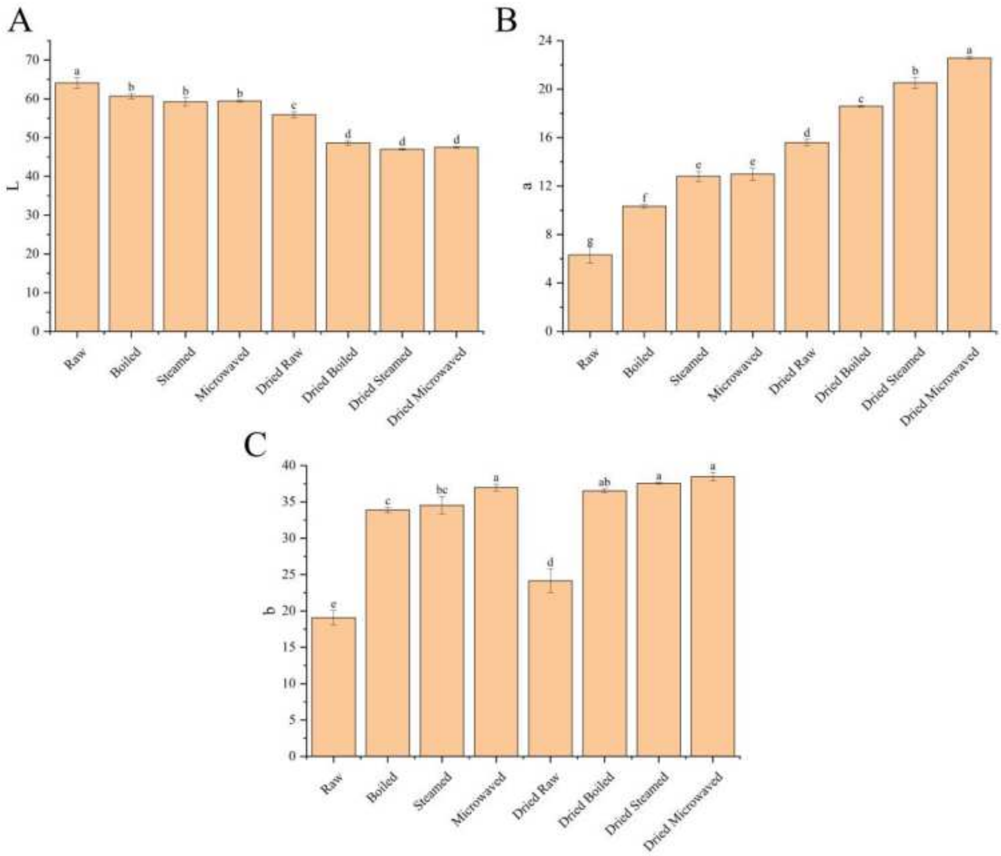

Fig. 3: Color analysis results of different samples, lightness (A), yellowness (B), and redness (C).

3.5 Effect of cooking methods on color

The analysis of color parameters (L*, a*, b*) in sweet potatoes reveals significant changes across various cooking methods (Fig. 3). The raw samples exhibited the highest lightness (L* = 64.11), followed by boiled (60.68) and steamed (59.21) samples, with microwaved samples showing a similar value (59.43). These findings align with research by Buratti, Cappa, Benedetti and Giovanelli [20], who noted that cooking methods significantly affect the color attributes of vegetables, with boiling typically resulting in darker colors due to cell wall breakdown and pigment release. Additionally, the increase in redness (a*) and yellowness (b*) observed in boiled, steamed, and microwaved samples suggests that these cooking methods may enhance the visibility of carotenoids. The results indicate that boiling increased a* to 10.33 and b* to 33.88, supporting findings from Islam, Nusrat, Begum and Ahsan [5] that boiling can enhance carotenoid accessibility while potentially causing some nutrient losses. In contrast, dried samples exhibited lower lightness values, particularly for dried boiled (48.60) and dried steamed (46.98) sweet potatoes, indicating a significant loss of brightness compared to their raw counterparts. This reduction is consistent with findings from Akissoé, Hounhouigan, Mestres and Nago [22], which reported that drying processes can lead to color degradation due to oxidative reactions and pigment breakdown. Interestingly, dried microwaved samples maintained a relatively higher yellowness (38.48) compared to other dried treatments, suggesting that microwaving may help preserve some carotenoid content even after drying. This observation is supported by research from Yadav, Guha, Tharanathan and Ramteke [23], who highlighted that microwave cooking can enhance the retention of bioactive compounds while minimizing color degradation compared to traditional drying methods. Overall, these results emphasize the importance of selecting appropriate cooking methods not only for nutrient retention but also for preserving the visual appeal of sweet potatoes, which is crucial for consumer acceptance.

IV. CONCLUSION

This study provides compelling evidence regarding the impact of various cooking methods on the nutritional and functional properties of OFSP. The findings indicate that steaming is the most effective method for preserving total phenolic content, while microwaving significantly enhances carotenoid retention. Notably, both steaming and microwaving demonstrated a marked increase in antioxidant activity compared to boiling, which resulted in substantial nutrient loss. These results emphasize the critical role of cooking techniques in maximizing the health benefits of OFSP, a key food source for combating vitamin A deficiency. By optimizing cooking methods, we can enhance the nutritional value of OFSP, thus contributing to better dietary practices and health outcomes in populations at risk of vitamin A deficiency. Future research should continue to explore the intricate relationships between cooking processes and nutrient bioavailability to further refine food preparation practices that support public health initiatives.

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Recent Advances in the development of User-friendly Software Tools for Computational Protein Design, Modeling, and Molecular Docking

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***Abstract*— *Computational protein design, modeling, and Molecular Docking represent a group of vital in-silico methods employed in predicting protein sequences with desired functions, predicting protein structures, and several molecular interactions with proteins. The application of such in silico methods is seen in the screening of potential targets during new drug designs, the discovery of novel protein sequences that could play new and vital functions such as industrial processes, understanding of protein function by studying its residues, and understanding of the effects of position mutations to the structure and function of the protein. This means these tools find a lot more use in protein-related research. However, many scientists are basic computer users and not experts in utilizing sophisticated software involved in in-silico Protein methods. This limits the progress of mainly young researchers towards protein-related research ideas. This review therefore discusses the progress in the development of user-friendly tools for assisted Insilco protein design, modeling, and docking.*

Keywords*— *Computational protein design, molecular docking, in-silico methods, protein structure prediction, and user-friendly research tools.

I. INTRODUCTION

Computational protein design (CPD) refers to Insilco methods employed in the design of sequence and molecular structure of proteins aimed towards a desired function in a wide range of fields such as protein design for harsh industrial processes, cellular signaling manipulation through the introduction of novel proteins in metabolic pathways, and improved protein stability and activity. (Enzymes)

On the other hand, Molecular docking refers to the application of computational tools whose algorithms predict binding modes and interactions proteins form with ligands, nucleic acids, and other protein molecules. Molecular docking performed with several ligands can help in the first screening of candidates that would bind effectively. Such information could be used to discover new drug compounds, which bind and inhibit protein activities involved in disease. Previously, scientists required years to perform protein manipulations for industrial and pharmaceutical uses; however, the present generation has seen rapid development and application of high-throughput computational technologies that have increased Biotechnological research. Computational protein design (CPD) and molecular docking are among these new game-changing technologies that have provided time-saving alternative Biotechnological solutions.

A variety of computational tools utilized in computational protein design exist for mainly two roles; prediction and scoring of protein folding models, and denovo construction of proteins. (Obtaining new sequences of amino acids that are expected to fold in a desired pattern for a particular function) Protein modeling remains one of the crucial tools in CPD as it enables scientists to simulate various sequences and analyse the resulting structures while aiming toward a particular function and properties.

There are three types of modeling; Homology modeling, Threading, and Ab initio modeling. Homology modeling such as the SWISS model, depends on sequence alignments through blasting to fold sequences of interest. This highly depends on protein sequences stored in Protein Data banks and a 30% or more similarity could show chances of similar protein folding. Threading involves the use of known protein folds for proteins similar to the sequence of interest. Examples of such software include I-Tasser. Ab initio involves modeling a protein from only its amino acid sequence by calculating the most favorable energy conformations of the amino acids. However, it should be noted that in Ab initio, Protein Database information can still be used, for example in Rosetta, a common software that uses a stochastic approach based on Monte Carlo sampling to optimize a particular sequence. Different protein fragments stored in the Protein database are utilized during this modeling and these guide the folding of the protein sequence of interest taking into consideration that each fragment has a non-zero chance of being lined with the sequence of interest.

Denovo construction of proteins uses the energy function in the generation of the protein tertiary structure, designing of the amino acid identity, and side chain conformation at all residue positions. (Ben et al., 2021)

Molecular docking is also a form of modeling that involves the interaction of two or more molecules to give a stable adduct (complex). Molecular docking aims to predict the favored orientation of a molecular complex. (Protein-Protein, Protein-Ligand, or Protein-Nucleic acid) Several molecular docking software exist and these generally operate a scoring function that selects and ranks ligand conformation, orientation, and translation. Available docking programs have a common drawback where the protein surface is kept ridged which prevents flexibility as seen in induced fit mechanisms. (Serge & Igor, 2014)

Difficulties in molecular docking are largely due to the high number of degrees of freedom characterizing a complex system which increases time and cost of computational calculations. To overcome this challenge, several algorithms based on approximations are utilized such as rigid docking that considers only the three translational and three rotational degrees of freedom of protein and the docking molecules such as ligands, treating them as two separate rigid bodies. The most widely used algorithms at present allow docking molecules to fully explore conformational degrees of freedom in a rigid-body receptor.

Therefore, two different approaches exist in Computational protein design and molecular docking; Deterministic and Heuristic algorithms. Deterministic approaches are reproducible, in which a continuous and consistent list of results is obtained. This means that, according to their energy function, one will find the best possible solution for a design problem. The only drawback is energy functions are not so accurate, require experimental validation and computational analysis can be time-consuming. (Chen et al., 2009, Frey et al., 2010)

Heuristic algorithms use stochastic processes to search the space described by the model and offer the advantage of being fast and cheaper compared to deterministic approaches. Because of this, many protein design programs use *heuristic* optimization algorithms to compute low-energy sequences in the search space described by the biophysical model. (Samish, 2009) However, this means Heuristic approaches do not maximally search the best solution models towards the global minimum and hence give varying results per computational run. (Gainza et al., 2016, Bonet et al., 2019) To solve this, A large number of candidate decoys are generated by Heuristic CPD workflows such as the Rosetta modeling suite which increases the sample space of generated models. (Alford et al., 2017)

This however results in the challenge of the need for user-friendly analysis tools which has seen many developers resorting to analysis scripts provided by third parties to correctly study such a large amount of data and increase biomolecular research. (Jaume et al., 2019) This review will therefore summarize the most used user-friendly tools for performing computational design protein, molecular docking, and analysis of CPD data.

User-friendly tools for analysis of Rosetta CPD data

Several computational software exists for the prediction of protein models and range from locally installed computer programs to web savers operated on supercomputers. Among these tools, the Rosetta modeling suite is one of the most commonly used software having both local and web-based operations. (Leman et al., 2019) Initially, it was primarily designed for protein structure prediction and folding, however to date, the Rosetta software includes Rosetta dock, docking small ligands to proteins, antibody and immune system protein design, modeling membrane proteins, and Denovo design of proteins.

Despite its usefulness in scientific research, users especially scientists with low coding knowledge experience challenges with the Rosetta molecular modeling suite owing to the software being a command line-only application with approximately 1.7 million lines of c ++ code. This together with a large population of molecular decoys continued to limit research and therefore has led to a steady development of Graphical User Interfaces (GUI) that are user-friendly such as rstoolbox, pyrosetta, Rosettascripts, and Foldit suiting different use cases and workflow styles

PyRosetta Toolkit

PyRosetta is a Python-based Rosetta GUI for performing molecular modeling, Protein design, and analysis of Rosetta calculation results. (Adolf & Dunbrack, 2013) It is composed of the main window which allows the user to quickly specify protein regions and output options, perform quick analyses, and run standard protocols. (relaxing structures and regions) Additional functions can be found in the main menu. Visualization is aided by the PyMOL tool.

Main menu of PyRosetta shows a typical GUI. (The File Menu allows the user to load a structure from a PDB file or directly from the Protein Data Bank, prepare a PDB for use in Rosetta, save and load GUI sessions, and import or export a variety of Rosetta filetypes. The Options Menu allows the user to set the number of processors to use, setup the main score function, and interact with the Rosetta options system. The Visualization Menu allows the user to integrate modeling tasks directly with PyMOL using Rosetta's PyMOLMover. the Advanced Menu houses a variety of sub-windows and useful functions for analyzing Rosetta results. Four Rosetta-specific analyzers are implemented, including the Void Identification and Packing Analyzer (VIP), Packstat, InterfaceAnalyzer, and LoopAnalyzer). (Lewis & Kuhlman, 2011)

Python-based rstoolbox

Jaume et al (2019) developed a Python-based Rosetta silent (rs) toolbox to facilitate protein model analysis even with beginner-level coding skills. There are four functional modules within the Python library; rstoolbox.io (provides read and write functions for multiple data types), rstoolbox. Analysis (provides analysis functions responsible for scoring designed decoys), rstoolbox. Plot (Provides functions that aid in graphical generations to represent analysis results; such as Ramachandran plots), and rstoolbox. Utils. (Provides helper functions for data manipulation, design comparisons, and amino acid profile creation. In addition to the four functional modules, rstoolbox also contains decoy population data, position-specific scoring matrix (PSSM), and Rosetta fragments data which all together form a components module. Rosetta fragments data contains position and properties of fragments which is very important in Ab initio as the latter depends on fragments used during modeling. PSSM is a matrix containing information about the probability of a given amino acid occurring in each position as depicted from multiple sequence alignments. The design frame contains information on the decoy population such as energetic scores, sequence, and secondary structure.

This shows an advantage of the rstool box in increasing functional options that enable users to select desired decoys, with desired sequences and properties, together with choosing fragments that best represent a minimum energy.

With the plot functions, rstoolbox provides graphical representations which reflect on the properties of protein structural designs and fragments used in the case of Ab initio. Modeled protein designs have different dihedral angles present in polypeptide backbones and such angles directly relate to the stability of the protein. Analysis of such stability is aided by a Ramachandran plot which can show dihedral angle distributions of each amino acid present in a modeled structure. These tend to cluster in four different regions which can depict secondary protein structure. However, the clustering of amino acids disallowed regions shows the instability of a protein backbone owing to steric hindrances.

