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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.

Our commitment at IJEAB is to provide a robust platform for researchers, academicians, and practitioners to share their work and engage with a global audience. By fostering an interdisciplinary approach, we aim to bridge the gaps between different areas of study and promote holistic understanding and solutions to the challenges we face in these domains.

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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Perceived Effects of Climate change on Farmer's Livelihood in North Western Nigeria

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***Abstract*—** *Northwestern Nigeria has been identified as one of the most vulnerable regions to climate change in Nigeria. The study assessed the perceived effects of climate change on the farmer's livelihood. This study employed a combination of qualitative and quantitative analytical methods. Multi-stage sampling technique was used to select four local government areas (LGAs) from Kano State and random selection of 260 farmers from 52 cooperatives within these LGAs. The collected data were analysed appropriately to achieve the objectives of the results. The results indicate that 57.7% were aware of climate change and understood it through patterns of rainfall, temperature, and changes in yield. The majority of the farmers (84.2%) believed that climate change was responsible for an increase in the rate of diseases among the family members in the area and an increase in the distance travelled in search of drinking water. A reasonable percentage of farmers (62.7%) believed that the main road was eroding, making it difficult to get to the market, schools, and health centers. To cope with climate change, farmers used climate-sensitive varieties and crop diversification. In conclusion, climate change has had a real impact on resources like agriculture, water availability, family health, roads, and social networks. Therefore, we recommend providing farmers with technical training on the consequences of climate change and coping strategies.*

Keywords*—** ***Adaptation, Climate change, Effects, Farmers, Livelihood. Nigeria

I. INTRODUCTION

Climate change is one of the most pressing concerns of our day, having far-reaching repercussions for the planet's ecosystems and human progress in all sectors. From the exacerbation of poverty to the breakdown of infrastructure, to the loss of environmental, political, economic, and social security, the impacts of climate change are extensive [1]. The United Nations Framework Convention on Climate Change (UNFCC) characterises climate change as the result of human activity altering the composition of the global atmosphere, along with natural climatic fluctuations observed over comparable time periods. People often refer to it as a long-term shift in weather data, including averages. Climate change has an impact on crucial components of farmers' livelihoods, such as water, food, farmland, and health. It influences the frequency of floods, erosion, droughts, and heat waves, as well as infectious diseases and other health issues. It also has an impact on livelihood opportunities, particularly seasonal ones, as well as those related to natural resources. Climate change has become a reality for rural communities, especially those whose livelihoods are being washed away by floods and whose children's education is being truncated by the economic effects of climate change. According to [2], climate change will have an impact on crop and animal productivity, hydrologic balances, input supply, and other agricultural system components, as well as rural living standards in related developments. It is already affecting the lives and livelihoods of many communities in poor countries, such as Nigeria. As a result, no section of the nation is immune to the consequences of climate change. For example, desertification threatens more than two-thirds of the country. Nigerian states under threat, including Borno, Sokoto, Jigawa, Zamfara, Kebbi, Katsina, Yobe, Kaduna, Kano, Bauchi, Adamawa, and Niger, are vulnerable. [3]. Climate change has a significant influence on Nigeria, notably in agriculture, land use, energy, biodiversity, health, and water resources. Nigeria, like all Sub-Saharan African countries, is extremely sensitive to the effects of climate change [4]. Furthermore, about 67% of Nigeria's land cover is vulnerable to drought and desertification. Its water supplies are in jeopardy, posing a threat to electricity sources (such as the Kanji and Shiroro dams). Furthermore, rain-fed agricultural practices and fishing activities, on which the majority of Nigeria's population relies, are under serious threat, in addition to the high population pressures of 169 million people surviving on the physical environment through various activities within an area of 923,000 square kilometers. [2]. Northern Nigerian food crop farmers provide the majority of crops consumed locally and supplies to other regions of the country, and they are experiencing climate change even though they have not considered its implications, as evidenced by late rainfall and the drying up of streams and small rivers that normally flow year-round in the country [5].

Understanding climate change is one way to overcome this because local people perceive climate as having a powerful spiritual, emotional, and physical dimension. It is assumed that these communities possess innate, adaptive knowledge, enabling them to thrive in high-stress ecological and socioeconomic environments. Thus, knowing and measuring the effect of climate change on livelihoods, as well as the adaptation strategies utilised by them, is crucial.

1.1 Objectives of the Study

The broad objective of this study is to assess the perceived effects of climate change on the livelihood status of the farmers in the study area, The specific objectives were to:

1. Describe the perceptions of farmers about climate change.
2. Describe the impact of climate change on the livelihood of farmers. and
3. Identify the adaptive strategies used by the farmers in the study area to cope with climate change.

1.2 Conceptual Framework of the Study

The framework focuses on the effects climate change on livelihood strategies. Access to a range of livelihood resources, including natural, economic, human, physical, and social capital, enables the pursuit of various livelihood strategies. This includes agricultural intensification or reduction, livelihood diversification (Fig. 1). This study adopted and modified the Sustainable Rural Livelihood (SRL) framework approach to conceptualising the effect of climate change and understanding the diverse set of livelihood strategies pursued and their impacts on long term adaptation to climate change, as well as short-term coping mechanisms and/or responses. People's livelihoods' resilience depends on their ability to adapt to internal and external shocks and stress. The ability to adapt is largely dependent on the livelihood assets (natural, human, social, physical, and financial capital) that one has or can access, as well as how well these are utilized.

The institutions and processes operating from the household to the national level determine an individual's, a household's, or communities access to assets and livelihood options, thereby affecting their vulnerability to climate change impacts. Transforming the structures and processes of organisations that design and implement policies and legislation, deliver services, and perform other functions that affect livelihoods can reduce or worsen the effect of climate change on vulnerable people. These structures and processes form the link between individuals or households at the micro-level and national governments at the macro-level.

Livelihood strategies consist of a variety of activities that people engage in to achieve their livelihood goals. People choose different types of livelihood strategies (natural and/or non-natural resource-based activities) depending on the livelihood assets they have and the structures and processes that impact them under a given vulnerability context (climate change in this case). According to the SRL framework, understanding the diverse and dynamic rural livelihood strategies helps identify appropriate strategies for intervention to introduce new livelihood strategies and improve Numerous studies [6, 7] have identified numerous techniques for adapting to climate change in terms of livelihood. These strategies encompass modifications in crop variety and planting schedules, as well as crop diversification, irrigation development, water harvesting, tree planting, herd splitting, herd mobility, cattle breeding, and migration.

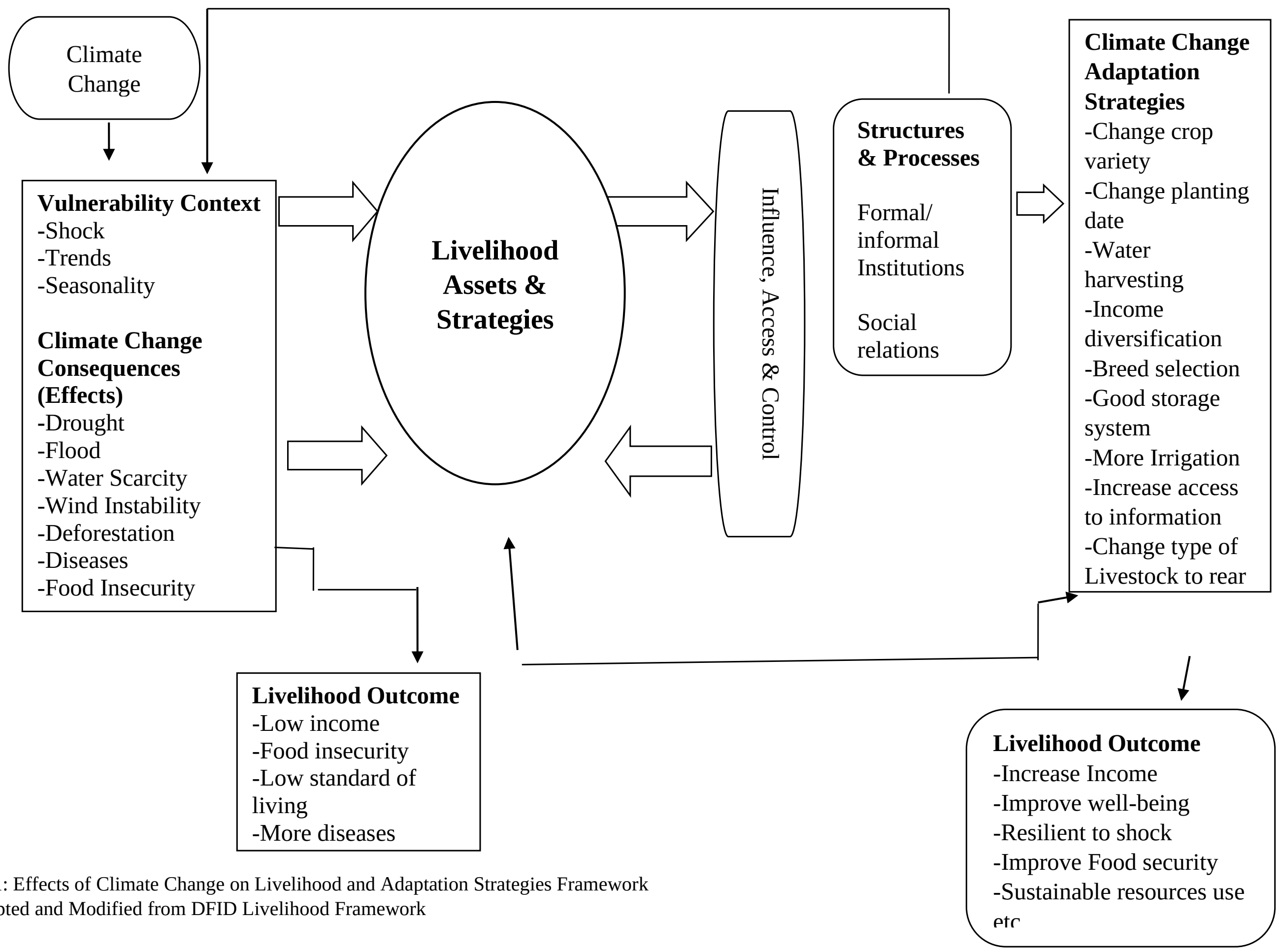

Fig.1: Effects of Climate Change on Livelihood and Adaptation Strategies Framework
Adopted and Modified from DFID Livelihood Framework

II. METHODOLOGY

2.1 Description of the Study Area

Kano State is situated in the Sudan Savannah Agro-Ecological Zone of Nigeria, ranging between latitudes 9^0 30' and 10^0 33' to 12^0 37' North and longitudes 7^0 34' to 9^0 25' East. The state has a total land area of 42,582.8 km^2. The states' borders are Katsina State to the west and northwest, Jigawa State to the east and northeast, Bauchi State to the south, and Kaduna State to the southwest [8]. The state has 44 local government areas with a total land area of 42,582.8 km^2, of which agricultural land is 30,684.8 km^2, and forest and grazing land is 11,898 km^2 [8]. More than half of the state's residents are farmers, cultivating legumes, grains, and vegetables. Livestock rearing and trading are also common in the state [9]. The National Bureau of Statistics (NBS) estimated the population of Kano State to be 15,462,200 in 2022. The climate of the study area is tropical dry, with a mono-modal rainfall distribution averaging 600mm per annum, with most rains occurring between May and September. Air humidity is high during the wet season and extremely low during the dry season. The average temperature is 29°C, with a minimum temperature of 15°C occurring from November to February and a maximum temperature of 39°C occurring from March to May [8]. Windblown sands, derived from acidic crystalline rocks in a basement complex, develop the main soil type. The soils are light, freely graining, and loamy, making them highly adaptable to intensive cultivation. Kano State typically reaches its highest elevation near its southwestern tip. It is about 1,200m above sea level; this decreases as one moves northward to 450m above sea level [9]. The state's natural vegetation is savannah, but this has given way to cultural vegetation.

2.2 Sample Procedure and Sample Size

This study employed a multi-stage sampling technique. There are 44 local government areas (LGAs) in Kano State and two agro-ecological zones: Sudan and the Northern Guinea Savannah. In stage one, three LGAs were randomly selected from the 42 LGAs that are situated in the Sudan Savannah. One LGA was selected from the two LGAs (T/Wada and Doguwa LGAs) that are located in the Northern Guinea Savannah; therefore, Doguwa LGA was selected as it encompasses the entirety of Northern Guinea. In Sudan Savannah, three LGAs were randomly selected from the three agricultural zones in Kano State. Kunchi from the Dabatta zone, Gwarzo from the Rano zone, and

Wudil LGA from the Gaya zone were selected. Giving a total of four LGAs for the study.

The second stage involves collecting a list of registered farmer groups from the KNARDA LGA office and using it for the random sampling procedure. In the four LGAs selected for the study, there were 1077 groups. A random sampling technique was used to select 4% of the total farmer group from each of the selected LGAs, giving a total of 43 cooperatives. Stage three involves the random selection of six farmers from each of the selected groups, making a total of 258 farmers in the study.

Table 1: Summary of the Sample Size of the Farmers' Co-operative Groups

Agro-ecological Zone	**LGA**	**No. of Farmers Co-operative/LGA**	**4% of the association selected**	**No. of Farmers**
Sudan Savannah				
	Kunchi	260	10	60
	Wudil	275	11	66
	Gwarzo	270	11	66
Northern Guinea Savannah				
	Doguwa	280	11	66
Total	**4**	**1077**	**43**	**258**

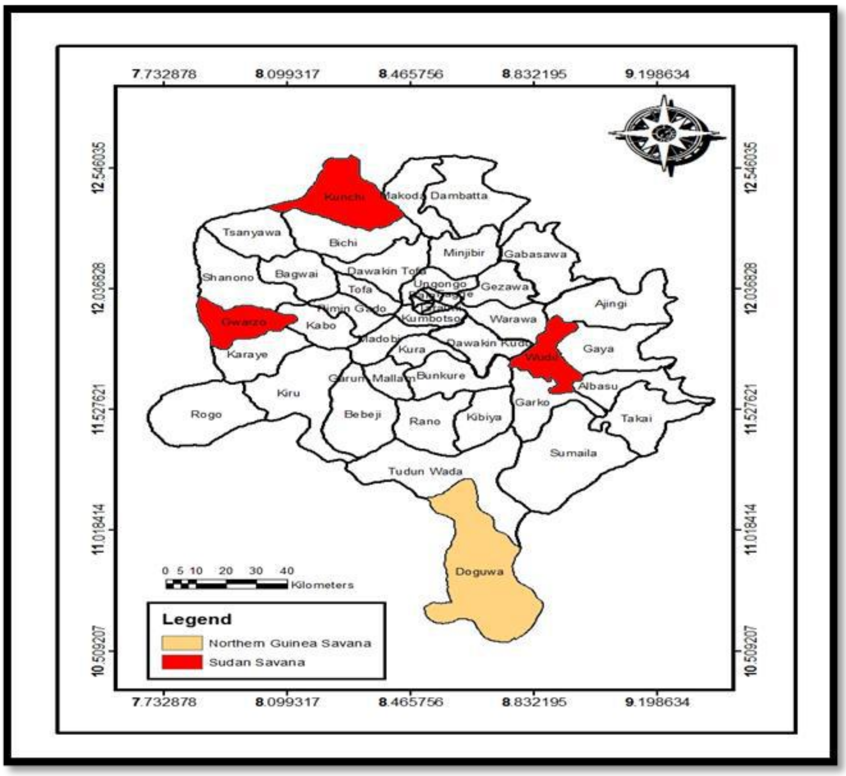

Fig. 2: Map of Kano State showing the Four LGAs Selected from the two agro-ecological zones

2.3 Method of Data Collection and Analysis

The primary data were collected through the use of a structured questionnaire and a semi-structured interview. The collected data were on farmers' socioeconomic characteristics, farmers' perceptions of climate change, climate change adaptive strategies, and the effect of climate change on the farmer's livelihood. The variables considered on the livelihood and effect of climate are affordability of health services, number of meals per day, source of water for domestic use, awareness of climate change, changes in climate over 5 years, effects of climate change on health, water for domestic use, season road, farmland, farm production, and adaptive strategies used by the farmers. To achieve the study's objectives, we analysed the collected data using descriptive statistics such as mean, minimum, maximum, and charts.

III. RESULTS AND DISCUSSION

3.1 Farmers' Perception on Climate Change

Perception is the way in which farmers regard climate change, understand it, and become aware of its effect on their livelihood. This section of the study displays the results of farmers' perceptions of climate change. As shown in Table 2, 58.1% of farmers were aware of climate change. Extension agents also made farmers (41.5%) aware of climate change. This emphasizes the importance of sources of awareness in disseminating knowledge about climate concerns, as well as the significance of extension agents in exposing farmers to climate change issues. [10] (Simi and Chaminda) reported that the farmers in Shendam and Riyom were aware of the consequences of climate change, and extension agents play a vital role in enlightening the farmers about the situation.

Table 2: Farmers Awareness on Climate Change

Variables	Frequency	Percentage
Awareness of Climate Change		
Aware	150	58.1
Not Aware	108	41.9
***Sources of Awareness**		
Friends	84	27.9
Extension agent	125	41.5
Radio	84	27.9
Television	8	2.7
Total	**258**	**100**

*Multiple response

Fig. 2 reveals that 98.80% of farmers experienced a change in climatic conditions during the last five years. Over the past five years, they (94.70%) have witnessed climate change in crop and animal production. This is consistent with the findings of [11] (Mustapha *et al*.), who found that 61.25% of farmers in Borno State, Nigeria, believed that climate change had an impact on agricultural productivity. Figure 2 also shows that 97.70% of farmers experienced a long-term temperature variation. The shift in temperature pattern is a way of understanding climate change. This is in line with [12] (Falaki *et al.*), who found that farmers in north-central Nigeria detected a rise in temperature over time as a result of climate change. The study's findings also revealed that farmers (97.30%) experienced changes in rainfall distribution patterns over the last five years. The farmers were aware of climate change through productivity factors such as rainfall and how it changed over time. And it's in agreement with the findings of [13] (Sofoluwe *et.al.*), who discovered that the majority of farmers in Osun State experienced a shift in rainfall and precipitation patterns.

3.2 Effect of Climate Change on Livelihood

Climate change is emerging as a serious threat to progress in people's livelihoods; it is the greatest challenge facing mankind's existence on earth in this century. This section discusses the effects of climate change on farmers' livelihoods. Table 3 shows that climate change affects family education (71.7%). These changes in climate affect the education of the farmers' families, especially children, because of the nature of the rain variability and floods that led to increases in disease and the destruction of roads. The results also showed that illnesses like malaria, asthma, and diarrhoea impacted 55.4% of the farmers' families, negatively impacting their educational processes. Only 5.4% and 4.7% dropped out of primary and secondary schools, respectively. Climate change does not really have a direct effect on children dropping out of school, which is probably due to parents' understanding of the importance of education and the low participation of primary and secondary youth in seasonal agriculture and other income-generating activities. This aligns with the findings of [14] (William *et al*.), who reported that climate change affected the education of 64.0% of farmers' children. Table 3 further demonstrates the impact of climate change on family feeding, with 76.7% of farmers acknowledging these changes. 44.2% of farmers claimed that a reduction in meal quality affected their family's feeding. Farmers' low income and low yields were also responsible for the reduction in quality meals consumed as a result of climate change. According to Giller *et al*. [15], households that rely solely on one form of farming activity are less food secure. Climate change also affected the health of farmers' families (Table 3), with 84.8% believing that it increased the incidence of diseases such as waterborne malaria, asthma, pneumonia, and diarrhoea. Farmer's family health is a very important aspect of livelihood; without good health, production and business activities can be seriously affected. 32.6% of farmers who changed their business types to increase returns reported a slight impact on their businesses. This suggests that farmers were diversifying their businesses beyond farming to enhance their living standards and offset the effects of climate change.

Table 3: Effect of Climate Change on Farmers' Livelihood (Natural capital)

Variables	Frequency	Percentage
Climate change affects family education		
Agree	185	71.7
Strongly agree	42	16.3
Very strongly agree	31	12.0
Effects on family education		
Low money to pay for school fees	86	33.3
Ill health	143	55.4
Destruction of road to school as a result of erosion	29	11.2
Children drop out from school as a result of climate change		
Primary	14	5.4
Secondary	12	4.7
None	232	89.9
Climate change affects family feeding		
Agree	198	76.7
Strongly agree	47	18.2
Very strongly agree	13	5.1
Effects on family feeding		
Reduction of number of meals	93	36.0
Reduction in quality of the meal	114	44.2
Inadequate cooking fuel	51	19.8
Effects on farmer's health		
Increase in diseases	219	84.8
Malnutrition	23	8.9
Death of some family members	16	6.2
Change of types of business		
Change business	84	32.6
Didn't change business	174	67.4
Total	**258**	**100**

Source: Field Survey, 2022

The farmers in the study area experienced changes (35.3%) in accessing available water for drinking and domestic use. This is due to an increase in the distance to search for water (55.1%), which invariably affects their schedule as presented in Table 4. Climate change has affected the majority of Ghanaian farmers in their search for domestic water, as reported by [14] (William *et al.*). The changes also had an impact on livestock production, with 55.4% of the farmers reporting a rise in livestock diseases. This is due to the high temperatures and drought in the study area, which affect livestock production. This is in line with [16] (Festus *et.al.*), who reported that the farmers in Ghana had lost crops or livestock production during the last few years due to the bad weather conditions. The climate variability significantly impacted farmers' farm production and farmland, resulting in low yields (79.60%). Moreover, erosion and flooding affected (46.50% and 53.50%) their farmland (Fig. 3), leading to the clearing of planted crops and nutrients and an increase in the rate of erosion.

Table 4: Effect of Climate Change on the Farmers' Livelihood (Natural capital)

Variable	Frequency	Percentage
Effects on the availability of water		
Not available	68	26.3
In adequate water	62	24.0
Available	91	35.3
Much available	37	14.3
Effects on distance to access water		
Increase distance	142	55.1
Increase in the depth of well	77	29.8
Ceased of the water from well and borehole	39	15.1
Effects on Livestock production		
Death of livestock	36	14.0
Low livestock reproduction	79	30.6
Increase in diseases	143	55.4
Total	**258**	**100**

Source: Field Survey, 2022

Table 5 exposed the consequences of climate change on seasonal roads, revealing that erosion (62.4%) and bridge breakage (7.8%) significantly impacted these roads. Farmers in remote areas had trouble getting in touch with neighbouring communities and getting their goods to market, which increased their profits from agricultural produce sold in main city markets. Furthermore, their communication network (28.3%) was poor, impacted their interactions with friends and family, and also limited their access to certain critical information. Heavy rainfall caused a decline in power supply (44.6%), leading to the destruction of electricity supply poles and wires. Climate change also affected the farmers' residences, another important resource (Table 5). A reasonable percentage (54.3%) of farmers experienced partial destruction of houses due to excessive rainfall that led to flooding, which damaged their homes and made it impossible for them to live in them. The distance to the market, children's school, and health centre were also part of the consequences of climate change felt by the farmers (Table 6). The majority of farmers (67.8%) agreed that the distance to market to sell their produce had increased. 69.4% of the farmers reported an increase in the distance to children's schools, while 65.1% reported a decrease in the distance to health centers. This is due to the increased distance; particularly in regions where the road has eroded and bridges have broken, the farmers have had to travel a considerable distance to their destination, which results in fatigue.

Table 5: Effect of Climate Change on Livelihood (Physical capital)

Variable	Frequency	Percentage
Effects of on the season road		
Erosion	161	62.4
Flood	77	29.8
Bridge Collapse	20	7.8
Effects on communication network		
Little	73	28.3
Much	54	20.9
Very much	44	17.1
No change	87	33.7
Effects on the electricity supply		
Increase	61	23.6
Decrease	115	44.6
No change	82	31.8
Effects on farmers' houses		
Flooding	28	10.9
Destruction of part of the house	140	54.3
Reduce the quality of the house	90	34.8
Effects on distance to market		
Affects the distance	175	67.8
Did not affects the distance	83	32.2
Effects on distance to children school		
Affects the distance	179	69.4
Did not affects the distance	79	30.6
Effects on distance to health center		
Affects the distance	168	65.1
Did not affects the distance	90	34.9
Total	**258**	**100**

Source: Field Survey, 2022

Table 6: Adaptive Strategies Used to Cope with Climate Change

Variables	Frequency	Percentage (%)	Rank
Use of climate sensitive varieties	200	18.0	1st
Crop diversification	180	16.2	2nd
Integrated farming	153	13.7	3rd
Planting date sensitive	122	11.0	4th
Income diversification	112	10.1	5th
Mixed cropping	103	9.2	6th
Improve irrigation efficiency	99	8.9	7th
Soil moisture conservation	65	5.8	8th
Planting/Replacement of trees	60	5.4	9th
Crop/Livestock insurance	20	1.8	10th

Source: Field Survey, 2022; *Multiple response

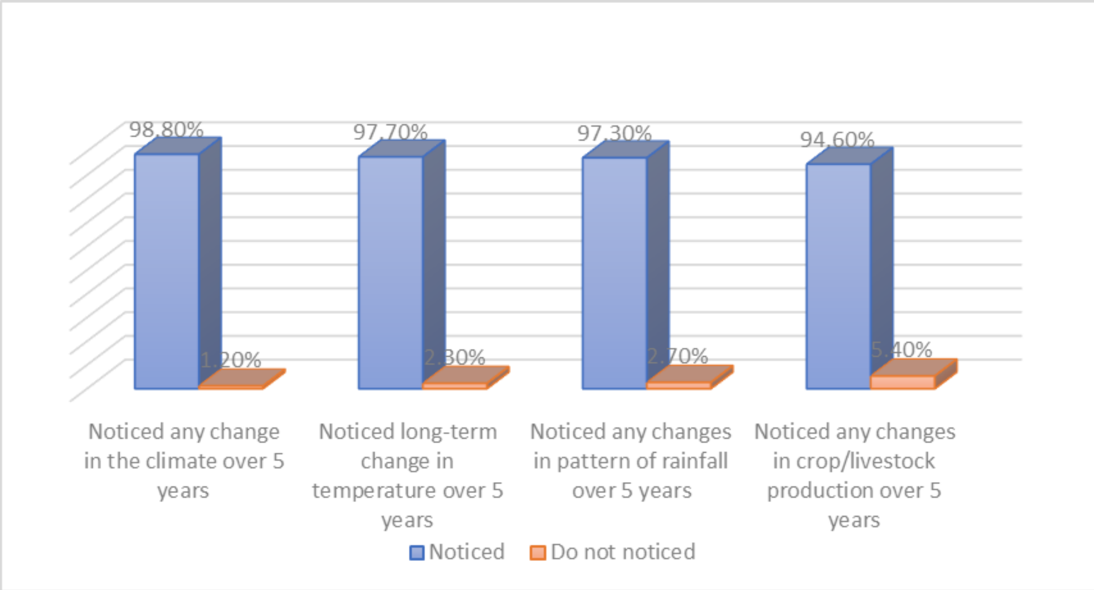

Fig. 3: Farmers' ability to Notice a change in climatic condition

Fig. 4 also presented the implications of climate change on farmers' livelihoods, as determined by the majority (70.0%). This was due to bridge failure and erosion, which made it impossible for farmers to attend meetings and other group gatherings to discuss production activities. Climate change also affected interrelationships with family and relatives (62.30%). Low technical support led to poor visitation (75.30%), which negatively impacted these relationships. Farmers experienced erosion and low yields, which negatively impacted their revenue. Fig. 5 delves into another impact of climate change: it significantly influenced farmers' yearly revenue, accounting for 40.80%. Low yields reduced the farmers' income, impacting their standard of living. Climate change also impacted access to credit, with only 32.7% remaining unaffected. The study area's increased demand for credit may have contributed to the difficulty farmers faced in acquiring financing.

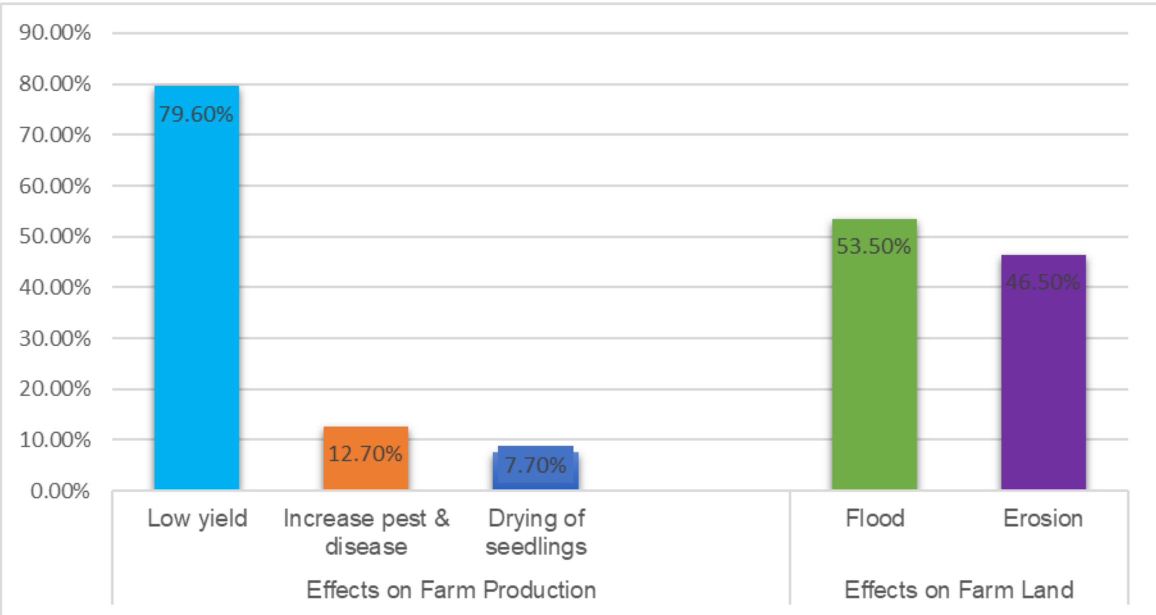

Fig. 4: Effects of climate change on farm production and farmland

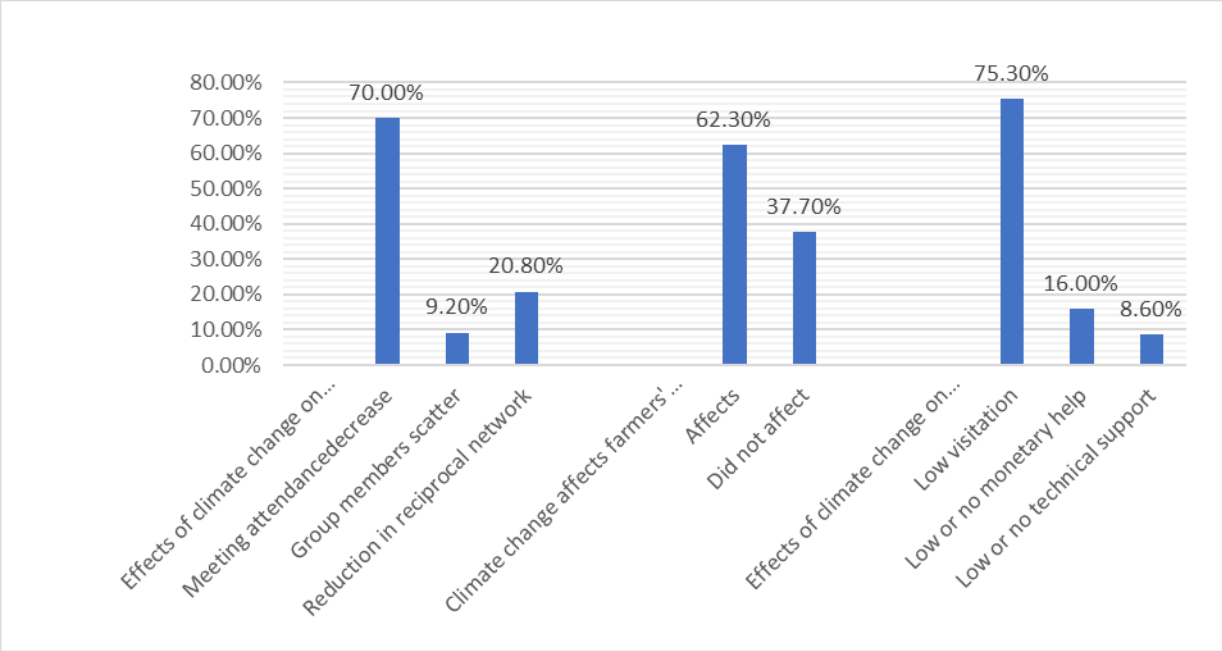

Fig. 5: Effects of Climate Change on Livelihood (Social Capital)

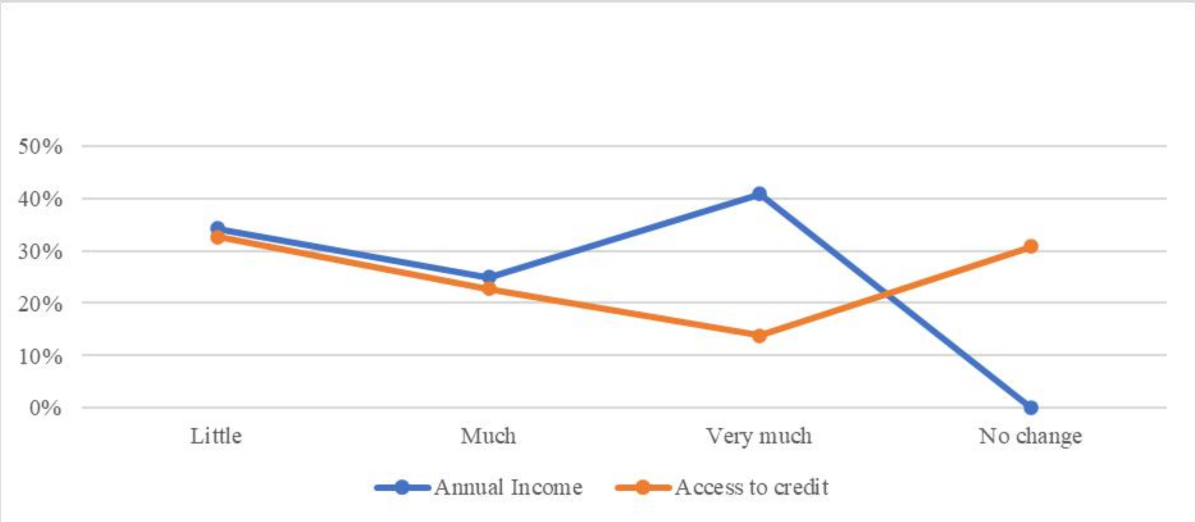

Fig. 6: Effects of climate change on Annual Income and Access to Credits

3.3 Adaptive strategies employed by farmers to cope with climate change

Adaptation is the ability to respond and adjust to the actual or potential impacts of changing climatic conditions in ways that moderate harm or take advantage of any positive opportunities that the climate may afford. The study discusses the results of adaptive strategies employed by farmers to cope with climate change. Table 6 presents the ranking of farmers' adaptation strategies to climate change, ranging from 1st to 10th position. Farmers prioritised using climate-sensitive varieties, ranking them first. Planting sensitive varieties, especially short-duration and drought-resistant crops, could help reduce the risk of vulnerability to climate change. The farmers employed crop diversification as their second adaptive strategy. Diversifying to high-value crops is a short- and long-term strategy to reduce the loss risk associated with monocultures in both non-irrigated and irrigated areas. The farmers identified integrated farming as the third strategy. An integrated farming system involves two or more enterprises that act symbiotically with one another. This is a system that is becoming more popular throughout the country because of its returns. Also, planting date-sensitive (4^{th}) was the next important strategy identified; the farmers became more sensitive to the date and time they needed to cultivate a particular crop at the right time, especially with the short duration of rainfall and the intensity of the rain that most often led to flood issues. Farmers also used income diversification (5th) as an adaptation strategy, as it provides opportunities, particularly in rural areas, to reduce the risk of low income due to climate variability. Furthermore, the sixth, seventh, and eighth-ranked strategies identified by the farmers were mixed cropping, improving irrigation efficiency, and soil moisture conservation, respectively. Farmers in the study area have been planting trees such as mango, lime, lemon, and others as a way of adapting to the effects of climate change. The study ranked crop and livestock insurance as the least important adaptation strategy. This is likely due to a lack of awareness of the role of insurance in the farming business and good management, which leads to underwriting agriculture and offering farm-based insurance products.

IV. CONCLUSION AND RECOMMENDATIONS

Climate change has impacted farmers' livelihood resources, such as farmland, water, family health, children's education, roads, and social networks, with climate-sensitive varieties and crop diversification being the most important adaptation techniques adopted by farmers. Therefore, we recommend that the relevant agencies launch a sensitization campaign to increase awareness about the effects of climate change, and provide farmers with technical training on how to adapt to these changes in agriculture and the wider community.

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Exploring Social Realism in Dickens' *Oliver Twist*: A Study of Victorian London's Underclass

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Abstract— *This paper explores into Charles Dickens' Oliver Twist to examine its portrayal of social realism amidst the backdrop of Victorian London's underclass. Through a multidimensional analysis, it scrutinizes Dickens' depiction of poverty, exploitation, and societal injustices faced by the marginalized segments of society. By exploring the lives of characters like Oliver, Fagin, and Nancy, the paper elucidates the intricate web of economic disparity, moral decay, and systemic oppression prevalent in the era. Drawing on historical context and literary analysis, it highlights Dickens' adeptness in capturing the harsh realities of urban poverty and the resilience of individuals navigating through adversity. Ultimately, this study contributes to a deeper understanding of Dickens' socio-political commentary and the enduring relevance of Oliver Twist in critiquing societal inequities.*

Keywords— ***Class, Exploration, Poverty, Realism, Victorian.***

I. INTRODUCTION

Charles Dickens' *Oliver Twist* stands as a quintessential work of Victorian literature, renowned for its vivid portrayal of the harsh realities faced by the underprivileged in 19th Century London. Through the lens of social realism, Dickens masterfully exposes the injustices and inequities rampant in a society starkly divided along class lines. Set against the backdrop of poverty, crime, and exploitation, the novel follows the orphaned protagonist, Oliver Twist, as he navigates the perilous streets of London in search of identity and belonging. This introduction sets the stage for a comprehensive exploration of Dickens' masterpiece, exploring into its themes of poverty, morality, and the struggle for social justice. By dissecting the intricate layers of *Oliver Twist*, this paper seeks to uncover the enduring relevance of Dickens' critique of societal injustices and his timeless portrayal of human resilience amidst adversity.

II. METHOD OF STUDY

This research paper employs a multidimensional approach to analyze Charles Dickens' *Oliver Twist* within the framework of social realism and Victorian socio-political context. Utilizing a combination of literary analysis and historical research, the study examines primary texts, secondary sources, and critical scholarship to unravel the complexities of Dickens' narrative. Textual analysis involves close reading of key passages to discern themes, character development, and narrative techniques employed by Dickens. Additionally, the study contextualizes the novel within the broader historical and socio-economic milieu of Victorian London, drawing on scholarly works, historical documents, and contemporary accounts. By triangulating these diverse sources of evidence, this research aims to provide a comprehensive understanding of the socio-political commentary of the novel and its significance in shedding light on the realities of life for the underclass in 19th Century England.

III. RESULT OF THE STUDY

Through this in-depth analysis of the novel, this research elucidates the profound exploration of social realism of the novel and its portrayal of the underclass of Victorian London. The study reveals Dickens' adeptness in capturing the grim realities of poverty, exploitation, and societal injustices prevalent in the era. By dissecting the lives of characters like Oliver, Fagin, and Nancy, the research highlights the intricate web of economic disparity, moral decay, and systemic oppression depicted in the novel. Moreover, the study underscores the enduring relevance of *Oliver Twist* in critiquing societal inequities and advocating for social reform. Dickens' poignant portrayal of human resilience amidst adversity resonates across time, offering valuable insights into the complexities of class struggle and the enduring quest for social justice.

IV. DISCUSSION

In exploring social realism in Dickens' *Oliver Twist*, it becomes evident that the novel serves as a powerful lens into the harsh realities of Victorian London's underclass. Through vivid depictions of poverty, exploitation, and societal injustice, Dickens sheds light on the plight of the marginalized during this era. The characters, settings, and plot intricacies intricately reflect the social conditions and moral dilemmas prevalent in Dickens' contemporary society. By immersing readers in the gritty world of workhouses, crime, and destitution, Dickens prompts critical reflection on the systemic issues that perpetuate poverty and inequality. *Oliver Twist* thus stands as a seminal work of social commentary, urging readers to confront uncomfortable truths about the human condition and advocate for social change.

V. CONCLUSION

We can conclude that *Oliver Twist* stands as a quintessential example of Charles Dickens' mastery in portraying social realism and advocating for societal reform. Through its poignant narrative and vivid characters, the novel offers a stark portrayal of Victorian London's underclass, highlighting the injustices and hardships faced by the marginalized. Dickens' critique of the prevailing social structures, coupled with his call for compassion and empathy towards the poor, resonates as strongly today as it did in the 19th century. By immersing readers in the grim realities of poverty, exploitation, and moral corruption, *Oliver Twist* challenges us to confront the systemic issues that perpetuate inequality and marginalization. Ultimately, the enduring relevance of Dickens' work underscores the importance of literature as a tool for understanding, empathy, and advocacy in addressing the complex social challenges of our time.

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Gas Chromatography Tandem Mass Spectrometry for Quantitative Analysis of Pesticides in Sitopaladi Churna: Multi-Residue Method Development

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Abstract— *Pesticide residues are a consistent concern for consumers. A method validation study was conducted to analyze pesticide residues in Sitopaladi Churna using gas chromatography tandem mass spectrometry (GC-MS/MS) in a multiple reaction monitoring (MRM) mode of electron impact (EI) determination. The method employed the QuEChERS (Quick, Easy, Cheap, Effective, Rugged, and Safe) approach in compliance with European SANTE standards. Results fell within the specified criteria outlined in the validation guidelines. Validation parameters were assessed to confirm the method's suitability for the intended analysis. The optimized method was applied to detect residues of 55 pesticides in the herbal formulation 'Sitopaladi Churna,' with maximum residue limits (MRLs) defined in the Ayurvedic Pharmacopoeia of India (API). Notably, the method demonstrated high effectiveness, providing accurate results (70–120.0%) with precision (<20%) at three concentrations (10 µg/kg, 25 µg/kg, and 100 µg/kg). Limits of quantification (LOQs) were 5 µg/kg, and limits of detection (LODs) were 2 µg/kg. The analysis exhibited strong linearity with a regression coefficient exceeding 0.99 for all compounds. Consequently, this method can be employed for the determination of 55 pesticides in Sitopaladi Churna, as well as similar matrices, to analyze pesticide residues.*

Keywords— ***Gas chromatography, Tandem mass spectrometry; Solid-phase extraction; Pesticide residues, Multiple reaction monitoring; Sitopaladi Churna***

I. INTRODUCTION

Ayurveda is a Sanskrit term, made up of the words "ayus" and "veda"meaning life and science; together translating to 'science of life'. A blend of several herbs and spices makes up the powdered mixture known as "churna". Depending on its intended use for medicinal, beauty, or culinary purpose, the recipe varies (Khalsa et al., 2008). Sitopaladi is in powder form and used for various respiratory ailments such as cough, cold, bronchitis, sinusitis, asthma, and chronic fever, loss of appetite, sore throat and tuberculosis. It is taken with adjuvants such as ghee, honey and also as an ingredient of combination therapy with other Ayurvedic medicines. Sitopaladi churna is an inimitable mixture of Sitopala, Tugakheeree, Pippali, Ela and Twak. For the preparation of Sitopaladi churna, 16 parts, 8 parts, 4 parts, 2 parts and 1 part of Sitopala, Tugakheeree, Pippali, Ela and Twak are used, respectively (Sharmila et al., 2021).A research by the World Health Organization (WHO) states that over 80% of the global population uses traditional medicines, the majority of which are derived from plants. Therefore, the safety of these herbs needs to be considered just as much as that of other foods. While efforts are being made to set the fundamental guidelines to ensure their safety and quality, a significant obstacle is the absence of suitable techniques for identifying certain pollutants and residues in herbal formulations. There are reports about pesticides found in herbal formulations all around the world. (Tripathy et al., 2015).To ensure the quality of Sitopaladi Churna as well similar matrix, a large number of pesticides are used during cultivation, drying, and processing; consequently, massive pesticide exposure can lead to pesticide accumulation in the body during consumption, which harms human health and causes various diseases. Due to the fact that the growing demand for medicinal herbs necessitates higher agricultural output and the application of broad and ongoing agricultural procedures, substances, such as insecticides and fertilizers. The presence of several pesticide residues in medicinal herbs could also be the result of cross-contamination from pesticide-treated production locations, storage, or transit. To detect pesticide residues in Sitopaladi churna, gas chromatography–tandem mass spectrometry (GC–MS/MS) with MRM detection mode was utilized. Currently, QuEChERS (Chen et al., 2014; Yadav et al., 2017; Soltani et al., 2012) and solid-phase extraction (SPE) account for the majority of the pretreatment of spices, tea and other matrixes(Huo et al., 2014 & 2016). Although QuEChERS is simple and quick to operate, its clean-up effect is significantly inferior to solid-phase extraction, particularly when the matrix is herbal formulation. Moreover, solid-phase extraction has a very high recovery rate and can reduce instrument maintenance costs. As a result, it became imperative to create a uniform procedure for identifying multiclass pesticides in widely used medicinal herbs. In light of this, a modified QuEChERS based approach was investigated for the purpose of identifying 20 different classes of pesticides in the Sitopaladi Churna, with GC–MS/MS analysis as a follow-up. Until now, no reports or determinations using GC–MS/MS have been made regarding residue detection techniques for the simultaneous detection of 55 pesticides in Sitopaladi Churna.

This work designed and optimized a system for identifying a subset of 55 pesticide residues using GC-MS/MS in conjunction with SPE clean-up. This approach meets the criteria for identifying different pesticide residues in Sitopaladi Churna and provides technical assistance for developing guidelines for recently introduced pesticide residues.

II. EXPERIMENTAL

2.1 Chemicals and Materials

All the pesticide standards were of >98% purity and purchased from Sigma Aldrich, Germany. Chromatography grade solvents (Toluene, acetonitrile, Glacial acetic acid) and analytical grade reagents like anhydrous magnesium sulphate ($MgSO_4$), sodium sulfate and Sodium Chloride, Sodium acetatewere purchased from Merck India Ltd., Mumbai, India. Primary secondary amine (PSA, 40 µm, Bondesil) and C18 sorbent was purchased from Agilent Technologies, the USA andde-ionized waterwas purchased from Thermo Fisher Scientific (Waltham, Massachusetts, US). Sitopaladi was used in this work and was purchased from a regular Ayurvedic dealer in Varanasi, Uttar Pradesh.

2.2 Standard Solutions and Calibration Curves

The stock solutions of the individual pesticide standards were prepared by accurately weighing 10 mg (±0.01 mg) of each analyte in volumetric flasks (certified 'A' class) and dissolving in10mL Toluene. These were stored in dark vials in a refrigerator at -20 °C (±1 C).An intermediate stock standard mixture of 10 mg/L was prepared by mixing the appropriate quantities of the individual stock solutions followed by requisite volume makeup and stored at -20 C (±1 °C). A working standard mixture of 1 mg/L was prepared by diluting the intermediate stock standard solution, from which the calibration standards within the range 1–100 µg/kg were prepared by serial dilution with Acetonitrile/toluene (1:1, v/v)

2.3 Extraction

Extraction was carried out according to a modified version of the QuEChERS method (Singh et al., 2020). To prepare sample extracts for GC-MS/MS analysis, in a polypropylene centrifuge tube weighed 5 grams of the homogenized sample. At this point, the recovery samples were prespiked with the mix pesticide standards in order to measure accuracy and precision. After spiking the standards, 15mL of Acetonitrile (with 1% acetic acid) was added and the mixture was vigorously shaken for a duration of one to two minutes. Emulsification is to be used to separate the various aqueous layers; 6 gm of $MgSO_4$ and 1.5 gm of Sodium acetate, buffering salts, were added, and vigorous shaking was allowed to occur for a duration of one to two minutes. The solution was subjected to centrifugation at 8000 rpm for five minutes.2 ml of supernatant was taken, and 150 mg of$MgSO_4$ and 50 mg of PSA was added. It was followed by vertexing for a short duration and then centrifugation at 10,000 rpm for five minutes. Extreme care was made to ensure that the experimental procedures and tools were accurate and precise; spike samples were prepared at the Limit of Quantification (LOQ) level in accordance with the guidelines. In this study, six replicates were prepared at LOQ (5µg/kg), 25µg/kg and 100µg/kg concentration. The control sample was also extracted without any spiking for the preparation of the matrix-matched calibration curve in a range of 1 to 100µg/kg.

2.4 *GC-MS/MS analysis*

Sample acquisition for the detection and quantification of pesticide residues in the sample has been carried out by using the gas chromatography GC-MS/MS analysis was performed using an Agilent 7890A GC, coupled with a 7693 auto sampler, a 7000 triple quadruple MS, and a computer with Mass Hunter software (version B.05.00412) for data acquisition and processing (Agilent Technologies, Palo Alto, CA, USA). Analytes were separated with DB-5 MS Ultra Inert capillary columns from Agilent (0.25 mm i.d. × 30 m, 0.25 µm film thickness)with the following operating conditions in Table 1 and triple quadruple mass spectrometer in electron impact (EI) ionization mode was operated with a 70 eV ionization voltage. The interface (transfer line to the tandem MS), ion source, and quadruple temperatures were maintained at 230 ◦C and 150 ◦C. Multiple reaction monitoring (MRM) mode was used for target detection and transition of each compounds are given in Table 2.

III. METHOD VALIDATION PARAMETERS

3.1 *Linear Range, Limit of Detection (LOD), and Limit of Quantification (LOQ)*

The performance of the analytical method was assessed as per SANTE validation guidelines. In accordance with the optimized experimental conditions, for the preparation of the matrix-matched calibration curve in a range of 1 to 100 µg/kg were prepared from the dilutions of the 55 pesticide standard solutions with blank Sitopaladi Churna sample extracts to calculate the standard curve. With a three-fold signal-to-noise ratio, the limits of detection (LODs) and limits of quantification (LOQs) of the 55 pesticides were calculated. The results indicated that the correlation coefficients between the concentrations of the 55 pesticide compounds and their peak areas in the range of 1 to 100 µg/kg were all greater than 0.99.The percent residual was in the range of ±20% (Figure1).Calibration curve for Dieldrin and Atrazin observed in matrix-matched linearity are shown in Figure 2. The limits of detection (LODs) and limits of quantification (LOQs) of the 55 pesticides in sample were 2 µg/kg and 5 µg/kg, respectively as shown in Table 3. As indicated in Ayurvedic Pharmacopoeia of India Standard Maximum Residue Limits for Pesticides in Herbal formulation (Ayurvedic Pharmacopoeia of India Part 1- Vol. 1) the LOQs for all 55 pesticides were significantly lower than the maximum residue levels specified, indicating that the method described in this paper meets the actual detection requirements. Finally, satisfactory recoveries (71.5 –114.6%) were achieved at three concentrations (10 µg/kg, 25 µg/kg, and 100 µg/kg).

3.2 *Matrix Effect*

The matrix effect refers to the presence of substances other than the target that appear to inhibit or boost the detection signal of the standard solution of the pure solvent. Sitopaladi Churna contains pigments, minerals, and other activities like tannins, saponins, alkaloids, glycosides, flavonoids and triterpenoids (Ekbote et al., 2019) that reduce the influence of endogenous substances on the precision of test results. The entire methodology has been performed to comply with the identification, confirmation, and performance parameters criteria as per the SANTE validation guidelines. The matrix effect was determined using the slope ratio of the matrix standard curve to the solvent standard curve (Steiner et al., 2020). More than±20 % matrix effect was observed for all 55 pesticide compounds according to the experimental results; therefore, a matrix-matched standard curve was utilized for quantification.

3.3 Spiked Recovery and Precision

Three mixed standard solutions of 10 µg/kg, 25 µg/kg, and 100 µg/kg were added to the blank matrix, and six parallel experiments were performed for each spiked level. The conditions were optimized for the determination. Based on the optimized work flow for these pesticides, Sitopaladi Churna from the market of Varanasi; were utilized to determine the pesticide residues in the same. As shown in Tables 3, the average percent recovery for six replicates has been observed in a range of 76.5 to 114.6 %; 78.2 to 109.8 % and 71.5 to 111.6 % for pre-spiked potato Sitopaladi Churna at a concentration level of 10 µg/kg, 25 µg/kg, and 100 µg/kg respectively (Figure 4). RSD analysis was performed for Sitopaladi Churna. The highest RSD of 10.9 % was observed for Parathion Ethyl, and a minimum of less than 0.5 % was observed for DDE-o, p' (Figure 5). Each molecule minimum of two ions was selected with a signal-to-noise ratio > 3, and both ions were overlapped at the same retention time. The % RSD of six replicates was in the range of 0.6 to 10.2 %:0.9 to 10.9 % and 0.5 to 10.2 % for pre-spiked Sitopaladi Churna sample at a concentration level of 10 µg/kg, 25 µg/kg, and 100 µg/kg respectively. This workflow can effectively determine these 55 pesticide residues and thus, it is evident that the method offers excellent accuracy and precision and can be used to determine these 55 pesticide residues in Sitopaladi samples (SANTE/11312/2021).

3.4 Pesticide Residue Determination in Herbal Churna (Sitopaladi, Trikatu, Lavan Bhaskar Churna)

To evaluate the effectiveness and applicability of the developed method in measuring trace levels of the studied pesticides, the developed method was applied to the analysis of a total of 22 samples available for sale were used for pesticide residue determination. Traces of Chlorpyrifos Ethyl (an organophosphorus pesticide) residues were detected in one samples of Trikatu Churna purchased from Varanasi and in one sample of Lavan Bhaskar Churna obtained from Ghazipur Uttar Pradesh, but the level was below the Limit of Quantification (LOQ). None of the other samples were found to contain any other pesticide residues. The results obtained using the described preparation method for these real samples were accurate and precise. The proposed method was suitable for the analysis of the studied pesticides in herbal formulations as well related matrix (medicinal herb samples).

IV. RESULTS AND DISCUSSION

4.1 Optimization of GC-MS/MS Condition

GC-MS Solution version 4.45 and Microsoft Excel™ based files (MRM Optimization Tool and GC/MS/MS pesticide database version 1.01) were used to optimize the GC and MS parameters of all evaluated pesticides. All substances were examined in full scan mode between 45 and 650 m/z prior to MS-parameter tuning. After that, MS was run in MRM mode. The three strongest transitions and ideal collision energies (CE) for every pesticide were identified using the Agilent MRM Optimization Tool. The operating parameters of the MS, such as dwell periods, CE, MRM transitions, and retention times, are compiled in Table-1. Furthermore, the detector voltage (up to 0.5 kV) was tuned both absolute and in relation to the tuning result modes. The best sensitivity was found for chromatographic peak heights at a detector voltage of 2 kV. Using the optimized approach, mixtures of the 55 pesticide standards were found; the extracted ion chromatograms (EIC) are displayed in Figure 3.

4.2 Selection of the sample extraction method and optimization of clean up procedure

The challenge of determining the residual pesticides in herbal formulations is challenging due to the presence of diverse pigments and secondary metabolites. The widely used Quick, Easy, Cheap, Effective, Rugged and Safe (QuEChERS) strategy was utilized for sample preparation since it is a very versatile approach that provides numerous alternatives for analysis based on the variety of pesticides and matrices being examined. Following a thorough examination of the study's bibliography, we decided to employ acetonitrile due to its efficiency in removing both polar and non-polar pesticides from a variety of matrices, as well as its ability to yield high recoveries for a broad range of pesticide polarity (Anastassiades et al. 2003; Masˇtovska´ and Lehotay, 2004). Prior researchers have already thoroughly examined the physicochemical and practical benefits of acetonitrile over other solvents, such as ethyl acetate, in pesticide residue analyses (Anastassiades et al. 2003; Masˇtovska´ and Lehotay, 2004; Lehotay et al. 2010; Ramasubramanian et al. 2014; Tripathy et al., 2017). In order to allow the extraction solvent to more fully penetrate the dry plant tissues and guarantee full transfer of the analytes from naturally contaminated samples, we also reduced the sample amount (to 5 g) and added 15 mL of acetonitrile (with 1% acetic acid) prior to the extraction process. Thus, a modified QuEChERS-based methodology using acetonitrile as an extraction solvent was employed for additional research.Because of C18's strong affinity for fats and lipids, the QuEChERS technique inherently involves a dispersive-solid phase extraction (dispersive-SPE) step. In this step, sorbents such as primary secondary amine (PSA) are primarily used to remove organic acids and other polar matrix compounds. It was decided not to utilize graphitized carbon black (GCB) because it adsorbs pesticides with planar functionality, which causes many pesticides that are vulnerable to this adsorption to have inadequate recoveries (Tripathy et al., 2017). Consequently, PSA and C18 were chosen to clean up samples at all three spiked level 10 µg/kg, 25µg/kg, and 100 µg/kg. For every spiking level, six separate trials were carried out in parallel with respect to the blank matrix. For the determination, the conditions were optimized. To ascertain the pesticide residues in samples, the optimal methodology for these 55 pesticides was employed. This procedure can successfully identify these 55 pesticide residues, as Tables 3 demonstrate. It is clear from this that the approach can be used to determine these 55 pesticide residues in Sitopaladi Churna as well as related matrixes, and that it gives great accuracy and precision.

Table 1: GC-MS/MS analysis of phytochemical compounds in the hydro-alcoholic extract of Pistacia integerrima (PI).

S. No	Compound name	Molecular formula	RT	CAS number	Peak area
1	cis-5,8,11,14,17-Eicosapentaenoic acid	$C_{20}H_{30}O_2$	5.138	10417-94-4	0.33
2	Ethanone, 1-(1H-pyrrol-2-yl)-	C_6H_7NO	5.531	1072-83-9	0.54
3	Cholestan-22(26)-epoxy-3,16-dione	$C_{27}H_{42}O_3$	5.754	997857-38-1	0.27
4	Benzene, 1-methyl-3-(1-methylethenyl)-	$C_{10}H_{12}$	6.010	1124-20-5	0.07
5	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-	$C_6H_8O_4$	7.091	28564-83-2	0.65
6	Octanoic acid	$C_8H_{16}O_2$	7.488	124-07-2	5.60
7	Bicyclo[3.1.1]heptan-2-ol, 2,6,6-trimethyl-	$C_{10}H_{18}O$	7.529	473-54-1	0.71
8	3-Cyclohexen-1-ol, 4-methyl-1-(1-methylethyl)-	$C_{10}H_{18}O$	7.561	562-74-3	0.77
9	Octanoic acid, ethyl ester	$C_{10}H_{20}O_2$	7.620	106-32-1	2.86
10	1-Cyclopentene-1-methanol, 2-methyl-5-(1-	$C_{10}H_{18}O$	7.752	80113-82-2	0.30
11	(1S)-1,3,3-trimethylnorbornan-2-ol	$C_{10}H_{18}O$	7.830	470-08-6	1.99
12	Bicyclo[3.1.1]hept-3-en-2-one, 4,6,6-trimethyl-,	$C_{10}H_{14}O$	7.958	1196-01-6	2.74
13	(2E)-3-(2-Hydroxyphenyl)-2-propenoic acid	$C_9H_8O_3$	8.149	614-60-8	0.78
14	Dihydrojasmone	$C_{11}H_{18}O$	8.678	1128-08-1	0.04
15	Butanedioic acid, hydroxy-, diethyl ester, (.+/-.)-	$C_8H_{14}O_5$	8.870	626-11-9	0.56
16	1,7,7-Trimethylbicyclo[2.2.1]hept-5-en-2-one	$C_{10}H_{14}O$	9.171	22516-10-5	0.33
17	2,4-Cycloheptadien-1-one, 2,6,6-trimethyl-	$C_{10}H_{14}O$	9.509	503-93-5	0.09
18	3,7,7-Trimethylbicyclo[4.1.0]hept-3-ene-2,5-dione	$C_{10}H_{12}O_2$	9.632	6617-34-1	0.19
19	3-Isopropyl-1-methyl-4-methylamino-pyrrole-2,5-	$C_9H_{14}N_2O_2$	9.805	997151-53-1	0.11
20	Methane, [(1-ethynylcyclohexyl)oxy]methoxy-	$C_{10}H_{15}DO_2$	10.047	5609-21-2	0.43
21	2,5-Octadecadiynoic acid, methyl ester	$C_{19}H_{30}O_2$	10.229	57156-91-9	0.45
22	Guanidine, N,N'-diphenyl-	$C_{13}H_{13}N_3$	10.453	102-06-7	0.42
23	Guanidine, N,N'-diphenyl-	$C_6H_6O_3$	10.617	87-66-1	0.40
24	Bisphenol C	$C_{17}H_{20}O_2$	10.850	79-97-0	0.85
25	Benzoic acid, 4-(1-methylethyl)-	$C_{10}H_{12}O_2$	11.096	536-66-3	0.16
26	Methanone, (4-bromo-5-methyl-2-nitro-3-	$C_{12}H_8BrNO_3S_2$	11.324	997735-67-2	0.35
27	cis-Pinonsaeure	$C_{10}H_{16}O_3$	11.393	473-72-3	0.22
28	2-Piperidinemethanol, .alpha.,.alpha.-diphenyl-	$C_{18}H_{21}NO$	11.479	467-60-7	0.26
29	Octadecanal, 2-bromo-	$C_{18}H_{35}BrO$	11.575	56599-95-2	0.05
30	1H-Cyclopropa[a]naphthalene, 1a,2,6,7,7a,7b-(1a.alpha.,7.alpha.,7a.alpha.,7b.alpha.)]-	$C_{15}H_{22}$	11.630	34143-96-9	0.30
31	4,7,10,13,16,19-Docosahexaenoic acid, methyl	$C_{23}H_{34}O_2$	11.671	2566-90-7	0.07
32	cis-2-phenyl-1, 3-dioxolane-4-methyl octadec-9, 12,	$C_{28}H_{40}O_4$	11.730	997894-27-7	0.05
33	4-Isopropyl-1,6-dimethyl-1,2,3,4-	$C_{15}H_{22}$	11.762	483-77-2	0.03
34	1,1,7-Trimethyl-4-methylene-1a,2,3,4,6,7,7a,7b-	$C_{15}H_{22}$	11.904	112362-74-0	0.05
35	Heneicosapentaenoic Acid methyl ester	$C_{22}H_{34}O_2$	12.182	65919-53-1	0.04

36	2,4-Di-tert-butylphenol	$C_{14}H_{22}O$	12.250	96-76-4	0.41
37	Bicyclo[4.1.0]heptan-2-ol, 1.beta.-(3-methyl-1,3-acetoxy-	$C_{16}H_{24}O_3$	12.342	997432-87-7	0.17
38	Benzoic acid, 3-hydroxy-, 2-methylpropyl ester	$C_{11}H_{14}O_3$	12.506	997187-49-7	0.04
39	Quinine	$C_{20}H_{24}N_2O_2$	12.574	130-95-0	0.10
40	Dodecanoic acid	$C_{12}H_{24}O_2$	12.926	143-07-7	0.12
41	fv	$C_{17}H_{28}O_2$	12.994	2306-78-7	0.65
42	4,4-Dimethyl-3-oxoandrost-5-en-17-yl acetate	$C_{23}H_{31}D_3O_3$	13.072	997740-43-1	0.16
43	Dodecanoic acid, ethyl ester	$C_{14}H_{28}O_2$	13.341	106-33-2	0.07
44	1H-Cycloprop[e]azulen-7-ol, decahydro-1,1,7-(1a.alpha.,4a.alpha.,7.beta.,7a.beta.,7b.alpha.)]-	$C_{15}H_{24}O$	13.386	6750-60-3	0.56
45	(-)-Globulol	$C_{15}H_{26}O$	13.514	489-41-8	1.62
46	1H-Cycloprop[e]azulen-4-ol, decahydro-1,1,4,7-(1a.alpha.,4.beta.,4a.beta.,7.alpha.,7a.beta.,7b.alp	$C_{15}H_{26}O$	13.642	552-02-3	0.29
47	2-Naphthalenemethanol, 2,3,4,4a,5,6,7,8-(2.alpha.,4a.beta.,8.beta.)]-	$C_{15}H_{26}O$	13.765	63891-61-2	0.32
48	1,4-Diiodooctahydropentalene	$C_{15}H_{24}O$	13.874	74842-43-6	0.10
49	2-Naphthalenemethanol, decahydro-(2.alpha.,4a.alpha.,8a.beta.)]-	$C_{15}H_{26}O$	13.979	473-15-4	0.10
50	2-((2R,4aR,8aS)-4a-Methyl-8-	$C_{15}H_{24}O$	14.086	515-20-8	0.33
51	Sulfuric acid, 5,8,11-heptadecatrienyl methyl ester	$C_{18}H_{32}O_3S$	14.198	56554-67-7	0.46
52	1-S-[(1E)-2-(1H-Indol-3-yl)-N-	$C_{16}H_{19}N_2O_9S_2$	14.358	4356-52-9	0.34
53	2-Naphthalenemethanol, decahydro-[2R-(2.alpha.,4a.alpha.,8a.beta.)]-	$C_{15}H_{26}O$	14.404	51317-08-9	0.09
54	Pentadecanoic acid, 14-methyl-, methyl ester	$C_{17}H_{34}O_2$	15.042	5129-60-2	0.10
55	cis-2-phenyl-1, 3-dioxolane-4-methyl octadec-9, 12,	$C_{28}H_{40}O_4$	15.125	997894-27-7	0.04
56	Tetradecanoic acid	$C_{14}H_{28}O_2$	15.677	544-63-8	0.07
57	Lactaropallidin	$C_{15}H_{24}O_3$	15.909	997389-81-8	5.16
58	Tetradecanoic acid, ethyl ester	$C_{16}H_{32}O_2$	16.133	124-06-1	0.13
59	Nonacosane	$C_{29}H_{6}0$	16.247	630-03-5	4.88
60	1,11,11-Trimethyl-1,2,3,4-tetrahydro-1,4-	$C_{16}H_{18}N_2$	16.685	997341-19-0	0.10
61	Hexadecanoic acid, 2,3-dihydroxypropyl ester	$C_{19}H_{38}O_4$	16.749	542-44-9	0.11
62	Pentadecanoic acid	$C_{15}H_{30}O_2$	17.301	1002-84-2	0.28
63	Ethyl gallate	$C_9H_{10}O_5$	18.035	831-61-8	0.24
64	7-Hydroxy-4-(3,4,5-trimethoxyphenyl)chromen-2-	$C_{18}H_{16}O_6$	18.460	858002-39-8	1.04
65	9-Hexadecenoic acid	$C_{16}H_{30}O_2$	19.167	2091-29-4	0.72
66	n-Hexadecanoic acid	$C_{16}H_{32}O_2$	20.011	57-10-3	22.18
67	Hexadecanoic acid, ethyl ester	$C_{18}H_{36}O_2$	20.617	628-97-7	2.86
68	Hexadecanoic acid, 2,3-dihydroxypropyl ester	$C_{19}H_{38}O_4$	21.256	542-44-9	0.15
69	Ethyl iso-allocholate	$C_{26}H_{44}O_5$	21.703	997888-97-8	0.06

70	12,24-Divinyl-1,13-dioxacyclotetracosane-2,14-	$C_{26}H_{44}O_4$	21.872	997866-77-6	0.07
71	Eicosanoic acid	$C_{20}H_{40}O_2$	22.287	506-30-9	0.47
72	Butyl 4,7,10,13,16,19-docosahexaenoate	$C_{26}H_{40}O_2$	22.944	997801-29-9	0.30
73	cis-Vaccenic acid	$C_{18}H_{34}O_2$	23.501	506-17-2	5.22
74	Ethyl (9Z,12Z)-9,12-octadecadienoate	$C_{20}H_{36}O_2$	23.756	544-35-4	1.52
75	Octadecanoic acid	$C_{18}H_{36}O_2$	23.838	57-11-4	5.30
76	Hexadecanoic acid, ethyl ester	$C_{18}H_{36}O_2$	23.962	628-97-7	10.50
77	8-Chloro-1-octanol, benzyldimethylsilyl ether	$C_{17}H_{29}ClOSi$	24.007	997600-55-4	6.23
78	Octadecanoic acid, ethyl ester	$C_{20}H_{40}O_2$	24.149	111-61-5	0.52
79	9,12-Octadecadienoic acid (Z,Z)-	$C_{18}H_{32}O_2$	24.500	60-33-3	0.13
80	Flavonol 3',4',5,7-OH,3-O-Araglucoside	$C_{26}H_{30}O_{16}$	24.856	0-00-0	0.04
81	Octadecanal, 2-bromo-	$C_{18}H_{35}BrO$	25.540	56599-95-2	0.04
82	Eicosanoic acid	$C_{20}H_{40}O_2$	25.759	506-30-9	0.57
83	Squalene	$C_{30}H_{50}$	26.015	111-02-4	0.88
84	(Z)-3-(Heptadec-10-en-1-yl)phenol	$C_{23}H_{38}O$	26.887	111047-33-7	0.09
85	Phenol, 3-pentadecyl-	$C_{21}H_{36}O$	27.083	501-24-6	0.25
86	1,2-Benzenedicarboxylic acid, 3-nitro-	$C_8H_5NO_6$	27.320	603-11-2	0.06
87	Sabinyl linoleate	$C_{28}H_{46}O_2$	27.421	997857-49-5	0.16
88	Heptacosane, 1-chloro-	$C_{27}H_{55}Cl$	29.127	62016-79-9	0.29

Table 2: GC-MS/MS analysis of phytochemical compounds in the aqueous extract of Pistacia integerrima (PI).

S. No	Compound name	Molecular formula	RT	CAS number	Peak area
1	Octanoic acid, ethyl ester	$C_{10}H_{20}O_2$	7.620	106-32-1	7.43
2	Dodecanoic acid	$C_{12}H_{24}O_2$	12.953	143-07-7	3.34
3	1H-Cycloprop[e]azulen-7-ol decahydro-1,1,7-trimethyl-4-methylene-, [1ar-ta.,7b.alpha.)]-(1a.alpha.,4a.alpha.,7.beta.,7a.be	$C_{15}H_{24}O$	13.377	6750-60-3	5.09
4	Tridecanoic acid, 12-methyl-,methyl ester	$C_{15}H_{30}O_2$	15.051	5129-58-8	1.41
5	7-Methyl-Z-tetradecen-1-olacetate	$C_{17}H_{32}O_2$	15.977	997448-21-4	3.30
6	Tetradecanoic acid, ethyl ester	$C_{16}H_{32}O_2$	16.160	124-06-1	12.46
7	n-Hexadecanoic acid	$C_{16}H_{32}O_2$	19.855	57621	22.78
8	Hexadecanoic acid, ethyl ester	$C_{18}H_{36}O_2$	20.621	628-97-7	11.11
9	n-Propyl 5,8,11,14,17-eicosapentaenoate	$C_{23}H_{36}O_2$	22.920	997702-88-3	4.98
10	9,12-Octadecadienoic acid (Z,Z)-	$C_{18}H_{32}O_2$	23.377	60-33-3	1.87
11	cis-Vaccenic acid	$C_{18}H_{34}O_2$	23.463	506-17-2	3.07
12	Ethyl (9Z,12Z)-9,12-octadecadienoate	$C_{20}H_{36}O_2$	23.746	544-35-4	3.39
13	Ethyl Oleate	$C_{20}H_{38}O_2$	23.828	111-62-6	3.26
14	Octadecanoic acid, ethyl ester	$C_{20}H_{40}O_2$	24.134	111-61-5	2.31
15	1,3-Dioctanoin	$C_{19}H_{36}O_5$	25.904	1429-66-9	4.15

16	Phenol, 3-pentadecyl-	$C_{21}H_{36}O$	27.068	501-24-6	2.45
17	(Z)-3-(Heptadec-10-en-1-yl)phenol	$C_{23}H_{38}O$	29.067	111047-33-7	2.13
18	Carbonic acid, eicosyl vinyl ester	$C_{23}H_{44}O_3$	29.135	997764-68-7	5.46

Table 3: GC-MS/MS analysis of phytochemical compounds in the hydro-alcoholic extract of Quercus infectoria (QI).