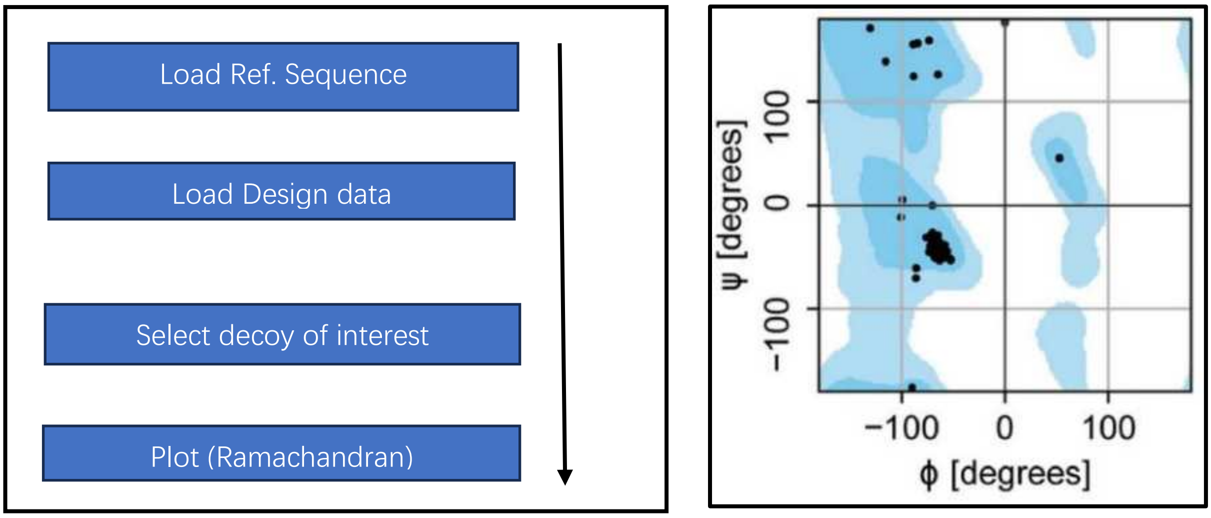

Fig. 1 shows a summary of procedures executed by commands while analyzing structural stability using rstoolbox. However, this can only be useful with already locally installed Rosetta software. With this, and with imported rstoolbox, loading of rosetta predicted design with input functions, .io results in the generation of data containers defined in the components module from which decoys of interest are selected for stability analysis via the Ramachandran plot.

The Ramachandran plot in Fig 1 represents a general form, in which the clustering of amino acids is limited to particular regions as shown. However, there are other forms of Ramachandran plots namely glycine, Proline, and Pre-proline that can also be generated by the toolbox.

The toolbox also offers easy-to-use analysis and plotting functions of novel protein structures predicted by Ab initio, by comparing local structure similarity of designed protein (target) with PDB fragments used during modeling as shown in Fig. 2

Interestingly, the rstoolbox facilitates interactive computational design approaches, meaning several rounds of design are performed and each generation of designs is used to guide the next one. The toolbox offers a variety of functions that facilitate this, for example; the selection of decoys with a particular mutation of interest or the generation of designs with a minimum number of mutations

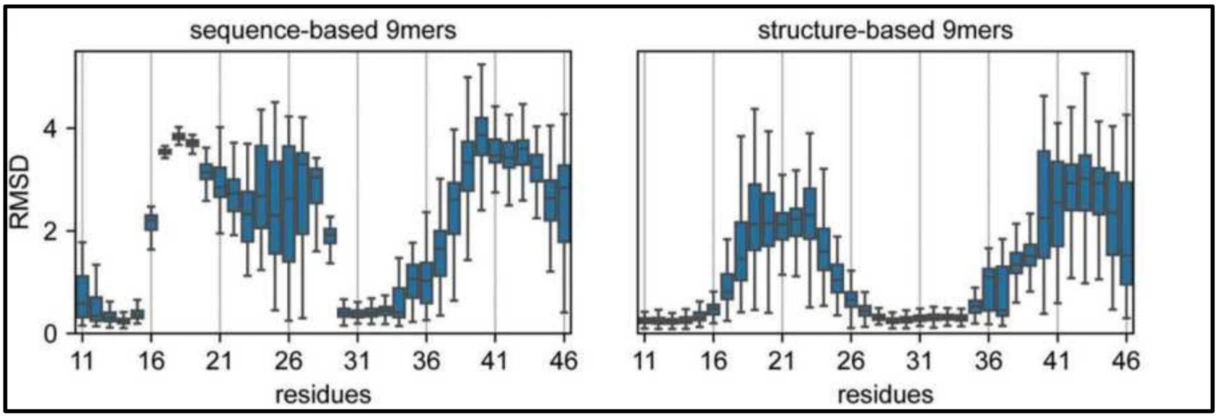

Fig. 2 demonstrates both sequence and structure-based fragments, and from the graphs, the root mean square deviation (RMSD) of structure-based 9mers is generally lower than that of sequence-based 9mers. (Jaume et al.,2019) This shows that there are fewer differences in amino acid residues at a particular position of the structure-based 9mers (fragment) and the target.

AMDock (Assisted molecular docking with AutoDock4 and AutoDockVina)-Python-based

A large number of docking programs have been developed during the last three decades, based on different search algorithms and scoring functions. Aiming to make these docking programs more user-friendly, especially to beginners, different graphical user interfaces (GUIs) have been developed to assist in the preparation of molecular systems, the execution of the calculations, and/or the analysis of the results. (Valdés et al., 2020)

AutoDock vina and AutoDock 4 are both AutoDock programs, a widely used free access docking software, and work similarly by pairing an empirically-weighted scoring function with a global optimization algorithm. However, the two differ in such a way that AutoDock Vina performs calculations of a gradient while seeking a local optimum. AutoDock 4 on the other hand uses stochastic approaches to generate random conformations for testing. (Chang et al., 2010)

AMDock includes both Auto Dock Vina and AutoDock 4 which labels it as a multi-platform tool. The tool further includes ADT scripts (Responsible for preparation of ligand and receptor files), Auto Ligand, (Harris et al., 2007) Open Babel, (Boyle et al., 2011) PDB2PQR, (Dolinsky et al., 2004) PyMOL, (Schrödinger, 2002) and AutoDock4Zn for proteins whose active sites contain Zinc ions.

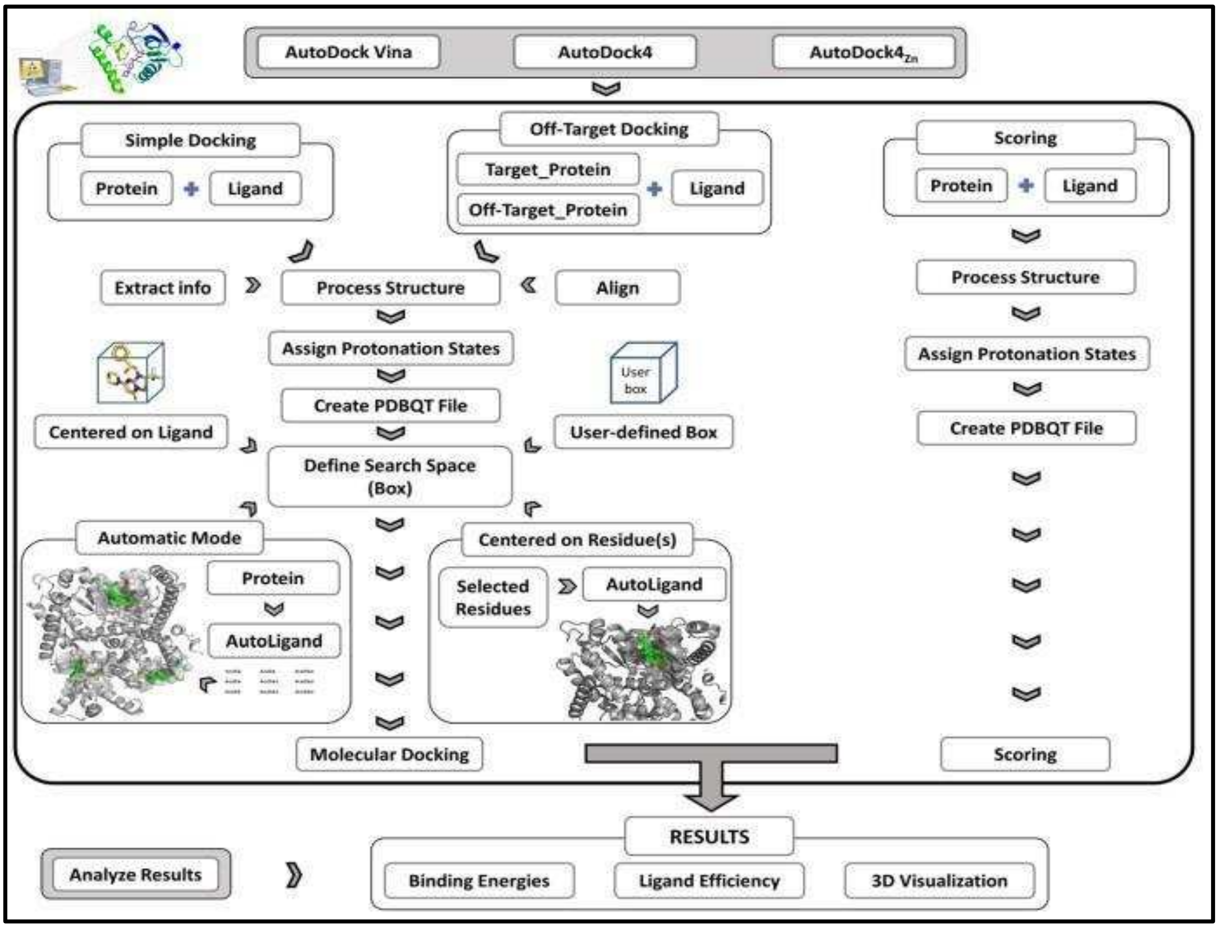

Fig 3: (Valdés et al., 2020) illustration of the workflow utilized by AMDock.

From **Fig 3**, AMDock consists of five tabs; Home, Docking options, Analysis, configuration, and Info. It is therefore much easier for the user to select the appropriate docking approach from the Home tab. (AutoDock Vina, AutoDock 4 engines and AutoDock 4_{Zn}.) Selection of any of these leads to an automatic shift to the Options tab in which simple docking (Protein and ligand), off-target docking (ligand with a protein having two ligand-receptor sites), or scoring can be performed which further increases the AMDock applications. After this, ADT scripts prepare the input files for docking. Another advantage of AMDock is that the user can define the pH under which docking is predicted. Molecular docking using Vina is typically conducted using the default box size and this is calculated based on the coordinates of the native ligand interacting with a protein of interest in the experimental structure. (Feinstein & Brylinski, 2015)

AMDock offers four different approaches to defining search box center and size; Automatic, Center, Hetero, and Box. In the automatic approach, the program uses Auto Ligand to predict possible binding sites and then generates a box with optimal dimensions cantered on each Auto Ligand object at each predicted binding site (Morris et al., 2009)

Center on Ligand involves the use of AutoLigand to generate an object with a volume similar to the ligand size, using it as a reference to the geometric center of the selected residues. Then, a box with optimal dimensions is centered on the formed object.

Center on Hetero involves a box placed on the geometric center of an existing ligand (if the receptor was given in complex with a ligand). The box approach involves the box center and dimensions are defined by the user. Running docking involves just a click (run) and generated results are analyzed using the analyze results tab where Affinity, Estimated Ki values, and Ligand Efficiencies are listed for the different resulting complexes. Visualization of these results is performed using PyMOL software.

Shortcomings of AMDocking

Despite providing a novel, simple, and user-friendly workflow, some challenges have been identified in the software. It does not perform hydrated docking (A concept in which water molecules might not be completely displaced by ligand molecules, but some remain and contribute to the overall complex) and neither covalent docking which means that the docking approach by AMDock for protein ligands cannot be used to screen probable drug or active substances owing to system inability to take into account of chemical reactions leading to covalent bond formation. (Scarpino et al., 2020)

Flexible side chains and ligands are not implemented during structural manipulation which roughly means it is dependent on a local and key approach. This limits the number of possible docking complexes as a result of decreased degrees of freedom hence reducing computational predicting power. (Sheng, 2018)

Virtual Screening, a concept utilized so much in drug discovery is not supported by AMDock. In this approach, computational tools are used to analyze small molecule (ligand candidates) libraries to come up with a lead molecule having the highest score of binding. Owing to this approach not being incorporated, it limits the application of AMDock in results analysis for drug-related research. (Lavecchia & Di Giovanni, 2013)

PyMOL Visualisation & analysis software

PyMOL is another example of GUI that aids visualization of 3D data resulting from proteins, nucleic acids, small molecules, electron densities, surfaces, and trajectories. (Yuan et al., 2017) The role of PyMOL is this review will be limited to Visualization and analysis of protein models, docking data, molecular simulations, and role in drug design. It is an open and widely used Python-based software to create high-quality movies and images such as ribbons, cartoons, dots, spheres, surfaces, or lines while providing a wide range of other functions such as estimation of the distance between neighboring atoms, and differential representation of molecules. To date, PyMOL accommodates a wide range of Plugins with further increased applicability.

Protein structure analysis with PyMOL

To date, PyMOL accommodates a wide range of Plugins and so with increased applicability. For Protein structure analysis;

DSSP and Stride: These assign secondary structures to protein models and provide graphical user interfaces for coloring according to predicted secondary structures.

Mole: This assists in rapid and automatic location and characterization of channels, funnels, and pores in molecular structures.

PyANM: Allows users to build and visualize Anisotropic network models (Entropic models demonstrated as captures of Internal energy)

Protein-ligand modeling/Docking

This is also Protein-Ligand docking, and it involves several steps all supported by PyMOL. These include; protein homology modeling, protein preparation, ligand alignment, ligand preparation and finally docking. The most useful application of protein modeling is seen in new drug discoveries and involves the steps below, (Yuan, 2017)

Homology Modeling: Using this approach, a 3D model of the target protein sequence is generated using a homologous template. Plugins to assist in homology modeling within PyMOL include PyRosetta and PyMod which combines a majority of other homology modeling tools such as Modeller, PSI-BLAST, Clustal Omega, Muscle, and PSIPRED. The purpose of Homology modeling is to predict a 3D protein design that is required in docking.

Protein preparation: Protonation states of mainly Asparagine and Glutamine are so important because the amide residues at the end of the molecules tend to form up to four Hydrogen bonds that contribute so highly to Protein structure and stability. (Weichenberger et al., 2007)

With the Amber plugin, one can enhance predictions of the modeled protein structure. This comes with the addition of pKa information and optimization of conformations/protonation state of Asparagine, Histidine, and glutamine, refining the H-bond network and energy minimization.

Ligand Alignment: Proteins that bind a common ligand may have similarities and a conserved active site structure. PyMOL plugin LigAlign offers a reliable approach in which PDB files of proteins complex with the common ligand are obtained from a databank. It then aligns the protein complexes according to the minimum root mean square deviation (RMSD) and so enabling the user to identify conserved structural patterns. This enables the user to identify and define ligand search space.

Ligand preparation: Any molecule imported into PyMOL can have its energy minimized by the Optimize plugin. (3D geometries, proper bond orders, accessible tautomer, and proper ionization states of molecules are altered towards minimum energy)

Protein-Ligand Docking: PyMOL can include Docking pie, a plugin that that provides an easy-to-use interface to four docking programs together with scoring functions; Smina, Autodock Vina, RxDock (Proteins and nucleic acids) and AutoDock for Flexible Receptors (AutoDockFR). (Ravindranath et al., 2015)

Virtual screening with PyMOL

Two types of virtual screening exist; Ligand and Structure-based virtual screening. Ligand-based virtual screening employs a concept of Scaffold hopping, in which different basic scaffolds can have similar or even better biochemical activities compared to an already-known compound. The PyMOL plugin Lisica utilizes this concept and aids scientists in using structural activity data from a set of known bioactive molecules to identify probable candidate compounds which reduces the amount of experimental validation. (PyMOL here is used as a compound screening tool) (Dilip et al., 2016)

On the other hand, Structural-based virtual screening involves the use of 3D data of protein targets obtained using Protein modeling or from NMR and X-ray methods to dock active compounds into the binding sites and then rank them using scoring functions. It is evident therefore that structure-based virtual screening is dependent on the 3D structure of the target protein and similar protein-ligand complexes present in a data bank. (Li & Shah, 2017)

Molecular dynamics (MD) simulations using PyMOL

Molecular dynamics simulation is an approach to obtain kinetic and thermodynamic characteristics of biomolecular structures. MD simulation software is therefore very useful in the establishment of macromolecular stability, identification of allosteric sites, elucidation of mechanisms of enzymatic activity, molecular recognition and properties of complexes with small molecules, association between proteins, protein folding, and its hydration.