S. No	Compound name	Molecular formula	RT	CAS number	Peak area
1	Hi-oleic safflower oil	$C_{21}H8_{22}O_{11}$	5.166	8001-23-8	1.08
2	Phenol, 2-methoxy-	C_7HO_2	5.941	90-05-1	0.55
3	3-Octanol, 3,7-dimethyl-	$C_{10}H_{22}O$	6.142	78-69-3	0.62
4	(+)-2-Bornanone	$C_{10}H_{16}O$	7.004	464-49-3	0.54
5	Glucosamine, N-acetyl-N-benzoyl-	$C_{15}H_{19}NO_7$	7.196	997642-31-4	1.53
6	Butanedioic acid, diethyl ester	$C_8H_{14}O_4$	7.314	123-25-1	1.33
7	Oxalic acid, isobutyl nonyl ester	$C_{15}H_{28}O_4$	7.706	997461-38-4	1.88
8	2-hydroxybutanedioic acid diethyl ester	$C_8H_{14}O_5$	8.745	626-11-9	2.75
9	1,3-Dioxocane, 2-pentadecyl-	$C_{21}H_{42}O_2$	8.888	41583-11-3	1.15
10	Ethyl (9Z,12Z)-9,12-octadecadienoate	$C_{20}H_{36}O_2$	9.171	544-35-4	0.97
11	1-Octen-4-one	$C_8H_{14}O$	9.212	997033-68-1	0.41
12	4H-1-Benzopyran-4-one, 2-(3,4-dimethoxyphenyl)-3,5-dihydroxy-7-methoxy-	$C_{18}H_{16}O_7$	9.271	6068-80-0	0.43
13	Phenol, 2,6-dimethoxy-	$C_8H_{10}O_3$	10.001	91-10-1	0.41
14	Tridecane	$C_{13}H_{28}$	10.745	629-50-5	0.54
15	Chlorothymol, trimethylsilyl ether	$C_{13}H_{21}ClOSi$	10.927	997402-91-6	15.10
16	Mefloquine	$C_{17}H_{16}F_6N_2O$	11.876	53230-10-7	0.31
17	2,4-Di-tert-butylphenol	$C_{14}H_{22}O$	12.264	96-76-4	1.24
18	3-Pyridinecarboxylic acid, 6-amino-	$C_6H_6N_2O_2$	12.565	3167-49-5	0.58
19	2-Hydroxy-5-methylbenzophenone,trimethylsilyl ether	$C_{17}H_{20}O_2Si$	12.688	997505-02-4	0.31
20	2-Hydroxy-5-methylbenzophenone,trimethylsilyl ether	$C_{17}H_{20}O_2Si$	12.816	997505-02-4	0.21
21	Dodecanoic acid	$C_{12}H_{24}O_2$	12.948	143-07-7	1.35
22	1,2-Benzenedicarboxylic acid,diethyl ester	$C_{12}H_{14}O_4$	13.386	84-66-2	1.58
23	Tetradecane	$C_{14}H_{30}$	13.441	629-59-4	0.81
24	2,2-Dideutero octadecanal	$C_{18}H_{34}D_2O$	14.157	56555-07-8	0.34
25	Nonacosane	$C_{29}H_{60}$	14.728	630-03-5	0.21
26	Tetradecanoic acid	$C_{14}H_{28}O_2$	15.576	544-63-8	1.80
27	Pentadecanoic acid, ethyl ester	$C_{17}H_{34}O_2$	16.119	41114-00-5	0.89
28	Nonacosane	$C_{29}H_{60}$	16.247	630-03-5	0.26
29	Benzene, 1,1'-ethylidenebis[3,4-dimethyl-	$C_{18}H_{22}$	16.735	1742-14-9	0.45
30	2l,4l-dihydroxyeicosane	$C_{20}H_{42}O_2$	17.009	997609-18-5	0.28

31	ethyl 3,5-dihydroxy-4-methoxybenzoate	$C_{10}H_{12}O_5$	17.063	997245-87-8	0.25
32	Ethyl gallate	$C_9H_{10}O_5$	18.081	831-61-8	3.28
33	Fluroxypyr	$C_7H_5Cl_2FN_2O_3$	19.240	69377-81-7	4.01
34	n-Hexadecanoic acid	$C_{16}H_{32}O_2$	19.732	57-10-3	10.11
35	Hexadecanoic acid, ethyl ester	$C_{18}H_{36}O_2$	20.640	628-97-7	3.85
36	Ethyl cis-6-Hydroxy-7-oxobicyclo[4.3.0]nonanecarboxylate	$C_{12}H_{18}O_4$	20.727	997296-40-2	0.01
37	Ethyl cis-6-Hydroxy-7-oxobicyclo[4.3.0]nonanecarboxylate	$C_{12}H_{18}O_4$	20.837	997296-40-2	12.18
38	9-Octadecenoic acid, (2-phenyl-1,3-dioxolan-4-yl)methylester,cis-	$C_{28}H_{44}O_4$	22.292	56599-45-2	0.34
39	9,12-Octadecadienoic acid (Z,Z)-	$C_{18}H_{32}O_2$	23.401	60-33-3	2.23
40	cis-Vaccenic acid	$C_{18}H_{34}O_2$	23.492	506-17-2	6.81
41	Octadecanoic acid	$C_{18}H_{36}O_2$	23.793	57-11-4	7.72
42	Ethyl Oleate	$C_{20}H_{38}O_2$	23.843	111-62-6	3.88
43	Pentadecanoic acid, ethyl ester	$C_{17}H_{34}O_2$	24.145	41114-00-5	0.88
44	(2R,4aS,5S,8aS)-2,5-Dipentyldecahydroquinoline	$C_{19}H_{37}N$	24.464	220024-74-8	0.29
45	FLAVONOL 3',4',5,7-OH,3-O-ARAGLUCOSIDE	$C_{26}H_{30}O_{16}$	25.746	0-00-0	0.33
46	Hexanedioic acid, mono(2-ethylhexyl)ester	$C_{14}H_{26}O_4$	25.975	4337-65-9	0.59
47	Ethyl iso-allocholate	$C_{26}H_{44}O_5$	26.267	997888-97-8	0.41
48	1,2-Benzenedicarboxylic acid, 3-nitro-	$C_8H_5NO_6$	27.316	603-11-2	0.30

Table 4: GC-MS/MS analysis of phytochemical compounds in the aqueous extract of Quercus infectoria (QI).

S. No	Compound name	Molecular formula	RT	CAS number	Peak area
1	1,2,3-Benzenetriol	$C_6H_6O_3$	10.580	87-66-1	46.22
2	N-methyl-5-aminobicyclo[2.2.2]oct-2-ene	$C_9H_{15}N$	10.736	116907-45-0	14.79
3	Bisphenol C	$C_{17}H_{20}O_2$	10.859	79-97-0	28.72
4	Nonacosane	$C_{29}H_{60}$	25.854	630-03-5	2.17
5	Docosane, 11-decyl-	$C_{32}H_{66}$	28.620	55401-55-3	8.10

Table 5: GC-MS/MS analysis of phytochemical compounds in the hydro-alcoholic extract of *Terminalia chebula* (TC).

S. No	Compound name	Molecular formula	RT	CAS number	Peak area
1	Hi-oleic safflower oil	$C_{21}H_{22}O_{11}$	5.148	8001-23-8	1.11
2	Ethanone, 1-(1H-pyrrol-2-yl)-	C_6H_7NO	5.544	1072-83-9	1.00
3	1-(2-Furanyl)-2-hydroxyethanone	$C_6H_6O_3$	5.941	17678-19-2	2.54
4	3,6,6-trimethyl-1-cyclohex-2-enone	$C_9H_{14}O$	7.114	997050-80-5	0.81
5	Heneicosane	$C_{21}H_{44}$	7.711	629-94-7	0.41

6	Ethanone, 1-(2-furanyl)-	$C_6H_6O_2$	7.880	1192-62-7	0.44
7	2-Furancarboxaldehyde, 5-(ethoxymethyl)-	$C_8H_{10}O_3$	8.104	997080-80-1	1.32
8	5-Hydroxymethylfurfural	$C_6H_6O_3$	8.327	67-47-0	4.95
9	3-Methoxy-4-methyl-2-methylenepentanenitrile	$C_8H_{13}NO$	8.396	997052-52-5	0.07
10	2-hydroxybutanedioic acid diethylester	$C_8H_{14}O_5$	8.756	626-11-9	1.40
11	Cyclohexane, 1,4-dimethyl-2-octadecyl-	$C_{26}H_{52}$	9.221	55282-02-5	0.10
12	5-Acetoxymethyl-2-furaldehyde	$C_8H_8O_4$	9.353	10551-58-3	1.52
13	4-Hydroxy-2-methylacetophenone	$C_9H_{10}O_2$	9.504	875-59-2	0.12
14	Formic acid, 2,6-dimethoxyphenylester	$C_9H_{10}O_4$	10.006	997151-27-4	0.39
15	(4,6-dimethyl-2-methylsulfanyl-3-pyridyl)methanamine	$C_9H_{14}N_2S$	10.111	997151-58-2	0.37
16	1,2,3-Benzenetriol	$C_6H_6O_3$	10.635	87-66-1	15.72
17	Nonacosane	$C_{29}H_{60}$	10.736	630-03-5	1.86
18	Bisphenol C	$C_{17}H_{20}O_2$	10.832	79-97-0	9.50
19	2-Propenoic acid, 3-phenyl-	$C_9H_8O_2$	11.192	621-82-9	1.83
20	(E)-Ethyl cinnamate	$C_{11}H_{12}O_2$	11.771	103-36-6	0.30
21	N-[1-(3-methylphenyl)-2,3-dihydropyrrolo[2,3-b]quinolin-4-yl]-2-(1-piperidinyl)acetamide	$C_{25}H_{28}N_4O$	11.876	997832-76-4	0.17
22	Octadecane, 3-ethyl-5-(2-ethylbutyl)-	$C_{26}H_{54}$	11.967	55282-12-7	0.09
23	Ethyl 3-hydroxybenzoate	$C_9H_{10}O_3$	12.091	7781-98-8	1.36
24	2,4-Di-tert-butylphenol	$C_{14}H_{22}O$	12.250	96-76-4	0.60
25	4-[(2,3-dimethylquinoxalin-6-yl)carbamoyl]-3,3-dimethylbutanoic acid	$C_{17}H_{21}N_3O_3$	12.332	997611-15-6	0.12
26	Benzoic acid, 3-ethoxy-	$C_9H_{10}O_3$	12.492	621-51-2	0.47
27	Ingol 12-acetate	$C_{22}H_{32}O_7$	12.752	51906-01-5	0.06
28	Hexadecanoic acid, 2,3-dihydroxypropyl ester	$C_{19}H_{38}O_4$	12.889	542-44-9	0.18
29	Phthalic acid, butyl undecyl ester	$C_{23}H_{36}O_4$	13.336	997783-85-1	1.28
30	Docosane, 11-decyl-	$C_{32}H_{66}$	13.436	55401-55-3	0.26
31	Benzene, 1,2,3-trimethoxy-5-(2-propenyl)-	$C_{12}H_{16}O_3$	14.029	487-11-6	0.20
32	8,14-Seco-3,19-epoxyandrostane-8,14-dione, 17-acetoxy-3.beta.-methoxy-4,4-dimethyl-	$C_{24}H_{36}O_6$	14.244	997866-38-8	0.11
33	Hexadecanoic acid, 1-[[[(2-aminoethoxy)hydroxyphosphinyl]oxy]methyl]-1,2-ethanediyl ester	$C_{37}H_{74}NO_8P$	14.727	3026-45-7	0.21
34	Isochiapin B	$C_{19}H_{22}O_6$	15.348	997706-97-3	0.11
35	Tetradecanoic acid	$C_{14}H_{28}O_2$	15.540	544-63-8	0.47
36	1-Hexadecanol, 2-methyl-	$C_{17}H_{36}O$	16.133	2490-48-4	0.81

37	Nonacosane	$C_{29}H_{60}$	16.242	630-03-5	0.23
38	Dasycarpidan-1-methanol,acetate (ester)	$C_{20}H_{26}N_2O_2$	16.625	55724-48-6	0.26
39	Octadecanal, 2-bromo-	$C_{18}H_{35}BrO$	16.990	56599-95-2	0.14
40	1,2-Benzenedicarboxylic acid,bis(2-methoxyethyl) ester	$C_{14}H_{18}O_6$	17.373	117-82-8	0.23
41	6-Fluorobenzofuroxane, 5-[4-(2-pyrimidyl)piperazin-1-yl]-	$C_{14}H_{13}FN_6O_2$	17.611	997613-06-7	0.31
42	4H-1-Benzopyran-4-one, 2-(3,4-dimethoxyphenyl)-3,5-dihydroxy-7-methoxy-	$C_{18}H_{16}O_7$	18.427	6068-80-0	0.26
43	n-Hexadecanoic acid	$C_{16}H_{32}O_2$	19.627	57-10-3	6.23
44	Hexadecanoic acid, ethyl ester	$C_{18}H_{36}O_2$	20.585	628-97-7	7.63
45	E-2-Methyl-3-tetradecen-1-olacetate	$C_{17}H_{32}O_2$	21.443	997448-18-4	0.19
46	Ethyl 9-hexadecenoate	$C_{18}H_{34}O_2$	22.821	54546-22-4	0.10
47	Ethanol, 2-(9,12-octadecadienyloxy)-, (Z,Z)-	$C_{20}H_{38}O_2$	23.364	17367-08-7	0.63
48	cis-Vaccenic acid	$C_{18}H_{34}O_2$	23.446	506-17-2	1.98
49	Ethyl (9Z,12Z)-9,12-octadecadienoate	$C_{20}H_{36}O_2$	23.742	544-35-4	5.67
50	Ethyl Oleate	$C_{20}H_{38}O_2$	23.824	111-62-6	8.84
51	Ethyl 13-methyl-tetradecanoate	$C_{17}H_{34}O_2$	24.130	997455-69-6	0.99
52	Linoleic acid ethyl ester	$C_{20}H_{36}O_2$	24.778	544-35-4	0.16
53	(5.beta.)Pregnane-3,20.beta.-diol,14.alpha.,18.alpha.-[4-methyl-3-oxo-(1-oxa-4-azabutane-1,4-diyl)]-, diacetate	$C_{28}H_{43}NO_6$	26.005	997941-65-3	0.36
54	1,2-Benzenedicarboxylic acid,mononony1 ester	$C_{17}H_{24}O_4$	27.315	24539-59-1	0.65
55	Licarin A	$C_{20}H_{22}O_4$	28.096	51020-86-1	0.36

Table 6: GC-MS/MS analysis of phytochemical compounds in the aqueous extract of Terminalia chebula (TC).

S. No	Compound name	Molecular formula	RT	CAS number	Peak area
1	1-(2-Furanyl)-2-hydroxyethanone	$C_6H_6O_3$	5.941	17678-19-2	1.84
2	1,2,4,5-Tetrazine	$C_2H_2N_4$	7.104	290-96-0	0.51
3	Octadecane, 1-chloro-	$C_{18}H_{37}Cl$	7.711	3386-33-2	0.38
4	2-Furancarboxaldehyde, 5-(ethoxymethyl)-	$C_8H_{10}O_3$	8.103	997080-80-1	0.62
5	5-Hydroxymethylfurfural	$C_6H_6O_3$	8.304	67-47-0	29.22
6	5-Acetoxymethyl-2-furaldehyde	$C_8H_8O_4$	9.353	10551-58-3	1.96
7	1,2,3-Benzenetriol	$C_6H_6O_3$	10.735	87-66-1	1.45
8	Ethanone, 1-[4-methoxy-3-(4-methylphenoxy)phenyl]-	$C_{16}H_{16}O_3$	10.822	116345-94-9	1.30
9	2-Phenylethyl hydrogencarbonate	$C_9H_{10}O_3$	12.077	997108-68-2	0.59

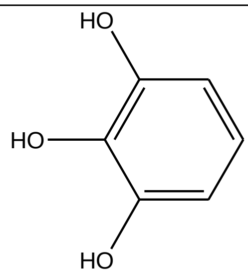
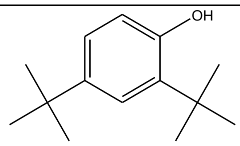
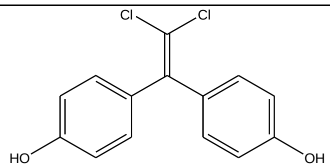
10	2,4-Di-tert-butylphenol	$C_{14}H_{22}O$	12.245	96-76-4	0.23
11	Hexadecane, 1,1-bis(dodecyloxy)-	$C_{40}H_{82}O_2$	13.345	56554-64-4	0.49
12	Tricosane	$C_{23}H_{48}$	13.436	638-67-5	0.37
13	Hexadecane, 1,1-bis(dodecyloxy)-	$C_{40}H_{82}O_2$	16.123	56554-64-4	0.49
14	Glycerol tricaprylate	$C_{27}H_{50}O_6$	26.675	538-23-8	21.88

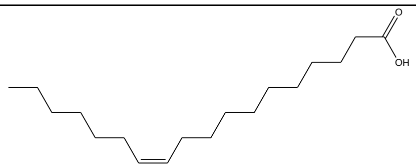
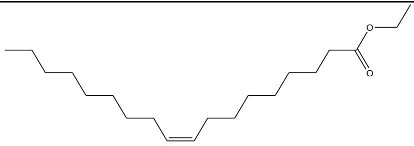
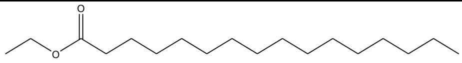
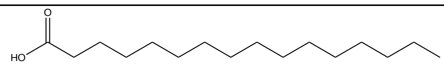
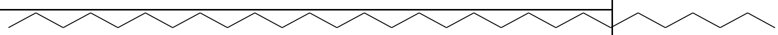
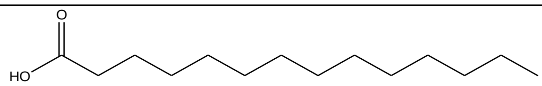
Table 7: List of common compounds present in different extracts of Pistacia integerrima (PI), Quercus infectoria (QI) and Terminalia chebula (TC)by GC-MS/MS.

S.No.	Compound name	Molecular formula	CAS number	PI-HA	PI-Aq	QI-HA	QI-Aq	TC-HA	TC-Aq
1	(Z)-3-(Heptadec-10-en-1-yl)phenol	$C_{23}H_{38}O$	111047-33-7	+	+	-	-	-	-
2	1-(2-Furanyl)-2-hydroxyethanone	$C_6H_6O_3$	17678-19-2	-	-	-	-	+	+
3	1,2,3-Benzenetriol	$C_6H_6O_3$	87-66-1	+	-	-	+	+	+
4	1,2-Benzenedicarboxylic acid, 3-nitro-	$C_8H_5NO_6$	603-11-2	+	-	+	-	-	-
5	1H-Cycloprop[e]azulen-7-ol, decahydro-1,1,7-(1a.alpha.,4a.alpha.,7.beta.,7a.beta.,7b.alpha.)]-	$C_{15}H_{24}O$	6750-60-3	+	+	-	-	-	-
6	2,4-Di-tert-butylphenol	$C_{14}H_{22}O$	96-76-4	+	-	+	-	+	+
7	2-hydroxybutanedioic acid diethyl ester	$C_8H_{14}O_5$	626-11-9	-	-	+	-	+	-
8	4H-1-Benzopyran-4-one, 2-(3,4-dimethoxyphenyl)-3,5-dihydroxy-7-methoxy-	$C_{18}H_{16}O_7$	6068-80-0	-	-	+	-	+	-
9	5-Acetoxymethyl-2-furaldehyde	$C_8H_8O_4$	10551-58-3	-	-	-	-	+	+
10	5-Hydroxymethylfurfural	$C_6H_6O_3$	67-47-0	-	-	-	-	+	+
11	9,12-Octadecadienoic acid (Z,Z)-	$C_{18}H_{32}O_2$	60-33-3	+	+	+	-	-	-
12	Bisphenol C	$C_{17}H_{20}O_2$	79-97-0	+	-	-	+	+	-
13	cis-Vaccenic acid	$C_{18}H_{34}O_2$	506-17-2	+	+	+	-	+	-
14	Docosane, 11-decyl-	$C_{32}H_{66}$	55401-55-3	-	-	-	+	+	-
15	Dodecanoic acid	$C_{12}H_{24}O_2$	143-07-7	+	+	+	-	-	-
16	Ethanone, 1-(1H-pyrrol-2-yl)-	C_6H_7NO	1072-83-9	+	-	-	-	+	-
17	Ethyl (9Z,12Z)-9,12-octadecadienoate	$C_{20}H_{36}O_2$	544-35-4	+	+	-	-	-	-
18	Ethyl (9Z,12Z)-9,12-octadecadienoate	$C_{20}H_{36}O_2$	544-35-4	-	-	+	-	+	-
19	Ethyl gallate	$C_9H_{10}O_5$	831-61-8	+	-	+	-	-	-
20	Ethyl iso-allocholate	$C_{26}H_{44}O_5$	997888-97-8	+	-	+	-	-	-

21	Ethyl Oleate	$C_{20}H_{38}O_2$	111-62-6	-	+	+	-	+	-
22	FLAVONOL 3',4',5,7-OH,3-O-ARAGLUCOSIDE	$C_{26}H_{30}O_{16}$	0-00-0	+	-	+	-	-	-
23	Hexadecanoic acid, 2,3-dihydroxypropyl ester	$C_{19}H_{38}O_4$	542-44-9	+	-	-	-	+	-
24	Hexadecanoic acid, ethyl ester	$C_{18}H_{36}O_2$	628-97-7	+	+	+	-	+	-
25	Hi-oleic safflower oil	$C_{21}H_{22}O_{11}$	8001-23-8	-	-	+	-	+	-
26	n-Hexadecanoic acid	$C_{16}H_{32}O_2$	57621	+	+	+	-	+	-
27	Nonacosane	$C_{29}H_{60}$	630-03-5	+	-	+	+	+	-
28	Octadecanal, 2-bromo-	$C_{18}H_{35}BrO$	56599-95-2	+	-	-	-	+	-
29	Octadecanoic acid	$C_{18}H_{36}O_2$	57-11-4	+	-	+	-	-	-
30	Octadecanoic acid, ethyl ester	$C_{20}H_{40}O_2$	111-61-5	+	+	-	-	-	-
31	Octanoic acid, ethyl ester	$C_{10}H_{20}O_2$	106-32-1	+	+	-	-	-	-
32	Pentadecanoic acid, 14-methyl-, methyl ester	$C_{17}H_{34}O_2$	5129-60-2	+	-	+	-	-	-
33	Phenol, 3-pentadecyl-	$C_{21}H_{36}O$	501-24-6	+	+	-	-	-	-
34	Tetradecanoic acid	$C_{14}H_{28}O_2$	544-63-8	+	-	+	-	+	-
35	Tetradecanoic acid, ethyl ester	$C_{16}H_{32}O_2$	124-06-1	+	+	-	-	-	-
36	Tricosane	$C_{23}H_{48}$	638-67-5	-	-	+	-	-	+

Table 8: List of compounds present in all species of Pistacia integerrima (PI), Quercus infectoria (QI) and Terminalia chebula (TC)by GC-MS/MS.

S. No.	Compound name	Molecular weight	Structure
1	1,2,3-Benzenetriol	126.11	
2	2,4-Di-tert-butylphenol	206.32	
3	Bisphenol C	281.1	

4	cis-Vaccenic acid	282.5	
5	Ethyl Oleate	310.5	
6	Hexadecanoic acid, ethyl ester	284.5	
7	n-Hexadecanoic acid	256.42	
8	Nonacosane	408.8	
9	Tetradecanoic acid	228.37	

V. CONCLUSION

The study was initiated to develop a GC-MS/MS method to analyze pesticide residues in herbal formulation. A rapid and sensitive quantitative method is always a major goal for analytical laboratories involved in pesticide analysis. The approach was proven to be linear, specific, recoverable, and repeatable with little time spent on sample preparation. This technique is useful for finding and verifying the presence of minute amounts of pesticides in challenging matrices, like herbal churnas. The technique may be able to identify trace amounts of chemicals at 5µg/kg of concentration. Finding out which pesticides are present in herbs is crucial for evaluating consumer safety and preventing long-term use-related chronic toxicity. Creating regulatory standards for the management of pesticide residues in herbal products would benefit greatly from the development of sensitive and straightforward analytical techniques. In light of this, a sensitive and quick method has been developed for the extraction of multiclass pesticides from various popular medicinal herbs in India. The method that has been standardized in this study will also be very helpful in monitoring market samples of herbal churna to guarantee food safety and quality for consumers across the globe.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

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Several imperious physical characteristics of the *Trachyspermum ammi L.* (ajwain seed)

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***Abstract*—** *In this study, ajwain seeds measured 2.64 ± 0.45 mm in length, 1.65 ± 0.34 mm in width, and 0.92 ± 0.15 mm in thickness at a moisture content of 6.45% (wet basis). The mean geometric diameter and sphericity were 2.16 ±0.10 mm and 0.635 ± 0, respectively. The ajwain seed has an oval shape and a ridged appearance. Its surface area and bulk density are 11.43 ±0.52 mm2 and 466.22 ±9.18 kg/m3, respectively. The angle of repose obtained was 39.90 degrees. The coefficient of friction between the ajwain seed and galvanized steel was 0.53.*

Keywords*— *Ajwain seeds, Geometric diameter, Bulk density, Angle of repose, Coefficient of friction

I. INTRODUCTION

The physical attributes of spices pertain to their qualities, which are important for industrial procedures such as processing, handling, packaging, and storage. Ajwain, scientifically known as *Trachyspermum ammi L.*, is a member of the Apiaceae family and originated in Egypt and India. This herb is grown in dry and semiarid regions worldwide, including Iran, Pakistan, and Afghanistan. The seeds of Ajwain are extensively utilized in India and other parts of eastern Asia, both for culinary purposes and in traditional medicine. Due to its essential oil, Ajwain is considered a valuable commercial plant, particularly in the flavor and food industries. Spices play a crucial role in agriculture, serving as essential ingredients in culinary practices by enhancing the taste, aroma, and overall appeal of various dishes. (Pruthi, 1974). (Bairwa et al., 2012). Properties are essential for optimizing manufacturing processes and ensuring the quality and consistency of spice-based products in the food industry.

Ajwain seeds have distinct flavors and are utilized for a variety of culinary and therapeutic purposes due to their physical characteristics. Attributes may differ considerably among various varieties. The level of moisture in seeds plays a crucial role in the design of machinery and equipment used for planting, transporting, handling, storing, processing, and extracting seed oil (Kumar et al., 2016). Ajwain seeds are composed of a yellowish-brown essential oil (2-4%), which is utilized in numerous ayurvedic medications as well as in various food industries. Ajwain seeds have been traditionally utilized in ayurvedic and unani medicines for treating various ailments. The extracts derived from this spice are occasionally used as carminatives to alleviate flatulence and indigestion. Thymol, known for its germicidal and antiseptic properties, can be utilized in the formulation of remedies for cold and cough. In India, a decoction of ajwain seeds is frequently used to relieve asthma (Yadav, et al., 2011).

Singh, H., and Meghwal, M. (2020) described characteristics concerning seed quality, acceptability to consumers, and the behavior of ajwain before, during, and after manufacturing, storage, and consumption. The features that assist in designing handling, drying, and separation systems include size, shape, volume, surface area, density, and porosity. The grading and sizing equipment will be determined by the size and shape of the ajwain seeds. Additionally, the density and porosity of the seeds aid in sizing the hoppers and storage containers. In regard to separating seeds based on density or specific gravities, the density of the seeds will also play a crucial role. Furthermore, the design of storage bins, chutes, hoppers, screw conveyors, threshers, and fodder harvesters can be facilitated by considering frictional qualities such as the coefficient of friction and angle of repose.

The objective of the present research was to determine the impact of the physical characteristics of the ajwain seed *Trachyspermum ammi L.*

II. MATERIALS AND METHODS

Ajwain seed

The Nathwani group of companies, situated in Jamnagar, Gujarat, India, furnished a large quantity of uniform ajwain seeds (*var. Gujarat Ajwain 1*). The ajwain seeds were stored at ambient temperature after being placed in aluminum laminates.

Fig 1. Ajwain seed

Characteristics

The characteristics that are important for size reduction include shape, size, sphericity, bulk density, surface area, etc. The physical properties of the ajwan seeds were determined using the methods described below.

Size and shape

After random selection from the bulk sample, the major (longest intercept), intermediate, and minor diameters of the Ajwain seeds were measured using a digital micrometer digital screw gauge (Figure). The digital screw gauge had a minimum length of 0.01 mm.

Fig.2. Digital micrometer screw gauge

The form was recognized by sketching the longitudinal and lateral cross sections on a cardboard, matching it with the shapes on the standard chart, and subsequently describing it with a phrase. The geometric mean diameter and sphericity of each seed were calculated using the formula provided. (Mohsenin, 1986).

$$Geometric\ Mean\ Diameter, Dg = (L * B * T)^{\frac{1}{3}} \ldots (3.1)$$

$$Sphericity, (\varphi) = \frac{(L*B*T)^{1/3}}{L} \ldots\ldots (3.2)$$

where

L = Longest intercept, (Length) in mm;

B = Longest intercept normal to ‘L’ (Breadth) in mm;

T= Longest intercept normal to ‘L’ and ‘B’ (Thickness) in mm.

Surface area

The surface area of the seed was determined using the following equation (Altuntas, et al., 2005):

$$Surface\ area, (Sa) = \Pi * (Dg)^2 \ldots\ldots (3.3)$$

where

Dg = Geometric mean diameter (mm)

Bulk density

To calculate the bulk density, seeds were added to a stainless steel cylinder until it was full. Any remaining seeds were then gently rolled over the container's rim with a cylindrical glass rod without applying any pressure (Carmen 1996). The bulk density was calculated by dividing the mass of the seeds that were placed inside the cylinder by its volume. The bulk density was computed using the method described in equation 3.4.

$$\rho_b = \frac{Mx}{Vc} \ldots\ldots (3.4)$$

where

ρ_b =Bulk density (kg/m^3)

Mx=Weight of sample, (kg)

Vc=Volume of the container, (m^3)

Angle of repose

A vertical cylinder constructed from a sheet that was open at both ends (Figure) was used to measure the angle of repose of the ajwain seeds. The cylinder was then filled with the seed and gently raised (Dutta, et al., 1988). Equation 3.5 was used to determine the angle of repose.

$$Angle\ of\ repose, \emptyset = tan^{-1}\frac{2h}{d} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

where

h = height of the cone (mm)

d = diameter of the cone (mm)

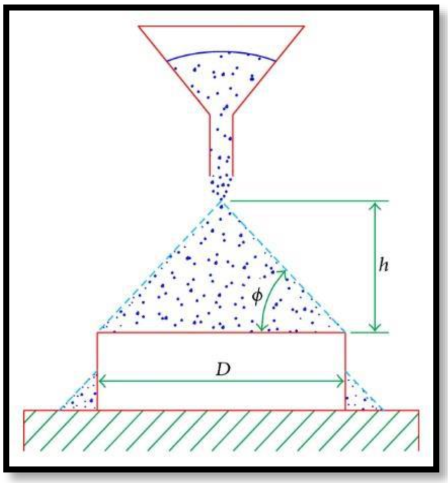
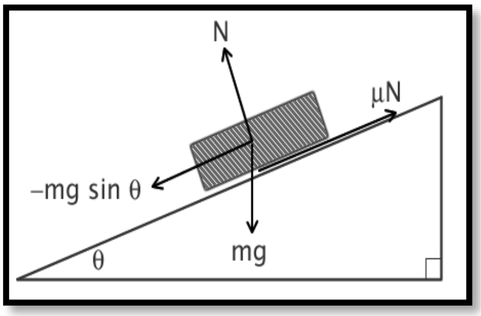


Fig.3. Measurement of the angle of repose

Coefficient of friction

The coefficient of static friction for the ajwain seeds was measured on galvanized steel using a box without a top or bottom. The surface was gradually elevated until the filled cube began to slide down, and the angle at this point was noted. The coefficient of static friction was then calculated using the provided formula. (Orhevba, et al., 2013).

$$\mu = \tan\theta \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.6)$$



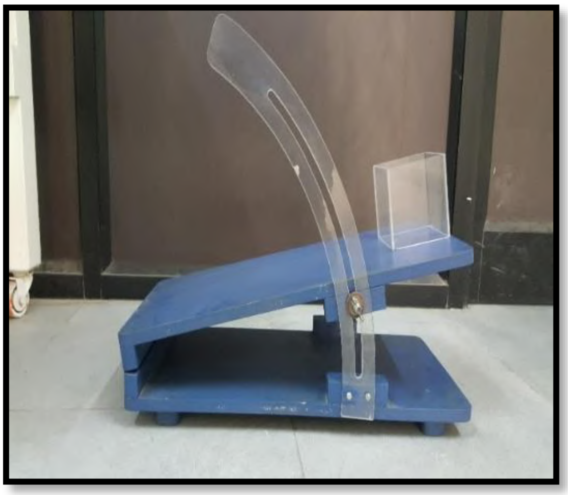


Fig.4. Measurement of the coefficient of friction

III. RESULTS AND DISCUSSION

Physical characteristics

The present analysis focused on the engineering properties of ajwain seeds, specifically their characteristics, such as size, shape, surface area, sphericity, coefficient of friction and angle of repose, which were determined according to the procedure described in the previous section. The data obtained are presented in Table.1

The average dimensions of the ajwain seeds, including length, width, and thickness, were 2.64 ± 0.45 mm, 1.65 ± 0.34 mm, and 0.92 ± 0.15 mm, respectively, with a moisture content of 6.45% (wet basis). These measurements play a crucial role in determining sieve apertures and various parameters in machine design (Mohsenin, 1986). Additionally, the average geometric mean diameter was 2.16 ± 0.10 mm, with a sphericity of 0.635 ± 0. The shape of the ajwain seeds was identified as oval with a ridged appearance, highlighting the importance of roundness and sphericity in predicting the drying behavior of agricultural grains (Orhevba, *et al*., 2013).

The average bulk density and surface area were found to be 466.22 ±9.18 kg/m3 and 11.43 ±0.52 mm2, respectively. When designing a storage system for ajwain seeds prior to processing, the surface area and bulk density are important factors to consider. The measured angle of repose was

39.90°. It was discovered that there was a 0.53 coefficient of friction between the galvanized steel and the ajwain seed. The design of hoppers, which are critical to the processing of agricultural products, depends on these discoveries. The physical characteristics that were noted are consistent with those that Zewdu (2011) reported; the few differences might be ascribed to variations in cultivars and environmental circumstances.

Table 1: Characteristics of ajwain seeds

Parameter	Mean values ± SDs
Size	Length: 2.64±0.45 mm
	Width: 1.65 ± 0.34 mm
	Thickness : 0.92 ± 0.15 mm
	Geometric mean diameter: 2.16±0.10 mm
Shape	Oval in shape with a ridged appearance.
Sphericity	0.635 ± 0.05
Surface area	11.43 ± 0.52 mm^2
Bulk density	466.22 ±9.18 kg/m^3
Coefficient of friction	0.53
Angle of repose	39.90°

IV. CONCLUSION

An investigation was conducted to examine the physical attributes of the ajwain seeds. Under conditions of constant moisture content, the measurements included dimensions, shape, sphericity, surface area, bulk density, coefficient of friction, and angle of repose, these several imperious physical characteristics are related to their qualities, which are significant for industrial processes like handling, processing, packing, and storing.

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Potential influence of lime treated sewage sludge application on soil micro fauna and their impact on growth of Radish

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Abstract— *Lime-treated sewage sludge (LTSS) is a potential soil amendment with both benefits and drawbacks. This study aims to investigate the influence of LTSS application on soil microfauna and their subsequent impact on the growth of radish (Raphanus sativus). Soil microfauna, comprising nematodes, protozoa, and other small invertebrates, play a crucial role in nutrient cycling. LTSS application can alter soil properties like pH, nutrient availability, and organic matter content. These changes can influence the abundance and diversity of microfauna populations. LTSS can be a source of essential nutrients for radish growth, potentially leading to increased biomass and yield. Additionally, some microfauna, like certain nematodes, can promote plant growth through root-fungus interactions. High application rates of LTSS could disrupt the microfauna community, potentially reducing beneficial populations and hindering nutrient cycling. Furthermore, LTSS may contain residual heavy metals or pathogens that could negatively impact radish growth. This study hypothesizes that LTSS application will have a biphasic effect on radish growth. At moderate application rates, LTSS may enhance radish growth by stimulating beneficial microfauna populations and improving nutrient availability. However, at high application rates, negative effects on microfauna and potential heavy metal contamination might hinder radish growth*

Keywords— *Sewage sludge, soil, radish and plant growth*

I. INTRODUCTION

The radish *(Raphanus sativus L)* is a versatile root vegetable enjoyed globally. Originally hailing from Europe and Asia, it belongs to the Brassicaceae family (Gill, 1993). In India, radishes thrive year-round in various regions. This popular vegetable offers more than just its crisp, edible root. Radishes are typically eaten raw in salads or cooked as a side dish. But that's not all! The leafy greens are packed with vitamins A and C and can also be enjoyed cooked. Additionally, young radish pods, known as "mongree," are a culinary delight, eaten raw or cooked on their own or mixed with other vegetables. Radishes boast significant medicinal value. They are often recommended for individuals suffering from piles, liver problems, and jaundice (Khan et al., 2008).

As mentioned, radish performance heavily depends on these factors. Different varieties have specific soil type and climate preferences for optimal growth .This is a crucial factor influencing radish growth and yield. However, the specific nutrient needs vary depending on: Different soil types hold nutrients differently, impacting availability for the radish plant. Richer soils may require less fertilizer amendments compared to less fertile ones. Factors like temperature and rainfall can influence nutrient uptake and utilization (Rahman et al., 2016).

Municipal wastewater treatment generates sewage sludge, a heterogeneous mixture of solid, semi-solid, and liquid residues (National Research Council, 2002). The industry increasingly utilizes the term bio solids to designate treated sludge intended for beneficial reuse (U.S. EPA, 1999). This distinction highlights the processing steps that transform raw sludge into a potential soil amendment. Historically, wastewater sludge disposal posed a significant challenge for urban environments. Traditional methods like incineration and landfilling are becoming less favourable due to limited landfill capacity, rising disposal costs, and environmental concerns . Ocean disposal, once practiced, is no longer considered an acceptable option. Bio solids offer a potential solution, as they contain valuable nutrients like nitrogen, phosphorus, and micronutrients, along with organic matter (U.S. EPA, 2000). Land application represents a sustainable approach to nutrient recycling and organic matter replenishment in soil. However, this strategy necessitates a risk-benefit analysis (Nadeem & Wajid, 2018). Bio solids can harbor metals such as Lead, Cadmium, Chromium, Copper, Zinc, Mercury, etc., and pathogenic microorganisms, posing threats to human health, agricultural productivity, and ecological integrity. Heavy metal mobilization within the soil system is a key concern. These contaminants can be absorbed by plants or leached into drainage water, potentially contaminating associated water resources. Industrial activities significantly contribute to heavy metal concentrations in bio solids. These activities includes the sources such as surface treatment processes employing elements like Cu, Zn, Ni, and Cr, along with the industrial waste improperly disposed of through drainage systems.

II. MATERIALS AND METHODS

The glassware utilized in the present study includes conical flasks, measuring cylinders, pipettes, funnels, Petri plates, test tubes, volumetric flasks, and beakers. Additionally, miscellaneous materials such as inoculating needles, scalpels, spirit lamps, corks borers, and rubber bands were employed. To prepare the glassware for experimentation, they were first immersed in tap water overnight and subsequently washed with detergent powder under running tap water. After sun drying, the cleaned glassware was individually wrapped in clean paper and subjected to sterilization in a hot air oven at a temperature of 150°C for two to four hours. Petri dishes and pipettes were similarly wrapped and sterilized at 160°C for 2 hours. Solid and liquid media were sterilized by autoclaving at a pressure of 1.1 kg/cm² (121.6°C) for 20 minutes during all laboratory studies. All cultural experiments were conducted under aseptic conditions within a laminar airflow hood. Finally, the tips of inoculation needles, forceps, and cork borers were sterilized using an open flame.

2.1 Nutrient Agar

Nutrient Agar is a basic culture medium commonly used for the cultivation of non-fastidious microorganisms specially bacteria.

Materials used:

- Nutrient agar powder
- Distilled water
- Autoclave or pressure cooker
- Conical flask
- Stirring rod
- pH meter or pH paper

2.2 Potato Dextrose Agar (PDA)

Potato Dextrose Agar (PDA) is a widely employed microbiological growth medium that serves as a foundation for cultivating and identifying yeasts and molds. It is prepared by infusing potatoes with dextrose, which provides a source of energy for fungal growth. PDA is particularly useful for the isolation and cultivation of various fungi, including those associated with plant pathogens.

Materials used:

- Potatoes
- Dextrose (glucose)
- Agar powder
- Distilled water
- Autoclave or pressure cooker
- Conical flask
- Sterilized petri dishes

Fig. 2.1 Potato dextrose agar media

2.3 Experimental site

The research study was conducted during two consecutive Zaid seasons in 2017 and 2018 at the Research Farm of the Department of Environmental Science & Natural Resource Management (NRM), College of Forestry, Sam Higginbottom University of Agriculture, Technology, and Sciences (SHUATS), located in Prayagraj, Uttar Pradesh, India. The university campus spans approximately 1020 acres and is situated on the right bank of the Yamuna River in the southern region of Allahabad city. The geographical coordinates of the area are latitude 25°24’42" N and longitude 81°50’56" E, with an altitude of 98 meters above mean sea level.

2.4 Percent pore space

Porosity was calculated from the particle density and bulk density of the soil using formula given by Muthuval et al., (1992)

(1) % pore space = $(1 - \frac{Bulk\ Density}{Partial\ Density}) \times 100\%$

(2) Soil pH
A soil-water suspension was meticulously prepared using a 1:2.5 ratio (10 g of soil mixed with 25 mL of distilled water). Subsequently, the pH value was determined using a pH meter (Jackson 1958).

(3) Electrical conductivity (dS m-1)
The soil water suspension prepared for measurement of pH was utilized to analyze the electrical conductivity of soil. Soil suspension was allowed to settle till supernatant become clear. Electrical conductivity was measured with the help of EC meter and expressed as dS m- 1 (Wilcox 1950).

(4) Organic carbon (%) (Walkley and Black, 1934)
Procedure: One g of soil was taken in a 500 ml of conical flask. Ten ml of 1 N K2Cr2O7 solution was added and stirred. Then 20 ml of Conc. H2SO4 was added, the flask was swirled 2-3 times and allowed to stand for 30 minutes on an asbestos sheet for the reaction to occur. The suspension was diluted with 200 cc of distilled water. Ten ml of 85 percent H3PO4 and 1 ml of diphenylamine indicator were added and titrated against the solution of 0.5 N Ferrous Ammonium Sulphate till color changed from violet to bright green. A blank titration was also carried out.

(5) Electrical conductivity (dS m-1)
The soil water suspension prepared for measurement of pH was utilized to analyze the electrical conductivity of soil. Soil suspension was allowed to settle till supernatant become clear. Electrical conductivity was measured with the help of EC meter and expressed as dS m- 1 (Wilcox 1950).

III. RESULT AND DISCUSSION

3.1 Mechanical analysis of the soil

Table 3.1 Mechanical analysis of the soil of experimental field during 2017 and 2018

Physical analysis of soil	Value (unit)		Method (references)
	2017	2018	
Sand	57.58 (%)	58.12 (%)	Bouyoucos hydrometer method (Bouyoucos, 1927)
Silt	24.78 (%)	24.62 (%)	
Clay	15.24 (%)	15.26(%)	
Textural class	Sandy loam	Sandy loam	Triangular method (Piper, 1950)
Bulk density	1.35 (mg m^{-3})	1.39 (mg m^{-3})	Muthuvel, *et al.*, 1992
Particle density	2.65 (mg m^{-3})	2.61(mg m^{-3})	
Pore space%	48.47(%)	49.76(%)	
Solid space %	51.53 (%)	50.24 (%)	

Table 3.2 Total bacteria from raw sewage sludge

S. No.	Total number of colonies	Type of colonies	Texture of colony
1.	300	1 type	smooth
2.	300	1 type	smooth or whitish
3	290	1 type	smooth

Fig. 3.1 Isolation of bacteria colonies on Nutrient Agar

Table 3.3 Total bacteria from raw lime

S. No.	Total number of colonies	Type of colonies	Texture of colony
1.	5	1 type	smooth
2.	20	1 type	smooth
3	21	1 type	smooth

Fungi Isolation

A total of 6 fungal strains were successfully isolated from the lime treated sewage sludge. The isolated fungal strains displayed diverse morphological features, including hyphal structure, spore formation, and colony pigmentation (Table 3.2 & Fig. 3.1). Initial identification based on colony morphology suggested the presence of various fungal genera, including *Fusariumaspergillus niger*, *Aspergillus tirius*, *Mucur Penicillium*, *Aspergillus flavus*, and *Aspergillus fumigatus* (Table 3.5). Overall, the isolation results indicate the presence of a diverse microbial community in lime treated sewage sludge, comprising both bacteria and fungi with potential implications for bioremediation and nutrient cycling processe (Raouf MS & Raheim ARM, 2016).

Table 3.4 Isolation of total fungi from sewage sludge

S. No.	Total number of colonies	Type of colony	Texture of colony
1.	13	3 types (black yellow and green)	Rough cottony (Smooth)
2.	12	4 types (black yellowish, greenish whitish	rough, smoothy, cottony (smoothy or cottony)
3	15	2 types (black and whitish)	rough, colony
4	13	3 types (black, white, yellowish and greenish	rough cottony smoothy
5	1	1types black color	black rough
6	1	types (brownish)	brownish rough

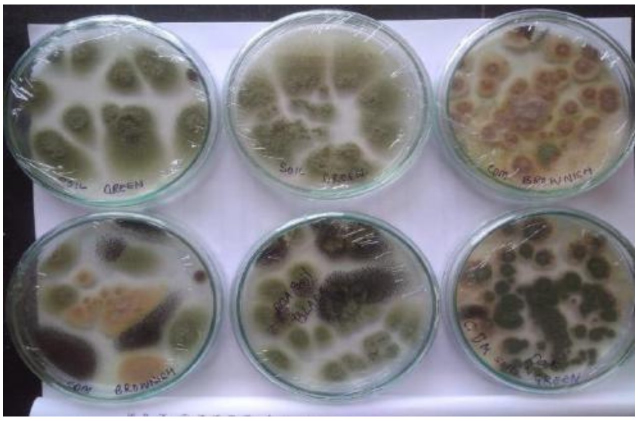

Fig. 3.2 Isolation of total fungi from sewage sludge

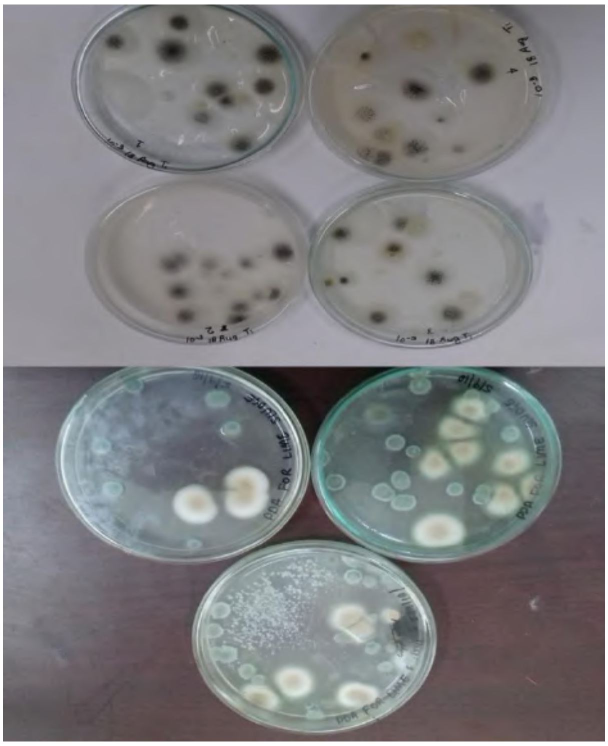

Fig 3.3 Identification of Fungi.

Table 3.5 Identification of fungi

S. No.	Fungi	Colour
1.	Aspergillus niger	black colony
2.	Aspergillus tirius	brown whitish colony
3.	Mucur	Pure white
4.	Penicillium	green colonies
5.	Aspergillus flavus	
6.	Aspergillus fumigatus	

Table 3.6 Effects of Sewage sludge and soil management practices on plant height of Radish

Treatments	Treatment explanation	Plant height (cm)		
		2016-2017	2017-2018	Pooled
T_1	Control	28.01	30.64	29.33
T_2	RSS 100% (Raw Sewage Sludge)	31.38	33.54	32.46
T_3	LTSS 100% (Lime Treated Sewage Sludge)	32.90	34.53	33.71
T_4	CDM 100% (Cow Dung Manure)	33.43	35.36	34.40
T_5	RSS 50% + CDM 50%	35.96	36.50	36.23
T_6	LTSS 50% + CDM 50%	36.25	37.12	36.68
	F-Test	S	S	S
	C.D at 0.5%	2.372	0.512	1.143
	S.Ed	1.065	0.230	0.513

Table 3.7 Effects of Sewage sludge and soil management practices on number of leaves per plant

		Number of leaves per plant		
Treatments	Treatment explanation	2016-2017	2017-2018	Pooled
T_1	Control	9.56	10.31	9.94
T_2	RSS 100% (Raw Sewage Sludge)	10.66	11.56	11.11
T_3	LTSS 100% (Lime Treated Sewage Sludge)	11.05	12.09	11.57
T_4	CDM 100% (Cow Dung Manure)	11.51	13.64	12.58
T_5	RSS 50% + CDM 50%	12.42	14.50	13.46
T_6	LTSS 50% + CDM 50%	13.64	15.27	14.46
	F-Test	S	S	S
	C.D at 0.5%	0.671	0.650	0.445
	S.Ed	0.301	0.292	0.200

Table 3.8 Effects of Sewage sludge and soil management practices on root length (cm)

		Root length (cm)		
Treatments	Treatment explanation	2016-2017	2017-2018	Pooled
T_1	Control	10.65	16.54	13.60
T_2	RSS 100% (Raw Sewage Sludge)	15.37	17.60	16.49
T_3	LTSS 100% (Lime Treated Sewage Sludge)	16.08	18.55	17.31
T_4	CDM 100% (Cow Dung Manure)	17.51	19.66	18.59
T_5	RSS 50% + CDM 50%	18.60	20.40	19.50
T_6	LTSS 50% + CDM 50%	19.75	21.71	20.73
	F-Test	S	S	S
	C.D at 0.5%	1.296	0.518	0.800
	S.Ed	0.582	0.233	0.359

Table 3.9 Effects of Sewage sludge and soil management practices on Root weight (gm)

		Root weight (gm)		
Treatments	Treatment explanation	2016-2017	2017-2018	Pooled
T_1	Control	102.62	101.99	102.31
T_2	RSS 100% (Raw Sewage Sludge)	105.29	110.94	108.12
T_3	LTSS 100% (Lime Treated Sewage Sludge)	110.42	117.44	113.93
T_4	CDM 100% (Cow Dung Manure)	116.12	121.20	118.66
T_5	RSS 50% + CDM 50%	119.93	127.46	123.69
T_6	LTSS 50% + CDM 50%	131.94	135.40	133.67
	F-Test	S	S	S
	C.D at 0.5%	6.777	5.202	2.820
	S.Ed	3.401	2.335	1.266

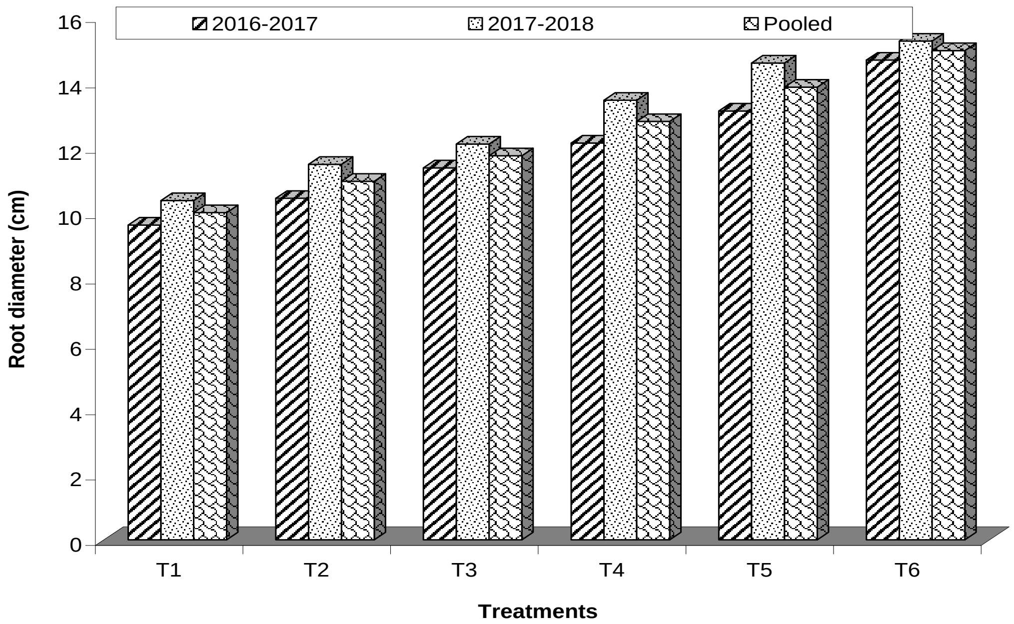

Fig. 3.4 Effects of Sewage sludge and soil management practices on Root diameter (cm)

IV. CONCLUSION

The maximum plant height (cm) (36.25, 37.12 and 36.68) was recorded for the treatment T_6 LTSS 50% + CDM 50%. Whereas the minimum plant height (28.01, 30.60 and 29.33) was found in treatment T_1 Control during 2016-17 and 2017-18 with pooled data respectively.

The maximum number of leaves per plant (13.64, 15.27 and 14.46) was recorded for the treatment T_6 LTSS 50% + CDM 50%. Whereas the minimum number of leaves per plant (9.56, 10.31 and 9.94) was found in treatment T_1 Control during 2016-17 and 2017-18 with pooled data respectively.

The maximum root length (cm) (19.75, 21.71 and 20.73) was recorded for the treatment T_6 LTSS 50% + CDM 50%. Whereas the minimum root length (cm) (10.65, 16.54 and 13.60) was found in treatment T_1 Control during 2016-17 and 2017-18 with pooled data respectively.

The maximum root weight (gm) (131.94, 135.40 and 133.67) was recorded for the treatment T_6 LTSS 50% + CDM 50%. Whereas the minimum root weight (gm) (10.65, 16.54 and 13.60) was found in treatment T_1 Control during 2016-17 and 2017-18 with pooled data respectively.

The maximum root diameter (cm) (14.68, 15.26 and 14.97) was recorded for the treatment T_6 LTSS 50% +

CDM 50%. Whereas the minimum root diameter (cm) (9.63, 10.38 and 10.01) was found in treatment T_1 Control during 2016-17 and 2017-18 with pooled data respectively.

The maximum fresh weight of plant (gm) (229.22, 233.60 and 231.41) was recorded for the treatment T_6 LTSS 50% + CDM 50%. Whereas the minimum fresh weight of plant (g) (201.82, 204.48nd 203.15) was found in treatment T_1 Control during 2016-17 and 2017-18 with pooled data respectively.

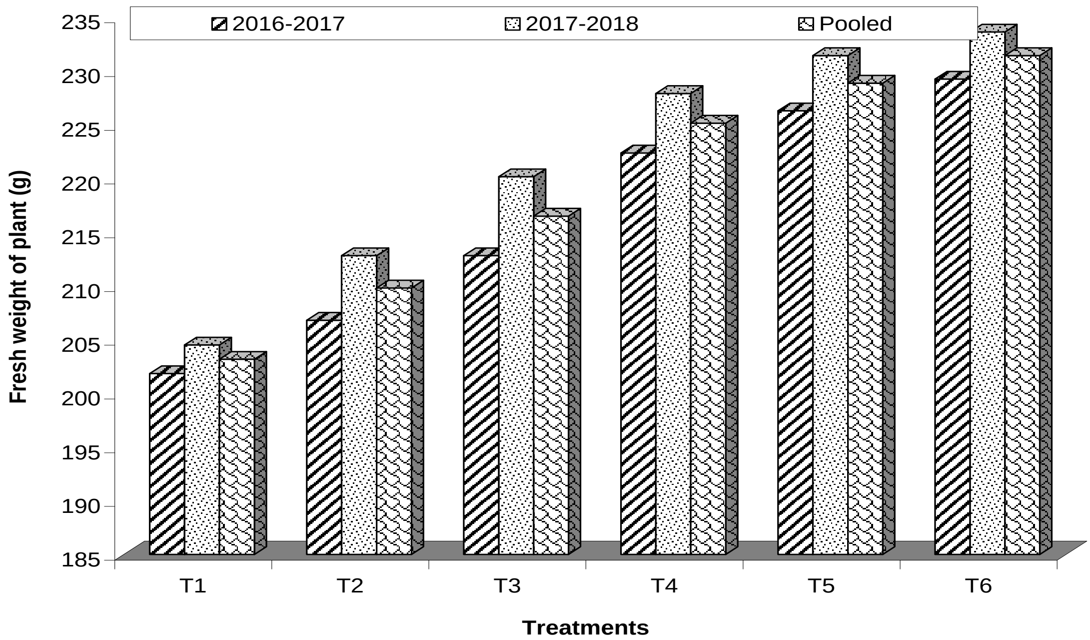

Fig. 3.5 Effects of Sewage sludge and soil management practices on Fresh weight of plant (gm)

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Prospects and strategies for enhancing Phosphorus efficiency in Soybean production in the Nigerian savannah Regions: A review

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***Abstract*— *Low crop production negatively affects most farming systems in Sub-Saharan Africa (SSA). Grain legumes like soybeans (Glycine max (L.) Merrill) tend to have lower yields in SSA due to various biological and environmental factors. Soybean is susceptible to low soil Phosphorus (P) levels and requires large amounts of P for adequate biological nitrogen fixation through its root nodules. Unfortunately, most small-scale African farmers face difficulties affording the exorbitant costs of mineral fertilizers as over 75% of the fertilizers used are imported, which puts a significant strain on local currencies. This research study has examined previous and ongoing interventions in phosphorus application, explicitly focusing on soybean cultivation in the savannah ecological zones of Nigeria. The aim is to identify the most effective ways to advise farmers on enhancing production and encouraging the adoption of efficient Phosphorus application methods to achieve optimal yields in the face of climate change challenges. The study's significant findings include the following key points: (1) Understanding the crop's morphology to guide appropriate varietal selection. (2) Identifying the soil qualities necessary for successful Soybean cultivation. (3) Determining the appropriate rate of Phosphorus application for optimal results. (4) Selecting the most efficient method of Phosphorus application. (5) Timing the application of Phosphorus correctly to maximize its effectiveness.*

Keywords*— *biological nitrogen fixation, internal use efficiency, Phosphorus deficiency, Phosphorus efficiency.

I. INTRODUCTION

Grain legumes are leguminous plants that produce dry, edible seeds. Soybean (*Glycine max* (L.) Merrill) holds global economic importance among these legumes. They are known for their substantial economic value as they contain a high oil content of around 18% and high-quality proteins of approximately 40%. In addition to its economic value, Soybean is crucial in enhancing soil fertility, promoting high productivity, and ensuring profitability in agricultural systems. Due to these remarkable attributes, experts often call Soybeans a "miracle crop" (Rajni *et al.*, 2020). Phosphorus (P) is a crucial nutrient limiting biomass production in legumes as it plays vital roles in various aspects of plant development. It is a key component of nucleic acids, proteins, ATP (adenosine triphosphate), genetic material, and energy storage and transfer. It is also essential for important plant processes such as photosynthesis, regulation of enzymatic activities, root development, and seed formation. Hence the application of P is reported to affect most Soybean growth and yield parameters (Tehulie *et al.*, 2021). This point was buttressed as Phosphorus absorption created a direct stimulation of cellular exercise in roots and leaves because it is a constituent of enzymes and proteins; adenosine diammonium phosphate (ADP), adenosine triphosphate (ATP), ribonucleic acids (RNA) and deoxyribonucleic acids (DNA). However, the extra addition of Phosphorus negatively influences soybean boom parameters such as leaf area, number of leaves per plant, leaf location index, number of nods per plant and spread of plants and others (Tehulie *et al*., 2021). The availability of Phosphorus is a critical factor that influences nitrogen fixation and the overall nitrogen economy in various tropical ecosystems (Bello, 2015). Yang *et al*. (2022) observed from their study that Leaf area index and plant height were generally increased with P in plants as it enhances leaf expansion, increasing light interception for photosynthesis and greater assimilating accumulation, they buttressed that P is an indispensable nutrient requirement for Soybean. In legumes, a deficiency of P has a substantial negative impact on growth and biomass accumulation. Insufficient P levels can constrain the proliferation of a population of free-living rhizobia in the rhizosphere consequently affecting nodulation and impairing nodule function. Ultimately, this limitation on nodulation and impaired nodule function hampers the overall growth of the host plant (Bello, 2015). Furthermore, Phosphorus (P) can enhance plant resistance by influencing the activation of genes related to resistance and defense characteristics through the jasmonate signalling pathway reducing susceptibility to various fungal diseases. Similar findings in other crops support this notion, as studies have shown that phosphorus application induces systemic resistance in Cucumber plants against *Colletotrichum legendarium* (the pathogen causing anthracnose) and in beans against *Uromyces viciae fable* (the pathogen causing rust) (Tchemadon *et al*., 2021).

Phosphorus efficiency is a plant's capacity to uptake phosphorus from the soil and efficiently employ it in the production of biomass or the development of harvestable organs (Tehulie *et al*., 2021). The Nigerian Savannas have experienced a significant boost in Soybean production due to the introduction of improved varieties. However, this production's sustainability could increase by improving the soil's prevalence of low phosphorus (P) levels. Compared to cereal crops, Soybean is more susceptible to Phosphorus insufficiency and drought, which prevents the attainment of their potential yield (Tehulie *et al*., 2021). In the tropical and subtropical regions where Soybean cultivation is widespread, the soils typically have a high capacity for phosphorus fixation, resulting in limited availability of Phosphorus for crops (Yang *et al*., 2022). Research has highlighted P-level variations across distinct Savannah regions in Nigeria. Soil phosphorus (P) levels in the Sudan and Guinea savannas of Northeast Nigeria are found to be majorly insufficient. P levels varied between 0.3 and 10.4 mg/kg in the Southern Guinea Savanna (SGS) in the Sudan Savanna (SS) spanned from 0.3 to 7 mg/kg. While in the Northern Guinea Savanna (NGS), the range was 1.4 to 9.5 mg/kg. Significantly, the study reported that most fields surveyed in these regions had P levels below the critical values (5-7 mg/kg) recommended for the Nigerian Savanna. Phosphorus deficiency was observed in 78% of fields in the Southern Guinea Savanna (SGS), 93% in the Sudan Savanna (SS) and 92% in the Northern Guinea Savanna (NGS) (Bello, 2015).

II. MATERIALS AND METHODS

This research was conducted as a review work. It was based on a systematic review of research publications where Phosphorus efficiency in Soybean fields played a central role. The literature analysis was first contextualized by presenting a brief overview of related scholarly articules, presenting a descriptive methodological analysis of field approaches in the production of Soybean. The review is descriptive and follows an integrative synthesis approach, which "attempts to summarize the contents of multiple studies and minimizes any interpretation on the reviewer's part". Several peer-reviewed journals and articles reporting the results of quantitative and qualitative research studies in Soybean production were utilized (Krippendorff, 2018).

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2.1 Collation and analysis of articules

Data from peer-reviewed journal articles were systematically selected and analyzed. This approach provides valuable insights into the effectiveness and impact of Phosphorus in Soybean production. This method conformed to the one Snelson (2016) used in selecting and analyzing reports, which proceeded through four stages: pre-research, search, data cleaning, and analysis.

2.1.1 Stage 1: Pre research

A thorough pre-research was conducted to conceptualize the topic and develop a clear and focused research plan by *defining the Scope*: The specific terminologies in Phosphorus efficiency in Soybean cultivation were thoroughly researched. *Literature Review*: An extensive literature review to understand the existing research and theories identifying key concepts, trends, and gaps. *Timeline and Resources*: A timeline was developed for the research project, identifying resources needed, such as access to literature databases. *Potential Impact*: the potential impact of the research and how the findings contribute to efficient Soybean cultivation theory, practice, and policies were observed.

2.2.2 Stage 2: Search

Google Scholar was included as one of the databases searched for during this literature review due to its broad reach across interdisciplinary academic scholarship indexed on the Internet and its use in prior literature review studies (Snelson, 2016).

2.2.3 Stage 3: Data Cleaning

The eligibility of articles for the review was determined by reviewing both abstracts and full-text copies. Selection criteria included publication in a peer-reviewed journal or academic literature, relevance to Soybean cultivation research, and the availability of a full-text English version of the article (Snelson, 2016).

2.2.4 Stage 4: Analysis

A qualitative content analysis methodology, based on a multiphase approach, was used to review the content at different time points and cross-check results for consistency. The articles had all been reviewed for eligibility for the study during the data-cleaning stage, but the actual analysis of content began with a round of review and tagging (Snelson, 2016).

III. RESULTS AND DISCUSSION

3.1 Achieving Phosphorus Efficiency in Soybean Production in The Savanna Regions of Nigeria.

Depending on the fertilisation method, tillage system, and variety employed, the response of soybeans to P fertilisation can vary. The high cost of P fertiliser in SSA restricts its use, while organic inputs' low P content prohibits them from releasing sufficient P for optimal crop growth (Bello, 2015). Phosphorus is immobile in soil; therefore, plant uptake of Phosphorus may additionally be low in the first year after application (Tehulie *et al.*, 2021). Studies have shown that using phosphate sources with associated technologies increased the soybean crop's relative agronomic efficiency and productivity (Soares *et al.*, 2021). The following should be considered to achieve phosphorus fertilizer efficiency;

3.1.1 Varietal Selection

The selection of the appropriate Soybean variety significantly impacts the efficiency of P. Different Soybean cultivars exhibit varying responses to factors like flood irrigation, and the root system of the plants plays a crucial role in adapting to adverse conditions such as dry regions or poorly drained soils (Nunes *et al.*, 2021). The interaction between varieties and Phosphorus on the yield of Soybeans planted on a field in the Gwagwalada area (North Guinea Savannah) of Nigeria is presented in Table 1. The V x P interaction significantly impacted the yield (Kg/ha), indicating that all varieties exhibited higher yields with Phosphorus than the control. Moreover, there was variability among the different varieties at the same Phosphorus application rate, with certain varieties demonstrating notably higher yields. This pattern was consistent in the in two trial locations in Borno State (Sudan Savannah) during the 2004 and 2005 cropping seasons (Table 2). as well as the Lafia (North Guinea Savannah) during the 2018 and 2019 cropping seasons (Table 3),

Table 1: Interaction between Varieties and Phosphorus on the Yield (Kg/ha) of Soybean in 2022 at the University Research farm, Gwagwalada, Abuja

Yield (Kg/ha)			
	Phosphorus levels (Kg/ha)		
Varieties	**0**	**20**	**40**
TGX 1485-1D	2054.1e	2322.9d	2633.9bc
TGX 1448 -2E	2148.7e	2484.3cd	2971.5a
TGX 1987-10F	2413.4d	2711.6b	2972.2a
SE± 59.87			

Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT), SE=Standard error

Culled from effects of Rhizobium (*Bradyrhizobium japonicum*) inoculation and phosphorus fertilizer rate on the nodulation, growth and yield parameters of soybean [*Glycine max* (l.) Merrill] varieties in the Southern Guinea Savanna of Nigeria by Adeshina (2023).

Table 2. The yield (kg/ha) of four Soybean varieties assessed under three P fertilizer rates in two trial locations in Borno State in 2004 and 2005 cropping seasons.

Variety	Phosphorus levels (Kg/ha)		
	0	**20**	**40**
TGX 1448 -2E	1200	1850	2110
TGX 1904 -6F	1280	1890	2180
TGX 1485 -1D	1190	1870	1960
TGX 1830 -20E	1280	1910	1810
Mean	1240	1880	2020
SED (Phosphorus)		70	
SED (Variety x Phosphorus)		140	

(r =0.82, p ≤ 0.001), number of pods per plant (r =0.67, p ≤ 0.001), and seed weight (r =0.66, p ≤ 0.001). Grain yield was also weakly but significantly associated with harvest index.

Culled from Phosphorus effects on yield of Soybean by Kamara *et al*., 2007.

Table 3. Impact of Phosphorus and Variety on Seed yield of Soybean during the 2018 and 2019 cropping seasons in Lafia.

Treatment	Seed Yield (Kg/ha)		
	2018	**2019**	**Combined**
Phosphorus (Kg/ha)			
0	949.0[d]	958.0[d]	953.5[d]
13	1068.7[c]	1110.0[c]	1089.4[c]
26	1289.0[b]	1306.0[b]	1297.5[b]
39	1561.3[a]	1606.7[a]	1584.0[a]
LSD (0.05)	0.46	0.42	0.8
Variety			
TGX 1985 -10F	834.0[c]	853.3[c]	843.7[c]
TGX 1987 -10F	1126.0[c]	1160.7[c]	1143.4[c]
TGX 1448 -2E	949.3[d]	952.0[d]	950.7[d]
TGX 61987 -62F	1543.3[b]	1526.7[b]	1535.0[b]
TGX 1989 -19F	1591.7[a]	1624.0[a]	1607.9[a]
TGX 1835 -10E	786.7[f]	803.0[f]	794.9[f]
LSD (0.05)	0.56	0.51	0.9
Interactions			
P x V	NS	NS	NS

Values of the same letter (s) in each column of treatment group are not significantly different at 5% level of significance. NS – Not significant.

Culled from Seed yield and economic returns of Soybean (*Glycine max* (L.) Merill) influenced by Phosphorus fertilizer rates and varieties at Lafia, Nasarawa State by Jibrin *et al*., 2021.

These results buttress the point that several Soybean varieties have been developed to thrive in different environmental conditions to ensure proper absorption of soil P, optimal growth, and long-term crop productivity. The interaction between soil P and roots occurs primarily through diffusion; it is essential to have roots capable of effectively absorbing the nutrient, thus emphasizing the importance of a robust root system for P availability (Nunes *et al*., 2021).

Soybeans employ various strategies to acquire P, which involve a combination of below-ground morphological, physiological, and symbiotic traits (Wang *et al*., 2022). The roots display a high degree of plasticity, both physiologically and morphologically, in response to the availability of nutrients in the soil. It is essential to avoid high concentrations of P in a small volume of soil, as it can harm the apical meristem of the roots (Nunes *et al*., 2021). Therefore to achieve optimal yields it is imperative that the variety suitable for a region should be used.

3.1.2 Rate of fertiliser applied

Phosphorus fertilizer administration poses significant challenges in many tropical soils due to their low native content and the high immobilization within the soil. It is a reactive element which does not exist in its elemental form in the soil; as such most of the P in most soils is present in insoluble forms that are inaccessible to plants. Excess and under-application of Phosphorus will adversely affect soybean growth, yield and yield components (Tehulie *et al*., 2021). From an agronomic perspective, it is essential to employ crop management strategies that increase P efficiency and decrease the demand for fertilizers (Ibrahim and Ibrahim, 2019). In fertile soil, an extensive element of the total Phosphorus is in slightly soluble forms, which act as a "ready reserve" to fill up the pool of soluble Phosphorus as it is depleted by other organisms (Ibrahim and Ibrahim, 2019). Continuous application of P fertilizers to soybeans may lead to a build-up of available P in the soil, reducing the subsequent P application rate. Several studies have evaluated the response of Soybeans and other crops to applied and residual P in the soil (Bello, 2015).

Scientists agree that Soybean responds to P readily, but the optimum level has remained in contention, hence, figuring out the ranges of Phosphorous fertilizer is an essential consideration for maximizing crop yield. The recommended rates for phosphorus use vary by location and are determined by the local soil conditions (Tehulie *et al*., 2021). In the survey in Gwagwalada 2022 to evaluate different Soybean varieties at varying phosphorus rates, 40KgP/ha rate showed the highest yield for all varieties studied (Table 1). In Borno, a rate of 40KgP/ha resulted in the highest yield across all varieties (Table 2), while for the case of Lafia, the optimal rate was 39KgP/ha (Table 3) under examination. These results can be attributed to the notable role Phosphorus plays in improving soybeans' growth yield and quality. Findings showed that the nodule formation of Soybeans is directly dependent on applying P fertilizer. However, though the application of Phosphorus increases the yield of soybeans, on the other hand, the application of surplus quantity will lead to adverse effects on the yield of soybeans (Khan *et al*., 2020). This position was supported by Soares *et al*. (2021) who suggested that applying Phosphorus (P) fertilizer resulted in a positive response in Soybean grain yield as it facilitated the biological nitrogen fixation process by nodules in legumes, which depend on an ample Phosphorus supply. However excessive application of Phosphorus can restrict plant nodulation. Accurate estimation of crop nutrient demand, seed nutrient removal, and the availability of nutrients from native soil sources is essential for sustainable fertilization and balanced nutrition. Achieving these objectives requires optimizing nutrient use efficiency (Bomeisl *et al*., 2020).

3.1.3 Internal Use Efficiency

The commonly employed metric for guiding fertilizer recommendations is internal use efficiency, defined as the total nutrient uptake or removal with seeds per unit of seed yield. This approach operates under the assumption that replenishing seed nutrient removal is necessary to maintain nutrient budgeting (Salvagiotti *et al*., 2021). Beyond nutrient uptake, it is crucial to consider the proportion of seed nutrient removal and the nutrients remaining in residues to effectively quantify fertilizer repositioning and estimate nutrient recycling within the system (Salvagiotti *et al*., 2021). Based on the local soil conditions, different regions have different suggested rates for using Phosphorus (Tehulie *et al*., 2021). The application of a phosphorus fertilizer showed an increase in agronomic efficiency at 40 and 80 kg/ha P_2O_5, and the highest values of agronomic efficiency were obtained at doses above 80 kg/ha P_2O_5. Usage of the appropriate phosphorus fertilizer rates promotes the growth of Soybean significantly (Soares *et al*., 2021, Tehulie *et al*., 2021).

3.2 Method of Phosphorus application.

Aside from determining the optimal rate for each region, the application method is critical to success. Given that phosphorus is recognized as a non-mobile nutrient in the soil the fertilizer placement strategy can greatly improve nutrient use efficiency for different soybean varieties consequently affecting their productivity (Rosa *et al*., 2020). Ensuring sufficient phosphorus uptake, promoting crop growth, and achieving optimal grain yield over the long term requires the implementation of management systems that enhance the bioavailability of phosphorus in the soil and facilitate its accessibility by plant roots. Some application methods used for fertilizer placement include broadcast and incorporation, pinnacle dress, seed-positioned Phosphorus, and aspect banding phosphorus. Under the no till system of cropping using the broadcast and band placement methods is advantageous. This is due to the advantage in labour, cost and time of application. It has also been observed that applying P to the surface makes it more accessible to plant increasing access to the roots as P is a highly immobile nutrient (Rosa *et al*., 2020). In non-tillage systems, there is a notable difference in the depth distribution of Phosphorus, with P accumulating in the fertilizer application zone. This zone is typically within 0-5 cm deep for broadcast application, while for row application, it extends to 5-10 cm deep. In contrast, traditional tillage results in a more uniform dispersion of phosphorus throughout the soil profile, exhibiting relatively higher concentrations below 10 cm deep. Despite these disparities in distribution, the average phosphorus content in the 0-20 cm profile remained comparable across both soil management systems and application modes (Nunes *et al*., 2020). Applying phosphate fertilizer in rows reduces soil contact, leading to a smaller fertilized area. However, this method enhances phosphorus availability compared to broadcast application and reduces the depth gradient (Nunes *et al*., 2020). Research findings indicated that the application of phosphorus in bands near soybean seeds produced superior outcomes compared to broadcast treatment in soils characterized by low phosphorus levels (Rosa *et al*., 2020).

3.2.1 Timing of Phosphorus application

The timing of application plays a significant function in the proper development of crops, as some strategies are more environmentally friendly than others (Tehulie *et al*., 2021). Band applications of P fertilizer aid in optimizing P availability during Soybeans' early growth and reproductive (Rosa *et al*., 2020). Research has indicated that around 75% of Soybeans' P concentration in the seeds and the yield are greatly influenced by its uptake during the reproductive stages as the highest P uptake occurs at this period and employing management strategies that improve P uptake is crucial during this growth stage.

3.3 Choice of soil used for planting

The soil used for planting is a critical factor in achieving Phosphorus efficiency as the soil pH., Soil type, Soil Cation exchange capacity (CEC), and availability of Organic materials play a significant role.

3.3.1 Soil pH

Soil pH is the degree of hydrogen ions present in the soil and is represented by a negative logarithm of hydrogen ions concentration; it indicates the general chemical environment in the soil. It is a measure of relative acidity and alkalinity. A soil of pH 7.0 is neutral; *acid soils* are defined as soils with pH below 7.0 and above seven are alkaline. The pH of the soil influences the nutrient available to plants as it plays a crucial role in influencing the availability of P, plant nutrients, and microbial activity, including atmospheric nitrogen (N) fixation by nodules. Limited phosphorus availability in tropical soils poses a notable constraint to soybean production. Studies indicate that optimal phosphorus availability occurs within a pH range of 6 to 7. In ferrasols, the pH typically ranges from 5.0 to 6.0, and several other soil properties can impact nutrient availability (Philips, 2021). Phosphorus is readily available in soils with slightly acidic to near-neutral pH levels. However, P is a nutrient that exhibits low mobility in soil and is naturally deficient in acidic soils. Its availability is regulated by solubility and the propensity to become fixed in the soil through reactions between aluminium and phosphorus, forming insoluble phosphate precipitates. P-fixing soils are common in tropical regions, and highly weathered tropical soils possess a high capacity to adsorb P, consequently reducing the availability of P inputs for crops (Bomeisl *et al*., 2020).