Despite of application of MD simulations, most tools present are used in command line form and continue to challenge researchers with little computational skills. (Vieira et al., 2023)

MDBuilder is a PyMOL plugin that offers an easy-to-use GUI that assists researchers in building the starting structures for multiple popular MD simulation packages. Also, the Dynamics PyMOL plugin assists in MD simulation by using GROMACS tools to provide an easy-to-use GUI for molecules loaded directly to PyMOL.

Hydration site prediction

Water molecules that are bound to the active site of a protein can aid in substrate/ligand binding and so prediction of the properties and location of the hydration site is crucial in understanding protein function. PyMOL plugin WATsite provides analysis for hydration sites while providing an easy-to-use GUI. (Yang et al., 2017)

Many more plugins can be utilized in PyMOL software. With such a number, PyMOL is enhanced with several molecular functions that label it as a modern platform for computational drug design.

Protein-Ligand docking with Instadock

Compared to other docking platforms, Instadock provides one of the most user-friendly GUIs for docking and virtual screening. (Mohammad et al., 2021)

Several Docking programs have been released as GUIs for example; Raccoon, (Cosconati et al., 2010) PaDEL-ADV, PyRx, (allakyan $ Olson, 2015) AUDocker LE, (Sandeep et al., 2011) VSDocker, (Prakhov et al., 2010) DockingApp, (Di Muzio et al., 2017) MOLA, (Abreu et al., 2010) and DockoMatic (Bullock et al., 2010). However, these have several limitations to non-expert owing to being command line-based programs and their inability to handle all tasks required of a docking system. Such tasks include; Grid (configuration) file generation by ADT, conversion of import files to AutoDock standard format of PDBQT as they are not flexible with a variety of file formats, ligand preparation, and Visualisation. This means that the majority of earlier docking GUI still required individuals to perform manual preparation before docking and visualization.

However, InstaDock provides an easy-to-use and automated performance towards automatic detection of imported ligand and receptor files, preparation of the files, generation of search space configuration parameter files, (Specifies grid size, grid location, and atoms to be utilized in docking), conversion of ligand files into PDBQT and assigning appropriate atoms, if necessary, in just one click of a button. it also provides multiple docking parameters such as binding affinity, p*Ki*, torsional energy, and ligand efficiency for a compound and this also illustrates the diversity of the easy-to-use program. (Mohammad et al., 2021)

Alongside a single-click automated approach, InstaDock also provides a user-directed docking option by which a variety of standalone programs are provided in the tools section of the Interface which helps in virtual screening and other various Individual tasks such as receptor preparation, configuration generation, ligand preparation, file conversion, Hit identification, vina splitter, library splitter, Inspection of receptor PDB files and visualization and complex generation.

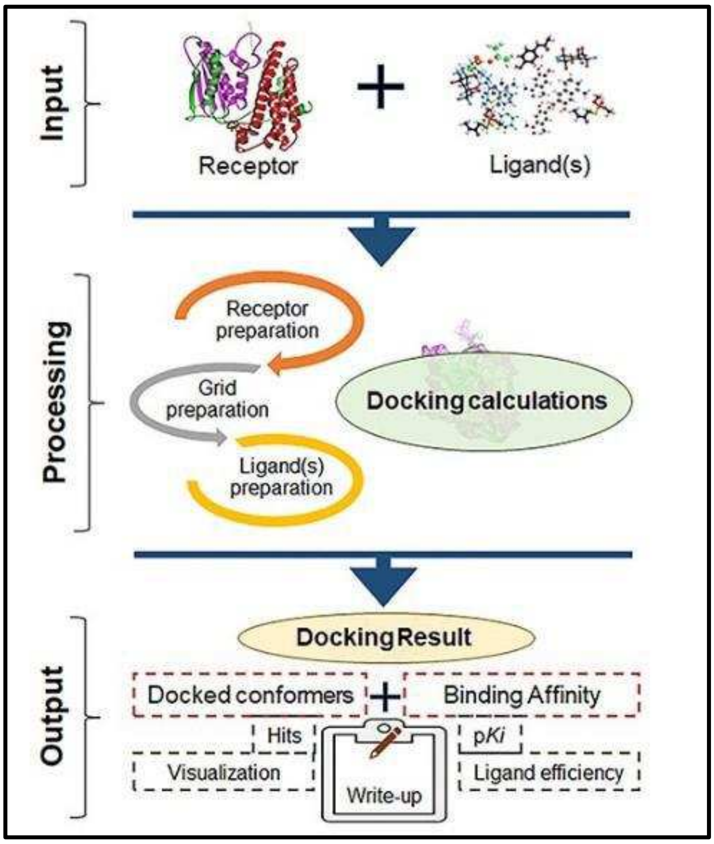

Fig. 4 (Mohammad et al., 2021) workflow of InstaDock illustrates the input of Receptor and Ligand files followed by automated processing of files and lastly output of docking results in a results folder containing different docked poses arranged according to binding affinity.

Limitations of computational protein modeling and molecular docking

Computational protein modeling energy functions that guide protein folding are aimed at improving computational power and therefore these functions only approximate resulting models. These approximations are due to the inability to accurately balance polar, and nonpolar interactions and solvation effects, particularly at the interfaces of proteins. (Kuhlman et al., 2019)

A single protein may display multiple activities as a consequence of having access to multiple protein structures either through allosteric regulation, post-translational modifications or other environmental factors. These multiple conformations are still a challenge to deal with in protein modeling.

The present mathematical protein modeling functions do not provide solutions to the prediction of protein activity; however, they just predict folding toward minimum energy. This leaves molecular docking (proteins with ligands or substrates for cases of enzymes) as the present method that can be used in predicting protein activity by specifying docking to amino acid residues expected to be involved in the desired biochemical process. However, it should be noted that the binding of a protein to a ligand does not mean it is activated or involved in a certain biochemical pathway. For example, binding of a substance to an enzyme does not only mean catalysis but also activation or inhibition. Also, binding of a transcription factor to DNA does not mean transcriptional activation but can also mean inhibition of transcription of DNA structural modifications. Therefore, finding a mathematical function that not only detects protein structure but also possible activity remains a challenge. (Del Río, 2021)

Bind of ligands to target proteins can sometimes follow synergism, where the binding of one alters the structure of the protein facilitating the being of the other. Currently, no molecular docking approach answers this, so there could remain a gap in the detailed understanding of how certain ligands affect proteins.

The existence of a variety of computational tools for molecular docking and protein modeling offers a wide range of choices for scientists, However, this creates another problem; the need for a standardized tool or approach for testing and validation that will minimize the diversity of data from computational analysis.

Molecular docking utilizes 3D proteins that are already modeled towards their minimum conformations. It is with such stable conformations that prepared ligands are docked which means it will dock with the most stable conformations and not the others, However, this can be misleading as binding of ligands to even other conformations not necessarily having low energy could yield an overall stable and highly favorable complex. (Docking should not be static but flexible if accuracy is required)

AlphaFold: AI-driven Protein design (A solution to the folding problem)

Experimental X-ray and Nuclear Magnetic Resonance remain quite expensive and time-consuming for the determination of protein structure. Also, previous protein design approaches such as Rosetta and other user-friendly computational approaches could not achieve a reasonably high GDT meaning such computational approaches don't fully solve the folding problem which therefore led to further research utilizing machine learning as a probable solution.

AlphaFold is an artificial intelligence (AI) approach developed by Deepmind and fully depends on machine learning to solve the protein folding problem. This approach has produced an easy-to-use tool with good results that are very similar when compared to experimentally determined structures and it is better than any other prediction software with over 70% and 92% Global Distance Test (GDT) results from AlphaFold 1 (2018) and AlphaFold (2020) respectively.

AlphaFold carries three distinct steps towards protein folding prediction of an imported amino acid sequence of interest, first, it searches the Protein data bank (an important requirement for machine learning) to extract sequences with similarity with the input thereby generating a multiple sequence alignment (MSA) representation. It also pairs the Input sequence to form a pairwise alignment and searches structural databases for proteins with similar sequences. The templates extracted from the structural databases and pairwise alignment are utilized to generate a pairwise representation of the input and this represents the relationship of every pair of residues in the target protein. The second step occurs in the Evoformer and consists of two parts; the MSA representation tower and the pair representation tower which communicate with each other to yield a neural network that is responsible for the evaluation of residues of both pair representation and MSA data to create refined MSA and pair representations. The third and last step involves structural model generation utilizing both the refined representations to perform rotations and translations. The generated structural models can be recycled back to the Evoformer three or more times before yielding the final structure.

Local computational utilization of AlphaFold requires complicated computational power and a wide knowledge of the Linux operating system, which can be a limiting factor for most scientists. To solve this problem, AlphaFold can be accessed using cloud computing and a simple web interface available from the Phenix GUI. This offers options for uploading or protein sequences, and customizing (number of predicted models, template utilization from Protein Data Bank and MSA) all aimed at increasing accuracy by default. This shows an advantage of how even inexperienced scientists can perform highly accurate model prediction that is equally as accurate as experimental procedures. The interface continues to provide results with numeric indicators of model accuracy, such as plDDT (predicted local-distance difference test) values and PLE plots. (predicted aligned error, a confidence of pairwise orientation) (Mirdita et al., 2021; Jumper et al., 2021)

Therefore, the application of machine learning in Computational protein design represents a great achievement in the generation of highly accurate protein models that can be further utilized in other studies and fast improvement of the available size of data banks.

II. CONCLUSION

Structural data about proteins is increasingly growing and to deal with this, new analysis tools such as rstoolbox have to be designed to offer accessibility to users even with beginner-level coding experience, for analysis of CPD data and generation of novel protein sequences with new functions. There is however a challenge of developing software that is both highly accurate and easy to use. The only solution to this is the application of machine learning in computational protein design and analysis. This concept is seen in AlphaFold modeling software which is easy to use and produces models with over 90% GDT and this therefore leaves artificial intelligence as a future for an easy-to-use approach in computational protein design, modeling, and docking.

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Comparative Analysis of Nutritional Composition and Antimicrobial Properties of Organically and Chemically Cultivated Garlic (Allium sativum)

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***Abstract*— *Garlic (Allium sativum) is renowned for its culinary uses and medicinal properties, attributed to its bioactive compounds such as allicin and protein. Organic farming practices have been increasingly recognized for producing crops with higher nutrient content and lower environmental impact compared to conventional methods. This study aimed to compare the nutritional composition and antimicrobial properties of organically and chemically grown garlic. Nutritional analysis revealed that organic garlic had significantly higher levels of bioactive elements compared to chemically grown garlic. Specifically, organic garlic contained 161,879.31 mg/kg of protein and 13.64% allicin content, whereas chemically grown garlic had 123,047.28 mg/kg of protein and 11.25% allicin content. Statistical analysis showed significant differences between the mean values of sodium (organic: 9,455.54 ppm, chemical: 5,486.90 ppm), protein (organic: 161,879.31 mg/kg, chemical: 123,047.28 mg/kg), and allicin (organic: 13.64%, chemical: 11.25%). The antimicrobial study demonstrated that organic garlic juice exhibited greater antimicrobial activity against both Salmonella typhi ($p < 0.001$) and Staphylococcus aureus ($p < 0.01$) compared to chemical garlic juice. Organic cultivation significantly enhances the nutritional and antimicrobial properties of garlic, making it a healthier and more environmentally friendly choice. These findings underscore the importance of organic farming practices for improving food quality and safety.*

***Keywords*— Garlic, bioactive compounds, organic farming, nutritional composition, antimicrobial properties.**

I. INTRODUCTION

Garlic is a widely cultivated and cherished spice, valued for its flavor and therapeutic properties. It is renowned for its antifungal, antibacterial, antiviral, antithrombotic, antitumor, hypotensive, hypoglycaemic, and hypolipidemic effects (Khanum, F., 2010). Recent studies have highlighted its therapeutic potential in managing cardiovascular diseases (Kik, C.,2001; Collin, H. A., 2004) and cancer (Le Bon M.H., 2000). Among various medicinal plants like pumpkin seed, thyme, onion, Nigella sativa, lemon balm, and stinging nettle, garlic stands out for its extensive and intensive use globally. Garlic is consumed in various forms, including fresh, powdered, and oil (Goncagul, G., 2010).

Garlic's unique sulphur chemistry includes numerous bioactive compounds beneficial to human health (Charron, C.S., 2016). Over 3,000 publications have validated garlic's efficacy in preventing and treating various diseases, thus acknowledging its traditional uses. The stable, water-soluble organosulfur compounds in garlic are considered the bioactive principles behind its numerous health benefits (Chandrashekhar, P.M.,2009). Allicin, the primary medicinal compound in garlic, is derived from alliin and is preferred by the pharmaceutical industry at concentrations exceeding 4.5 mg allicin per gram of fresh weight (FW). Alliin ($C_6H_{11}NO_3S$) and its derivative allicin ($C_6H_{10}OS_2$) are responsible for garlic's distinctive flavor and health benefits. The chemical formula of alliin was first determined by Stoll and Seebeck. Two alliin molecules react to form allicin, indicating that sulfur nutrition significantly contributes to the allicin content in garlic bulbs (Nguyen, B.T., 2022).

Nutritionally, 100 grams of garlic provides 149 kcal and contains substantial amounts of potassium (21 g/kg), phosphorus (6 g/kg), magnesium (1 g/kg), sodium (532.78 mg/kg), calcium (363.61 mg/kg), and iron (52.91 mg/kg). Additionally, garlic contains selenium and germanium, with their concentrations depending on soil mineral content (Nguyen, B.T.,2022). Garlic is also rich in vitamins, particularly thiamin, which exhibits high bioavailability due to specific sulfur-containing components (Sajid, M.,2014).

Garlic's identified health benefits have led to the production of numerous commercial products, such as garlic oil, garlic powder, and garlic capsules. The sulfur in allicin and its precursor alliin is critical for these benefits (Nguyen, B.T.,2022). For instance, garlic oil has been shown to reduce the toxicity of tributyltin (Rana, S.V.,2011), and at a supplementation rate of 5 mg/kg body weight, it has anticoagulant effects in animal studies (Rana, S.V.,2011). Additionally, allicin enhances lipoperoxide production in fungal plasma membranes, improving the efficacy of polymyxin B against fungal vacuoles (Ogita, A.,2007).

Research indicates that the effects of increasing sulfur in garlic cultivation should be considered alongside other mineral fertilizing components like nitrogen and selenium, as well as atmospheric sulfur sources. Sulfur application during plant growth periods significantly increases alliin content in garlic bulbs, while high nitrogen doses may reduce or have no effect on organic sulfur compounds in plants (Huchette, O.,2007). Sulfur directly influences the development, yield, and biological value of garlic. Studies suggest that vermi-compost application results in maximum plant height, leaf number, clove count per bulb, bulb diameter, weight, and yield (Singh Solanki, S.,2020). Additionally, when cultivated with fodder radish, garlic plants accumulate more nitrogen, sulfur, total phenolic acids, amino acids, and glutathione in bulbs (Salata, A.,2021).