Soybean roots take up Phosphorus primarily in the ionic structure of either H_2PO_4 or HPO_4 (orthophosphate). The ionic form that is predominantly absorbed depends on soil pH; H_2PO_4 is easily absorbed in low-pH soils, whereas PHO_4 is preferentially absorbed in high-pH soils. There are two forms in which Phosphorus can exist in water: dissolved (soluble) and particulate (affixed to or a part of particulate particles). Ortho phosphorus is the principal dissolved phosphorus structure accessible to algae and aquatic plants. Most Phosphorus discharged from wastewater remedy services is dissolved (Tehulie *et al*., 2021). Soil's acidity hinders the symbiotic fixation of N_2, limits Rhizobium survival in the soil, decreases nodulation, and leads to nutrient imbalance. Challenges with soil acidity constitute a significant factor in low yields, weak plant vigour, and nodulation of legumes. At a pH of 4.3, Rhizobium rhizosphere growth and nodulation were inhibited (Dabessa and Tana, 2021). When the soil pH is 7.0, both types of P exist in equal quantities. However, as the pH level increases beyond 7.0, the dominance of P shifts towards the secondary orthophosphate ion. Its uptake is frequently constrained under very low solubility in the soil (Tehulie *et al*., 2021). The pH of the soil plays a crucial role in influencing the survival and longevity of beneficial microorganisms, such as Rhizobia, and their interactions with plant roots; It influences the function and association of arbuscular mycorrhizal (AM) fungi with plant roots. In acidic soils, there tends to be an abundance of acidobacteria, which are potential antagonists of fungi, including AM fungi, suppressing their activity (Wang *et al*., 2022). In the Western and Eastern Wollega Zones of Ethiopia, farmers had to temporarily or permanently abandon their land (fallowing) in certain areas due to the challenges of poor fertility and soil acidity However, with increasing population pressure, abandoning farmland is no longer feasible. As a result, farmers are adopting soil fertility management practices to sustain productivity and address the challenges of soil acidity and low fertility (Dabessa and Tana, 2021). It is not recommended to utilize highly soluble Phosphate fertilizer sources that have a higher capacity for P adsorption in acidic tropical soils. These soils can quickly convert P to less available forms and decrease fertilizer efficiency. Instead, it is advisable to use reactive natural P sources that promote gradual phosphorus solubilization. This approach limits specific adsorption by clays and enables greater fertilizer efficiency, which is more desirable (Nunes *et al*., 2021).

3.3.2 Soil Cation exchange capacity (CEC) and availability of Organic materials in soil

Despite large amounts of P in a soil it may still be unavailable for absorption to the plants due to challenges of dissolved P fixation and low solubility. Aluminum (Al), iron (Fe), calcium (Ca), potassium (K), and magnesium (Mg) can undergo reactions with phosphorus fertilizer, resulting in the formation of compounds that are not readily soluble (Faozi *et al*., 2019). Studies indicate that phosphorus is most accessible within a pH range of 6 to 7, but this accessibility is influenced by its solubility and how readily it becomes fixed in the soil due to aluminium reacting with phosphorous to form insoluble phosphate precipitates (Philips, 2021). In acidic soils characterized by elevated levels of aluminum (Al), iron (Fe), and manganese (Mn), phosphorus fixation takes place in the form of aluminum-phosphate (Al-P), iron-phosphate (Fe-P), and manganese-phosphate (Mn-P). These compounds are poorly soluble, rendering phosphorus unavailable to plants (Dabessa and Tana, 2021). In response to various environmental conditions, particulate Phosphorus can switch from one structure to another (a process known as cycling). The component is found in organic matter such as algae, plant and animal tissue, waste solids, or other naturally occurring materials that can be counted (Tehulie *et al*., 2021). Phosphorus is introduced into the biosphere as microorganisms and plants absorb it, and its release into the soil occurs during the decomposition of organic materials. The amount of phosphorus in the soil can be influenced by organic matter, as approximately 20-80% of its overall phosphorus comes from alterations in organic matter. Fertilization in the form of manure, mineral fertilizer, and sewage sludge is recommended to enhance the availability of phosphorus in the soil. However, it's important to note that the distribution of the phosphorus element can be influenced by soil and environmental conditions, which can lead to either concentration or leaching (Faozi *et al*., 2019). Microbial decomposition of natural compounds can convert natural particulate P to dissolved Phosphorus. Some of the Phosphorus in soil mineral particles can additionally be transformed to dissolve P both in the water column and at some stage in chemical and physical modifications in backside sediment (Tehulie *et al*., 2021).

3.3.3 Soil type

P-fixing soils are common in tropical regions, and highly weathered tropical soils have a solid ability to adsorb P, resulting in reduced P availability for crops. In soils with higher R_2O_3 and clay materials there was a decrease in yields Soybean yields. As opposed to this, yields in sandier soils containing higher soil test P levels were unaffected by lower P inputs even in severely worn and P-fixing soils, as residual soil P can support crop output. They recommend lowering reliance on phosphate rock fertilisers (Bomeisl *et al*., 2020).

IV. CONCLUSION

Despite recent improvements in P management, more research is required to determine the environmental suitability of varieties and recommended rates for different regions based on their local soil situation (Rosa *et al*., 2020). Farmers need to have a thorough understanding of the precise determination of crop nutrient requirements, seed nutrient removal, contribution of nutrients by indigenous soil sources, and the optimization of nutrient use efficiency in achieving sustainable fertilization. Utilizing residual Phosphorus (P), often referred to as "legacy P," present in the soil and accumulated over time, can be crucial in supporting crop yields. By harnessing this residual P, it is possible to reduce the reliance on P fertilizers to sustain the future global food system. This approach helps conserve valuable non-renewable P resources and enhances the effectiveness of P fertilization, maintaining a balanced nutrition to promote a healthier environment in agriculture (Bomeisl *et al*., 2020).

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author (s).

DATA AVAILABILITY STATEMENT

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

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Productivity and Cost Analysis of Chinese Cabbage (Brassica rapa) in Hydroponic Wick System Based on Formula

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Abstract— *Organic fertilizers have emerged as a vital alternative to address the environmental and human health concerns associated with the use of inorganic fertilizers. This research aims to develop the right nutrient formula for cultivating Pak Choi (Chinese cabbage) using the Wick hydroponic system. Considering factors such as variety selection, cultivation system, and nutrient requirements, this study explores the productivity of Pak Choi plants and the cost structure of cultivation. The research methodology involves testing various nutrient formulas and observing post-harvest plant metrics like wet weight, leaf width, leaf count, and plant height. Descriptive analysis and ANOVA tests reveal significant differences among treatments in plant morphology. Furthermore, cost analysis highlights the efficiency and profitability of each treatment, with Treatment F3 emerging as a cost-effective option with low expenses and good gross profit. These findings offer practical guidance for farmers to enhance vegetable production economically and sustainably in hydroponic cultivation.*

Keywords— ***Productivity, Hydroponics, Formula.***

I. INTRODUCTION

Fertilizers play a crucial role in increasing agricultural production nowadays. However, long-term use of inorganic fertilizers can harm the environment and human health. The rising prices of chemical fertilizers have led to a decrease in purchasing power among communities, resulting in reluctance to cultivate vegetables, even though the government has subsidized inorganic fertilizers. The use of inorganic fertilizers is also increasing, while the raw materials for fertilizers are depleting (Utami Lestari et al., 2018). One example of an inorganic fertilizer is ABMix hydroponic fertilizer, suitable for both leafy and fruit vegetables. The need for fertilizers in hydroponic technology is crucial, especially since the medium used is water and nutrients. If the nutrient requirements are not met or the fertilizers are not applied properly, the plants cannot grow vigorously. Organic fertilizers provide a solution to the current fertilizer situation, as they can utilize green plants around us that contain the necessary elements for plants to grow vigorously, such as Moringa oleifera, Azolla Microphylla, Ananas comosus, fruit waste, and household waste. Liquid organic hydroponic nutrients are organic nutrients derived from natural or plant-based sources that can be used to combine with inorganic fertilizers to reduce costs.

Pakcoy (Brassica rapa) is a popular vegetable among Indonesian farmers because it is easy to grow conventionally, either in hydroponics or directly in soil (Putri et al., 2023). According to Kilmanun (2020), the highest revenue is obtained from Pak Choy vegetables, totaling Rp. 1,400,000 out of Rp. 4,385,000. The types of vegetables cultivated include green lettuce, sweet mustard greens, spinach, and water spinach, as Pak Choy is highly sought after by consumers due to its delicious taste. When producing hydroponic vegetables, it is necessary to consider the types of vegetables and tailor them to the preferences of consumers or customers. One of the popular agricultural cultivation methods in urban areas is hydroponic farming. Hydroponic cultivation not only requires the right nutrients but also requires selecting a system suitable for the characteristics and types of plants. One cost-effective hydroponic system is the wick system.

According to Putera T.D. (2015), the wick system is a static or passive hydroponic system that relies on the capillary principle of water through the use of a wick as a mediator. This hydroponic system is simple, as it does not require electricity or a water pump for nutrient distribution, resulting in cost efficiency. Referring to previous research, Sri Utami (2018) discussed the chemical elements using Azolla plants for leafy vegetable plants. The analysis of Azolla microphylla compost composition shows a total N of 2.57%, available P of 0.54%, and K of 0.03%. According to Fahmi et al. (2020), the treatment with various concentrations of ABMix nutrients and banana rhizome organic compound (POC) showed that the best nutrient concentration was ABMix 8.5 ml/L and POC 40 ml/L water, resulting in plants with a 35-day growth period (21.3 cm), leaf count (9 leaves), leaf area (3.14 cm), and fresh weight (22.14 g). In previous research, POC used was a single POC, so it is necessary to combine other ingredients to meet the macro and microelement contents required by vegetables, especially leafy vegetables such as Chinese cabbage. Based on the above facts, the author is interested in analyzing the appropriate organic fertilizer formula to increase the productivity of Chinese cabbage (Pakcoy) and minimize cultivation costs. The analysis process also considers factors that influence plant productivity, including selecting superior varieties, cultivation systems, and nutrient requirements such as nitrogen (N), phosphorus (P), and potassium (K), as well as several other micronutrients such as calcium (Ca), magnesium (Mg), and others. This research aims to: 1) Determine the optimal nutrient formula for Chinese cabbage growth in the wick hydroponic system. 2) Measure Chinese cabbage productivity (plant wet weight, leaf width, leaf count, and plant height) in the wick hydroponic system. 3) Analyze the cost structure of Chinese cabbage cultivation by applying various nutrient formulas in the wick hydroponic system. 4) Plan Chinese cabbage production using the wick hydroponic system. According to Dahlan et al. (2017), hydroponic vegetable cultivation has advantages and disadvantages. Its advantages include: (1) Easy renewal of plants without depending on land conditions and seasons, (2) Growth and harvest quality can be controlled, (3) Labor-saving, (4) Clean and more hygienic products, (5) Water and fertilizer savings (environmentally friendly), (6) Shorter cultivation period, (7) Low operational costs. However, its disadvantages include: (1) Higher initial investment costs, (2) Highly influenced by fertilizer composition and concentration, pH, and temperature. Dewi et al. (2020) conducted research on the effect of rice washing water waste on the growth of Pak Coy Chinese cabbage using the wick system. This research lasted for 27 days with three repetitions. Good Plant Nutrition Concentration and Rice Washing Water Waste factors became the RAL analysis factors in this study. The observed parameters included plant height, leaf count, wet weight, initial water pH, and final water pH. There was no significant relationship between good plant nutrition and rice washing water waste. The research results showed that rice washing water waste did not affect plant height, leaf count, wet weight, initial water pH, and final water pH; however, good plant nutrition affected the leaf count at twenty days after planting, but not the plant height at ten or thirty days after planting. Feni et al. (2017) investigated the costs and profits of vegetable farming in the Ratu Agung District, Bengkulu City. In that area, water spinach, mustard greens, and spinach are the most commonly cultivated vegetables. This study used proportional random sampling survey methods. Both primary and secondary data were used in this research. As a result of the study, vegetable farmers in the Ratu Agung District, Bengkulu City, have the potential to meet the demand for vegetables in Bengkulu City. The R/C value of the three types of vegetables is more than 1, indicating that this business is profitable. In addition, except for spinach vegetables with a B/C ratio of less than one, the Break Even Point (BEP) volume of production and BEP price for all types of vegetables have exceeded the break-even point. Arianto (2021) conducted research on pakcoy Chinese cabbage farming in the Medan Deli District, North Sumatra. The purposive sampling method, which means intentionally selecting samples according to the required sample criteria, was used in the sample determination process. Both primary and secondary data were used in this research. Analysis of revenue, income, average cost (AC), and Cost Revenue Ratio (R/C) are some of the data analyses conducted. The research results showed that pakcoy Chinese cabbage farming in the Medan Deli District, North Sumatra, has the following costs and profits: fixed costs amounted to Rp 87,472,000.50, variable costs amounted to Rp 272,747,000.00, with a total cost of Rp 360,219,002.50 and an average cost of Rp 12,007,300.08.

Revenue reached Rp 666,320,000.00, with an average revenue of Rp 22,210,666.67. Pakcoy Chinese cabbage farming in the Medan Deli District, North Sumatra, generated an average income of Rp 10,203,366.58, with a total income of Rp 306,100,997.50. Pakcoy cabbage farming has a Cost Revenue Ratio (R/C) of 1.8, meaning that every Rp 1 expenditure can generate Rp 1.8 in revenue. Since the R/C result is greater than 1, it can be concluded that pakcoy cabbage farming is profitable and worthy of development. Rizal's study (2017) was conducted from January to April 2017 at the Integrated Laboratory of PGRI University Palembang. This study investigated the effect of nutrients on the growth of pakcoy Chinese cabbage (Brassica rapa L.) cultivated hydroponically. This study used a Completely Randomized Design (CRD) with three treatments and nine replications. Additionally, the wick hydroponic system was used for cultivation. Three nutrient treatments were used in this study: AB mix (N1), liquid organic fertilizer (N2), and NPK+growmore (N3). The research results show how the fertilizer concentration given to hydroponically grown pakcoy Chinese cabbage affects its growth. Liquid organic hydroponic nutrients are natural or plant-based nutrients derived from organic sources through anaerobic or airtight fermentation processes, with the addition of bioactivators, namely decomposing bacteria, to accelerate the composting process. Bacteria contained in bioactivators include lactobacillus sp, Azotobacter sp, Rhizobium sp, Pseudomonas sp, T., as well as Tricoderma sp, Actinomycetes sp, pathogenicity, nitrogen fixers, and phosphorus solubilizers. For the composting process to run smoothly, food for these bacteria is needed, which can be sugar cane syrup or brown sugar. The elements contained in NHOC already include macro elements needed by plants for vigorous growth. The application of NHOC to plants ensures healthier vegetable quality and fewer chemical residue contents. The materials used for liquid organic hydroponic nutrients include Moringa, Azolla, Pineapple, and coffee grounds. According to Tjendapati (2017), POC nutrient application can be carried out during seedling or when vegetable seedlings are already in the hydroponic installation, with a ratio of 1:5, meaning that for every liter of POC, 5 liters of clean water are used, and 1 liter of POC is added every two days. POC nutrients can be used for various types of leafy vegetables. The growing medium used in the wick hydroponic system can be rockwool, rice husk charcoal, or sawdust. Sponge waste can be used as a substitute for rockwool. The medium used must be sterile to avoid contamination by pests and plant diseases, as this will affect the plant growth process in hydroponic vegetable seedlings.

II. LITERATURE REVIEW

2.1 Cost Theory

According to Novitasari D. (2020), investment cost is the amount of money used by business owners at the beginning of starting a business. Operational costs consist of fixed costs and variable costs. Fixed costs are expenses incurred for business operations that are not affected by the quantity and do not deplete within one production cycle. Variable costs are expenses whose amount is influenced by the quantity of production. The total cost incurred each year is the sum of total fixed and variable costs. According to Kilmanun J.C (2020), vegetable cultivation with hydroponic systems is considered exclusive because it requires significant expenses. The exclusive vegetable market has not been fully tapped yet, so the market opportunities remain wide open because hydroponic vegetables are needed by supermarkets, cafes, and hotels in big cities.

2.2 Moringa Plant

The moringa tree (Moringa oleifera) almost all parts of the plant can be a high-nutrient food source, ranging from leaves, stems, fruits, flowers, to young roots, moringa seed cake with its high mineral and protein content is excellent for use as organic fertilizer. Moringa leaves contain seven times the vitamin C of oranges, four times the calcium of milk, four times the vitamin A of carrots, twice the protein of milk, and three times the potassium of bananas (Suwahyono, 2008). Sources of organic fertilizer Waste extraction of oil and coagulant compounds from moringa seeds, in the form of seed cake, can be utilized as fertilizer because it contains a lot of protein, especially as a source of microelements needed by plants (Suwahyono, 2008). Moringa leaf extract as an effective fertilizer, moringa leaves contain active compounds like zeatin, categorized as plant hormones from the Cytokinin group, as leaf fertilizer and also functions as a protectant that makes plants resistant to pest attacks and diseases.

2.3 Azolla Plant

The Azolla plant can be cultivated and contains the nitrogen elements required by leafy vegetable plants. The parts of the Azolla plant can be used for organic nutrition in plant cultivation (Widodo, 2015). According to Kusumaningsih (2023), the combination of liquid organic fertilizer application from Azolla has an impact on the growth of plants in floating raft installations. Azolla plants, often referred to as "mosquito fern" or "water fern," are small aquatic plants that thrive in freshwater environments. They are known for their ability to fix nitrogen from the atmosphere, making them valuable contributors to soil fertility. Cultivating Azolla can provide a sustainable source of organic nitrogen for various crops, particularly leafy vegetables, which have high nitrogen requirements for vigorous growth.

Research conducted by Widodo in 2015 highlights the significance of Azolla as a source of organic nutrition in plant cultivation. The plant's nitrogen-rich composition makes it an ideal supplement for promoting the growth and development of leafy vegetables. Azolla can be incorporated into agricultural practices as a natural fertilizer, reducing the reliance on synthetic fertilizers and promoting environmentally friendly farming methods. Furthermore, recent findings by Kusumaningsih in 2023 emphasize the positive impact of applying liquid organic fertilizer derived from Azolla on plant growth, particularly in floating raft installations. This suggests that integrating Azolla-based fertilization techniques into hydroponic or aquaponic systems can enhance the overall productivity and sustainability of vegetable cultivation practices.

2.4 Pineapple Plant

When ripe, pineapples have a sweet taste, but when overly ripe, they can taste slightly tangy due to their high oxalate acid content. Within the fruit, there is bromelain, an enzyme that acts as a protein digestant (meat tenderizer). Pineapple waste is commonly used to produce liquid organic fertilizer (Sunarjono, 2010). Pineapples, known for their tropical flavor and juicy texture, undergo significant chemical changes as they ripen. Initially, the fruit's acidity gives it a refreshing tang, but as it matures, the sugars increase, leading to a sweeter taste profile. However, if left to ripen for too long, the fruit can develop an overly acidic taste due to the accumulation of oxalic acid.

Bromelain, found abundantly in pineapples, is a proteolytic enzyme that breaks down protein molecules. This enzyme's presence contributes to the tenderization of meat, making pineapple juice or extracts a popular choice for marinades or meat tenderizers in culinary applications. Additionally, pineapple waste, such as peels and cores, contains valuable nutrients and organic matter. Sunarjono's research in 2010 underscores the utilization of pineapple waste as a raw material for producing liquid organic fertilizer. This sustainable practice not only reduces waste but also harnesses the nutritional benefits of pineapple residues to enrich soil fertility, promoting healthier plant growth in agricultural settings.

2.5 Hydroponic Wick System

Hydroponic vegetable cultivation is a farming method that can be applied in limited land areas, typically in urban regions but also found in non-urban areas. There are various types of hydroponic systems, including the Wick System, NFT system, Drip System, Floating Raft System, Aeroponic System, Ebb and Flow System, Aquaponic System, and Deep System (Nugroho, 2016). Hydroponic systems that require minimal costs can utilize the Wick System. This system is cost-effective in installation and does not require a water pump, thus saving electricity costs and making it accessible to people of various ages.

In this system, the addition of a wick is used, which can be made of flannel cloth or recycled fabric that absorbs plant nutrients, ensuring adequate moisture conditions and nutrient supply without excessive use. The materials used in the installation can be recycled, and maintenance of the Wick System hydroponic installation is relatively easy and straightforward. Vegetables commonly cultivated in this system are leafy vegetables such as pak choi, Chinese cabbage, kale, spinach, and lettuce. Wick systems that use buckets or Dutch buckets can be used for fruiting vegetables such as chili, eggplant, tomato, cucumber, and others. The growing medium used in hydroponic wick systems can be rockwool, rice husk charcoal, or sawdust. Sponge waste can be used as a substitute for rockwool. The medium used must be sterile to avoid contamination by pests and plant diseases, as this will affect the plant growth process in hydroponic vegetable seedlings.

2.6 Production theory

Production is an activity aimed at increasing the value of a product by involving several factors of production together (Rahmadani, n.d., 2020), an activity conducted to transform inputs into outputs or to add value to the outputs. In a production process, inputs are required in the form of factors of production, which are tools or resources used in production activities. According to Rahmadani (n.d., 2021), factors of production include: (1) Natural resources, the earth and all its contents. (2) Labor, which involves individuals with skills and integrity. (3) Capital, encompassing all goods used to support the production process. (4) Management Organization, to manage activities within the business.

According to Harahap QH (2018), in hydroponic vegetable production, plants not only require a growing medium to support their growth and a suitable nutrient solution for plant growth and production but also require sufficient sunlight for the photosynthesis process. This proves that the height of the plant, number of leaves, leaf width, leaf color, and yield of pak choi plants are inseparable from the combination of treatments between the growing medium and the nutrient solution provided. The most influential type of nutrient on pak choi plant growth is the ABMIX fertilizer, while the growing medium that affects plant height, leaf area, leaf color, number of leaves, plant weight, and plot weight is using Rockwool.

According to Zahara VM (2021), the production function is a function or equation that shows the physical or technical relationship between the amount of production factors used and the amount of product produced per unit of time, without considering prices, both for production factor prices and product prices. The Production Function is the technical relationship between input (independent variable) and output (dependent variable). Basic assumptions about the nature of the production function are used in economic theory, where the problem is subject to the Law of Diminishing Returns (a law stating that the aim of production includes: (1) Maintaining business continuity by continuously increasing the production process, (2) Increasing business profits by minimizing production costs. (3) Increasing the quantity and quality of production. (4) Obtaining satisfaction from production activities. (4) Fulfilling the needs and interests of producers and consumers.

According to Ma'arif et al., (2022), production factors include land area, labor, seeds, nutrients, and medications. According to Kilmanun J.C (2020), the amount of production and price greatly affect revenue, with the average selling price of hydroponic vegetables being Rp. 5,000 per net pot. Increasing consumption of hydroponic vegetables provides significant opportunities for hydroponic vegetable production businesses. According to Harahap, Q.H (2018), the causes of decreased cabbage production are: 1) Decreasing interest of farmers in growing vegetables because it is considered unprofitable and many agricultural land areas are being converted, and there is currently a lot of imported vegetables. 2) Decreasing agricultural land conditions, while on the other hand, the fulfillment of food needs from agricultural products is increasing, if this condition is left unchecked, it is not impossible that in a few years we will experience a vegetable shortage.

Research on Production and Cost Analysis of pak choi based on ABMix and NHOC nutrients. This research system is an experimental type of research with a completely randomized design (CRD) single factorial method. A single-factor experiment is an experiment designed involving only one factor with several levels as treatments. The completely randomized design is used when the experimental units used are relatively homogeneous, such as experiments conducted in a laboratory. Factors: NHOC Treatment Moringa oliefera, Azolla microphylla, Ananas comosus L, and Coffee grounds. P0 = Non-formula (Negative control), P1 = Formula 1, P2 = Formula 2, P3 = Formula 3, P4 = Formula 4, P5 = ABMix 100% (Positive control). If these research factors are combined, it will result in 54 replications with 6 wick system installations, each installation differentiated according to the type of NHOC treatment. The determination of the number of replications refers to the formula for calculating a completely random calculation according to Tribudi (2020), as follows: $t\ (r\text{-}1) \geq 15$. Explanation: t = treatment (number of treatments), r = replication (number of replications), 15 = degrees of freedom. The number of treatments in this research is 6 (six), so the calculation of replications in this research is as follows: $t(r\text{-}1) > 15$; $6(r\text{-}1) > 15$; $6r - 6 > 15$; $6r > 15{+}6$; $6r > 21$; $r > 21/6$; $r > 3.5$ replications. r = 4 (replication/number of replications). Based on the calculation above, it is obtained that the minimum replication is 4 times replication in each treatment in the research. The replication used in this research is 9 times replication, so the total number of pak choi plants (Brassica rapa) is 54 plants.

Table.1: Experimental Design Treatment Formula

Treatment Fertilizer	**Replication**									**Mean**
	1	2	3	4	5	6	7	8	9	
P0	P01	P02	P03	P04	P05	P06	P07	P08	P09	
P1	P11	P12	P12	P14	P15	P16	P17	P18	P19	
P2	P21	P22	P23	P24	P25	P26	P27	P28	P20	
P3	P31	P32	P33	P34	P35	P36	P37	P38	P39	
P4	P41	P42	P43	P44	P45	P46	P47	P48	P49	
P5	P51	P52	P53	P54	P55	P56	P57	P58	P59	
Overal Mean										

2.7 Cost Design

According to Maarif (2022), the fixed costs in this study include equipment rental and depreciation, while the variable costs include seed costs, ABMix nutrients, NHOC, labor, and water.

Table.2: Cost Description

No.	Type of Cost	Description
1	Fixed Cost	1. Rental space
		2. Depreciation of Installation
		3. Depreciation of Netpots
		4. Depreciation of seedling trays
		5. Depreciation of supporting equipment (TDS and PH meters)
		6. Depreciation of Measuring cups
		7. Depreciation of Buckets
2	Variable Cost	1. Seeds
		2. Rockwool growing media
		3. ABmix nutrients
		4. NHOC nutrients
		5. Organic pesticides
		6. Water costs
		7. Flannel cloth
		8. Labor wages

III. RESEARCH METHOD

3.1 Research Time and Location

This research was conducted from August 23rd to November 23rd at the Agricultural Vocational School UPT. BLK Wonojati Malang. It involved the formulation, hydroponic seeding, construction of the Hydroponic Wick System installation, planting, plant maintenance, harvesting, and post-harvest activities, as well as the measurement of parameters for Pakchoy (Brassica rapa) plants in the Hydroponic Greenhouse.

3.2 Research Tools and Materials

The equipment used in this research includes seeding trays, hacksaw, Netpots, 1.5 cm hole puncher for PVC pipes, ruler, NHOC drums with locking lids, measuring cups, scale, water pass hose, bucket, ladle, blender, pestle, stirrer, labels, ruler, marker, water bottles, scissors, TDS meter, EC meter, pH meter, ice box, covers, flannel cloth, while the research materials include Moringa oleifera leaves, Azolla Microphylla, Ananas comosus, coffee grounds, Pak choi F1 seeds, sugarcane molasses, M21, coconut water, rice washing water, shallots, toothpicks, and rockwool.

3.3 Research Variables

This research utilizes several variables:

1. Independent variables, including P0 as the negative control (without nutrient), P1 Formula 1, P2 Formula 2, P3 Formula 3, P4 Formula 4, P5 using 100% ABMix at 5 ml/liter water (as the positive control).
2. Dependent variables in this study are the measurement of plant height, leaf width, leaf count, and wet weight of Brassica rapa L. plants grown in rockwool hydroponic wick systems.
3. Control variables in this study include the use of Brassica rapa L. seeds.

IV. RESULT AND DISCUSSION

4.1 Descriptive Statistics

The descriptive analysis focuses on the productivity and cost of Chinese cabbage in the Wick System hydroponic system. Variables such as plant wet weight, plant height, number of leaves, leaf width, nutrient concentration, acidity level of nutrient solution, and success rate in pest control are examined. Descriptive statistics are used to analyze each parameter, displaying the distribution of plant weight, growth, variation in leaf number and size, nutrient concentration, pH of the solution, and pest resistance level. The results will be presented in descriptive tables.

Table.3: Statistics Descriptive

Variable	**Treatment**	**N**	**Mean**	**Deviation**	**Std. Error**
Leaf Width	F0	9	1.11	0.22	0.07
	F1	9	9	1.22	0.41
	F2	9	7.56	0.53	0.18
	F3	9	7.22	0.44	0.15
	F4	9	4.78	0.83	0.28

	F5	9	8.22	0.97	0.32
	Total	54	6.32	2.79	0.38
Leaf Width	F0	9	7.17	0.43	0.14
	F1	9	25.44	2.46	0.82
	F2	9	23.11	1.05	0.35
	F3	9	22.67	0.71	0.24
	F4	9	14.89	2.09	0.7
	F5	9	24.67	1.73	0.58
	Total	54	19.66	6.79	0.92
Number of Leaves	F0	9	4.89	0.6	0.2
	F1	9	21.89	2.37	0.79
	F2	9	22.67	1	0.33
	F3	9	21.78	1.2	0.4
	F4	9	13.44	2.96	0.99
	F5	9	21.67	2.12	0.71
	Total	54	17.72	6.85	0.93
Root Length	F0	9	9	1.8	0.6
	F1	9	13.56	3.09	1.03
	F2	9	13.11	3.14	1.05
	F3	9	12.89	2.15	0.72
	F4	9	9	2.55	0.85
	F5	9	18.89	5.21	1.74
	Total	54	12.74	4.53	0.62
Wet Weight	F0	9	10	0	0
	F1	9	222.22	38.33	12.78
	F2	9	196.67	7.07	2.36
	F3	9	189.44	10.14	3.38
	F4	9	85.56	17.04	5.68
	F5	9	186.67	38.81	12.94
	Total	54	148.43	79.34	10.8

Table 3 presents the descriptive statistics of Chinese cabbage (Brassica rapa) in the Wick System hydroponic system, providing a comprehensive overview of its various characteristics. Leaf width, for example, shows variation across treatments, with F1 having the highest mean (9.00), followed by F5, F2, F3, F4, and F0. Similar patterns emerge for leaf length, where F1 also exhibits the highest mean (25.444), followed by F5, F2, F3, F4, and F0. The analysis also highlights leaf count, with F2 showing the highest mean (22.67), followed by F1, F3, F5, F4, and F0. Treatment F5 demonstrates the highest mean root length (18.89), while F1 exhibits the highest mean wet weight (222.22). Variability among treatments is evident from the differing means and standard deviations, reflecting variations in plant responses to the hydroponic system. This provides valuable insights into the growth of Chinese cabbage in the Wick System hydroponic environment.

4.2 ANOVA Test for Brassica Rapa in the Wick System Hydroponic System

Analysis of Variance (ANOVA) is a statistical technique used to compare means among three or more groups. In the context of Chinese cabbage (Brassica rapa) morphology in the Wick System hydroponic setup, ANOVA is employed to assess whether there are significant differences in plant morphology characteristics among various treatments. The dependent variables in the ANOVA test for Chinese cabbage morphology are these morphological characteristics, such as leaf width, leaf length, leaf count, root length, and wet weight. Treatments are the groups or conditions being tested, in this case, different growth conditions of Chinese cabbage plants in the Wick System hydroponic setup. Each treatment may involve differences in nutrient composition, light intensity, or other environmental factors affecting plant growth. Testing with ANOVA is conducted by forming hypotheses as follows:

$H_0: \mu1 = \mu2 = \mu3 = \cdots = \mu k$

H_1: At least two groups have different means..

Table.4: ANOVA Test

Variables		Sum of Squares	df	Mean Square	F	Sig.
Leaf Width	Between Groups	383.87	5	76.774	125.869	0
	Within Groups	29.278	48	0.61		
	Total	413.148	53			
Leaf length	Between Groups	2324.912	5	464.982	183.697	0
	Within Groups	121.5	48	2.531		
	Total	2446.412	53			
Number of Leaf	Between Groups	2311.278	5	462.256	127.845	0
	Within Groups	173.556	48	3.616		
	Total	2484.833	53			
Root Length	Between Groups	599.481	5	119.896	11.82	0
	Within Groups	486.889	48	10.144		
	Total	1086.37	53			
Wet Weight	Between Groups	306291.2	5	61258.24	107.51	0
	Within Groups	27350	48	569.792		
	Total	333641.2	53			

The results of the ANOVA test in Table 4.3 indicate significant differences in the morphology of Brassica rapa plants in the Wick System hydroponic cultivation of Chinese cabbage. The observed parameters include leaf width, leaf length, leaf count, root length, and wet weight. There is significant variation among treatments for all parameters with $p < 0.05$, indicating a significant impact on plant morphology characteristics. These findings suggest that differences in treatments in the Wick System hydroponic setup significantly affect the morphology of Chinese cabbage plants. This insight provides valuable information for managing hydroponic growth environments and improving Chinese cabbage production.

4.3 Cost Analyze

In this subsection, the cost of the Wick System hydroponic system will be analyzed by investigating all factors influencing the investment and expenses associated with this cultivation method. The cost analysis picture is presented as follows:

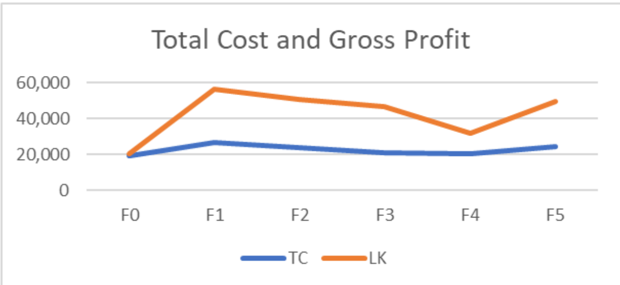

Fig.1: Graph Cost Analyze

Based from Figure 1 for each treatment, the total cost (TC) represents the overall expenditure incurred for that treatment, while the gross profit (GP) is the gross income generated from that treatment. Gross profit is obtained by subtracting the total cost from the gross income. Here is the cost analysis of the six treatments: Treatment F0 with Total Cost (TC): 19,184; Gross Profit (GP): 1,350, Treatment F1 with Total Cost (TC): 26,648.04; Gross Profit (GP): 30,000.00, Treatment F2 with Total Cost (TC): 23,903.54; Gross Profit (GP): 26,550.00, Treatment F3 with Total Cost (TC): 21,192.54; Gross Profit (GP): 25,575.00. Treatment F4 with Total Cost (TC): 20,150.04; Gross Profit (GP): 11,550.00. Treatment F5 with Total Cost (TC): 24,425.54; Gross Profit (GP): 25,200.00.

V. CONCLUSION

The results of the research and analysis highlight several key findings regarding the growth and cost of Pak Choi plants in the Wick System hydroponic system. It was found that various nutrient formulas have a significant impact on plant growth, with Formula 1 standing out as the most effective in increasing plant height, leaf width, and wet weight. Specific treatments, such as F1, F2, and F3, exhibited better growth compared to others. However, cost analysis revealed interesting variations, where certain treatments, despite having higher total costs, also yielded higher net profits. This underscores the importance of considering both costs and profits when selecting the most optimal formula for cultivating Pak Choi plants in hydroponic systems.

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Performance Evaluation of Spring Rice Variety Chaite-5 with Varied Age of Seedlings and Plant Spacing in Rajapur, Bardiya District of Nepal

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***Abstract*— *Despite the considerable potential for spring rice production in Bardiya District, the average yield remains below the national average. Various factors affect spring rice production, with seedling age and spacing being significant determinants of productivity. The utilization of older seedlings and improper spacing often lead to decreased yields in transplanted rice systems. Therefore, this study aimed to identify the optimal seedling age and planting spacing for Spring rice cultivars (Chaite-5) in transplanted rice systems. A field experiment was conducted to evaluate the performance of spring rice (var. Chaite-5) grown with different seedling ages and planting configurations in Rajapur, Bardiya during the spring season of 2022. The experiment included seedlings from four age groups (19, 22, 25, and 28 days) and three planting geometries (15×15cm, 20×20cm, and 25×25cm). Various parameters such as plant height, number of tillers per hill, effective tillers per hill, panicle length, filled grains, total grains per panicle, sterility percentage, thousand-grain weight (TGW), and grain yield were recorded. The findings revealed that the growth cycle was shortened by 19-22 days for young seedlings (13-day-old) compared to older seedlings (28-day-old), indicating accelerated growth with the transplantation of younger seedlings. Moreover, 22-day-old seedlings exhibited significantly higher numbers of tillers per hill (19) and effective tillers per hill (11), along with higher thousand-grain weight (18.88 g) and grain yield (5121.88 kg/ha). Similarly, crops planted with a spacing of 20 ×20 cm demonstrated significantly higher numbers of tillers per hill (19), effective tillers per hill (10.97), higher thousand-grain weight (20.15 g), and grain yield (5106.50 kg/ha).*

***Keywords*— Seedling, Spacing, Transplantation, Yield**

I. INTRODUCTION

Rice (Oryza sativa L.) holds a paramount position among cereal crops globally, playing a vital role in sustaining the dietary needs of more than half of the world's population daily (Chauhan *et al.*, 2011). With approximately 2.5 billion people, predominantly in developing nations, relying on rice as a staple food, its consumption is pervasive, with Asia alone accounting for 90% of consumption. In contrast, the remaining 10% is distributed among America, Africa, Australia, and Europe (Dahipahle and Singh, 2018).