Considering these research findings, the present study aims to quantitatively compare essential nutrients in chemically grown versus organically grown garlic cultivated in open fields with similar soil conditions. This comparison will help elucidate the impact of different cultivation practices on the nutritional and therapeutic value of garlic.

II. METHODOLOGY

1. Interviews with Farmers

Ten farmers were selected for interviews, including five who practice organic garlic cultivation and five who use inorganic methods. The interviews were conducted to gather comprehensive insights into their agricultural practices and the cultural consumption habits of garlic within their families. The focus of these discussions included soil management strategies, fertilizer application techniques, pest and disease management practices, and overall cultivation methods. These interviews provided valuable information regarding local agricultural traditions and preferences.

2. Collection of Garlic Samples

Fresh and mature garlic samples were collected from the village of Aajangaon in the Arvi block of Wardha district. This selection ensured that the soil strata were consistent across all sampling locations, serving as a control factor to minimize potential soil-related variations in the garlic samples. During the collection process, meticulous documentation was conducted to record the specific inputs utilized by the farmers. This documentation encompassed details on the types and quantities of fertilizers, pesticides, and other agricultural treatments applied during the cultivation of garlic.

3. Comparative Analysis of Bioactive Elements in Garlic

The Kjeldahl distillation method, as described in the Handbook of Food Analysis, was used to estimate the protein content. Sodium content was analyzed using ash samples prepared at 500°C and measured with a flame photometer. Sulfur content was determined through spectrophotometric analysis. Allicin analysis was carried out at Anacon Laboratories, Nagpur, using High-Performance Liquid Chromatography (HPLC).

4. Estimation of Anti-Microbial Properties of Garlic

To evaluate the antimicrobial properties of garlic, the following methodology was employed:

Fresh garlic bulbs were carefully peeled, weighed, and cleaned to ensure that no external contaminants were present. The cloves were then crushed in a sterile mixer and filtered through sterile cheesecloth to obtain a concentrated garlic extract, which was considered to be 100% fresh garlic juice. This concentrated juice was further diluted to varying concentrations (10%, 25%, and 50%) by mixing with sterile distilled water. These diluted garlic juice samples were inoculated on nutrient agar media and incubated at 37°C overnight for a well-diffusion assay. The antimicrobial assay was conducted against *Staphylococcus aureus* and *Salmonella typhi*, common pathogens known to cause foodborne illnesses and other infections (Bajpai, P.,2015). This assay provided valuable insights into the antimicrobial efficacy of garlic extracts at different concentrations.

This methodological approach ensured rigorous and systematic evaluation of the bioactive and antimicrobial properties of garlic, contributing to a comprehensive understanding of its health benefits and cultivation practices.

III. RESULTS AND DISCUSSIONS

The chemical analysis of bioactive elements in organic and conventionally grown garlic samples revealed significant differences in several key nutrients. The results are summarized in Table 1:

Table 1 – Comparison of Bioactive Elements in Organic and Conventionally Grown Garlic

Nutrient	Organic Garlic (Mean ± SD)	Conventionally Grown Garlic (Mean ± SD)	p-value
Sodium (ppm)	9455.54 ± 125.71	5486.90 ± 95.62	0.021
Sulfur (ppm)	71135.20 ± 890.46	59149.52 ± 760.28	0.149
Protein (mg/kg)	161879.31 ± 2123.67	123047.28 ± 1876.94	0.022
Allicin (Area %)	13.64 ± 0.35	11.25 ± 0.29	0.079

The p-values for sodium (0.021), protein (0.022), and allicin (0.079) are less than the significance level of 0.05, indicating significant differences between the mean values of these bioactive elements in organic and conventionally grown garlic. Organic garlic showed significantly higher levels of sodium, protein, and allicin compared to conventionally grown garlic. Although the p-value for sulfur (0.149) did not reach statistical significance, organic garlic showed a trend towards higher sulfur content compared to conventionally grown garlic.

These findings are consistent with previous research demonstrating genuine differences in nutrient content between organic and conventionally grown crops (Worthington,V.,2001). Additionally, studies have reported significantly higher ash content in organically grown garlic (Bajpai, P.,2015). Moreover, research indicates that organically cultivated garlic contains approximately 1.6 times more allicin compared to conventionally grown garlic (Raslan, M., 2015), which aligns with the higher allicin content observed in the organic garlic samples in this study.

Contrary to studies showing lower nitrate and protein content in organically grown crops compared to conventionally grown crops, this study observed higher protein content in organically grown garlic (Worthington, V.,2001; Bajpai,P.,2015). The higher availability of nitrogen from mineral fertilizers used in conventional farming is likely the reason for the increased protein content in vegetables grown under this method (Czeh, A.,2022). In contrast, lower crude protein content in organically grown vegetables might be attributed to the slower release of nitrogen from organic manures, leading to inadequate nitrogen availability throughout the crop growth period (Bajpai, P.,2015). In this study, farmers used Jivamruta, a type of liquid manure, along with farmyard manure for fertilizing the garlic crop. Literature supports that these liquid manures, known as Sanjeeva, are rich sources of beneficial microbes that enhance nutrient availability to crops (Phate, S.,2014).

Furthermore, studies on forestry and foliar applications have shown that liquid manure and humic liquid extracts from vermicompost improve plant growth and nutrient uptake, supporting higher protein levels observed in organically grown garlic (Phate, M.,2023; Balmori, D.M.,2019). The data from this study highlight that organic garlic not only contains significantly higher levels of sodium, protein, and allicin compared to conventionally grown garlic but also demonstrates substantial nutrient advantages over conventionally grown garlic. These findings underscore the nutritional benefits of organic farming practices and their impact on bioactive compound content in garlic. Organic farming methods contribute to improved nutritional quality in garlic, making it a healthier choice for consumers seeking foods with enhanced bioactive compounds and reduced chemical residues.

Table 2: Inputs applied for Garlic Cultivation by the farmers (The inputs listed above were applied according to the practices adopted by participating farmers for fertilizing the crop and managing pest attacks)'

Input	Organically Grown Garlic	Conventionally Grown Garlic
Crop Duration	4 months	4 months
Farm Yard Manure	4 qt/acre	-
Jivamruta (Liquid Manure)	1,200 lit/acre	-

Foliar Spray (Twice)	14 lit water + 1 lit Bitter butter milk + 50 gm Asafoetida	-
Urea	-	50 kg/acre
10:26:26 (NPK)	-	50 kg/acre
Foliar Spray (Once)	-	Imidacloprid 225 ml/acre
Water	Irrigated	Irrigated

The table illustrates the distinct approaches used in organic and conventional garlic cultivation. Organic practices include the use of farmyard manure, Jivamruta (a type of liquid manure), and a specific foliar spray regimen designed to enhance soil fertility and manage pests naturally. In contrast, conventional practices rely on synthetic fertilizers such as urea and 10:26:26 (NPK), alongside chemical insecticides like Imidacloprid, to achieve similar objectives.

Organic garlic cultivation aims to maintain soil health and sustainability by utilizing natural fertilizers and biologically friendly pest management techniques. These practices contribute to higher nutrient content and bioactive compounds in organic garlic, as observed in the chemical analysis (Table 1).

Conventional garlic cultivation, on the other hand, utilizes synthetic inputs to ensure rapid growth and pest control. This method may result in lower levels of certain bioactive compounds and nutrients, as indicated by the comparative analysis. The choice of inputs significantly influences the nutritional quality and chemical composition of garlic. Organic farming practices, as demonstrated in this study, offer a sustainable and nutritionally superior alternative to conventional methods, promoting healthier food choices for consumers.

Table 3: Comparative Analysis of Antimicrobial Activity of Garlic

Sr. No.	Dilution of Garlic Juice	*Salmonella typhi* (cm) Organic Garlic Juice	*Staphylococcus aureus* (cm) Chemical Garlic Juice
1	Control	0.0	0.0
2	5%	1.2	0.7
3	10%	2.0	0.9
4	25%	2.5	2.2
5	50%	3.1	2.8
6	100%	2.7	3.0
	Pr(>F)	0.00022	0.00522

The table presents the comparative analysis of the antimicrobial activity of organic and chemical garlic juice against *Salmonella typhi* (Gram-negative) and *Staphylococcus aureus* (Gram-positive).

The results show significant differences between the means of the dilutions of organic and chemical garlic juice for all four combinations of bacteria type and garlic juice type (all p-values < 0.05). Here's the interpretation of the findings:

Salmonella typhi (Gram-negative bacteria)

- Organic garlic juice inhibited the growth of Salmonella typhi more effectively compared to chemical garlic juice at all dilutions. The zone of inhibition increased with higher concentrations of garlic juice, with organic garlic juice showing superior activity. The p-value (0.00022) indicates a highly significant difference.

Staphylococcus aureus (Gram-positive bacteria)

- Organic garlic juice also showed stronger antimicrobial activity against Staphylococcus aureus compared to chemical garlic juice across all dilutions. Again, the zone of inhibition increased with higher concentrations of garlic juice, and organic garlic juice exhibited greater efficacy. The p-value (0.00029) indicates a highly significant difference.

The results align with earlier studies that demonstrated the antibacterial activity of garlic, particularly local varieties, against Salmonella groups (Noman, Z.A.,2023). The present study confirms that organically grown garlic exhibits stronger antimicrobial properties compared to chemically grown garlic. This finding is consistent with previous research by Nauman Khalid, which showed effective inhibition of *Salmonella typhi* and *Staphylococcus aureus* by garlic extracts (Khalid, N.,2014).

Moreover, allicin, a compound found in garlic, has been shown to possess antimicrobial activity against various pathogens, including drug-resistant strains of *Mycobacterium tuberculosis* (Bhatwalkar, S.B.,2021). This study further supports the notion that organic garlic, which likely contains higher levels of allicin and other bioactive compounds, is more effective in exerting antimicrobial effects compared to chemical garlic. The findings highlight the significant antimicrobial potential of garlic, particularly when grown organically. This supports the use of garlic as a natural antimicrobial agent and underscores the importance of organic farming practices in enhancing the bioactive properties of garlic.

Based on the comprehensive analysis conducted in this study, organic cultivation of garlic has been shown to significantly enhance the nutritional and bioactive profile of garlic bulbs compared to conventional chemical-based methods. The study focused on a detailed comparison of important bioactive elements, specifically protein and allicin, between garlic grown organically and those grown using chemical methods.

IV. CONCLUSION

The findings of the study revealed that organic garlic exhibited substantially higher levels of bioactive elements compared to chemical garlic. Organic garlic contained 161,879.31 mg/kg of protein, which was approximately 31% higher than the 123,047.28 mg/kg found in chemical garlic. Similarly, the allicin content in organic garlic was measured at 13.64%, whereas chemical garlic contained 11.25%, indicating an approximate 21% increase in allicin content in organic garlic.

The higher protein content observed in organic garlic can be attributed to the organic fertilization practices employed, such as the application of farmyard manure and liquid manure (Jivamruta). These organic inputs promote soil health by enhancing microbial activity and nutrient availability. Consequently, this supports better mineralization processes in the soil, leading to increased protein accumulation in the garlic bulbs.

Furthermore, organic garlic demonstrated enhanced antibacterial activity against both gram-positive (*Staphylococcus aureus*) and gram-negative (*Salmonella typhi*) bacteria compared to chemical garlic. Organic garlic juice consistently exhibited larger inhibition zones in antimicrobial assays, indicating its superior efficacy in combating bacterial pathogens.

These findings highlight the environmental and health benefits associated with organic cultivation practices. Organic farming methods contribute to soil biodiversity, reduce reliance on synthetic chemicals, and promote sustainable agricultural practices. This aligns with existing research showing that organic produce tends to be healthier and more environmentally friendly than conventionally grown produce.

In conclusion, organic cultivation of garlic emerges as a beneficial practice for promoting ecosystem health and human well-being. The higher levels of bioactive compounds, particularly protein and allicin, in organically grown garlic support its use as a natural alternative for enhancing health and combating bacterial infections. This study provides valuable insights into the advantages of organic farming and advocates for its further adoption to improve food quality and safety in agricultural practices.

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Effect of different fertilizer doses and spacing on performance of Pearl Millet (*Pennisetum glaucum* L.) under Tripura Agro-Climatic Condition

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Abstract*— A field experiment was conducted to study the effect of fertilizer and spacing on performance of Pearl Millet under Tripura agro-climatic condition during pre-kharif season in 2024 at the Experimental Farm of College of Agriculture, Tripura Lembucherra(23º56' N latitude and 91º10' E longitude, 160 m.s.l.) in a sandy loam soil with 12 treatment combinations (fourfertilizer level in main plot and three level of spacingin sub-plot) in a split plot design replicated thrice.Recommended Dose of Fertilizer (RDF) is 80:40:40 kg ha^{-1} as N: P_2O_5: K_2O. The main plot treatments are F_1: RDF 100%, F_2: RDF 75%, F_3: RDF 125%, F_4: RDF 150%. The sub-plot treatments were S_1: 30 cm X 20 cm, S_2: 45 cm X 20 cm, S_3: 60 cm X 20 cm. The study revealed that both the levels of fertilizer and spacing significantly influenced almost all the growth parameters, yield attributing characters, thegrain yield(kg ha^{-1}) and stover yield (kg ha^{-1}). The highest values of growth parameters, yield attributing characters, thegrain yield (kg ha^{-1}) and stover yield (kg ha^{-1}) were recorded when fertilizer applied @ 125% RDF (F3) in combination with spacing of 45cm x 20 cm (S_2).

***Keywords*—Fertiliser, Spacing, Pearl Millet, Yield, Tripura.**

I. INTRODUCTION

Pearl millet is an important dual-purpose, staple crop in the crop-livestock production systems of the arid zones of Rajasthan, North-West India. Globally, dry and semi-arid climates cover about 40% of the land area (Gamo, 1999). The hardest warm-season cereal crop in the world is pearl millet (*Pennisetum glaucum* L.) (Reddy *et al*., 2013). In terms of area, it comes in sixth place globally behind rice, wheat, maize, barley, and sorghum (Khairwal*et al*., 2007), and it accounts for 42% of global production (Ramesh *et al*., 2006). According to Ramesh *et al*. (2006), pearl millet is an essential semi-arid and dry crop grown in India for both food and feed on more than 8.3 million hectares of land. It ranks fourth among all grains (Yadav *et al*., 2011).

Efficient fertilizer management plays important role in increasing the crop yield through efficient utilization of limited moisture/water supply. The soils of these areas are deficient in various nutrient elements in general and nitrogen in particular. It is, therefore, imperative to have better understanding of growth, yield and quality of this crop in relation to nitrogen for promoting its adoption by farmers of these regions. (Singh *et al*.,2013).

Nutrient management, encompassing the application of fertilizers and soil amendments, directly affects the growth and productivity of pearl millet. The right balance of essential nutrients can enhance plant vigor, improve resistance to pests and diseases, and ultimately increase grain and yield. Similarly, plant spacing—the distance between individual plants and rows—plays a crucial role in determining the plant's access to resources such as light, water, and nutrients, which can influence both vegetative growth and grain production. Generally, pearl millet has been known for growing under low N management (Gascho *et al*., 1995) but, several studies showed that N application can increase millet production efficiency (Singh *et. al*., 2010).

Despite their importance, the optimal nutrient doses and spacing for maximizing pearl millet yield are not uniformly established and can vary based on local soil conditions, climate, and cultivar characteristics. Therefore, this study aims to evaluate the effects of different nutrient doses and spacing configurations on the yield of pearl millet. By systematically assessing these factors, the research seeks to provide actionable insights and recommendations for improving pearl millet cultivation practices.

Understanding the interplay between nutrient management and plant spacing will not only contribute to higher yields but also support sustainable agricultural practices by optimizing resource use and minimizing environmental impact. Through this investigation, the study aspires to enhance the productivity and economic viability of pearl millet farming, thereby contributing to global food security and agricultural sustainability.

The climate of Tripura is Warm and humid sub-tropical with average annual rainfall of 2200 mm. But there are no scientific agronomical cultivation practices of Pearl millet in Tripura condition. In view of the above facts, one field experiment was conducted on *"Effect of fertilizer and spacing on performance of Pearl Millet under Tripura Agro-Climatic Condition"* to find out the effect of fertilizer doses spacing and their interaction effect on growth, yield attributes and yield of Pearl millet.

II. MATERIALS AND METHOD

A field experiment was conducted during two consecutive *pre-Kharif* seasons of 2024 at the research farm of College of Agriculture, Tripura situated at 23°56' N latitude and 91°10' E longitude, with an altitude of 160 m from mean sea level. The Lateritic red soils (Tilla Lands) of the experimental site in Tripura was sandy loam having pH of 5.45, 0.45% organic carbon, 8.56 kg available phosphorus, 152 kg available potash and 15 kg available sulphur per hectare. The experiment was conducted during pre-kharif season where the climate of hilly zone is sub-tropical with distinctive characteristics of high rainfall, high humidity with a prolonged winter. The bulk density of soil was 1.40 mg/m^3 and pore space was 39%.Recommended Dose of Fertilizer (RDF) is 80:40:40 kg ha^{-1} as N: P_2O_5: K_2O. Half dose of nitrogen (N) and full dose of P_2O_5 and K_2O were applied as basal and remaining half dose of nitrogen (N) was applied at 30 Days after sowing.Twelve treatments comprising of 4 different fertilizer doses and 3 different spacing were considered as main plot and sub plot, respectively, and replicate thrice in Split Plot design. The main plot treatments are F_1= RDF 100%, F_2= RDF 75%, F_3= RDF 125%, F_4= RDF 150%. The sub-plot treatments were S_1= 30 cm X 20 cm, S_2= 45 cm X 20 cm, S_3= 60 cm X 20 cm.

The experimental data pertaining to each parameter of study were subjected to statistical analysis by using the technique of analysis of variance and their significance was tested by "F" test (Gomez and Gomez, 1984). Standard error of means (SEm+) and critical difference (CD) at 5% probability (p=0.05) were worked out for each parameter studied to evaluate differences between treatment means.

III. RESULTS AND DISCUSSION

Plant Height

The plant height of pearl millet was significantly affected by the different level of fertilizers at the time of harvesting. The tallest plant of Pearl millet (151.0 cm) was produced by the F_4 treatment (150% RDF) (Table 1) followed by F_3 treatment (125% RDF) and they are statistically at par. The shortest plant height (115.2 cm) was recorded in F_1 treatment (100% RDF).

The different levels of spacing non-significantly affected the plant height of pearl millet. However the S_1 treatment (30 cm x 20 cm) recorded the tallest plant (138.2 cm) (table-1) followed by the S_3 treatment (60 cm x 20 cm). The shortest plant (126.5 cm) was recorded in treatment S_2 (45 cm x 20 cm).

Moreover, the interaction effect between different fertilizer levels and spacing on plant height of Pearl millet was significant at harvest (Table2). Within the same level of spacing, the tallest plant (151.0 cm) of Pearl millet was recorded under F_4 treatment (RDF 150%) followed by F_3 (RDF 125%) and they are statistically at par. The F_1 treatment (RDF 100%) showed the shortest plant height (115.3 cm).

Table 1: Effect of levels of fertilizer and spacing on Growth attributes of Pearl millet

Treatments	Plant Height (cm)	Plant Population
Fertilizer Doses		
F_1(100% RDF)	**115.2**	**115065**
F_2(75% RDF)	**124.2**	**115600**
F_3(125% RDF)	**143.5**	**114530**
F_4(150% RDF)	**151.0**	**116670**
SEm(±)	**6.51**	**17.60**
CD	**22.53**	**60.94**
CV	14.64	0.046
Spacing		
S_1(30 cm x20 cm)	**138.2**	**160556**
S_2(45 cm x20 cm)	**126.5**	**105565**
S_3(60 cm x20 cm)	**135.7**	**80278**
SEm(±)	**4.58**	**396**
CD	**NS**	**1186**
CV	11.88	1.19

Table 2: Interaction effect of fertilizer and spacing on plant height (cm) of Pearl millet

Spacing Treatments	Plant height (cm)				
	Fertilizer Treatments				
	F_1	**F_2**	**F_3**	**F_4**	**Mean**
S_1(30 cm x20 cm)	**115.4**	**158.1**	**132.1**	**147.3**	**131.4**
S_2(45 cm x20 cm)	**102.0**	**86.4**	**157.9**	**159.74**	**130.9**
S_3(60 cm x20 cm)	**128.4**	**128.1**	**140.6**	**146.0**	**137.2**
Mean	**115.3**	**124.2**	**143.5**	**151.0**	
	F*S		**S*F**		
$SE_{m\,(\pm)}$	**9.16**		**9.92**		
CD at 5%	**27.45**		**31.71**		

With same level of fertilizer doses different spacing levels are significantly affected. The tallest plant (138.2 cm) was observed in S_1 (30 cm X 20 cm) followed by S_3 (60 cm X 20 cm) and they are statistically at par to each other. The shortest plant (126.5 cm) was recorded in S_2 (45 cm X 20 cm).

Plant Population

Plant Population of Pearl millet was affected significantly by different fertilizer doses as well as different spacing levels (Table1). The maximum numbers of plants (116279 nos) were recorded in F_4 (RDF 150%) treatment followed by F_2 (RDF 75%) and they are statistically significant. The minimum numbers of plant (113777 nos) were recorded in F_3 (RDF 125%). In case of different spacing level maximum population of plant (159947 nos) were counted in S_1 (30 cm X 20 cm) treatment followed by S_2 (45 cm X 20 cm) and also significant to each other. The minimum population (80006 nos) was counted in S_3 treatment (60 cm X 20 cm).

The interaction effect of different fertilizer doses and different levels of spacing on Plant Population were significant (Table 3). With the same level of spacing, the maximum population of plants (116279 nos) was observed in F_4 (RDF 150%) followed by F_2 (RDF 75%) and they are statistically at par. The lowest one (113777 nos) was observed in F_3 (RDF 125%). With same level of fertilizer the maximum number of plants (159947 nos) was recorded in S_1 (30 cm X 20 cm) treatment followed by S_2 (45 cm X 20 cm) and they are statistically significant. The lowest plant population (80006 nos) was recorded in S_3 treatment (60 cm X 20 cm).

Table 3: Interaction effect of fertilizer and spacing on plant population of Pearl millet

Spacing Treatments	Plant Population				
	Fertilizer Treatments				
	F_1	**F_2**	**F_3**	**F_4**	**Mean**
S_1(30 cm x20 cm)	**160556**	**160556**	**160556**	**160556**	**160556**
S_2(45 cm x20 cm)	**104361**	**105967**	**102756**	**109178**	**105566**
S_3(60 cm x20 cm)	**80278**	**80278**	**80278**	**80278**	**80278**
Mean	**115065**	**115600**	**114530**	**116671**	
	F*S		**S*F**		
$SE_{m\ (\pm)}$	**791**		**646**		
CD at 5%	**2372**		**1938**		

These results of growth attributes were in conformity with the findings of Shahin *et al.*, (2013) and Prasad *et al.*, (2014)

Yield attribute

No. of ears ha^{-1}.

Number of ears per ha were significantly influenced by different levels of fertilizer and different levels of spacing (Table 4). In case of different fertilizer doses, the highest number of ears ha^{-1} (100196) was recorded in F_1 treatment (RDF 100%) followed by F_4 (RDF 150%) treatment and they are significant. The lowest number (89122) was counted in treatment F_3 (RDF 125%). In different levels of spacing the highest ears (115396) were counted S_1 (30 cm X 20 cm) followed by S_2 (45 cm X 20 cm) and they are significant. The lowest one (73632) is treatment S_3 (60 cm X 20 cm).

In interaction effect, level of fertilizer doses and level of spacing were significant (Table5). With the same level of spacing the highest number of ears (100196) were found in the treatment F_1 (RDF 100%) followed by F_4 (RDF 150%) and they are statistically at par. The lowest number of ears (89122) was observed in treatment F_3 treatment (RDF 125%).

With same level of fertilizer the highest ears number (115396) was recorded in S_1 treatment (30 cm X 20 cm) followed by S_2 (45 cm X 20 cm) and they are significant to each other. The lowest number (73632) was found in S_3 (60 cm X 20 cm).

No. of grains ear^{-1}

The number of grains per ear was non-significant (Table 4). With different fertilizer doses, the highest grain numbers $ears^{-1}$ (479.9) was observed in F_3 (RDF 125%) followed by F_1 (RDF 100%) and the lowest one (429.4) was F_2 (RDF 75%). With different spacing levels, the highest grain number (474.4) was recorded in S_1 treatment (30 cm X 20 cm) followed by S_3 (60 cm X 20 cm) and lowest number of ears (402.6) was recorded in S_2 (45 cm X 20 cm).

In interaction effect, the main plots and sub plots were significantly correlated (Table 6). With same spacing level the highest grain number per ears (479.9) was recorded in F_3 treatment (RDF 125%) followed by F_1 (RDF 100%) and they are statistically at par. The lowest grain number (429.4) was recorded in treatment F_2 (RDF 75%). With same fertilizer doses S_1 treatment was recorded as highest grain number per ears (474.4) followed by S_3 (60 cm X 20 cm) and they are statistically at par. The lowest number of grains per ears (402.6) was recorded in S_2 treatment (45 cm X 20 cm).

The improvement of yield attributes with progressive increase of nitrogen levels was also reported by Ali, (2010) and (Cakmak *et al.*, 2010).

Yield

Grain yield (kg ha^{-1})

The grain yield of Pearl millet was significantly affected by different level of fertilizer doses and spacing (Table 7). In main plots, the highest grain yield (1526.1 kg ha^{-1}) was recorded in the F_3 treatment (RDF 125%) followed by F_1 (RDF 100%) and they are significant. The lowest grain yield (1028.9 kg ha^{-1}) was recorded in treatment F_4.

In sub plots, the highest grain yield (1482.9) was observed in S_2 treatment (45 cm X 20 cm) followed by S_1 and they are significant. The lowest grain yield (1147.3 kg ha^{-1}) was observed in S_3 (60 cm X 20 cm) treatment.

In interaction effect, the main plot and sub plot treatments are significant (Table 8). With same level of spacing the highest grain yield (1526.1 kg ha^{-1}) was recorded in F_3 treatment (RDF 125%) followed by F_1 treatment (RDF 100%) and they are statistically at par. The lowest grain yield (1028.9 kg ha^{-1}) was recorded in F_4 treatment (RDF 150%). With same level of fertilizer the highest grain yield (1482.9 kg ha^{-1}) was observed in S_2 treatment (45 cm X 20 cm) followed by S_1 (30 cm X 20 cm) and they are statistically at par. The lowest grain yield (1147 kg ha^{-1}) was observed in S_3 treatment (60 cm X 20 cm).

Table 4: Effect of levels of fertilizer and spacing on No. of ears per sq. m and no of grains per ear of Pearl millet

Treatments	No. of ears per sq. m.	No. of grains per ear	Seed index (g)
Fertilizer Doses			
F_1(100% RDF)	**100196**	**449.4**	**11.27**
F_2(75% RDF)	**89500**	**429.4**	**8.84**
F_3(125% RDF)	**89122**	**479.9**	**10.68**
F_4(150% RDF)	**93739**	**438.4**	**11.93**
SEm(±)	**1218**	**32.74**	**0.294**
CD	**4214**	**NS**	**1.018**
CV	3.92	21.86	3.4604559
Spacing			
S_1(30 cm x20 cm)	**115396**	**474.4**	**9.47**
S_2(45 cm x20 cm)	**90390**	**402.6**	**10.77**
S_3(60 cm x20 cm)	**73632**	**470.8**	**11.80**
SEm(±)	**4152**	**31.44**	**0.323**
CD	**12448**	**NS**	**0.969**
CV	26.52	24.24	2.9979988

Table 5. Interaction effect of fertilizer and spacing on seed index of Pearl millet

Spacing Treatments	No. of ears per sq. m				
	Fertilizer Treatments				
	F_1	F_2	F_3	F_4	Mean
S_1(30 cm x20 cm)	**8.93**	**7.93**	**13.10**	**7.90**	**9.47**
S_2(45 cm x20 cm)	**11.07**	**8.25**	**10.33**	**13.43**	**10.77**
S_3(60 cm x20 cm)	**13.80**	**10.33**	**8.60**	**14.47**	**11.80**
Mean	**11.27**	**8.84**	**10.68**	**11.93**	
	F*S		**S*F**		
$SE_{m\ (\pm)}$	**0.646**		**0.604**		
CD at 5%	**1.937**		**1.877**		

Table 6: Interaction effect of fertilizer and spacing on No. of ears per sq. m of Pearl millet

Spacing Treatments	No. of ears per sq. m				
	Fertilizer Treatments				
	F_1	F_2	F_3	F_4	Mean
S_1(30 cm x20 cm)	**127294**	**96311**	**127844**	**110133**	**115396**
S_2(45 cm x20 cm)	**97994**	**98000**	**66450**	**99117**	**90390**
S_3(60 cm x20 cm)	**75300**	**74189**	**73072**	**71967**	**73632**
Mean	**100196**	**89500**	**89122**	**93739**	
	F*S		**S*F**		
$SE_{m\ (\pm)}$	**8304**		**6889**		
CD at 5%	**24896**		**20752**		

Table 7: Interaction effect of fertilizer and spacing on no of grains per ear of Pearl millet

Spacing Treatments	No of grains per ear				
	Fertilizer Treatments				
	F_1	F_2	F_3	F_4	Mean
S_1(30 cm x20 cm)	**535.5**	**556.0**	**295.0**	**511.2**	**474.4**
S_2(45 cm x20 cm)	**354.2**	**360.1**	**640.1**	**256.0**	**402.6**
S_3(60 cm x20 cm)	**458.7**	**372.0**	**504.7**	**548.0**	**470.9**
Mean	**449.5**	**429.4**	**479.9**	**438.4**	
	F*S		**S*F**		
$SE_{m\ (\pm)}$	**62.88**		**60.89**		
CD at 5%	**188.5**		**190.7**		

Table 8: Effect of levels of fertilizer and spacing on grain weight and Stover yield of Pearl millet

Treatments	Grain Yield ($kg\ ha^{-1}$)	Stover Yield ($kg\ ha^{-1}$)
Fertilizer Doses		
F_1(100% RDF)	**1308.9**	**21746**
F_2(75% RDF)	**1191.3**	**23328**
F_3(125% RDF)	**1526.1**	**27149**
F_4(150% RDF)	**1028.9**	**23246**
SEm($\pm$)	**63.69**	**772**
CD	**220.38**	**2670**
CV	15.12	9.69
Spacing		
S_1(30 cm x20 cm)	**1161.2**	**25844**
S_2(45 cm x20 cm)	**1482.9**	**23724**
S_3(60 cm x20 cm)	**1147.3**	**22034**
SEm($\pm$)	**63.14**	**463**
CD	**189.30**	**1389**
CV	17.31	6.73

Stover yield

Stover yield of Pearl millet was significantly affected by different fertilizer doses and different spacing levels (Table 7). With different fertilizer doses, the highest stover yield (27149 kg ha^{-1}) was produced by the treatment F_3 (RDF 125%) followed by F_2 (RDF 75%) and they are statistically significant. Treatment F_1 (RDF 100%) produced the lowest stover yield (21746 kg ha^{-1}).