In Nepal, rice production takes precedence as the primary agricultural pursuit, contributing around half of the nation's total cereal output (Ghimire *et al.*, 2013). The diverse topography of Nepal, ranging from the low-lying Terai to the towering mountains, fosters a rich variety of rice ecosystems. These ecosystems accommodate various landraces tailored to diverse agro-climatic conditions and farmers' preferences. Known as "Dhaan" in Nepali, rice belongs to the Poaceae Family and significantly contributes to the country's agricultural Gross Domestic Product (GDP) by constituting 50% of total edible cereal production and providing more than 50% of the required caloric intake for Nepalese citizens (Basnet, 2008).

Achieving uniformity in population and regulating the growth and yield of rice crops depend significantly on the age of seedlings at the time of transplanting (Zhimomi *et* al., 2021). Proper transplanting at the right age enhances effective tiller and crop growth with significant differentiation (Reuben et al., 2016). However, delayed transplanting or using aged seedlings more than 25 days old results in poor seedling establishment and the production of fewer tillers, leading to lower yields (Li et al., 2020). Transplanting delays are common in the rain-fed lowland fields of the central Terai region of Nepal due to unpredictable rainfall patterns and a lack of weather forecasting facilities. The farmers prepare the rice seedling nursery depending on the onset of rains, and unknown patterns of rainfall, they are compelled to plant either too young seedlings or old aged seedlings (Shah and Yadav 1970, VLW Bara report 2022). Early plantation during heavy rainfall and flooding conditions lead to low survival rates of seedlings due to anaerobic conditions, root rot caused by fungal development, and hot weather combined with stagnant water for more than a week (Dhungana et al., 2020). Therefore, understanding the appropriate seedling age is crucial for sustainable rice cultivation.

Optimizing seedling age and row spacing are pivotal factors in enhancing rice yield. Proper spacing regulates plant density per unit area, directly influencing yield. While narrow spacing fosters intense competition among plants for nutrients, air, and light resulting in weaker growth and reduced yield, wider spacing may lead to decreased grain yield due to diminished competition and increased straw production (Alam et al., 2012; Sultana et al., 2012). Optimal spacing ensures efficient utilization of solar radiation and nutrients, facilitating proper growth and development of rice plants (Mohaddesi et al., 2011). Closer spacing hampers intercultural operations, leading to more competition among plants for nutrients, air, and light, resulting in weaker plants and reduced yield (Alam et al, 2012). Wider spacing also increases competition among crop plants and weeds.

Furthermore, seedling age at transplanting significantly impacts rice production, influencing tiller production, panicle length, and grain yield. Younger seedlings tend to exhibit superior growth characteristics yielding more tillers and higher grain yield than older counterparts (Ginigaddara and Ranamukhaarachchi, 2011). The use of over-aged seedlings hampers the overall performance of the crop leading to drastically reduced yields (BRRI, 1981), as farmers are often unaware of this factor in rice production. Studies have shown that seedlings aged 21 days contribute to higher grain yields compared to those aged 28 days, with an optimal age of 25 days resulting in maximal panicle production, grain weight, and overall yield (Kewat et al., 2002; Krishna et al., 2008; Abou-Khalifa, 2005).

Bardiya is one of the major rice-producing districts, with rice cultivation spanning an area of 1600 hectares, resulting in a total production of 8688 metric tons and an average yield of 5.43 metric tons per hectare (MOALD, 2023). Rajapur municipality and Geruwa rural municipality within the Bardiya district have been identified as key rice production zones under the Prime Minister's Agriculture Modernization Project (PMAMP). However, rice farmers in these areas lack awareness regarding the optimal seedling density per hill required to achieve maximum yield. Therefore, there exists a significant disparity between the demand for rice and the current domestic production. This gap could be narrowed by promoting the widespread cultivation of spring rice along with the adoption of appropriate agronomic management practices.

Prior research has predominantly investigated seedling age and spacing, primarily on rainy-season rice. However, given the unique ecological and cultivation conditions of spring rice, it is essential to conduct trials specifically examining the effects of row spacing and seedling age on yield. Consequently, this study was undertaken to evaluate the influence of different seedling ages and spacing configurations on the performance, yield, and economic considerations of spring rice. The objective of this study is to explore the combined impacts of row spacing and seedling age on the yield and its components of spring rice in the Bardiya district, addressing key factors influencing rice productivity in the region.

II. MATERIALS AND METHOD

2.1 EXPERIMENTAL SITE

The experiment was conducted within farmers' plots in Mahuliya village, representing the Terai region, which is a designated Rice Super Zone implementation site under the Prime Minister's Agriculture Modernization Project (PMAMP) in Bardiya, during the spring season of 2022. The geographical coordinates of the site are 28°39'N latitude and 81°10'E longitude. Bardiya district experiences a tropical climate characterized by hot summers and cold winters. Meteorological data for the 2022 cropping season were obtained from NASA Power as shown in Fig 2. The average monthly rainfall during the experimental period was recorded at 1.08 mm/day, with the highest rainfall occurring in June (3.64 mm/day) and the lowest in April (0.16 mm/day). Previous studies have suggested that a minimum rainfall of 1250 mm is required for the vegetative growth of rice. The mean maximum temperature ranged from 34.06°C to 44.38°C during the experimental period, with the highest temperatures observed in May and the lowest in February. Similarly, the mean minimum temperature during the cropping period ranged from

16.77°C to 29.21°C, with the highest temperatures occurring in May and the lowest in February.

The physicochemical analysis of the experimental soil revealed it to be loamy in texture, with a neutral pH of 6.84. The soil exhibited medium levels of total nitrogen (0.08%) and organic matter (1.68%), while available phosphorus and potassium were found to be low, at 20.06 kg/ha and 121.2 kg/ha, respectively.

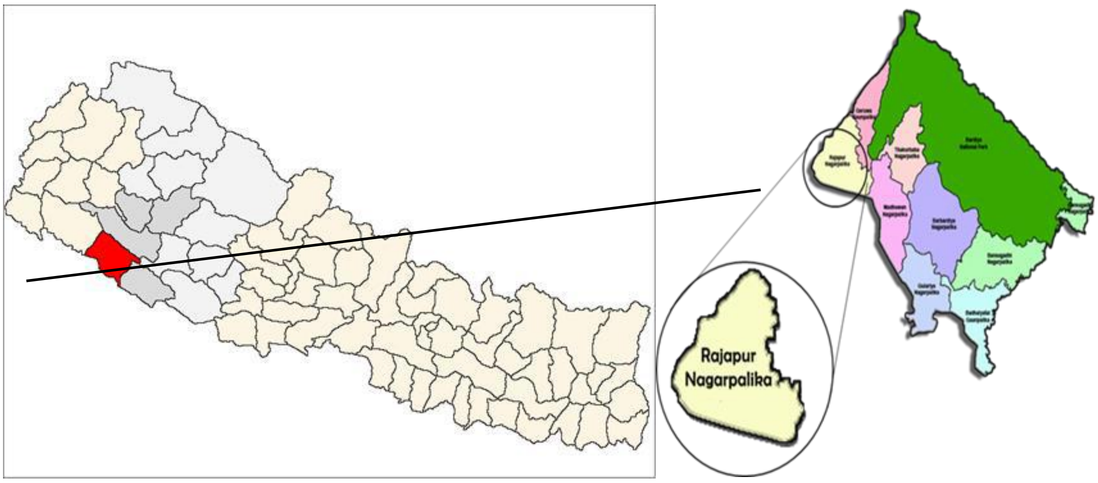

Fig.1. Map of Nepal showing the research location

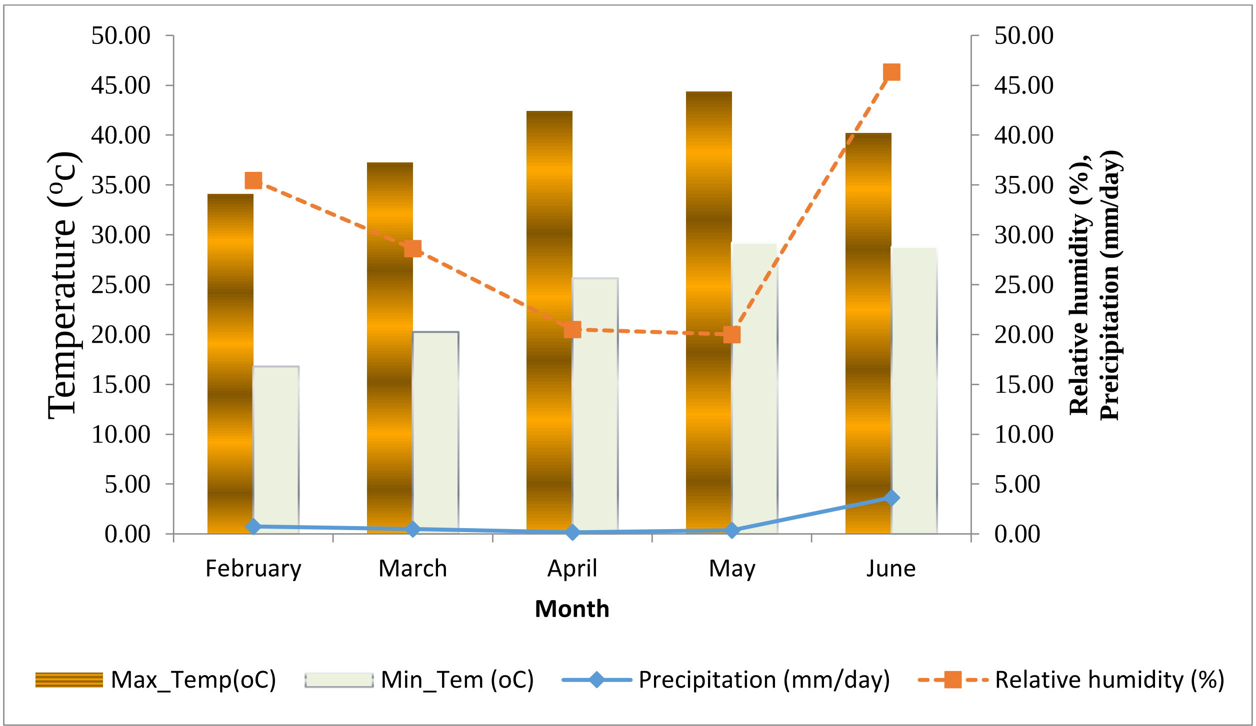

Fig.2. Meteorological data of research location obtained from NASA power.

2.2 Experimental detail

The experiment followed a two-factor split-plot design with three replications and a total of 12 treatments. The treatments comprised combinations of two factors: seedling age and row spacing. The seedling age factor included four levels (19 days, 22 days, 25 days, and 28 days), denoted as A1, A2, A3, and A4, respectively. The row spacing factor consisted of three levels (15 cm × 15 cm, 20 cm × 20 cm, and 25 cm × 25 cm), denoted as R1, R2, and R3, respectively. The treatment combinations and layout of the experimental field is presented in Tables 1 and 2 respectively. The experimental design utilized a split-plot design with three replications and 12 treatments. Each plot measured 3 m × 2 m, with a spacing of 1 m between replications and 0.5 m between treatments.

Table 1. Different treatment combinations are applied in each replication

Treatment	Combinations	Symbols
T1	19 days seedling at 15cm×15cm spacing	A1R1
T2	19 days seedling at 20cm×20cm spacing	A1R2
T3	19 days seedling at 25cm×25cm spacing	A1R3
T4	22 days seedling at 15cm×15cm spacing	A2R1
T5	22 days seedling at 20cm×20cm spacing	A2R2
T6	22 days seedling at 25cm×25cm spacing	A2R3
T7	25 days seedling at 15cm×15cm spacing	A3R1
T8	25 days seedling at 20cm×20cm spacing	A3R2
T9	25 days seedling at 25cm×25cm spacing	A3R3
T10	28 days seedling at 15cm×15cm spacing	A4R1
T11	28 days seedling at 20cm×20cm spacing	A4R2
T12	28 days seedling at 25cm×25cm spacing	A4R3

Table 2. Layout of experimental field

Replication 1		
S1A1	S2A2	S3A4
S1A2	S2A3	S3A2
S1A3	S2A1	S3A1
S1A4	S2A4	S3A3
Replication 2		
S2A3	S3A4	S1A3
S2A2	S3A3	S1A1
S2A1	S3A1	S1A4
S2A4	S3A2	S1A2
Replication 3		
S3A1	S1A1	S2A3
S3A3	S1A3	S2A4
S3A4	S1A4	S2A2
S3A2	S1A2	S2A1

2.3 Cultivation Practices

2.3.1 Nursery Preparation

Seeds were sown in trays placed on well-prepared nursery beds. The nursery beds were irrigated on four different dates spaced three days apart starting from the 23rd of February 2022. Before sowing, seed priming was conducted. Seeds were broadcasted over a film of water on the wet bed. Before sowing, the seeds were treated with a salt solution (200-300 gm salt in 1 liter water). Manual sowing of seeds was carried out in the trays. Approximately 1.5-2 kattha of seed bed area was required per bigha of rice field. Adequate irrigation, drainage, and well-fertilized soil were essential for optimal seedbed preparation. Nurseries were not established in areas where the previous year's paddy crop had been threshed to prevent varietal admixture.

2.3.2 Main Field Preparation

The land was plowed twice to achieve a good tilth. The field was flooded 1-2 days before plowing, and the surface was kept covered with water. Main field preparation involved puddling, and a rotavator was employed three times for this purpose. Thirty-six plots each measuring 3m×2m were created. Different ages of seedlings were transplanted at three different plant spacings.

2.3.3 Manure and Fertilizer

In the nursery bed, manure and fertilizer were applied as per requirements. In the main field, chemical fertilizers such as urea (46% N), DAP (18% N, 46% P_2O_5), and MOP (60% K_2O) were applied at rates of 120:60:40 kg NPK/ha. FYM was incorporated into the soil 15 days before transplanting at a rate of 10t/ha. FYM was incorporated into the soil 15 days before transplanting at a rate of 10t/ha. Half of the nitrogen dose and the full doses of phosphorus and potash were applied as basal doses during transplanting, while the remaining half of the nitrogen was applied as top dressing.

2.3.4 Uprooting of Seedlings

Seedlings of different ages were uprooted individually from the trays at the time of transplanting, ensuring that the roots were not damaged. Water was supplied before uprooting to facilitate the process.

2.3.5 Transplanting of Seedlings

Seedlings of different ages (19, 22, 25 & 28 days) were transplanted at varying distances 15×15 cm, 20×20 cm & 25×25 cm. Planting three seedlings per hill was recommended.

2.3.6 Irrigation

Rice requires abundant water especially during critical stages such as vegetative growth, panicle initiation, and grain filling. Irrigation was scheduled at 7 days after transplanting (DAT) 30 DAT during tillering, and subsequently in a monthly alternating dry and wet pattern. Water was sourced from pumps and waterways.

2.3.7 Weed Management

Pre-emergence herbicides were applied within three days of transplanting followed by hand weeding at 15-20 DAT and 45 DAT to effectively manage weeds.

2.3.8 Plant Protection Methods

Integrated pest management practices were employed to prevent rice stem borers, and chemical pesticides were used only in cases of severe infestation.

2.3.9 Harvesting

Manual harvesting was conducted using traditional sickles. The central 1m square area of each plot was marked and harvested separately.

2.3.10 Threshing

Rice heads were sun-dried and manually threshed. Grains were cleaned by winnowing, and their weight was measured using an electric balance. Moisture content was determined using a portable digital moisture meter available at the PMAMP office.

2.4 Observation and Measurement

2.4.1 Growth Parameters

Plant Height: Ten random plants from each plot were tagged and measured for plant height at 15-day intervals with final measurements taken on 90 DAT.

Number of Tillers per Square Meter: One-meter row length was marked on the 8th row of each plot, and the total number of tillers was counted at 15-day intervals from 30 DAT to 90 DAT.

2.4.2 Yield and Yield Attributing Parameters

Number of Effective Tillers per Square Meter**:** The number of panicle-bearing tillers was counted from a 1m row length on the 8th row of any side of the plot before harvest.

Panicle Length: Twenty panicles were randomly selected from each plot, and their lengths were measured using a scale.

Number of Filled Grains per Panicle: The number of filled grains per panicle was counted from each selected panicle.

Spikelet Sterility Percentage: The percentage of spikelet sterility was calculated using the formula provided.

$$\text{Sterility\%} = \frac{\text{Number of unfilled grains per panicle} \times 100}{\text{Total number of grains per panicle}}$$

Thousand-Grain Weight: Thousand filled grains from each plot were counted and weighed using an electronic digital balance.

Grain Yield: Grain yield was determined from the net plot area of each plot, adjusted for moisture content, and expressed in kilograms per hectare.

$$\text{Grain yield (kg/ha)} = \frac{(100\text{-MC}) \times \text{plot yield (kg)} \times 10000 \text{ (sq.m)}}{(100\text{-}14) \times \text{net plot area (sq.m)}}$$

2.5 Statistical Analysis

Data were arranged systematically based on various observed parameters and analyzed using R studio with R stat Software of 4th edition. Treatment means were separated using Duncan's Multiple Range Test (DMRT) at a 5% level of significance. Analysis of variance (ANOVA) was employed to test differences among the factors.

III. RESULT AND DISCUSSION

3.1 Agronomic Characters

3.1.1 Plant Height

The height of rice plants was significantly influenced by varying spacing configurations throughout their growth stages, as illustrated in Table 3. Notably, the tallest plants consistently emerged when spaced at 20 cm × 20 cm intervals. Specifically, at 30 days after transplanting (DAT) the tallest plants measuring 55.25 cm were observed in the 20 cm × 20 cm spacing followed by 15 cm × 15 cm (49.90 cm) and 25 cm × 25 cm spacing (48.84 cm). Likewise, at 45 DAT the tallest plants (75.01 cm) were noted in the 20 cm × 20 cm spacing followed by the 15 cm × 15 cm spacing. By 60 DAT the tallest plants (100.48 cm) were recorded in the 20 cm × 20 cm spacing followed by 25 cm × 25 cm. This pattern persisted with the tallest plants observed at 20 cm × 20 cm spacing at 75 DAT (105.16 cm) and 90 DAT (109.08 cm). The increased plant height associated with 20 cm × 20 cm spacing compared to narrower spacing (15 cm × 15 cm) can be attributed to enhanced spatial availability and reduced competition for nutrients. This observation diverges slightly from the findings of Banjade et al. (2023), who reported that plant height peaked with a 30 cm × 30 cm spacing. Additionally, Ram et al. (2014) observed that closer spacing (25 cm × 25 cm) resulted in significantly taller plants and a higher leaf-area index compared to wider spacing (30 cm × 30 cm), likely due to heightened competition for solar light interception and utilization under closer spacing. Despite the recognized significance of spacing and seedling age during the initial stages of crop development, as highlighted by Durga et al. (2015) and Zhimomi et al. (2021), these factors did not exert a significant impact on overall plant height.

In terms of seedling age, notable disparities were evident, except at 30 DAT and 45 DAT, as delineated in Table 3. At 60 DAT, the tallest plants originated from 22-day-old seedlings (96.56 cm), followed by 28-day-old seedlings (93.12 cm). Subsequently, at 75 DAT, the tallest plants were observed in 22-day-old seedlings, followed by 28-day-old seedlings (98.78 cm). Likewise, at 90 DAT, the plant height of 22-day-old seedlings surpassed that of 19-day-old seedlings (106.43 cm). These findings are in accordance with those of Shrestha et al. (2019), who reported that transplanting at an early age yielded significantly taller plants, with a height increase of 4 cm. The prolonged growth period provided by early transplanting allowed plants to accumulate more photosynthates, consequently leading to increased plant height, as observed by Sarkar et al. (2011). Similarly, Naresh (2012) documented that plants exhibited up to a 9 cm increase in height when comparing seedlings aged 20 to 60 days in Andhra Pradesh, India. Moreover, Ram et al. (2014) noted that older seedlings at ten days also displayed significantly greater height.

Table 3. Plant height of Chaite-5 as influenced by different ages of seedlings under different spacing at Bardiya,Nepal

Treatment	Plant height(cm)				
Spacing	30DAT	45DAT	60DAT	75DAT	90DAT
15×15cm	49.90^{b}	69.05^{b}	88.42^{b}	98.75^{b}	104.02^{c}
20×20cm	55.25^{a}	75.01^{a}	100.48^{a}	105.16^{a}	109.08^{a}
25×25cm	48.84^{b}	67.90^{b}	89.75^{b}	96.75^{b}	105.69^{b}
SEM_1±	0.626	0.598	0.946	0.83	0.19
LSD_a(0.05)	2.46	2.35	3.71	3.26	0.78
CV(a)%	4.2%	2.9 %	3.5%	2.9%	0.6%
F-test	*	**	**	**	***
Age of seedlings					
28 days old	49.99^{b}	69.95^{a}	93.12^{b}	98.78^{b}	102.87^{c}
25 days old	51.13^{ab}	70.10^{a}	89.89^{b}	98.44^{b}	106.16^{b}
22 days old	48.84^{b}	71.66^{a}	96.56^{a}	105.00^{a}	109.59^{a}
19 days old	51.36^{ab}	70.91^{a}	91.96^{b}	98.67^{b}	106.43^{b}
SEM_2±	0.723	0.691	1.092	0.95	0.23
LSD_b(0.05)	2.53	2.03	3.21	3.87	2.28
CV(b)%	5%	2.9 %	3.5%	3.9%	2.2%
F-test	NS	NS	**	**	***
Grand mean	51.33	70.65	92.88	100.22	106.26

*Note: Treatment means separated by DMRT and columns represented with the same letter(s) are non-significant at a 5% level of significance, *** indicates a 1% level of significance, ** indicates a 5% level of significance, * indicates a 10% level of significance, DAT: days after transplanting, NS= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance*

3.1.2 Number of Tillers per Hill

The number of tillers per hill exhibited notable variations based on spacing across all growth stages, as shown in Table 4. At 30 days after transplanting (DAT), the highest number of tillers (17.14) was recorded with 20 cm × 20 cm spacing, followed by 25 cm × 25 cm spacing (16.39). This differs slightly from the findings of Ghimire et al. (2023), who reported that 30 days after transplanting, the maximum number of tillers (23.23 tillers/plant) was observed in rice planted at 25 cm × 20 cm spacing, succeeded by 20 cm × 20 cm (22.03 tillers/plant). Similarly, at 45 DAT, the 20 cm ×

20 cm spacing displayed the highest number of tillers (18.59), followed by 25 cm × 25 cm spacing (16.05). By 60 DAT, the maximum number of tillers (17.34) was observed at 25 cm × 25 cm spacing, followed by 20 cm × 20 cm spacing (16.83). The tiller counts increased and peaked at 60 DAT before undergoing a decline due to tiller mortality. By 75 DAT, the highest tiller count (14.95) was associated with 20 cm × 20 cm spacing, followed by 25 cm × 25 cm spacing (13.75). Subsequently, at 90 DAT, the highest tiller count (12.73) was observed with 20 cm × 20 cm spacing, trailed by 25 cm × 25 cm (11.65) and 15 cm × 15 cm (8.01) spacing, respectively. These findings suggest that 20 cm × 20 cm spacing was most efficacious in augmenting tiller count.

Regarding seedling age, notable variances were observed in tiller count, as elucidated in Table 4. At 30 DAT, the maximum tiller count (18.61) was noted with 22-day-old seedlings, succeeded by 19-day-old seedlings (15.76). Similarly, at 45 DAT, the peak tiller count was recorded with 22-day-old seedlings (18.86), followed by 19-day-old seedlings (16.57). At 60 DAT, 75 DAT, and 90 DAT, significantly higher tiller counts (18.51, 14.98, and 12.13, respectively) were documented with 22-day-old seedlings, trailed by 19-day-old seedlings (15.84, 13.05, and 11.14, respectively). Analogous results were reported by Dhungana et al. (2020), who observed noteworthy disparities in total tillers per hill based on seedling age during transplantation. They noted greater tiller counts (10.94) in plants with 20-day-old seedlings and lower counts (10.22) in those with 30-day-old seedlings.

Table 4. Effect of Spacing and Seedling Age on Tiller Number of Chaite-5 at Bardiya, Nepal

Treatment	Tillers per hill				
Spacing	30DAT	45DAT	60DAT	75DAT	90DAT
15×15cm	14.10^b	14.89^b	12.77^b	10.38^c	8.01^c
20×20cm	17.14^a	18.59^a	16.83^a	14.95^a	12.73^a
25×25cm	16.39^a	16.05^b	17.34^a	13.75^b	11.65^b
SEM_1±	0.28	0.42	0.34	0.25	0.14
LSD_a(0.05)	1.13	1.66	1.35	1.02	0.58
CV(a)%	6.3%	8.9%	7.6%	6.9%	4.8%
F-test	**	**	**	***	***
Age of seedlings					
28 days old	14.31^c	15.21^c	15.78^b	11.55^c	9.23^c
25 days old	14.83^c	16.41^b	14.46^c	12.53^b	10.68^b
22days old	18.61^a	18.86^a	18.51^a	14.98^a	12.13^a
19 days old	15.76^b	16.57^b	15.84^b	13.05^b	11.14^b
SEM_2±	0.33	0.48	0.39	0.30	0.17
LSDb(0.05)	0.76	0.84	1.04	0.55	0.71
CV(b)%	4.9%	5.2%	6.7%	4.3%	6.7%
F-test	***	***	***	***	***
Grand mean	15.87	16.51	15.64	13.03	10.8

*Note: Treatment means separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, *** indicates a 1% level of significance, ** indicates a 5% level of significance, * indicates a 10% level of significance, DAT: days after transplanting, NS= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance*

3.2 Yield attribute

3.2.1 Effective Tillers per Hill

A significant result was found for effective tillers per hill due to spacing, as shown in Table 5. The treatment featuring 20 cm × 20 cm spacing exhibited the highest number of effective tillers (10.97), followed by 25 cm × 25 cm spacing with 9.80 tillers. This stands in contrast to the findings of Ram et al. (2014), who noted significantly higher counts of effective tillers per hill, panicles per hill, and grains per panicle in wider 30 cm × 30 cm spacing compared to closer spacing. Notably, seedling spacing did not exert influence on test weight but did impact tillers per square meter, as observed by Banjaeda et al. (2023). The peak count of effective tillers per hill was recorded at 20 cm × 20 cm spacing, showcasing a significant disparity from other spacing alternatives.

Regarding seedling age, the highest count of effective tillers (11.44) was attained with 22-day-old seedlings, trailed by 19-day-old seedlings (9.83). Similar findings were reported by Dhungana et al. (2020), who observed greater counts of effective tillers per hill in plants with 20-day-old seedlings (9.9) compared to those with 30-day-old seedlings (9.3). Conversely, the lowest count of effective tillers (8.26) was documented with 28-day-old seedlings. Additionally, another group of researchers noted a substantial reduction in total tiller production with delayed planting (Nayak et al., 2003). Ali et al. (2013) identified that 15-day-old seedlings exhibited superior efficacy in producing effective tillers compared to other seedling ages. The phenomenon of early planting potentially fosters more productive tillers due to the enhanced development of early-formed tillers up to the reproductive phase of the crop, while late planting may lead to tiller mortality owing to inadequate photosynthates, thereby diminishing the count of effective tillers.

3.2.2 Panicle Length

Spacing had a highly significant effect on the average panicle length, as shown in Table 5. The longest panicle length (27.08 cm) was recorded with 20 cm × 20 cm spacing, followed by 25 cm × 25 cm spacing (25.41 cm). Ghimire et al. (2023) reported that the greatest panicle length (23.68 cm) was observed with 25 cm × 20 cm spacing, followed by 20 cm × 20 cm (22.18 cm). Panicle length was also significantly influenced by the age of seedlings. The longest panicle length (27.07 cm) was recorded with 22-day-old seedlings, followed by 19-day-old seedlings (26.43 cm). Shrestha et al. (2019) also observed significantly longer panicles when transplanted at an earlier age compared to later transplanting. Correspondingly, Naresh (2012) noted panicles that were 1.1 cm longer in Andhra Pradesh, India. Concerning hybrid varieties, Kumar (2001) demonstrated that panicles were 1 cm longer when transplanted at 20 days compared to 25 and 30 days seedlings. The average panicle length exhibited a highly significant response to various spacing treatments.

3.2.3 Filled Grain per Panicle

The number of filled grains per panicle was greatly affected by spacing as shown in Table 5. The most filled grains per panicle (216.91) were found with 20 cm × 20 cm spacing, followed by 15 cm × 15 cm spacing (186.25). According to Rajesh and Thanunathan (2003), employing wider spacing resulted in diminished competition both below and above ground, leading to enhanced grain filling, increased grain weight, and a greater number of filled grains per panicle. The lowest count of filled grains (185.00) was observed at 25 cm × 25 cm spacing.

Likewise, significantly higher counts of filled grains per panicle (218.22) were obtained with 22-day-old seedlings, followed by 25-day-old seedlings (198.22). Conversely, fewer filled grains (179.67) were recorded with 28-day-old seedlings. Ghimire et al. (2023) observed that the highest count of filled grains per panicle (125.25) was associated with a spacing of 25 cm × 20 cm, which exhibited statistical similarity to spacing configurations of 20 cm × 20 cm (122.75) and 25 cm × 15 cm (119.25). Conversely, the lowest count of filled grains (107.25) was noted for 15 cm × 15 cm spacing, which displayed statistical similarity to 20 cm × 15 cm (109.5). In general, it can be inferred that wider spacing facilitated greater grain production per panicle compared to narrower spacing, attributable to reduced competition for nutrients, air, and light, thereby improving the growth environment for crops, as documented by Moro et al. (2016).

3.2.4 Total Grain per Panicle

Spacing and the age of seedlings didn't have a significant effect on the total grains per panicle, as shown in Table 5. However, according to a study by Ram *et al.* (2014), grains per panicle were significantly higher in wider 30 cm × 30 cm spacing than in closer spacing.

Table 5. Different yield attributing characters of Chaite-5 as affected by the spacing and age of seedlings at Bardiya, Nepal

Treatment		Yield attributes		
Spacing	Effective tillers(per hill)	Panicle length(cm)	Filled Grain	Total Grain Per Panicle
15×15cm	7.63^{c}	25.41^{c}	186.25^{b}	274.33^{a}
20×20cm	10.97^{a}	27.08^{a}	216.91^{a}	318.75^{a}
25×25cm	9.80^{b}	26.56^{b}	185.00^{b}	302.50^{a}
SEM1±	0.11	0.07	3.61	14.59
LSDa(0.05)	0.43	0.30	14.20	57.30
CV(a)%	4%	1%	6.4%	16.9%
F-test	***	***	**	NS
Age of seedlings				
28 days old	8.26^{c}	25.80^{c}	179.67^{c}	291.44^{a}
25 days old	9.23^{b}	26.09^{bc}	198.22^{b}	301.56^{a}
22 days old	11.44^{a}	27.07^{a}	218.22^{a}	308.89^{a}
19 days old	9.83^{b}	26.43^{b}	188.33^{c}	292.22^{a}
SEM2±	0.12	0.08	4.17	16.85
LSDb(0.05)	0.51	0.49	8.84	35.45
CV(b)%	5.5%	1.9%	4.6%	12%
F-test	***	***	***	NS
Grand mean	9.46	26.35	196.05	298.52

*Note: Treatment means separated by DMRT and columns represented with the same letter(s) are non-significant at a 5% level of significance, *** indicates a 1% level of significance, ** indicates a 5% level of significance, * indicates a 10% level of significance, DAT: days after transplanting, NS= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance*

3.2.5 Sterility Percentage

The sterility percentage was greatly affected by spacing, as shown in Table 6. The highest sterility percentage (37.46%) was seen with 15 cm × 15 cm spacing, followed by 25 cm × 25 cm spacing (32.21%). A significantly lower sterility percentage (29.49%) was found with 20 cm × 20 cm spacing.

Regarding the age of seedlings, the highest sterility was observed in 19-day-old seedlings (35.08%), which was statistically similar to 28-day-old seedlings (33.82%) and 25-day-old seedlings (33.32%). The lowest sterility percentage was recorded with 22-day-old seedlings (29.98%).

3.2.6 Thousand-Grain Weight

Thousand-grain weights were greatly affected by plant spacing, as shown in Table 6. The weight was higher in 20 cm × 20 cm spacing (20.15 gm) followed by 15 cm × 15 cm spacing (17.92 gm). Similarly, a significantly higher thousand-grain weight (18.85 gm) was obtained with 22-day-old seedlings, which was statistically similar to 19-day-old seedlings (19.15 gm). A lower thousand-grain weight (17.80 gm) was recorded with 28-day-old seedlings.

Ghimire et al. (2023) recorded that thousand-grain weights were significantly higher for seedlings transplanted at wider spacings as 25 cm × 20 cm (25.03 gm) and compared to narrower spacing treatments 20 cm × 20 cm (24.63 gm). Consistent with these findings, Rajesh and Thanunathan (2003) and Akondo and Hossain (2020) observed similar results, suggesting that employing broader spacing mitigated competition both below and above ground, consequently leading to increased thousand-grain weight.

3.2.7 Grain Yield

Grain yield was significantly affected by both spacing and the age of seedlings, as shown in Table 6. The highest grain yield (5106.50 kg/ha) was recorded with 20 cm × 20 cm spacing, which was statistically similar to 15 cm × 15 cm spacing (5058.41 kg/ha). The lowest yield (4833.05 kg/ha) was recorded with 25 cm × 25 cm spacing. Similarly, the maximum yield was obtained with 22-day-old seedlings (5121.88 kg/ha), which was statistically similar to 25-day-old seedlings (5076.89 kg/ha).

Spacing exerted a discernible impact on rice yield, with the maximum yield achieved at 20 cm × 20 cm spacing, a result that exhibited statistical significance compared to other spacing configurations. Shrestha et al. (2019) observed a notable decrease in rice yield when older seedlings, surpassing 25 days of age, were transplanted. Consistent with these findings, Naresh (2012) noted a reduction in grain yield of 676 kg per hectare when transplanted after 20 days for long-duration varieties. Multiple studies (Adhikari et al., 2004; Gautam et al., 2010; Mahato and Pathic, 1997) have demonstrated a significant decline in grain yield when comparing 20-day-old seedlings with those aged 65 days. Saphi et al. (2015) reported a yield decrease ranging from 20% to 30% when transplanting seedlings aged 35 to 55 days compared to 25-day-old seedlings. Correspondingly, Alam et al. (2002) identified significantly lower grain yield when very young seedlings (21 days old) were transplanted compared to those aged 28 to 35 days in Mymensingh, Bangladesh.

Table 6: Different yield attributing characters of Chaite-5 as affected by the spacing and age of seedlings at Bardiya, Nepal

Treatment	Yield attributes		
Spacing	Sterility%	Thousand Grain Wt (gm)	Grain Yield(kg/ha)
15×15cm	37.46[a]	17.92[b]	5058.41[a]
20×20cm	29.49[c]	20.15[a]	5106.50[a]
25×25cm	32.21[b]	17.67[b]	4833.08[b]
SEM_1 ±	0.58	0.17	12.80
LSD_a (0.05)	2.30	0.67	50.27
CV(a)%	6.2%	3.2%	0.9%
F-test	**	***	***
Age of seedlings			
28 days old	33.82[a]	17.80[b]	4891.02[b]
25 days old	33.32[a]	18.48[ab]	5076.89[a]
22 days old	29.98[b]	18.88[a]	5121.88[a]
19 days old	35.08[a]	19.15[a]	4907.56[b]
SEM_2 ±	0.67	0.19	14.78
LSDb(0.05)	1.72	0.80	56.81
CV(b)%	5.3%	4.4%	1.1%
F-test	***	*	***
Grand mean	33.05	18.58	4999.33

*Note: Treatment means separated by DMRT and columns represented with the same letter(s) are non-significant at a 5% level of significance, *** indicates a 1% level of significance, ** indicates a 5% level of significance, * indicates a 10% level of significance, DAT: days after transplanting, NS= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance*

3.3 Interaction Effect of Age of Seedlings and Planting Spacing on Various Growths and Yields Parameter

3.3.1 Interaction effect of age of seedlings and planting spacing on the number of tiller

The interaction effect of the age of seedlings and planting spacing on the number of tiller was significant only 60 DAT and 75 DAT as shown in Table 7. Maximum tiller number (20.83) was produced by the treatment 20×20cm spacing and 22 days seedling which was followed by the treatment 25×25cm and 22 days old seedling (18.87) at 60 DAT. At 70 DAT, the maximum tiller number (17.26) was produced by the treatment 20×20cm spacing and 22 days seedling which was followed by the treatment 25×25cm and 22 days old seedling (15.23).