In sub plot treatments, the highest stover yield (25844 kg ha^{-1}) was recorded S_1 treatment (30 cm X 20 cm) followed by S_2 (45 cm X 20 cm) and they are significant. The lowest stover yield (22034 kg ha^{-1}) produced by S_3 treatment (60 cm X 20 cm).

In interaction effect, main plot and sub plot treatments are significant (Table 9). With same spacing level the highest stover yield (27148 kg ha^{-1}) produced by F_3 treatment (RDF 125%) followed by F_4 (RDF 150%) and they are significant. The lowest stover yield (21746 kg ha^{-1}) was produced by F_1 treatment (RDF 100%). With same level of fertilizer doses the highest stover yield (25843 kg ha^{-1}) was produce by treatment S_1 (30 cm X 20 cm) followed by S_2 (45 cm X 20 cm) and they are statistically at par. The lowest stover yield (22034 kg ha^{-1}) was recorded in S_3 (60 cm X 20 cm) (Table 10).

Kennedy *et al.*, (2002) and Prasad *et al.*, (2014) also observed linear increase in grain yield and biological yield of pearl millet with increased nitrogen levels.

Table 9: Interaction effect of fertilizer and spacing on grain yield (kg ha^{-1}) of Pearl millet

Spacing Treatments	Grain Yield (*kg ha^{-1}*)				
	Fertilizer Treatments				
	F_1	**F_2**	**F_3**	**F_4**	**Mean**
S_1(30 cm x20 cm)	**1333.0**	**1051.4**	**1464.7**	**795.7**	1161.2
S_2(45 cm x20 cm)	**1304.0**	**1680.6**	**1807.0**	**1139.8**	1482.9
S_3(60 cm x20 cm)	**1289.6**	**841.8**	**1306.5**	**1151.3**	1147.3
Mean	1308.9	1191.3	1526.1	1028.9	
	F*S		**S*F**		
$SE_{m\ (\pm)}$	**126.28**		**121.19**		
CD at 5%	**378.60**		**378.81**		

Table 10: Interaction effect of fertilizer and spacing on stover yield (kg ha^{-1}) of Pearl millet

Spacing Treatments	**stover yield** (*kg ha^{-1}*)				
	Fertilizer Treatments				
	F_1	**F_2**	**F_3**	**F_4**	**Mean**
S_1(30 cm x20 cm)	**23193**	**25359**	**27963**	**26858**	25843
S_2(45 cm x20 cm)	**20701**	**24138**	**26688**	**23367**	23724
S_3(60 cm x20 cm)	**21343**	**20485**	**26794**	**19512**	22034
Mean	21746	23327	27148	23246	
	F*S		**S*F**		
$SE_{m\ (\pm)}$	**927**		**1081**		
CD at 5%	**2778**		**3495**		

IV. CONCLUSION

Thus, it could be concluded that fertilizer applied @125% RDF (F_3) in combination with spacing of 45cm x 20 cm (S_2) gave the best result with maximum grain yield. This implies that under optimum plant population condition, the fertilizers might be properly utilized by the plants. The optimum fertilizer dose might have positive impact on higher grain yield and higher fertilizer dose might have toxic effect on plant system. However, this is one year data. Further research work is needed for final conclusion of the experiment.

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The Effect of Mulching and Planting Materials on the Growth and Yield of Sweet Potato (*Ipomoea batatas* L.) Sari Variety

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Abstract— *The production of sweet potatoes (Ipomoea batatas L.) in Indonesia is still considered low compared to the national needs, which is approximately 2 million tons per year. Sweet potato yields can be improved by influencing both internal and external factors of the cultivation practices. The use of mulch has the potential to stabilize plants environment and growing condition. The use of different planting materials that has different characteristics and hormone contents will also influence the growth and yield of sweet potatoes. The aim of this study is to determine the interaction between the use of mulch and planting materials on sweet potatoes. The hypothesis of this research is that there will be an interaction between the two treatments, which could enhance yield. This research was conducted from February to May 2024 in Sidodadi Village, Garum Subdistrict, Blitar Regency. This study is a factorial experiment arranged based on a Randomized Block Design (RBD) consisting of 2 factors. The first factor is mulch with 3 levels: M0 (no mulch), M1 (silver-black plastic mulch) and M2 (rice straw mulch). The second factor is planting materials with 3 levels: T1 (upper shoot cuttings), T2 (middle shoot cuttings) and T3 (lower shoot cuttings). The results showed that the application of silver-black plastic mulch provided the best yield when applied together with upper shoot cuttings (28.40 tons ha^{-1}), middle shoot cuttings (28.05 tons ha-^{1}), and lower shoot cuttings (27.86 tons ha^{-1}). The rice straw mulch treatment provided the best yield when applied together with upper shoot cuttings (22.53 tons ha^{-1}) and middle shoot cuttings (21.68 tons ha^{-1}). The treatment without mulch provided the best yield when applied together with upper shoot cuttings (25.79 tons ha^{-1}). The choice of planting material can vary according to availability (upper, middle or lower of the shoot cutting) if using black silver plastic mulch.*

Keywords*— *Mulch, Planting Material, Sweet Potato

I. INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is a type of tuber plant that is widely cultivated in Indonesia. Sweet potato is a vining plant that is the fourth largest source of carbohydrates after rice, maize, and cassava. In addition to carbohydrates content, sweet potatoes have other nutritional content such as 0.26-1.42% fat, 3.71-6.74% protein, 91.42-93.45% carbohydrates, vitamin B1 (0.08 mg), vitamin B2 (0.05 mg), vitamin A (7100 IU) vitamin C (20 mg), and vitamin B3 (0.9 mg) (Pratiwi *et al*., 2020). Sweet potatoes can grow at ideal temperatures between 21-27°C and an altitude of 500-1,000 meters above sea level with optimal rainfall ranging from 750-1500 mm $year^{-1}$ (Yoandari, 2017).

National sweet potato production in 2021 reached up to 1,604,184 tons and in 2022 decreased to 1,511,041 tons (Indonesian Directorate General of Food Crops, 2023). On the other hand, the need for sweet potatoes for national consumption in Indonesia is around 2 million tons per year and continues to increase along with the increasing population (Paturohman and Sumarno, 2015). Sweet potatoes are plants with vining growth that will form adventitious roots on each stem segment that contacts with the soil surface. Adventitious roots require a lot of photosynthetic assimilates to support their growth, which causes inhibition of tuber formation due to a shift in the priority of assimilates distribution (Rohmadani and Wijaya, 2022).

The attempt to avoid the sweet potato stem node interactions with soil (growing medium) could be done by covering the soil surface with mulch. Commonly used mulches in the field are organic mulch (straw) and inorganic mulch (black and silver plastic). In addition to cover the soil surface, mulch is physically able to maintain soil moisture, temperature, water availability, and also prevent the growth of weeds due to its ability in limiting the sun light radiation exposure directly to the soil surface (Annisa *et al*., 2014).

The source of the planting material will also affect the growth and yield of sweet potato plants because each planting material has its own characteristics. According to Mardi *et al*. (2016), cuttings on the top shoot of the plant that have relatively young tissue and a lot of auxin accumulation can accelerate the growth process of sweet potatoes plant. In addition, cuttings of the stem of sweet potatoes that have epidermal tissue with stomata and chlorophyll cortex tissue will accelerate the growth of leaf shoots and roots faster due to photosynthesis activity (Rismanto, 2019).

II. MATERIALS AND METHOS

The research was conducted from February to May 2024 on Sidodadi St., Sidodadi Village, Garum District, Blitar Regency, East Java with an altitude of approximately 156 meters above sea level, average rainfall of 3585 mm year^{-1}, average temperature of 22 – 29 °C and humidity of 71-85%. The tools used include silver-black plastic mulch (1.2 m x 1 m per ridge), straw mulch, cultivation tools, ovens, digital scales, camera, and stationery. The materials used are sweet potato seedlings of the Sari variety with planting material source in the form of upper shoot cuttings; middle shoot cuttings; and lower shoot cuttings, goat manure, and NPK fertilizer. The research was arranged using a Factorial Randomized Block Design (FRBD) consisting of 2 factors. The first factor is mulch with 3 levels in the form of M0 (without mulch), M1 (silver-black plastic mulch) and M2 (rice straw mulch). The second factor is planting material consisting of 3 levels, which are T1 (upper shoot cuttings), T2 (middle shoot cuttings) and T3 (lower shoot cuttings). Growth variables consist of plant length (cm), number of leaves, number of vine, leaf area (cm^2), fresh weight (g) and biomass weight (g). Yield variables consist of number of tubers per plant, tuber diameter (cm), tuber weight per plant (g), yield per hectare (ton ha^{-1}) and root/shoot ratio. Microclimate variables consist of minimum and maximum soil temperature (°C). The data obtained were analyzed using analysis of variance (ANOVA) and continued with the Tukey Test at the 5% level if there is a significant effect.

III. RESULT AND DISCUSSION

A. Growth Variables

Length of Sweet Potato Plants

Based on the research, it was found that in each treatment experiments showed a significant effect on both factors (i.e the type of mulch and planting material) to the length of sweet potato plants. Both factors showed an effect on length of the plant at all observation intervals except for the observation at 84 DAP (Table 1).

Based on the observations (Table 1), it shows that the highest length of plant value was found in the silver-black plastic mulch treatment at the 42 and 63 DAP. This is in accordance with the opinion of Panjaitan *et al*. (2019) where sweet potato plants need hot and humid air for its optimal life cycle needs. This is also in line with the function of silver-black plastic mulch which is able to maintain soil temperature to be more stable and maintain the soil humidity around plant roots (Annisa *et al*., 2014). High air temperature (which will affect the soil temperature as well) can increase plant length because high temperature stimulates the activity of the gibberellin hormone (GA) in plants which stimulates the growth of the length of sweet potato plant branches (Hayati *et al*., 2016).

The highest plant length was reached by upper shoot cuttings at 21, 42 and 63 DAP. Rismanto (2019) mentioned that the result can happen because upper shoot cuttings came from plant's organs that are relatively young with huge proportions of epidermal tissue containing stomata and companion cells as well as cortex tissue that has chlorenchyma cells containing chlorophyll. So that they are able to stimuli photosynthesize activity to grow roots when it is planted in a humid conditions. The impact of early root development can increase the speed of plants to grow new shoots and will continue to develop into new plants (organism) that are able to produce and adapt to the environment in which they grow.

Table 1. Length of Sweet Potato Plants Affected by Several Type of Mulches and Source of Planting Materials

Treatments	Length of Plant (cm) in the age observation of (DAP)			
	21	42	63	84
Type of Mulches:				
Without Mulching	37.56	65.49 a	103.24 b	132.93
Silver-Black Plastic Mulch	34.41	77.86 b	105.14 b	142.24
Rice Straw Mulch	38.83	62.72 a	90.53 a	135.70
Tukey Test 5%	ns	8.33	8.59	ns
Source of Planting Materials:				
Upper Shoot Cuttings	46.22 c	76.13 b	105.82 b	143.11
Middle Shoot Cuttings	34.80 b	65.29 a	97.15 a	129.82
Lower Shoot Cuttings	29.79 a	64.64 a	95.94 a	137.94
Tukey Test 5%	4.86	8.33	8.59	ns
CV (%)	10.90	10.05	7.14	7.96

Annotations: Numbers followed by the same letter in the same column showed no significant difference based on the Tukey Test at the 5% level. CV=Coefficient of Variance. ns = not significant. DAP = Day After Planting.

Number of Leaf

The results of the analysis of variance showed that there was no significant interaction ($F_{count}<F_{table0.05}$) between the different use of mulch type and source of planting materials at all observation intervals. Each treatment showed a significant effect on both the different type of mulch and source of planting materials on the number of sweet potato leaves in observation interval age of 42 and 63 DAP but both treatments had no significant effect on 21 and 84 DAP (Table 2).

Table 2. Number of Leaf of Sweet Potato Plants Affected by Several Type of Mulches and Source of Planting Materials

Treatments	Number of Leaf (unit) in the age observation of (DAP)			
	21	42	63	84
Type of Mulches:				
Without Mulching	29.48	53.24 a	73.13 ab	86.67
Silver-Black Plastic Mulch	34.07	60.61 b	74.89 b	91.20
Rice Straw Mulch	26.50	52.59 a	69.17 a	84.78
Tukey Test 5%	ns	5.58	5.52	ns
Source of Planting Materials:				
Upper Shoot Cuttings	30.80	60.59 b	75.83 b	89.07
Middle Shoot Cuttings	30.69	53.07 a	69.57 a	86.54
Lower Shoot Cuttings	28.57	52.78 a	71.78 ab	87.04
Tukey Test 5%	ns	5.58	5.52	ns
CV (%)	22.01	10.02	6.32	6.20

Annotations: Numbers followed by the same letter in the same column showed no significant difference based on the Tukey Test at the 5% level. CV=Coefficient of Variance. ns = not significant. DAP = Day After Planting.

The number of leaf variable observations show that the silver-black mulch treatment resulting to the highest leaf number value at 42 and 63 DAP. However, at 63 DAP it was not significantly different from the treatment without mulching. This is related to the ability of silver-black mulch to reflect the direct sunlight exposure towards the soil surface. Based on the opinion of Soplanit *et al*. (2021) silver-black mulch can increase the number of sweet potato leaves by reflecting light back to certain degree of the light source. In addition, silver-black mulch also able to increase the efficiency in converting light radiation energy, especially not only in the upper leaves but also in the lower leaves which will increase the rate of photosynthesis activity and the number of leaves from the meristematic tissue. On the other hand, upper shoot cuttings also showed the highest value number of leaves at 42 and 63 DAP. This is in accordance with the results of research by Idoko *et al*. (2017) with the use of the upper shoot as a cutting source of sweet potato planting materials which can produce a great number of leaves because the upper shoot contains apical meristem tissue which is responsible for the growth of new leaves. Increasing the time of leaf shoot initiation in sweet potato cultivation will potentially increase the potential for increasing the number of leaves as well, which generally occurs when planting using planting material originating from upper shoot cuttings (Lencha *et al*., 2016).

Number of Vine

The results of the analysis of variance showed that there was no significant interaction ($F_{count}<F_{table0.05}$) between the use of different mulch and source of planting materials at all observation intervals. The treatment of different planting materials source was able to provide a significant effect on the number of sweet potato vines. Conversely, different mulch treatment did not show any significant effect on the number of sweet potato vines at 21, 42, 63, and 84 DAP (Table 3).

Table 3. Number of Vine of Sweet Potato Plants Affected by Several Type of Mulches and Source of Planting Materials

Treatments	Number of Vine (unit) in the age observation of (DAP)			
	21	42	63	84
Type of Mulches:				
Without Mulching	2.48	5.07	7.94	9.91
Silver-Black Plastic Mulch	2.30	4.48	7.02	9.56
Rice Straw Mulch	2.41	4.72	7.76	9.61
Tukey Test 5%	ns	ns	ns	ns
Source of Planting Materials:				
Upper Shoot Cuttings	2.00 a	4.28 a	6.96 a	9.02 a
Middle Shoot Cuttings	2.41 b	4.98 b	7.63 ab	9.83 ab
Lower Shoot Cuttings	2.78 c	5.02 b	8.02 b	10.22 b
Tukey Test 5%	0.27	0.64	1.01	1.14
CV (%)	9.34	11.21	11.08	9.76

Annotations: Numbers followed by the same letter in the same column showed no significant difference based on the Tukey Test at the 5% level. CV=Coefficient of Variance. ns = not significant. DAP = Day After Planting.

Based on Table 3, the treatment of different planting material sources has a significant effect on the number of vines of sweet potato plants. The treatment of different planting material sources shows that lower shoot cuttings have the best effect on the average number of vines and are not significantly different from middle shoot cuttings. This is because lower and middle shoot cuttings have a relatively larger diameter when compared to shoot cuttings. As stated by Bararyenya *et al*. (2020), that stem cuttings have pericycle tissue that plays a role in secondary stem growth including the stimulation of vines formation at stem nodes and triggering adventitious root formation. Meanwhile, the mulching treatment did not show any effect on the number of sweet potato vines at all observation intervals. According to Wijewardana *et al*. (2018), sweet potato vine growth are mostly influenced by natural factors such as the intensity and duration of sunlight radiation exposure. 12 hours of sunlight radiation can provide optimal conditions for sweet potatoes to form new branches/vines. In addition, optimal water availability can also affect the formation of sweet potato vines. Conditions of water shortage/drought will cause the photosynthesis rate of plants to decrease and the branch/vines formation process will be obstructed (Solis *et al*., 2014).

Leaf Area

The results from the analysis of variance showed that there was no significant interaction ($F_{count}<F_{table0.05}$)

between the use of different mulch and source of planting materials at all observation intervals. Each treatment showed a significant effect on both the use of different mulch and source of planting materials on the leaf area of sweet potato plants at 21, 42, 63, and 84 DAP (Table 4).

Table 4. Leaf Area of Sweet Potato Plants Affected by Several Type of Mulches and Source of Planting Materials

Treatments	Leaf Area (cm^2) in the age observation of (DAP)			
	21	42	63	84
Type of Mulches:				
Without Mulching	710.82 ab	1282.20 a	1763.77 b	2088.80 a
Silver-Black Plastic Mulch	841.37 b	1495.43 b	1845.63 b	2248.01 b
Rice Straw Mulch	606.48 a	1208.07 a	1587.30 a	1945.00 a
Tukey Test 5%	181.21	159.28	135.14	155.85
Source of Planting Materials:				
Upper Shoot Cuttings	747.78	1466.45 b	1829.80 b	2152.53 b
Middle Shoot Cuttings	707.27	1224.06 a	1602.90 a	1994.29 a
Lower Shoot Cuttings	703.63	1295.18 a	1764.00 b	2134.98 ab
Tukey Test 5%	ns	159.28	135.14	155.85
CV (%)	20.87	9.94	6.47	6.17

Annotations: Numbers followed by the same letter in the same column showed no significant difference based on the Tukey Test at the 5% level. CV=Coefficient of Variance. ns = not significant. DAP = Day After Planting.

The leaf area variable observations (Table 4) shows that different mulch treatments had a significant effect on all of the observation intervals with the highest leaf area value in silver-black plastic mulch. This is in accordance with the research of Muslim and Soelistyono (2017) where silver-black plastic mulch treatment had the highest effect on leaf area parameters caused by the silver color of the mulch surface which can reflect most of the sunlight radiation received. The amount of reflected sunlight radiation can increase the absorption of light used in the photosynthesis activity. The treatment of different planting material sources showed that shoot cuttings were able to produce the highest leaf area values at 42, 63, and 84 DAP but in the 63 and 84 DAP it was not significantly different from the lower shoot cuttings. This is in accordance with the opinion of Lencha *et al*. (2016), that upper shoot cuttings were able to provide the highest leaf area values when compared to stem cuttings (middle and/or lower). This is also related to the opinion of Rosnina *et al*. (2022) where the number of leaves is directly proportional to the leaf area so that the more leaves formed, the more sunlight will be absorbed so and the leaves will grow wider. Lower shoot cuttings were not significantly different from upper shoot cuttings at 63 and 84 DAP because in addition to leaf area being correlated with the number of leaves, lower shoot cuttings have a larger diameter of stem and tend to be able to support wider size of leaf (Suwitono *et al*., 2024).

Fresh Weight of Shoot

The results from the analysis of variance showed a significant interaction ($F_{count}>F_{table0.05}$) between the use of different mulch and source of planting materials to the fresh weight of plant's shoot. There was a significant effect on silver-black plastic mulch treatment on planting material treatment. Meanwhile, the treatment of planting material sourced from the upper and lower shoot cuttings also showed a significant effect on different types of mulch treatment (Table 5).

The fresh weight values of the plant's shoot (Table 5) observation variable show a significant interaction between the use of different mulching application and source of planting materials. The highest value was obtained in the interaction between silver-black plastic mulch treatment with the use of upper shoot cuttings as planting material. Based on the opinion of Soplanit and Rumbarar (2020), silver-black plastic mulch can increase photosynthetic activity by reflecting light and being intercepted by the plant leaf so that the amount of photosynthate assimilation produced can be increased and distributed to the shoots and roots/tubers. In addition, Amare and Desta (2021) stated that silver-black plastic mulch can increase water availability in the soil by minimizing evapotranspiration so that the amount of water will be optimal for the implementation in the plant's photosynthesis process. Meanwhile, upper shoot cuttings have the highest fresh weight value compared to middle shoot cuttings and lower shoot cuttings. This is in accordance with the opinion of Netsai *et al.* (2019), which is the fresh weight of the plant's shoot is directly proportional to the length of the plant and the number of leaves, so the longer the plant, and the higher number of leaves, the higher the fresh weight value will be. Meanwhile, in the middle and lower shoot cuttings, the number of branches is indeed higher than the upper shoot cuttings. However, the average length of the plants shoot in the middle and lower shoot cuttings treatment is lower than the upper shoot cuttings, so it's resulting to the fresh weight value of the upper shoot cuttings treatment to be lower.

Table 5. Fresh Weight of Plant's Shoot of Sweet Potato Affected by Several Type of Mulches and Source of Planting Materials

	Fresh Weight of Plant's Shoot (g)		
Type of Mulches	Planting Material Sources		
	Upper Shoot Cuttings	Middle Shoot Cuttings	Lower Shoot Cuttings
Without Mulch	778.43 a A	813.47 a A	858.53 a A
Silver-Black Plastic Mulch	1423.95 b C	985.86 a A	1081.00 a B
Rice Straw Mulch	1110.68 a B	955.58 a A	947.58 a AB
Tukey Test 5%		211.75	
CV (%)		10.18	

Annotations: Numbers accompanied by the same lower case letters in the same row or the same upper case letters in the same column show no significant difference based on the Tukey test at the 5% level. CV=Coefficient of Variance. DAP = Day After Planting.

Table 6. Dry Weight of Plant's Shoot of Sweet Potato Affected by Several Type of Mulches and Source of Planting Materials

	Dry Weight of Plant's Shoot (g)		
Type of Mulches	Planting Material Sources		
	Upper Shoot Cuttings	Middle Shoot Cuttings	Lower Shoot Cuttings
Without Mulch	226.66 a A	253.7 a A	232.96 a A
Silver-Black Plastic Mulch	370.49 b B	264.66 a A	310.46 a B
Rice Straw Mulch	330.18 b B	235.28 a A	253.52 a A
Tukey Test 5%		54.62	
CV (%)		9.49	

Annotations: Numbers accompanied by the same lower case letters in the same row or the same upper case letters in the same column show no significant difference based on the Tukey test at the 5% level. CV=Coefficient of Variance. DAP = Day After Planting.

Dry Weight of Shoot

The results of the analysis of variance showed a significant interaction ($F_{count}>F_{table0.05}$) between the use of different mulch and source of planting materials to the dry weight of plant's shoot. There was a significant effect on mulch treatment on planting material treatment, such as on the treatment of silver-black plastic mulch and rice straw mulch. Meanwhile, the treatment of different source of planting materials also showed a significant effect on the mulching treatment on the treatment of upper shoot cuttings and lower shoot cuttings (Table 6).

The dry weight variable of the plant's shoots also showed a significant interaction between mulching treatment and several source of planting material treatment. The high plant's shoot dry weight value was found in the interaction between silver-black or rice straw mulch and upper shoot cuttings. Plant's shoot dry weight is the result of carbohydrate accumulation in plant tissue as a product of photosynthesis. The total dry weight value indicates the plant's ability to store photosynthesis results into its tissue (Soplanit *et al*., 2021). Upper shoot cuttings are young organs that have apical meristem tissue that can stimulate branch length growth and leaf formation while silver-black plastic mulch acts as a reflector that reflects sunlight so that it can be captured by the plant shoot which can increase photosynthetic activity. In addition, the use of plastic mulch is also able to maintain the availability of water in the soil by minimizing evaporation so that it can provide water for plants to carry out photosynthesis optimally (Indawan *et al*.. 2020). Rice straw mulch in the other hand, has a similar function to be able to prevent weed growth and minimize competition for nutrients and water. According to Monica *et al*. (2020), rice straw mulch can also minimize evapotranspiration by lowering soil temperature, thereby reducing water loss on the soil surface.

B. Yield Variables

Weight of Tuber

The results from the analysis of variance showed a significant interaction ($F_{count}>F_{table0.05}$) between the use of different mulch and source of planting materials to the on the weight of sweet potato tubers. There was a significant effect of mulch treatments on the source of planting material treatments, namely in the treatment without mulch and rice straw mulch. Meanwhile, the treatments of planting material sources also showed a significant effect on mulch treatments in all treatments starting from upper shoot cuttings, middle shoot cuttings and lower shoot cuttings (Table 7).

Table 7. Weight of Sweet Potatoes Tuber Affected by Several Type of Mulches and Source of Planting Materials

	Dry Weight of Sweet Potatoes Tuber (g plant^{-1})		
Type of Mulches	Planting Material Sources		
	Upper Shoot Cuttings	Middle Shoot Cuttings	Lower Shoot Cuttings
Without Mulch	596.61 b	406.32 a	398.61 a
	AB	A	A
Silver-Black Plastic Mulch	656.95 a	648.87 a	644.54 a
	B	B	B
Rice Straw Mulch	521.29 b	501.45 ab	404.79 a
	A	A	A
Tukey Test 5%		112.05	
CV (%)		10.10	

Annotations: Numbers accompanied by the same lower case letters in the same row or the same upper case letters in the same column show no significant difference based on the Tukey test at the 5% level. CV=Coefficient of Variance. DAP = Day After Planting.

The results of tuber weight (Table 7) show that there is a significant interaction between mulching treatments and different source of planting materials. The highest value of plant's tuber weight was found in the interaction between silver-black plastic mulch treatment and any kinds of shoot cuttings. The silver-black plastic mulch treatment shows a value that is not significantly different in all cutting source treatments, indicating that the use of silver-black plastic mulch is suitable for application together with all different sources of planting material treatments. Based on the opinion of Soplanit *et al*. (2021), that in addition to its function as a sunlight reflector to increase the photosynthesis process, the black color of silver-black mulch also acts as an inhibitor of weed growth and limits the movement of weeds to sprout in the field. Treatment without mulching with upper shoot cuttings has an effect that is not significantly different from silver-black plastic mulch because treatment without mulch can also provide enough sunlight exposure, creating an optimal environment for the growth of sweet potato.

The treatment of planting material on the tuber weight variable shows that upper shoot cuttings produce the highest tuber weight value in all mulch treatments compared to middle shoot cuttings and lower shoot cuttings. This is in accordance with the results of Netsai *et al*. (2019) research where upper shoot cuttings were able to produce tuber with the weight of 29.53 tons ha^{-1}. Theoretically it is due to the ability of upper shoot cuttings to produce new and active cells that support the roots in providing auxin hormone supply from the plant's growing point. The early root formation encourages, will increases tuber growth and weight. Silver-black plastic mulch were able to suppress weed growth so that there is no competition for nutrients and also could act as a reflector. On the other hand, upper shoot cuttings play a role in supplying growth hormone (auxin) from the plant's growing point to stimulate root growth and accelerates tuber filling rapidly so that tuber weight can increase.

Number of Tuber

The results of the analysis of variance showed that there was no significant interaction ($F_{count}<F_{table0.05}$) between the use of different mulch and source of planting materials. The treatment of planting materials showed a significant effect on the number of tubers. While the mulch treatments did not show any significant effect on the number of tubers (Table 8).

Table 8. Number of Sweet Potatoes Tuber Affected by Several Type of Mulches and Source of Planting Materials

Treatments	Number of sweet potatoes tuber (unit $plant^{-1}$)
Type of Mulches:	
Without Mulching	3.54
Silver-Black Plastic Mulch	3.89
Rice Straw Mulch	3.72
Tukey Test 5%	ns
Source of Planting Materials:	
Upper Shoot Cuttings	4.15 b
Middle Shoot Cuttings	3.52 a
Lower Shoot Cuttings	3.48 a
Tukey Test 5%	0.59
CV (%)	13.26

Annotations: Numbers followed by the same letter in the same column showed no significant difference based on the Tukey Test at the 5% level. CV=Coefficient of Variance. ns = not significant. DAP = Day After Planting.

The observation variable of the number of tubers showed a significant effect on the treatment of different sources of planting material, but did not show a significant effect on the treatment of different types of mulch. The highest average value of the number of tubers in the treatment of different sources of planting material was in the treatment of upper shoot cuttings. The factor of the formation of the number of tubers is highly dominated by genetic influences compared to environmental factors (Armaini, 2017). Good physical soil conditions could support plant growth optimally, starting from the vegetative to generative phases including the formation of adventitious roots and branch growth affecting the number of sweet potato tubers (Etica and Husaini, 2019). The number of tubers produced in the upper shoot cuttings is greater than in the middle shoot cuttings and lower shoot cuttings because the amount of carbohydrates in the upper shoot tissue tends to be greater than the amount of lignin. In the stem cuttings, some of the pores contain lignin which can inhibit root growth. From that reasoning, it is thought to cause fewer tuber formation in the stem (middle to lower shoot) cuttings compared to the upper shoot cuttings (Mardi *et al*., 2016).

Diameter of Tuber

The results of the analysis of variance showed that there was no significant interaction ($F_{count}<F_{table0.05}$) between the use of different mulch and source of planting materials. The treatment of different planting material sources showed a significant effect on tuber diameter. While type of mulch treatment did not show any significant effect on tuber diameter (Table 9).