Table 7: Interaction Effect of Spacing and Age of Seedlings on the number of tillers

Treatments	No of tiller(60DAT)		
	Spacing		
Age of seedlings	15×15cm	20×20cm	25×25cm
28 days old	11.13f	14.53e	15.67de
25 days old	11.70f	14.50e	17.17bcd
22 days old	15.83cde	20.83a	18.87b
19 days old	12.40f	17.47bcd	17.67bc
LSD(0.05)	1.80		
F-test	*		
CV%	6.7%		
SEM±	0.69		
Treatments	No of tiller(75DAT)		
	Spacing		
Age of seedlings	15×15cm	20×20cm	25×25cm
28 days old	9.16g	13.40cd	12.08e
25 days old	9.68fg	13.85c	14.08c
22 days old	12.46de	17.26a	15.23b
19 days old	10.23f	15.31b	13.60c
LSD(0.05)	0.96		
F-test	*		
CV%	4.3%		
SEM±	0.51		

Note: Treatment means separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, DAT: days after transplanting

3.3.2 Interaction Effect of Spacing and Age of Seedlings on Effective Tillers per Hill and Filled Grain

The interaction of spacing and age of seedlings on effective tillers per hill was significant as shown in Table 8. The highest number of effective tillers per hill (13.33) was recorded with 20×20cm spacing and 22-day-old seedlings, followed by 25×25cm spacing and 22-day-old seedlings (12.10). Other treatments resulted in significantly lower numbers of effective tillers per hill. In terms of filled grain, the highest number (238.00) was found in 20×20cm spacing with 22-day-old seedlings, whereas the lowest (153.33) was recorded in 15×15cm spacing with 28-day-old seedlings.

Table 8: Interaction *Effect of Spacing and Age of Seedlings on Effective Tillers per Hill and Filled Grain*

Effective tillers per hill

Treatments	Spacing		
Age of seedlings	15×15cm	20×20cm	25×25cm
28 days old	6.93^{h}	9.76^{de}	8.10^{fg}
25 days old	7.50^{gh}	10.73^{c}	9.46_{de}
22 days old	8.90^{ef}	13.33^{a}	12.10^{b}
19 days old	7.20^{gh}	10.06^{cd}	9.53^{de}
LSD(0.05)	0.88		
F-test	*		
CV%	5.5%		
SEM±	0.22		

Filled grain

Treatments	Spacing		
Age of seedlings	15×15cm	20×20cm	25×25cm
28 days old	153.33^{h}	210.67^{b}	175.12^{fg}
25 days old	193.21^{cde}	211.00^{b}	190.67^{def}
22 days old	213.00^{b}	238.00^{a}	203.00^{bcd}
19 days old	185.66^{efg}	208.00^{bc}	171.33^{g}
LSD(0.05)	15.32		
F-test	*		
CV%	4.6%		
SEM±	7.23		

Note: Treatment means separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, DAT: days after transplanting

3.3.3 Interaction effect of spacing and age of seedlings on sterility % and grain yield of chaite-5 in Rajapur, Bardiya

The interaction of spacing and age of seedlings on sterility % was significant as shown in Table 9. The highest sterility % (40.04) was recorded in 15×15cm spacing of 19 days seedlings which was statistically at par with 15×15cm spacing of 28 days seedlings (38.45%) and 25 days seedlings (37.91%). The lowest sterility percentage (26.77%) was recorded in 20×20 cm spacing of 22 days seedling.

In the case of grain yield, the highest grain yield (5315.00 kg/ha) was found in 20×20cm spacing of 22-day-old seedlings whereas low grain yield (4856.47 kg/ha) was recorded in 25×25cm spacing of 19 days seedlings.

Table 9: Interaction effect of spacing and age of seedling on sterility % and grain yield

Sterility%			
Treatments	Spacing		
Age of seedlings	15×15cm	20×20cm	25×25cm
28 days old	38.45[ab]	32.81[cde]	30.21[def]
25 days old	37.91[ab]	28.95[fg]	33.11[cd]
22 days old	33.44[c]	26.77[g]	29.74[efg]
19 days old	40.04[a]	29.43[fg]	35.78[bc]
LSD(0.05)	2.98		
F-test	*		
CV%	5.3%		
SEM±	1.17		
Grain Yield			
Treatments	Spacing		
Age of seedlings	15×15cm	20×20cm	25×25cm
28 days old	4991.33[c]	4931.00[cd]	4750.67[e]
25 days old	5133.67[b]	5227.33[ab]	4869.37[d]
22 days old	5195.33[b]	5315.00[a]	4955.33[d]
19 days old	4991.33[cd]	4952.36[cd]	4856.47[d]
LSD(0.05)	98.40		
F-test	***		
CV%	1.1%		
SEM±	25.60		

Note: Treatment means separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, DAT: days after transplanting

3.4 Correlation regression

To understand the relationship between growth parameters, yield attributing traits, and grain yield, simple correlation coefficients were analyzed.

3.4.1 Effective tillers and grain yield

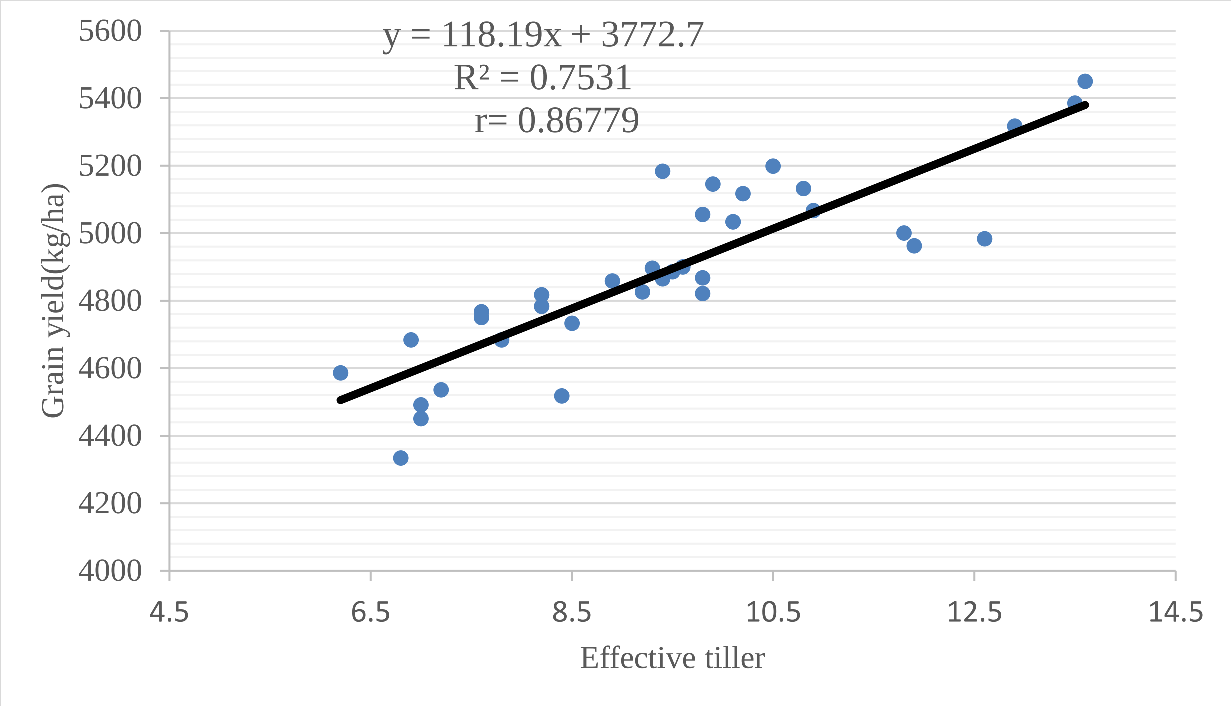

Fig.3. Linear relationship between effective tillers and grain yield of Chaite-5 at Rajapur, Bardiya

There exists a linear relationship between grain yield and effective tillers per hill. Effective tillers contributed to 75.31% of the total grain yield of rice, with the remaining contribution from other factors. A strong and significant correlation (r= 0.867) was found between grain yield and effective tillers per hill, indicating that an increase in the number of effective tillers per hill leads to an increase in grain yield.

3.4.2 Filled grain and grain yield

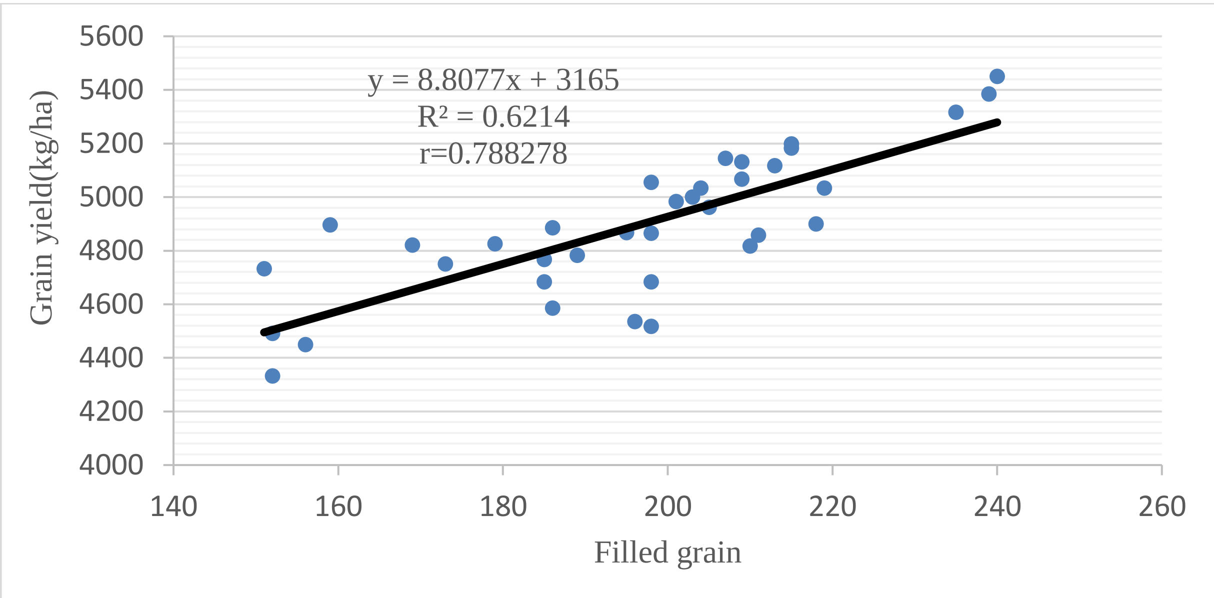

Fig.4. Polynomial relationship between filled grain and grain yield of spring rice as influenced by spacing at Rajapur, Bardiya

Filled grains contributed 62.14% to the paddy grain yield, with the remainder contributed by other factors. A strong and significant correlation (r= 0.788) was observed between grain yield and filled grains, indicating that an increase in filled grains results in higher grain yield.

3.4.3 Total grain per panicle and grain yield

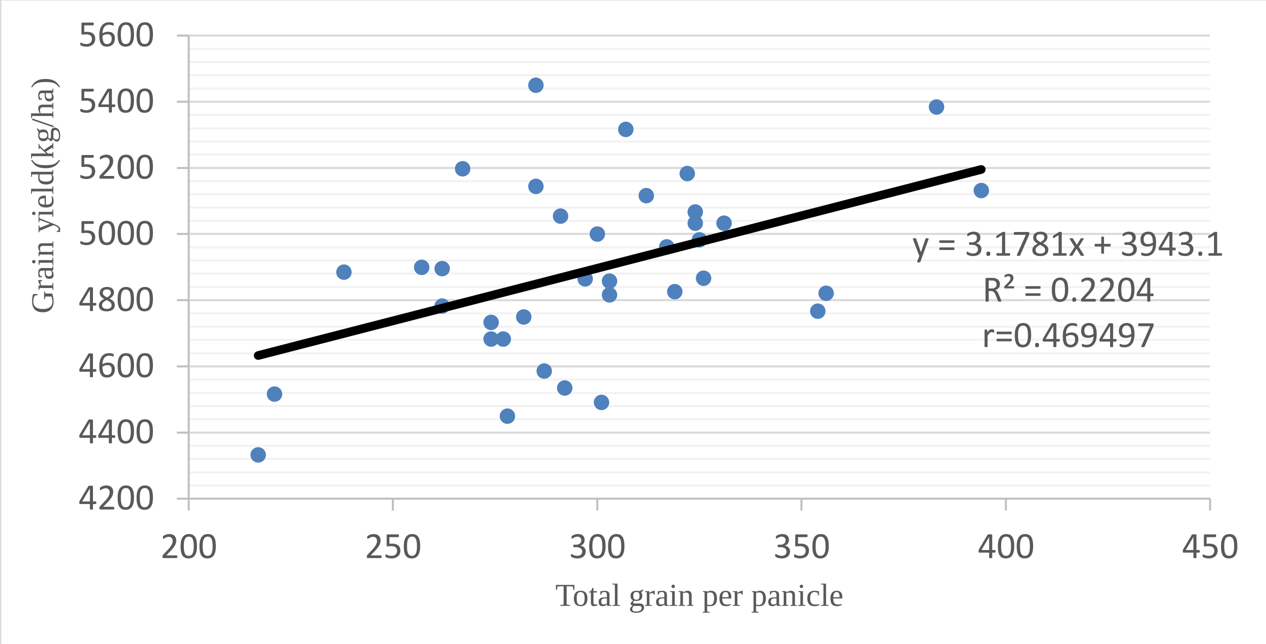

Fig.5: Logarithmic relationship between total grain per panicle and grain yield of Chaite-5 as influenced by planting spacing at Rajapur, Bardiya

Total grains per panicle contributed 22.04% to the grain yield of rice, with the remaining contribution from other factors. A strong and significant correlation (r = 0.469) was found between grain yield and the number of total grains per panicle, suggesting that an increase in the number of total grains per panicle leads to an increase in grain yield.

IV. CONCLUSION

Based on the findings it is evident that various growth parameters and yield-attributing parameters were significantly influenced by spacing and seedling age. Regarding growth parameters, plant height showed a significant increase up to 90 DAT, with 20×20 cm spacing resulting in the tallest plants. Similarly, the number of tillers per hill increased up to 60 DAT, with 20×20 cm spacing significantly increasing tiller numbers. Additionally, 22-day-old seedlings produced the maximum number of tillers per hill. In terms of yield and yield attributing parameters, panicle length varied across treatments, with the longest recorded at 20×20 cm spacing. Effective tillers per hill were significantly higher with 20×20 cm spacing, and 22-day-old seedlings also produced the highest number of effective tillers. The average number of filled grains per panicle was influenced by both spacing and seedling age, with 20×20 cm spacing and 22-day-old seedlings resulting in higher numbers of filled grains per panicle. However, thousand-grain weight was not significantly influenced by spacing and seedling age. Sterility percentage was highest at 15×15 cm spacing and with 19-day-old seedlings. Conversely, the lowest sterility was found in 20×20 cm spacing with 22-day-old seedlings. In terms of yield, the 20×20 cm spacing produced significantly higher grain yield, with 22-day-old seedlings also contributing to higher yields. It is important to note that there were similarities in grain yield between 22-day-old and 25-day-old seedlings.

Overall, these findings highlight the importance of spacing and seedling age in optimizing growth parameters and yield-attributing parameters in rice cultivation, with 20×20 cm spacing and 22-day-old seedlings showing promising results for maximizing grain yield. Further research and experimentation may be needed to fully understand and optimize these parameters for enhanced rice production.

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APPENDICES

Appendix 1. Mean square from ANOVA for the effect of the treatments on the height of Chaite-5 at Bardiya, Nepal, 2022 (30 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	4.815	2.408	NaN	NaN
Spacing	2	283.123	141.561	30.0429	0.003896 **
Ea	4	18.848	4.712	NaN	NaN
Age	3	37.193	12.398	1.8944	0.166737
Spacing:Age	6	15.183	2.531	0.3867	0.877945
Eb	18	117.799	6.544	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance and * indicates 10% level of significance

Appendix 2. Mean square from ANOVA for the effect of the treatments on the height of Chaite-5 at Bardiya, Nepal, 2022 (45 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	6.13	3.066	NaN	NaN
Spacing	2	349.76	174.880	40.6744	0.002196 **
Ea	4	17.20	4.299	NaN	NaN
Age	3	16.93	5.642	1.3401	0.292655
Spacing: Age	6	104.30	17.383	4.1289	0.008819 **
Eb	18	75.78	4.210	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance and * indicates 10% level of significance

Appendix 3. Mean square from ANOVA for the effect of the treatments on the height of Chaite-5 at Bardiya, Nepal, 2022 (60 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	28.43	14.21	NaN	NaN
Spacing	2	1048.83	524.41	48.8360	0.001548 **
Ea	4	42.95	10.74	NaN	NaN
Age	3	210.05	70.02	6.6487	0.003242 **
Spacing: Age	6	28.12	4.69	0.4450	0.839069
Eb	18	189.56	10.53	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance and * indicates 10% level of significance

Appendix 4. Mean square from ANOVA for the effect of the treatments on the height of Chaite-5 at Bardiya, Nepal, 2022 (75 DAT)

	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	142.06	71.028	NaN	NaN
Spacing	2	464.06	232.028	28.0302	0.004436 **
Ea	4	33.11	8.278	NaN	NaN
Age	3	274.44	91.481	5.9626	0.005239 **
Spacing: Age	6	88.39	14.731	0.960	0.478791
Eb	18	276.17	15.343	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance and * indicates 10% level of significance

Appendix 5. Mean square from ANOVA for the effect of the treatments on the height of Chaite-5 at Bardiya, Nepal, 2022 (90 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	22.585	11.292	NaN	NaN
Spacing	2	159.607	79.804	167.3735	0.0001394 ***

Ea	4	1.907	0.477	NaN	NaN
Age	3	203.988	67.996	12.7831	0.0001030 ***
Spacing: Age	6	35.089	5.848	1.0994	0.4003369
Eb	18	95.746	5.319	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance and * indicates 10% level of significance

Appendix 6.Mean square from ANOVA for the effect of the treatments on the number of tillers of Chaite-5 at Bardiya, Nepal, 2022 (30 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	0.237	0.119	NaN	NaN
Spacing	2	60.264	30.132	29.8994	0.003931 **
Ea	4	4.031	1.008	NaN	NaN
Age	3	99.282	33.094	55.7852	2.586e-09 ***
Spacing: Age	6	3.069	0.512	0.8623	0.540523
Eb	18	10.678	0.593	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance and * indicates 10% level of significance

Appendix 7.Mean square from ANOVA for the effect of the treatments on the number of tillers of Chaite-5 at Bardiya, Nepal, 2022 (45 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	0.861	0.430	NaN	NaN
Spacing	2	85.967	42.984	19.9975	0.008266 **
Ea	4	8.598	2.149	NaN	NaN
Age	3	75.596	25.199	34.3920	1.155e-07 ***
Spacing: Age	6	11.066	1.844	2.5173	0.060140
Eb	18	13.188	0.733	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance, and * indicates 10% level of significance

Appendix 8. Mean square from ANOVA for the effect of the treatments on the number of tillers of Chaite-5 at Bardiya, Nepal, 2022 (60 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	4.729	2.364	NaN	NaN
Spacing	2	150.907	75.454	52.8007	0.001332 **
Ea	4	5.716	1.429	NaN	NaN
Age	3	118.401	39.467	35.5647	8.946e-08 ***
Spacing:Age	6	18.842	3.140	2.8298	0.040416 *
Eb	18	19.975	1.110	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance and * indicates 10% level of significance

Appendix 9. Mean square from ANOVA for the effect of the treatments on number of tillers of Chaite-5 at Bardiya, Nepal, 2022 (75 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	0.396	0.198	NaN	NaN
Spacing	2	134.636	67.318	83.0908	0.0005525 ***
Ea	4	3.241	0.810	NaN	NaN
Age	3	56.423	18.808	58.7910	1.69e-09 ***
Spacing: Age	6	5.252	0.875	2.7361	0.0454730 *
Eb	18	5.758	0.320	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance, and * indicates 10% level of significance

Appendix 10. Mean square from ANOVA for the effect of the treatments on number of tillers of Chaite-5 at Bardiya, Nepal, 2022 (90 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	0.322	0.161	NaN	NaN
Spacing	2	147.215	73.607	274.3137	5.239e-05 ***
Ea	4	1.073	0.268	NaN	NaN
Age	3	39.269	13.090	24.8581	1.271e-06 ***
Spacing: Age	6	16.823	2.804	5.3246	0.00258 **
Eb	18	9.478	0.527	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance, and * indicates 10% level of significance

Appendix 11. Mean square from ANOVA for the effect of the treatments on the panicle length of Chaite-5 at Bardiya, Nepal, 2022

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	0.4554	0.2277	NaN	NaN
Spacing	2	17.6696	8.8348	124.3755	0.0002505 ***
Ea	4	0.2841	0.0710	NaN	NaN
Age	3	8.0867	2.6956	10.8485	0.0002675 ***
Spacing:Age	6	2.7411	0.4569	1.8386	0.1478145
Eb	18	4.4725	0.2485	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance, and * indicates 10% level of significance

Appendix 12. Mean square from ANOVA for the effect of the treatments on the effective tillers per hill of Chaite-5 at Bardiya, Nepal, 2022

Source	Df	Sum Square	Mean Square	F value	Pr(>F)
Replication	2	0.134	0.067	NaN	NaN
Spacing	2	68.967	34.484	234.6711	7.141e-05 ***
Ea	4	0.588	0.147	NaN	NaN
Age	3	51.214	17.071	63.4231	9.105e-10 ***
Spacing:Age	6	4.488	0.748	2.7792	0.04307 *
Eb	18	4.845	0.269	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance, and * indicates 10% level of significance

Appendix 13.Mean square from ANOVA for the effect of the treatments on the filled grains per panicle of Chaite-5 at Bardiya, Nepal, 2022

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	184.2	92.1	NaN	NaN
Spacing	2	7842.7	3921.4	24.9592	0.005504 **
Ea	4	628.4	157.1	NaN	NaN
Age	3	7330.3	2443.4	30.6139	2.773e-07 ***
Spacing: Age	6	1927.5	321.2	4.0249	0.009887 **
Eb	18	1436.7	79.8	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance, and * indicates 10% level of significance

Appendix 14. Mean square from ANOVA for the effect of the treatments on the sterility percentage of Chaite-5 at Bardiya, Nepal, 2022

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	1.21	0.604	NaN	NaN
Spacing	2	393.74	196.868	47.6095	0.001625 **
Ea	4	16.54	4.135	NaN	NaN
Age	3	128.00	42.668	14.0482	5.801e-05 ***
Spacing:Age	6	71.18	11.863	3.9058	0.011287 *
Eb	18	54.67	3.037	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance and * indicates 10% level of significance

Appendix 15.Mean square from ANOVA for the effect of the treatments on the thousand-grain weight of Chaite-5 at Bardiya, Nepal, 2022

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	0.326	0.1632	NaN	NaN
Spacing	2	44.842	22.4209	62.7549	0.0009539 ***
Ea	4	1.429	0.3573	NaN	NaN
Age	3	9.278	3.0927	4.6614	0.0140015 *
Spacing:Age	6	6.583	1.0972	1.6537	0.1899819
Eb	18	11.943	0.6635	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance, and * indicates 10% level of significance

Appendix 16. Mean square from ANOVA for the effect of the treatments on the grain yield of Chaite-5 at Bardiya, Nepal, 2022

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	2522	1261	NaN	NaN
Spacing	2	511375	255688	130.0106	0.0002295 ***
Ea	4	7867	1967	NaN	NaN
Age	3	370746	123582	37.5491	5.9e-08 ***
Spacing:Age	6	144288	24048	7.3067	0.0004499 ***
Eb	18	59242	3291	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance, and * indicates 10% level of significance

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An account of ornamental bird status and species assemblage in the bird shops of Rajshahi City Corporation, Bangladesh

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Abstract—The rearing and business of ornamental birds have become an important source of income in Bangladesh. The present study was conducted to determine the management and profitability of the ornamental birds, and species assemblage of the cage bird business in Rajshahi City, Bangladesh. A total of 30 ornamental bird shops were found and were working with new promise in the study area. This study identified 24 varieties of ornamental birds, including exotic and indigenous, that were traded in Rajshahi City. The most dominant order was Psittaciformes (6 species) followed by Passariformes (3 species), and Columbiformes (7 species) under the families Columbidae (seven), Psittaculidae (five), and Estrilididae (two) species, and only one species is found in the Fringillidae and Cacatuidae families. Shannon's index (H) for species diversity is 2.37, the evenness index (E) is 0.86, and Margalef's index (d) for species richness is 2.22. Most of the ornamental birds were imported by traders who fulfilled requirements to import them. The bird cages along with other accessories such as feed, medicine, and artificial pots were also traded in shops in this area.

Keywords— Ornamental birds, rearing, business, diversity and species

I. INTRODUCTION

Bangladesh is situated in a subtropical monsoon climate. It is the home of 690 different kinds of birds, of which 380 are permanent inhabitants, 209 are winter visitors, 11 are summer visitors, and 90 are vagrants. (Khan, 2008). Birds are crucial for the structure and function of ecosystems because they provide a multitude of ecological services, including seed dispersal and assisting in the restoration of forests (Lozada *et al*., 2007). Around 4,000 years ago, in prehistoric Egypt, cage birds were first recognized. They are fed two different kinds of food: oil and grain seeds. Such cage birds are fed various foods from Morocco, Canada, and Australia. The remaining ingredients are found in oil seeds, almonds, sunflower seeds, and mustard seeds, as well as in cereals (Alderton 2000, 2003, 2005). First, the idea of cage bird study came from aviculturists, who saw that the altricial or helpless chicks of birds from their hatch needed to care for humans. There are six color patterns in Cockatiel, and California is the major Cockatiel producer and supplier in the world (Grau and Roudybush, 1983). A study that was conducted in Dhaka Katabon, Bangladesh, in 2009 suggested that there were 33 species of birds out of 43 wildlife species (Sarker and Abdullah, 2009). The six basic fundamental needs for cage birds should be food, environment, disease-free life, company, and avoiding mental suffering. The cages of birds need to change their position twice a year, and when any new birds are introduced, they are observed for thirty days in quarantine (Animal Welfare Council, UK). International and local laws are designed for trade, and live animals are sold in regional open markets (Sullivan, 2003). Ecologists often use the richness, abundance, and community composition of birds to understand the diversity of species in natural occurrence (Joshi, 2001). Several studies on birds have been done sporadically in various parts of the country (Kabir, 2014), however, there is no record of Rajshahi pet birds. So, in this investigation, we have enlisted the available ornamental cage birds, and the possible diversity assemblage was determined that has been found in the pet shop of the Rajshahi City Corporation area of Bangladesh.

II. MATERIALS AND METHODS

The study was conducted in Rajshahi City to obtain detailed information about ornamental bird status, species availability, diversity, abundance, and prospects of bird shops in the Rajshahi City Corporation area. The total area is 8.20 sq. km, located between 24°21' and 24°23' north latitudes and between 88°32' and 88°36' east longitudes. The study period was conducted over six months (November to April) in 2022. The data was collected two times a month. The information was collected through survey methods, using questionnaires and cross-check interviews. In favor of this study, one of the PRA (Participatory Rural Appraisal) tools and FGD (Focus Group Discussion) were conducted to obtain more accurate data (Chambers, 1992; Nabasa *et al.*, 1995). The session was held in front of bird shops. At the beginning of the interview, a brief introduction about the objectives of the survey was given to each of the shopkeepers, who were assured that all information would be kept confidential. Each question was explained clearly and asked systematically for their sound understanding. Statistical analysis like relative abundance was done through a formula in Microsoft Excel and biodiversity indices were calculated following (Shannon and Wiener, 1949):

$$H'(S) = -\sum_{i=1}^{s} pi \ln pi$$

Where pi = fraction of entire population made up of species; S = total number of species; i = proportion of species.

Evenness Index (Hill, 1973):

$$E = H/ \ln S$$

Where, S = total number of species; H = Index of species;

Margalef's Index (Margalef, 1970):

$$d= (S-1)/ \ln N$$

Where, S = Total number of species; N = Total number of individuals in the sample.

III. RESULTS

During the study period, we collected data from 24 varieties of ornamental birds. From them, 16 species of three orders and five families were recorded from the pet bird shops in the Rajshahi City Corporation area. Among them, different species of love birds, finch birds, and different varieties of pigeons are mostly common. They are very gorgeous colors, nice-looking, and very attractive. From the collection list of ornamental birds in Rajshahi City's bird shop, we found that there are 3 orders of birds in Rajshahi City's bird shop. They are Psittaciformes, Passariformes, and Columbiformes. It is found that the Psittaciformes order has seven species, the Passeriformes order has three species, and the Columbiformes order has six species.

The Shannon-Wiener Diversity Index (H'), Evenness (E), and Margalef's Richness Index (d) were computed concerning the species. Studies on diversity indices in this area yielded the following findings: Shannon's index (H) for species diversity is 2.37, the evenness index (E) is 0.86, and Margalef's index (d) for species richness is 2.22.

Table 1: List of the ornamental birds in the bird shop of the Rajshahi City Corporation area

Common Name	Scientific Name	Number of Individuals	Relative abundance
Order: Psittaciformes **Family:** Psittaculidae			
Budgerigar	*Melopsittacus undulates*	100	11.76
Yellow-collared love bird	*Agapornis personatus*	80	9.41
Fisher's Love Bird	*A. fischer*	60	7.06
Lillian's love bird	*A. lilianae*	30	3.53
Black-winged love bird	*A. taranta*	20	2.35
Family: Cacatuidae			
Cockatiel	*Nymphicus hollandicus*	60	7.06
Order: Passeriformes			

Family: Esrtildidae			
Gouldian finch	*Chloebia gouldiae*	40	4.71
Zebra Finch	*Taeniopygia castanotis*	40	4.71
Family: Fringillidae			
American Goldfinch	*Spinus tristis*	30	2.35
Order: Columbiformes **Family:** Columbidae			
Eurasian collared dove	*Streptopelia decaocto*	20	2.35
Stock Dove	*Columba oenas*	20	2.35
Diamond dove	*Geopeliacun cuneate*	20	4.71
Spotted dove	*Spilopelia chinensis*	40	3.53
King Pigeon	*C. livia*	30	2.35
Silver siraji		20	2.35
Noton pigeon		20	4.71
Lahore pigeon		40	3.53
White Lahore		30	2.35
Chua chandan		20	3.53
Giribadge		30	4.71
Homar		40	3.53
Lakhma		30	1.18
Yellow eyed pigeon	*C. eversmanni*	10	2.35
Zebra Dove	*Geopelia striata*	20	3.53
Total		850	100

Table 1 shows 5 families of ornamental birds in the Rajshahi City area's bird's shop. The families are Psittaculidae, Esrtildidae, Fringillidae, Cacatuidae, and Columbidae. These families and family-wise bar diagrams are displayed below-

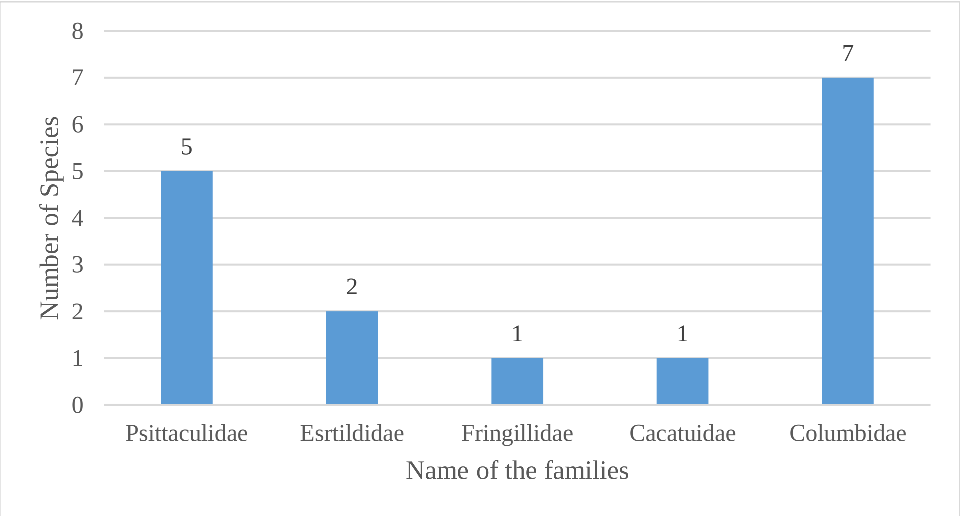

Fig. 1. Showing the families of different ornamental varieties

The bird cages with accessories such as feed, medicine, and artificial pots were also traded in shops in this area. All traders in markets made a considerable amount of profit.

IV. DISCUSSION

In this study, a total of 24 varieties and 16 species of ornamental birds were found under three orders and five families in Rajshahi City Corporation pet and ornamental bird shops during the study period. Columbidae has 7 species, Psittaculidae has 5 species, Estrilididae has 2 species, and only 1 species is found in the Fringillidae and Cacatuidae families. Kabir (2014) mentioned that there are 16 in total belonging to the families Psittacidae 6, Passeridae 5, Phasianidae 3, and Columbidae 2 in the districts of Kushtia and Dhaka Katabon, Bangladesh. According to Kabir (2014), previous and present studies in different locations have both similarities and dissimilarities, resulting in birds of the Phasianidae family not being found in the Rajshahi area, but birds of the Estrilididae and Cacatuidae were not found in the previous study. Popular cage birds found in Bangladesh are Canary, Munia, Red Munia, Java Sparrow, Gold Finch, Green Finch, Blue Finch, etc. (Url 1). But in our study area, it was found that love birds, finch birds, and different varieties of pigeons are mostly common; Munia was not found in this area at all. A report in 2015 indicated that the Australian lovebird is a prevalent species. Several works on avifauna have been done separately in various parts of the country, but there is no record of ornamental bird diversity in any bird market in Bangladesh. Birds are mainly imported from India, Pakistan, Australia, America, the UK, and China. The sellers of Katabon Market make sure that you will find safe food and medicine for your pets. They collect foods and medicines according to the guidance of different relevant books and manuals (Url 2). Among cage birds, the Budgerigar had the highest frequencies for the people. With the wild and foreign cage birds, some other indigenous birds like the rose-ringed parakeet, Chinese spotted dove and hill myna were occasionally found, which are now facing great ecological hazards (IUCN, 2000). People took wild or caged animals as not only pets but also food, medicine, decoration, and export goods (Martin and Phipps, 1996).

V. CONCLUSION

Ornamental birds are available everywhere around the globe. The ornamental bird business is a flourishing sector in the trendy business world. Considering the findings of all the present research work, it is clear that the introduction of ornamental birds in Bangladesh is a very common practice, and new species are introduced day by day. In our country, ornamental birds in the Rajshahi City Corporation area are also remarkable. However, shop owners are normally illiterate people, and they don't have formal training to maintain their living-sale items. It is also said that there is no doubt that Bangladesh is losing some of its valuable indigenous wildlife, especially birds. Therefore, people have to be conscious of wildlife, ornamental birds, nature, and the conservation of nature. It is our moral responsibility as such departments to implement laws and control the illegal trade of that animal.

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Review Paper on Millet: Production, Nutrients, Processing, and Food Products for Health and Sustainability

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***Abstract*— *Millet is an important ancient cereal crop known for its nutritional value. It has served as a staple food for various cultures for thousands of years, offering a rich source of carbohydrates, protein, fiber, vitamins, and minerals. Millet grains are small, round, and have a hard outer layer, making them versatile for processing into various food products. They are commonly ground into flour or grits for making porridge, bread, and crackers, and can also be used in fermented foods like beer and sourdough. In the context of climate change, water scarcity, and global population growth, millet's role in ensuring food security is becoming increasingly important. Food scientists, technologists, and nutritionists are showing growing interest in millet due to its nutritional benefits and potential health advantages. This review paper aims to enhance the processing methods of millet to support its consumption by a large and expanding population.*

***Keywords*— Functional characteristics, millet, nutritional value, processing.**

I. INTRODUCTION

An ancient crop that was cultivated early on is millets, a type of grain belonging to the Poaceae grass family. They are small-seeds and in round shape that are poised to become a global sensation. Millets, have been renamed as "nutricereals" to highlight their nutritional value and importance. Millets are highly nutritious food that offer a potential solution to the increasing prevalence of gut-related diseases and metabolic disorders. These grains, often termed "superfoods," are recognized for their exceptional nutrient density and health benefits. Despite once being a staple in traditional Indian cuisine, millets have largely been replaced by rice and wheat in modern diet. They are rich in protective polyphenols like hydroxycinnamic acid, catechin, quercetin, luteolin, orientin, apigenin, and isoorientin. These polyphenols exhibit antioxidant properties by scavenging free radicals and possess anti-inflammatory effects. Finger millet stands out for its high flavonoid content, whereas foxtail millet, pearl millet, and proso millet are notable for their elevated levels of phenolic acids. Ferulic acid, a type of hydroxycinnamic acid, is particularly abundant in millets and is known for its potent antioxidant capabilities (Jena *et al.*, 2023).

Millets are easy to cultivate due to their climate resilience and drought-tolerant properties, enabling them to survive in extreme temperatures. They can be cultivated in both kharif and rabi seasons and have a good shelf life. It require significantly less water for irrigation compared to wheat and rice, which require 26 times more water. They use 70% less water than rice and grow 50% faster than wheat. Millets are naturally resistant to pests, which reduces the necessity for pesticides. Millets exhibit adaptability to a wide range of ecological conditions, minimal vulnerability to environmental stresses, low irrigation requirements, and optimal growth and productivity under minimal input conditions (Kole et al., 2015). Despite being overlooked previously, the importance of millets is gaining recognition in today's world (Goron and Raizada, 2015). The biodiversity of millets provides researchers with access to potential candidate genes for further improving crop traits. Therefore, millets, particularly improved varieties of small millets, hold great promise in addressing the challenges posed by climate uncertainties and constraints on natural resources (Den Herder et al., 2010; Dai, 2011).

International Year of Millets 2023: Initiatives and Proposed Activities:

The Indian government proposed to the United Nations for declaring the year 2023 as the International Year of Millets (IYOM). With the support of 72 other countries, the United Nations General Assembly (UNGA) officially declared 2023 as the International Year of Millets on March 5, 2021. The initiative of the Indian government for celebrating IYOM 2023 involves increasing awareness of the nutritional benefits of millets and enhancing the acceptability of value-added millet products across the country and around the world. The International Year of Millets offers a significant opportunity to:

- Enhance the contribution of millets to food security.
- Increase global millet production.
- Improve efficiency in processing, transport, storage, and consumption of millets.
- Promote sustainable production practices and ensure millet quality with the involvement of stakeholders (APEDA, 2023).