Table 9. Diameter of Sweet Potatoes Tuber Affected by Several Type of Mulches and Source of Planting Materials

Treatments	Diameter of sweet potatoes tuber (cm)
Type of Mulches:	
Without Mulching	5.76
Silver-Black Plastic Mulch	6.41
Rice Straw Mulch	6.03
Tukey Test 5%	ns
Source of Planting Materials:	
Upper Shoot Cuttings	6.60 b
Middle Shoot Cuttings	5.79 a
Lower Shoot Cuttings	5.81 a
Tukey Test 5%	0.74
CV (%)	10.15

Annotations: Numbers followed by the same letter in the same column showed no significant difference based on the Tukey Test at the 5% level. CV=Coefficient of Variance. ns = not significant. DAP = Day After Planting.

The diameter of sweet potatoes tuber variable observation also showed something similar to the value of number of tubers where the planting material sources treatment had a significant effect on the result. The highest average tuber diameter value was found in the upper shoot cuttings treatment with a value of 6.60 cm. The shoot cuttings likely lengthen the sweet potatoes adventitious roots first before filling the tubers (Nedunchezhiyan *et al.*, 2012). The size of the adventitious roots achieved determines the size of the tubers produced by the plants. Tuber filling begins with the accumulation of carbohydrates at the bottom of the root and continues to the top. This is supported by the opinion of Netsai *et al.* (2019), that the amount of carbohydrates contained in the upper shoot cuttings tends to be greater than lignin produced, where these carbohydrates are stored at the bottom of the root and continue to fill the top of the root. Therefore, the shoot part that contains more carbohydrates than the other, it will be the main substrate for filling tubers which is carbohydrates. It can be said that cuttings in the shoot can produce larger tuber sizes in terms of carbohydrate accumulation in the shoot and also photosynthate products from photosynthesis activity.

Table 10. Yield of Sweet Potatoes Tuber per Hectare Affected by Several Type of Mulches and Source of Planting Materials

Type of Mulches	Tuber Yield of Sweet Potatoes (ton ha^{-1})		
	Planting Material Sources		
	Upper Shoot Cuttings	Middle Shoot Cuttings	Lower Shoot Cuttings
Without Mulch	25.79 b AB	17.56 a A	17.23 a A
Silver-Black Plastic Mulch	28.40 a B	28.05 a B	27.86 a B
Rice Straw Mulch	22.53 b A	21.68 ab A	17.50 a A
Tukey Test 5%	4.84		
CV (%)	10.10		

Annotations: Numbers accompanied by the same lower case letters in the same row or the same upper case letters in the same column show no significant difference based on the Tukey test at the 5% level. CV=Coefficient of Variance. DAP = Day After Planting.

Tuber Yield per Hectare

The results of the analysis of variance showed a significant interaction (F_{count}>$F_{table0.05}$) between the use of different mulch and source of planting materials to the on the weight of sweet potato tubers on the yield per hectare. There was a significant effect of mulching treatment on planting material source treatment especially on the treatment without mulch and rice straw mulch. In addition, the treatment of several planting material source also showed a significant effect on all mulching treatments, on upper shoot cuttings, middle shoot cuttings, and lower shoot cuttings (Table 10).

Based on Table 10, the yield per hectare variable observation has a similar trend with tuber weight result. The highest yield value is found in the interaction between the silver-black plastic mulch with any kinds of shoot cuttings. The yield is the ability or carrying capacity of agricultural land in the yield of certain crops, in this case tubers (carbohydrate storage) (Nurmala *et al*., 2012). This is in accordance with the opinion of Kharolina *et al*. (2023) where the yield is proportional to the weight of the tubers produced by plants, so that if the weight of the tubers produced is high, it will also produce a high yield. The value of tuber weight and yield value is greatly influenced by the initial growth factor of plant, especially in the vegetative phase. Therefore, to get a high yield, it must start from good plant maintenance during the initial vegetative period. Whereas if the plant has entered the generative phase, the vegetative process that takes place will be reduced (Azmi *et al*., 2011).

Root Shoot Ratio (RSR)

The results of the analysis of variance showed that there was a significant interaction (F_{count}>$Ft_{able0.05}$) between the use of different mulch and source of planting materials. Mulch treatments showed a significant effect on the RSR value. Likewise, the treatment of planting materials had a significant effect on the RSR value as well (Table 11).

Table 11. Root Shoot Ratio of Sweet Potatoes Affected by Several Type of Mulches and Source of Planting Materials

Type of Mulches	Root Shoot Ratio		
	Planting Material Sources		
	Upper Shoot Cuttings	Middle Shoot Cuttings	Lower Shoot Cuttings
Without Mulch	0.70 b B	0.43 a A	0.39 a A
Silver-Black Plastic Mulch	0.50 a A	0.59 a A	0.52 a A
Rice Straw Mulch	0.45 a A	0.47 a A	0.41 a A
Tukey Test 5%	0.18		
CV (%)	17.70		

Annotations: Numbers accompanied by the same lower case letters in the same row or the same upper case letters in the same column show no significant difference based on the Tukey test at the 5% level. CV=Coefficient of Variance. DAP = Day After Planting.

The RSR observation variable shows the interaction between 2 factors. Root Shoot Ratio (RSR) is the ratio between the fresh weight of the lower part of the plant (roots and tubers) and the fresh weight of the upper part of the plant (shoots) (Anjani *et al*., 2021). The root shoot ratio value is used to determine the allocation of translocated photosynthate to the shoot and tubers. In addition (Mubarok *et al*., 2024). RSR is generally observed at certain intervals to determine the growth phase of a plant starting from the beginning of the initial vegetative growth. The beginning of the formation of storage roots, tuber filling, until the maximum size of tuber. According to Alynad *et al*. (2023) the RSR value can indicate the allocation of plant photosynthate at a certain time such as when facing a lack of elements or sunlight (stress condition). The growth of the plant when facing a non optimum planting environment will be disturb and the photosynthate products will be allocated for survival needs.

C. Microclimate Observations

Minimum and Maximum Soil Temperature

The results from the analysis of variance showed that there was no significant interaction (F_{count}<$F_{table0.05}$)

between the use of different mulch and source of planting materials. Mulching treatment showed a significant effect on the minimum and maximum soil temperatures. While the treatment of several sources of planting materials did not show any significant effect on the minimum soil temperature (Table 12 and 13).

Table 12. Minimum Soil Temperature Affected by Several Type of Mulches and Source of Planting Materials

Treatment	Minimum Soil Temperature (ºC) in the age observation of (DAP)			
	21	42	63	84
Type of Mulches:				
Without Mulching	25.79 ab	25.30 a	24.14 a	24.24
Silver-Black Plastic Mulch	26.47 b	26.02 b	24.84 b	24.17
Rice Straw Mulch	25.21 a	24.77 a	23.88 a	23.83
Tukey Test 5%	0.99	1.03	0.82	ns
Source of Planting Materials:				
Upper Shoot Cuttings	25.93	25.21	24.23	23.87
Middle Shoot Cuttings	25.83	25.56	24.18	24.16
Lower Shoot Cuttings	25.71	25.32	24.46	24.21
Tukey Test 5%	ns	ns	ns	ns
CV (%)	3.19	3.37	2.80	2.19

Annotations: Numbers followed by the same letter in the same column showed no significant difference based on the Tukey Test at the 5% level. CV=Coefficient of Variance. ns = not significant. DAP = Day After Planting.

Table 13. Maximum Soil Temperature Affected by Several Type of Mulches and Source of Planting Materials

Treatment	Minimum Soil Temperature (°C) in the age observation of (DAP)			
	21	42	63	84
Type of Mulches:				
Without Mulching	32.55 ab	32.23 a	30.63 a	29.48
Silver-Black Plastic Mulch	33.45 b	32.87 b	31.77 b	29.07
Rice Straw Mulch	32.14 a	31.33 a	30.53 a	28.68
Tukey Test 5%	1.22	1.28	1.12	ns
Source of Planting Materials:				
Upper Shoot Cuttings	32.74	31.73	30.86	28.92
Middle Shoot Cuttings	32.47	32.32	31.11	29.29
Lower Shoot Cuttings	32.93	32.38	30.97	29.01
Tukey Test 5%	ns	ns	ns	ns
CV (%)	3.10	3.29	3.00	3.15

Annotations: Numbers followed by the same letter in the same column showed no significant difference based on the Tukey Test at the 5% level. CV=Coefficient of Variance. ns = not significant. DAP = Day After Planting.

Based from the observation (Table 12 and 13), it can be seen that mulching treatment statistically effecting the minimum and maximum soil temperatures. The highest minimum and maximum temperatures were found in the silver-black plastic mulch treatment. Silver-black plastic mulch has the colors that can transmit heat from the sun to the soil and store it in the soil to stabilize the soil temperature. Sweet potatoes can grow well at relatively high temperatures, because high temperatures will stimulate the formation of adventitious roots and the activity of gibberellins (GA) which play a role in plants growth. The minimum temperature has a very important role because the process of photosynthate translocation from the shoots to the roots is carried out in the nighttime until morning when the air temperature is at its lowest. A high minimum temperature value will be able to increase the stimulation of the photosynthate translocation process due to the high gibberellins (GA) activity (Wijewardana *et al*., 2018).

Sweet potatoes are plants that are sensitive to low temperatures. Based on the opinion of Dumbuya *et* al. (2021), low soil temperatures (<25°C) will inhibit the process of shoots growth in plant. In addition, Gajayanake *et al*. (2014) revealed that there was an increase in percentage of 6-7% plant growth for every 1°C of soil temperature increased. Meanwhile, according to Ramadhani (2010) the optimal soil temperature range for tuber formation is between 25-35°C. In addition, Hayati *et al*. (2016) stated that high temperatures in general can initiate the activity of gibberellin hormone (GA) which is very important for the early growth of sweet potatoes because it plays a role in activating the auxin hormone which can stimulate branch and root elongation. The results of the study by Setyorini and Ariffin (2023) revealed that the regression results showed that if the temperature increased by 1°C, it would increase production by 3 tons ha^{-1} in the lowlands and 2.5 tons ha^{-1} in the highlands.

IV. CONCLUSSION

1. The observation results show that there is a significant interaction between mulch treatment and source of planting materials. Application of silver-black plastic mulch gives the best results compared to no mulch and rice straw mulch treatment. Silver-black plastic mulch gives the same results on all types of planting material sources including upper shoot cuttings (28.40 tons ha^{-1}), middle shoot cuttings (28.05 tons ha^{-1}), and lower shoot cuttings (27.86 tons ha^{-1}). Rice straw mulch treatment gave the best results when applied together with upper shoot cuttings (22.53 tons ha^{-1}) and middle shoot cuttings (21.68 tons ha^{-1}). Treatment without mulching gave the best results when applied together with the use of planting materials in the form of upper shoot cuttings (25.79 tons ha^{-1}).
2. The use of upper shoot cuttings gave the best results with the use of no mulch and silver-black plastic mulch. While the use of middle shoot cuttings and lower shoot cuttings only gives the best results with the use of silver-black plastic mulch.
3. Application of silver-black plastic mulch was able to provide the best value on growth variables, namely leaf area (2248.01 cm^2 plant^{-1}), and microclimate variables, namely minimum soil temperature (26.47°C) and maximum soil temperature (33.45°C). Treatment without mulch was able to provide the best value on growth variables, namely the number of leaves (73.13 unit plant^{-1}).
4. Treatment of upper shoot cuttings was able to provide the best value on yield variables, namely the number of tubers (4.15 tubers plant^{-1}) and tuber diameter (6.60 cm plant^{-1}). Meanwhile, middle shoot cuttings were able to provide the best value on growth variables, namely the number of vines (9.83 unit plant^{-1}).

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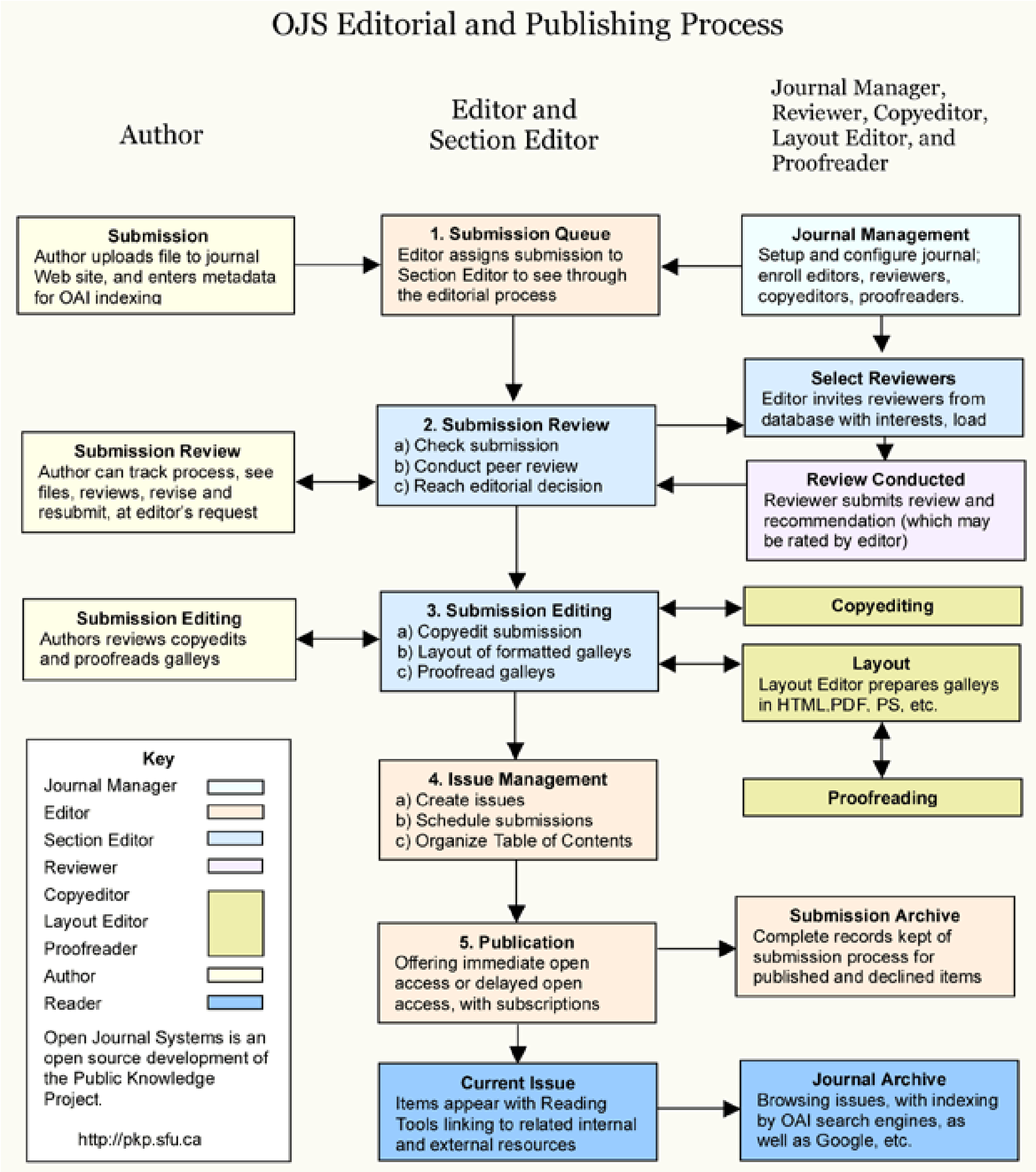

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