HISTORY AND ORIGIN

The history and origin of millets trace back to ancient times, with evidence suggesting that millets were among the earliest cultivated crops in human history (Gupta & Das, 2005). Millets are believed to have originated in Africa and Asia, where they were domesticated around 10,000 years ago, making them one of the earliest crops to be cultivated by humans (Harlan, 1992). Archaeological findings from sites in China and India provide insights into the early cultivation and use of millets by ancient civilizations (Kumar & Ganesamurthy, 2015). Millets played a crucial role in sustaining ancient populations due to their resilience in diverse agro-climatic conditions and their nutritional value (Harlan, 1992). They were staples in the diets of early civilizations like the Harappan civilization and ancient Chinese dynasties (Gupta & Das, 2005). Over time, millets spread to other parts of Asia, Europe, and Africa, adapting to different cultural and environmental contexts (Kumar & Ganesamurthy, 2015).

TYPES OF MILLET

Millets are categorized into two types: major millets and minor millets. The major millets include Pearl millet, Proso or white millet, Foxtail millet, and Finger millet On the other hand, the minor millets comprise Barnyard millet, Little millet, Guinea millet, Kodo millet and Sorghum. The distinctive characteristics of millets are outlined in Table 3.

Table 1: Distinctive features of millet (Kalse et al., 2022)

Millet	Picture	Scientific name	Common name	Color	Shape and size	Origin
Finger millet		*Eleusine coracana*	Ragi, Wimbi, Kapai, Nagli, Marua, Mandua, Nachni	Colour - Light brown to dark brown. .	Shape – Spherical Size - 1–2 mm in dia	East Central Africa (Uganda)
Pearl millet		*Pennisetum glaucum*	Bajra, Cattail millet, Black millet, German millet	Colour- White, grey, pale yellow, brown, or purple.	Size 3–4 mm length Shape - Ovoid	Tropical West Africa (Sahel)

Proso millet		*Panicum miliaceum*	Cheena, Common millet, Broom millet, Vari	Colour - White cream, yellow, orange	Size - 3 mm long and 2 mm in dia Shape - Spherical to oval	Central and eastern Asia
Foxtail millet		*Setaria italic*	Indian paspalum, Kangni, Water couch, Italian millet, Rala	Colour - Pale yellow to orange	Shape - Ovoid Size -2mm length	China
Kodo millet		*Paspalum scrobiculatum*	Kodara, Ditch millet, Creeping paspalum	Colour- Blackish brown to dark brown	Size - 1.2 to 9.5 μm long Shape - Elliptical to oval	India & West Africa
Barnyard millet		*Echinochloa crusgalli*	Bhagar, Sawan, Jhingora, Kudraivali, Oodalu, Barti	Colour – White	Size – 2-3 mm long Shape – Tiny round	Japan & India
Little millet		*Panicum sumatrense*	Kutki, Samai, Samalu, Haliv	Colour - Grey to straw white	Size - 1.8 to 1.9 mm long Shape - Elliptical to Oval	Southeast Asia

II. PRODUCTION STATUS

Millets are among the major cereal grains consumed globally, particularly in arid and semi-arid regions of Africa and Asia, notably India and China. They are valued for their high nutritional content and agro-industrial significance (Saleh et al., 2013).

World millet production

Millet ranks as the sixth-highest yielding grain worldwide. The global millet production was estimated at 31,019,370 tonnes, with India being the largest producer, followed by Niger, China and other countries (FAO, 2020). The millet production will total 30.802 million Metric Ton in 2023/2024, which corresponds to a decline of 4.1% compared to the previous year (Mundus Agri, 2024).

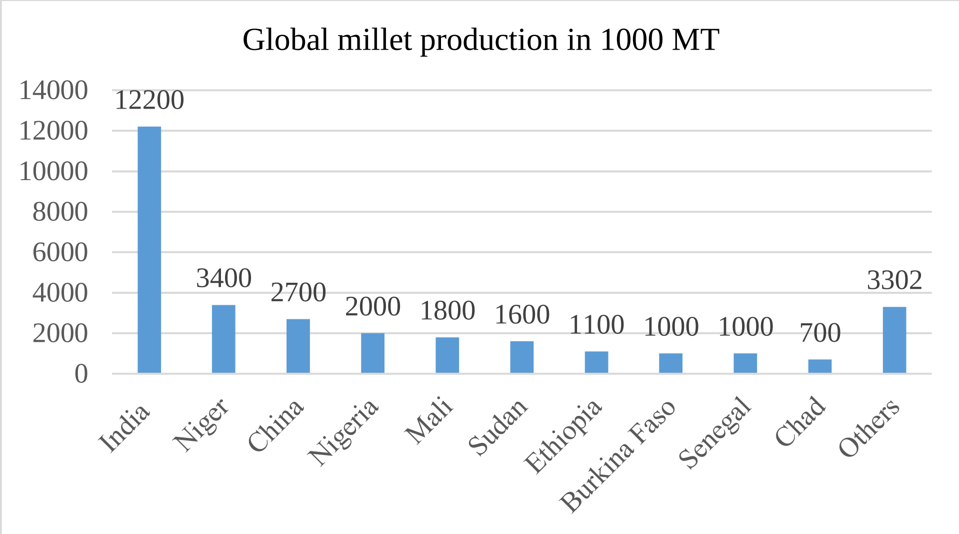

Fig.1: World production of millet (million tonnes), (Mundus Agri, 2024)

Millet production has shown stability in recent years, with an estimated output of 28 million metric tons in 2023. The majority of millet is cultivated in Africa, followed by Asia, with India leading as the largest producer, followed by Niger and China. Other significant millet-producing countries include Burkina Faso, Mali, and Senegal. Although millet is not a major food crop in developed nations, it holds significant importance in the diets of many people in developing countries (APEDA, 2023).

Indian millet production

In recent years, millet production in India has been increasing steadily. India is among the largest producers of millets globally, and Indian farmers are increasingly cultivating millets due to their drought-resistant nature. The Indian government has actively promoted millet production through initiatives like the National Food Security Mission. Consequently, millet production in India is projected to continue expanding in the future. The total production of Millets in the country during 2022-23 is 17.32 million tonnes (APEDA, 2023).

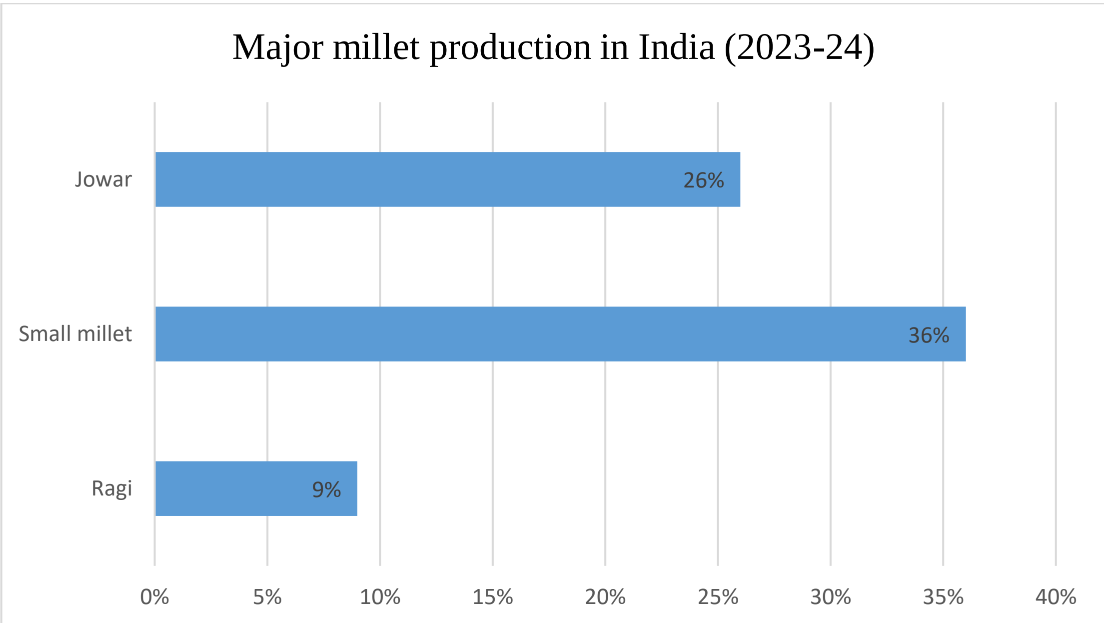

Fig.2: Millet production in India (APEDA, 2023)

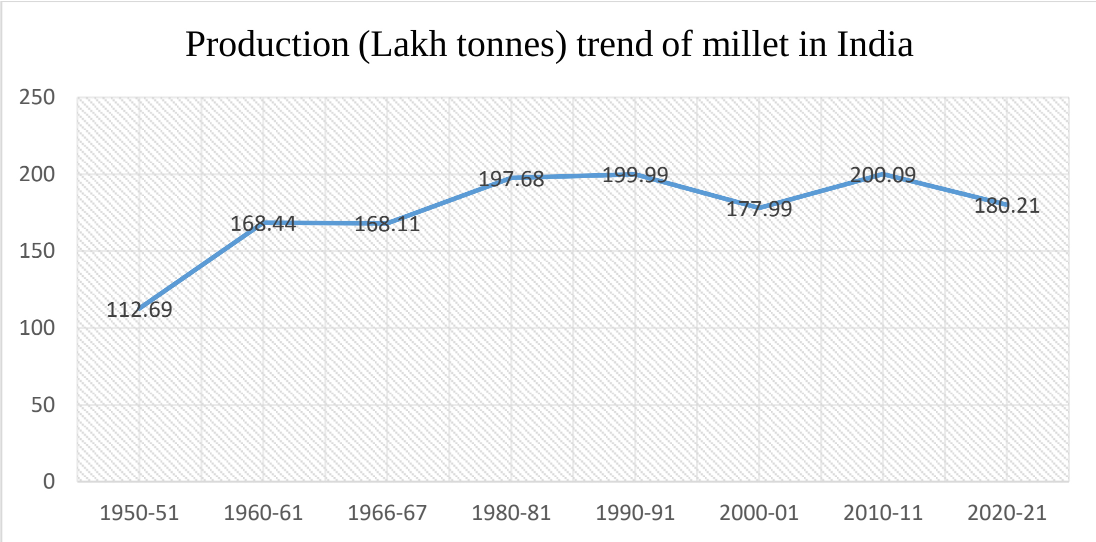

Fig.3: The production trends of millets in India (APEDA, 2022)

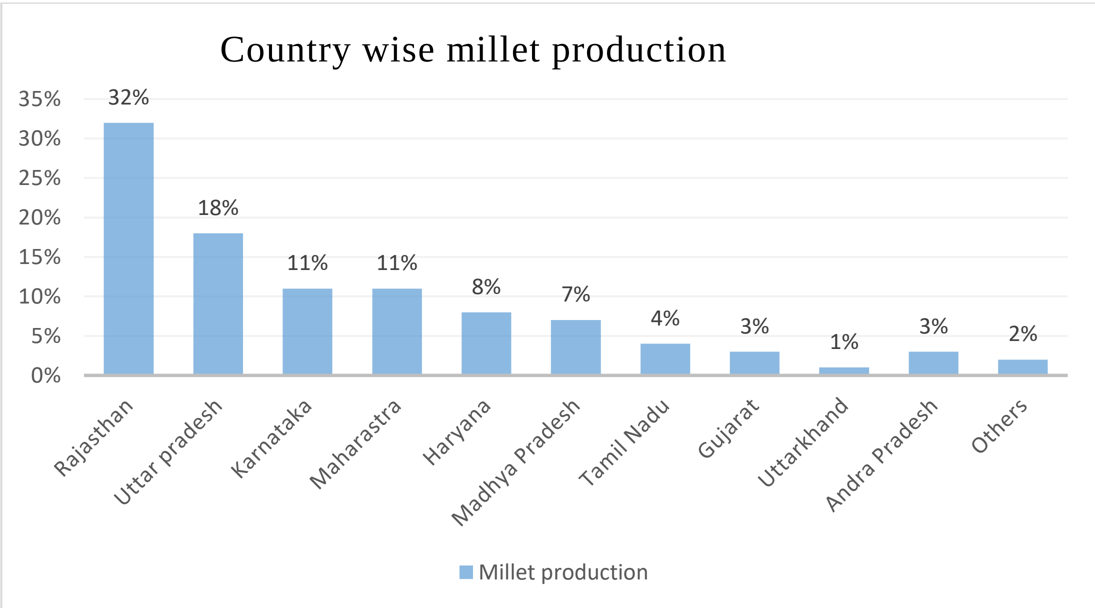

Fig.4: State wise production of millet (APEDA, 2023)

III. PHYSICAL CHARACTERISTICS OF MILLET

The kernel characteristics of various millets exhibit significant diversity. Millets can be categorized into two types based on their seed structure: utricles and caryopses. Utricle-type millets, such as finger millet, proso millet, and foxtail millet, have a pericarp that surrounds the seed like a sac but is attached to the seed at only one point. In these millets, the pericarp typically separates from the seed coat (testa), which is well-developed, thick, and forms a strong barrier around the endosperm. On the other hand, caryopsis-type millets, including pearl millet, fonio, and teff, have a pericarp that is completely fused to the seed. The endosperm accounts for the majority of the kernel weight across all millets. It comprises four structural parts: the aleurone layer, peripheral endosperm, corneous endosperm, and floury endosperm. All millets have a single-layer aleurone that surrounds the endosperm. The aleurone cells are rectangular with thick cell walls and contain protein, oil, minerals, and enzymes. The peripheral, corneous, and floury endosperm areas are located beneath the aleurone layer in that sequence (McDonough, 2000).

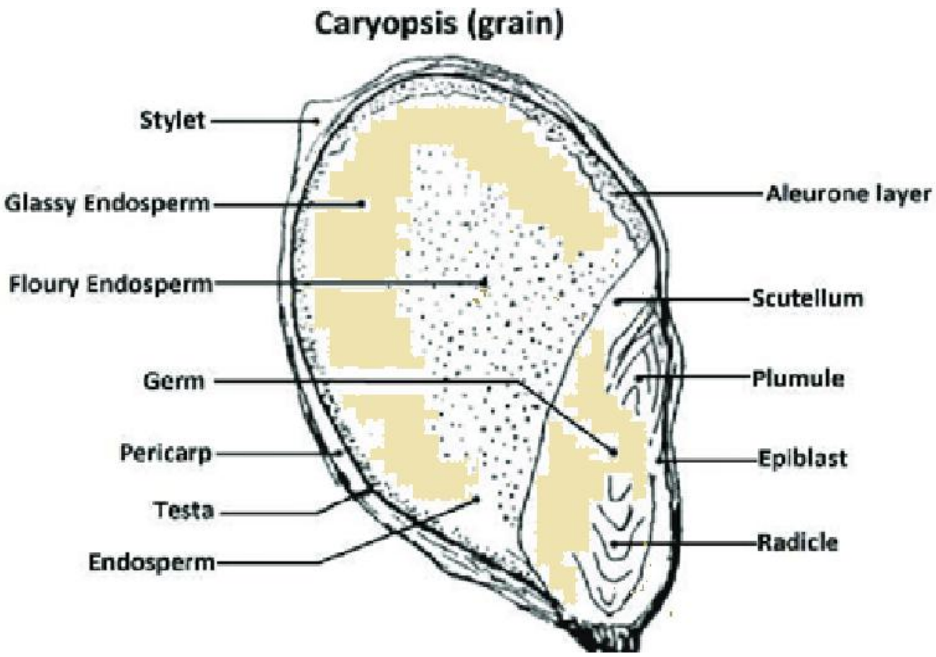

Fig.5: Structure of millet (Dayakar et al., 2016)

IV. NUTRITIONAL QUALITY OF MILLETS

The nutritional quality of food plays a critical role in maintaining overall human physical well-being, as it contributes to sustained health and development while maximizing human genetic potential. Therefore, addressing deep-rooted food insecurity and malnutrition requires a focus on dietary quality (Singh & Raghuvanshi, 2012). Whole-foods and plant-based diets have been shown to offer numerous health benefits and are associated with reduced risk of various diseases, including cancer, diabetes, obesity, and heart diseases (Chandrasekara & Shahidi, 2012).

Millets are rich in physiologically active substances and offer numerous health benefits, including a high antioxidant content, significant fiber content, low glycemic index, and gluten-free protein. Millets serve as an excellent source of energy, protein, and minerals due to their nutritional composition. They contain essential vitamins such as niacin (B3), thiamine, riboflavin, and folic acid. Approximately 70% of millet grains consist of carbohydrates, predominantly soluble carbohydrates and dietary fiber. The majority of millet polysaccharides comprise amylopectin and amylose (70–80%). Additionally, millets are abundant in polyphenols (0.2–0.5%), tannins, and phytates, which contribute significantly to their antioxidant activity and play a role in regulating the aging process. Finger millet, in particular, stands out with the highest calcium content among grains, at 344 mg/100 g (Tripathi *et al.*, 2023).

Millets and their food products are known to contain biologically active compounds with antioxidant potential (Izadi *et al.*, 2012). Millet-based products such as millet porridge, millet wine, and millet nutrition powder, both from whole grain and flour forms, are increasingly becoming part of people's daily lives (Subramanian *et al.*, 2007; Liu *et al.*, 2012). Resistant starch (RS) is a type of starch that resists enzymatic hydrolysis for at least 120 minutes after ingestion in the stomach and small intestine. RS is classified as a dietary fiber (DF) and offers similar health benefits to other non-starch polysaccharides (NSP) (Meenu & Xu, 2019; Shen et al., 2017; Nugent, 2005).It is considered a potential substitute for traditional dietary fibers such as inulin, β-glucan, and cellulose, mainly because of its minimal impact on sensory attributes and favorable cost economics (Charalampopoulos et al., 2002). The main source of starch comes from cereals. According to a FAO report, global cereal demand is projected to increase significantly, reaching 3036 million tons by 2028 (OECD/FAO, 2019).

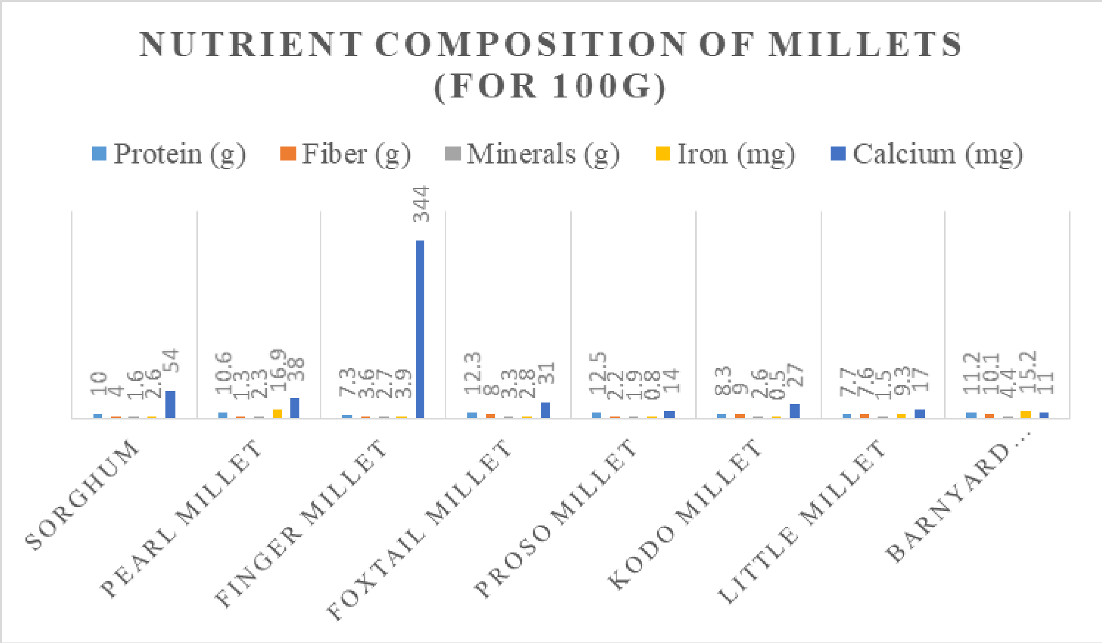

Fig.6: Nutritional composition of millets (for 100 g) (Indian Institute of Millet Research (IIMR))

FUNCTIONAL CHARACTERISTICS OF MILLET

Functional properties refer to the fundamental physicochemical and/or organoleptic properties of food components that provide health benefits to consumers (Chandra & Samsher, 2013; Siddiq et al., 2009). Ready-to-eat food is characterized by its texture, nutrient structure, nutritional value, and bioavailability of nutrients, among other factors, imparted by its various constituents. Parameters such as water absorption capacity, hydration (water binding), oil absorption capacity, swelling capacity, solubility, emulsifying activity, emulsion stability, foam capacity, foam stability, bulk density, gelatinization, dextrinization, denaturation, coagulation, gluten formation, aeration, elasticity, viscosity, jelling, and shortening (Chandra & Samsher, 2013) are essential considerations when selecting ingredients for functional foods. Additionally, the type, nature, structure, and configuration of components like carbohydrates, proteins, amino acids, fats and oils, and fiber must be analyzed.

Functional properties are essential physicochemical characteristics that describe how food components interact within specific environmental conditions. These properties help evaluate and predict how new proteins, fats, fibers, and carbohydrates will perform in different systems, assessing whether they can replace or complement traditional ingredients (Kaur *et al.*, 2006; Siddiq *et al.*, 2009). Food properties encompass the structure, quality, nutritional value, and consumer acceptability of a food product. Functional properties are defined by their physical, chemical, and sensory attributes (Abah *et al.*, 2020).

It is crucial to evaluate how processing conditions and parameters affect the behaviour of food constituents. For instance, the oil and water-binding capacities of food protein depend on factors such as conformation, amino acid composition, and surface polarity or hydrophobicity (Chandra & Samsher, 2013). In summary, before incorporating millet into a specific food product, it is important to thoroughly understand all of its essential physicochemical properties.

HEALTH BENEFITS ASSOCIATED WITH MILLETS

Diets rich in plant-based foods have demonstrated protective effects against various degenerative diseases, such as cancer, cardiovascular disease, diabetes, metabolic syndrome, and Parkinson's disease, based on epidemiological evidence (Chandrasekara *et al.*, 2012). The U.S. Department of Agriculture (USDA) has adjusted its nutritional guidelines to emphasize the importance of including grains or grain products in a regular diet for optimal health, placing them at the base of the food guide pyramid (USDA 2000; USDA 2005).

Table 2: Health benefits of millets

Millet type	Health benefits	Diseases	Positive side	Negative side	Refernces
Finger millet	Rich in calcium, iron and dietary fiber	Helps prevent anemia and osteoporosis	Gluten-free, high in antioxidants	May cause allergic reactions in some individuals	(Saleh et al., 2013)
Pearl millet	Good source of protein and B-complex vitamins	Aid in diabetes management	Drought-resistant, suitable for arid regions	Limited data on long-term effects	(Saleh et al., 2013; Gupta et al., 2018)
Foxtail millet	Low glycemic index, rich in antioxidants	Help in weight management	Easily digestible, gluten-free	May cause digestive issues for some individuals	(Saleh et al., 2013; Chandrasekara & Shahidi, 2010)
Proso millet	High in protein, low in	Support heart health and blood sugar control	Quick cooking time, versatile in recipes	Limited availability in some regions	(Saleh et al., 2013; Singh & Singh, 2015)
Barnyard Millet	Gluten-free, rich in fiber and essential amino acids	Assist in reducing cholesterol levels	Easily digestible, suitable for diverse diets	Limited studies on nutritional composition	(Saleh et al., 2013)
Little Millet	High in iron and essential minerals	Aid in managing blood pressure	Cultivates in various climates, sustainable crop	Limited awareness and market availability	(Saleh et al., 2013)
Kodo Millet	Contains antioxidants and essential fatty acids	Contribute to weight loss and diabetes control	Fast-growing crop, resistant to pests and diseases	May have a slightly bitter taste	(Saleh et al., 2013; Chandrasekara & Shahidi, 2010)

V. PROCESSING OF MILLETS

Various processing technologies are utilized to produce value-added food products while enhancing nutritional characteristics, sensory properties, and accessibility. The bioavailability of micronutrients in plant-based diets can be enhanced through traditional and mechanical food processing techniques, including germination/malting, soaking, fermentation, mechanical processing, and thermal processing. These methods aim to improve the physical accessibility of micronutrients, reduce antinutrient levels such as phytates, or increase the content of compounds that enhance bioavailability (Hotz & Gibson, 2007). The straightforward processing methods contribute to the continued use of these grains as staples in the diets of indigenous populations (Kalse *et al.*, 2022).

Table 3: The processing steps involved in millet processing

Processing Step	Description	Technical Details / Equipment Used
Cleaning	Removal of foreign materials, debris, and impurities	Winnowing, sieving, aspiration
Dehulling	Removal of outer hull or husk	Dehuller machine, abrasive rollers
Destoning	Removal of stones and heavier impurities	Destoner machine
Washing	Rinsing to remove dirt and residual impurities	Water rinsing or washing process

Drying	Reduction of moisture content to prevent spoilage	Sun drying, mechanical drying, hot air drying
Millin	Grinding millet grains into flour or meal	Hammer mill, stone mill, disc mill, attrition mill
Sievin	Separation of flour particles into different sizes	Vibrating sieve, mesh screen
Packagin	Packing processed millet products for storage and sale	Food-grade packaging materials

VI. MECHANISED PROCESSING TECHNOLOGY

1. Decortication/Dehulling

Decortication refers to the removal of the pericarp, hull, and outer coat of the grain. Millet grains like finger millet, pearl millet, and sorghum do not require decortication because they lack a husk covering (N. Sharma & Niranjan, 2018).

Small millets such as Foxtail, Little, Kodo, Proso, and Barnyard millet have a hard cellulosic husk layer that humans cannot digest, making husk removal a primary processing task (Tiwari *et al.*, 2023). The dehulling method and machinery used affect milling characteristics and nutrient retention. During large-scale processing, approximately 12 to 30 percent of the husk is removed along with almost all of the bran layer, leading to a decrease in nutritional value of millet products. Phenolic content, which is higher in the husk and seed coat, is lost during dehulling, resulting in reduced dietary fiber and beneficial chemicals (Goudar & Sathisha, 2016).

2. Milling/Grinding and Sieving

Grinding or milling of grains is commonly performed to separate the endosperm, bran, and germ, reduce particle size, and facilitate the production of refined flour. The chemical composition of millet can undergo significant changes during the milling process. Removal of the bran, which contains higher concentrations of phytic acid and polyphenols compared to whole millet grains, during milling reduces the levels of these substances and improves protein and starch digestibility in final processed products like chapatti, bread (Rathore, 2016). Sieving is a fundamental process in food processing and various industries, facilitating efficient particle size separation and refinement. It allows for precise control over particle size distribution, contributing to the quality and consistency of final products.

3. Fermentation

Fermentation is a natural process involving the conversion of sugars into alcohol or organic acids by yeast or bacteria and is one of the oldest and most economical methods of food preservation (Fujimoto *et al.*, 2019). Fermenting millet can enhance its nutritional value, safety, flavor, and texture. Common fermented millet products include millet beer, sourdough bread, and fermented porridge. It plays a vital role in modern food processing, offering efficient and controlled methods to harness the transformative power of microorganisms for food production and preservation.

4. Puffing

Puffing, a high-temperature short-time (HTST) processing method, is used to produce expanded cereals for snacks, breakfast, and ready-to-eat products, imparting desired flavor and aroma (Kapoor, 2013). This technique significantly alters the nutrient profile of grains and is commonly employed to create ready-to-eat snacks from various grains. To prepare popped millet, grains are pre-soaked to achieve the required moisture level, then exposed to hot sand at a ratio of 1:6 under high temperature (230-250 °C) for a short duration (20–30 s). Popping of decorticated finger millet is a common outcome when raw grains are rapidly heated to achieve expansion. Before heating, raw grains must be flattened and adjusted to the desired moisture content to achieve optimal expansion (Saleh *et al.*, 2013).

5. Malting

Malting involves the controlled germination of grains in a moist environment, activating enzymes like amylases and proteases that alter the grain's structure and composition (Awolu, 2017). This process enhances amino acids, total sugars, and B-complex vitamins while reducing starch and dry matter levels and increasing hydrolytic enzyme activity. The germination process activates enzymatic activity in sprouted seeds, leading to the breakdown of carbohydrates, proteins, and lipids into simpler forms (Singh *et al.*, 2015). Mechanized malting technology optimizes the malting process by providing controlled conditions that enhance enzyme activity, starch conversion and flavor development, ultimately producing high quality malt for brewing and other application.

VII. CONVENTIONAL PROCESSING TECHNOLOGIES

1. Soaking:

Soaking grains is a common household food processing technique that greatly enhances the cooking of millet. By soaking millet in cold or hot water overnight, its nutritional value can be significantly improved. Soaking promotes the absorption of nutrients, including vitamins and minerals, and reduces cooking time. Moreover, soaking millet helps to break down antinutrients like phytic acid, which can impede mineral absorption in the gut. Soaking millet for 6-8 hours or overnight enhances its nutritional value, making it easier to digest and boosting its overall nutrient content (Bindra & Manju, 2019).

2.Cooking

Cooking is a common household method used to prepare traditional staple foods, and it can lead to changes in the nutrients of millet (Patel & Thorat, 2019). The nutritional content of millet may be affected by cooking, resulting in the loss of certain vitamins and minerals. The degree of nutrient loss depends on factors like cooking time, temperature, and the cooking method employed. Boiling millet in water, for instance, may cause some B-vitamins and minerals to leach into the cooking water, reducing the overall nutritional quality of the grain. To minimize nutrient loss, it is advisable to use cooking methods that retain as many nutrients as possible, such as steaming or pressure cooking.

3. Roasting

Roasting millet involves heating the grain in a dry pan until it achieves a golden-brown color and releases a nutty aroma. This process not only enhances the flavor and aroma of the grain but also aids in making it easier to digest. Roasting can also contribute to extending the shelf life of millet by eliminating moisture and deactivating potential contaminants. The temperature and duration of roasting can be adjusted based on personal preference and desired outcomes. Moreover, roasting can enhance the variety of aroma components, imparting a distinctive aroma to millets (Bi *et al.*, 2019; 2020).

VIII. ADVANCED PROCESSING TECHNOLOGY

1. Microwave technology

Microwave technology utilizes electromagnetic radiation within the frequency range of 300 MHz to 300 GHz. The application of microwave energy can lead to rapid moisture reduction in food items, though it may result in a decrease in nutritional content (Ekezie *et al.*, 2017; Gavahian *et al.*, 2019). Studies have shown that small millets treated with microwaves exhibit certain nutritional benefits, a trend also observed in foxtail millet flours (Dayakar Rao *et al.*, 2016; Kumar, Kaur *et al.*, 2020; Kumar, Sadiq *et al.*, 2020; Rao *et al.*, 2021). Microwaving can alter the structure of millet grains, thinning the stromal wall and creating a more uniform network (Zheng *et al.*, 2020). Microwave treatment offers a rapid, effective, and environmentally friendly method of food processing, although it may impact certain nutritional aspects (Almaiman *et al.*, 2021).

2. Infrared Technology

Infrared (IR) technology is a non-thermal preservation technique that has proven effective in reducing grain spoilage and extending the shelf life of millet. This method involves subjecting grains to IR treatment either in bulk or in a packed system under carefully monitored dosage settings. IR dosages have been shown to positively impact millets' antioxidant properties and shelf life (Wani *et al.*, 2021). In a storage study, IR methods were used to assess the stability of three types of millets (foxtail millet, sorghum, and pearl millet) over 90 days. The research found that at 0.50 kGy, fungal counts were not effectively reduced, but at 0.75 kGy or higher, γ-irradiation doses inhibited the proliferation of fungal microorganisms. This study indicates that IR treatment is a safe postharvest method for both whole and dehulled millets (H. Huang *et al.*, 2021).

3. Cold extrusion

Cold extrusion is a method used to process food using a single screw at temperatures below 100°C. The raw material is heated to a consistent temperature while being hydrated, mixed, and shaped (Shelar & Gaikwad, 2019). Popular cold-extruded products include pasta, vermicelli, noodles, flakes, and extruded rice, among others. Proso millet pasta, with an amylose content of approximately 20%, shows potential for gluten-free pasta production due to its gelling ability and high cold-paste consistency. Vermicelli made from barnyard millet exhibits significant levels of beta carotene (1039 µg/100g) and iron (3.81 mg/100g) (Goel *et al.*, 2021). Millet-based cold-extruded products generally exhibit a superior nutritional profile compared to conventional cold-extruded products (Sarojani *et al.*, 2021).

Table 4: Impact of processing technology on millet (Bajpai & Ravichandran, 2023)

Processing technology	Impact on millet
Milling	Increase in digestibility & bioavailability of nutrients especially protein & starch

	Decrease in dietary fiber, vitamins & minerals
Germination	Increase in digestibility & availability of protein & minerals Decrease the digestibility of macronutrients
Fermentation	Increase in the level of vitamins, minerals & amino acid Decrease the level of anti-nutrients like phytic acid
Puffing	Increase the protein concentration Decrease anti-nutritive component
Cooking	Increase the digestibility & nutritional value Decrease in vitamin & minerals
Boiling & Steaming	Maintain the nutritional value intact, especially in water-soluble vitamins. Decrease the absorption of minerals & reduce the level of antinutrients

IX. MILLET-BASED FOOD PRODUCTS

1. Baked products

The widespread popularity of bakery items worldwide has led to a significant increase in production due to their affordability, diverse tastes and textures, attractive packaging, and extended shelf life for convenient marketing (Patel et al., 1996; Silva et al., 2021). Millets offer superior fiber content and micronutrient profiles when incorporated into bakery products, presenting a strong opportunity for millets to penetrate the baking industry with various value-added products (Verma & Patel, 2013). Given the lower gluten content in most millets, they are typically added in varying proportions, such as 10% to 50%, to standardize products like bread (20%), cake (30%), cookies (50%), soup sticks (20%), and khari (40%), all typically made using refined wheat flour (Patel, 2013).

2. Extruded Products

Extrusion cooking is a high-temperature short-time (HTST) cooking method suitable for both proteinaceous and starchy materials. It offers several advantages including versatility, high throughput, product quality enhancement, and improved in-vitro protein digestibility (Adeleye *et al.*, 2020; Dahlin and Lorenz, 1993), while minimizing waste in food production. The process involves applying heat directly via steam injection, indirectly through the jacket, or by mechanical energy from shearing within the mixture (Onyango *et al.*, 2004). Proper equipment settings for feed rate, temperature, residence time, and pressure are crucial. By varying flour compositions, feed rates, cooking temperatures, pressures, and residence times, a wide range of millet-based extruded products with diverse attributes can be produced (Kalse *et al.*, 2022).

3. Fermented products

In various regions of India, fermented dishes like dosa and idli are popular breakfast and evening meal options. Millets are rich in protein, but their protein quality is a focus due to their low lysine and tryptophan content. Fermentation not only enhances flavor but also improves the nutritional profile of food by increasing protein, calcium, fiber and vitamins. Additionally, fermentation boosts in vitro protein digestibility and reduces antinutrient levels (Ali Maha *et al.*, 2003; Chavan *et al.*, 1989; Ikram Ali., *et al.*, 2021; Verma *et al.*, 2013).

4. Flour/Composite Flour

Using millet flour, either alone or in combination with other common flours, is a traditional practice for human consumption. Blending millet flour with other types of flour in specific proportions is essential to achieve the desired physicochemical, nutritional, and functional characteristics. Studies have shown that substituting wheat flour with grains like finger millet, proso millet, or barnyard millet at ratios of 20%, 10%, and 15% respectively is feasible. However, increasing the amount of millet flour in the mixture leads to higher ash content but decreases protein content, gluten value, dough loaf volume, and the percentage of damaged starch (Kaur & Singh, 2005).

5. Millet-based pasta and other products

Pasta and other millet-based products, such as papad, are made using dried goods and flour from grains or legumes as the main ingredient. Noodles, which are commonly known as convenience foods, are pasta items produced using cold extrusion technology and become hard and brittle after drying. Pasta can be extruded by using a dolly pasta machine. Noodles, valued for their longer shelf life and commercial appeal, are a popular food among people of all ages. Barnyard millet exhibits a slow digestion rate of 25.88% and a relatively low carbohydrate content of 58.56% (Abah *et al.*, 2020; Veena *et al.*, 2010).

6. Puffed/popped and flaked millet products

Puffing or popping is an ancient technique involving the heating of grains to create a snack or morning cereal, often seasoned with spices, salt, or sweeteners. During puffing or popping, millet grains or preconditioned pasta undergo structural transformations, expanding and resulting in a puffed product with desirable texture and crispness. Engineering factors such as moisture content, porosity, bulk density, kernel size and ingredient composition (e.g., salt or sugar) influence popping volume and ratio (Sumathi *et al.*, 2007). Starch gelatinization levels are highest in roller-dried millet products, followed by popped, flaked and extruded varieties, each exhibiting distinct microstructural characteristics (Fujita *et al.*, 1996; Yanyu *et al.*, 2020).

Table 5: Millet-Based Products and Preparation Technologies

Millet based products	Technology Used	Key Characteristics	Reference
Millet Flour	Milling (stone or hammer mills)	Fine texture, versatile ingredient	Kumar et al., 2024
Millet Bread	Baking (conventional or artisanal)	Nutritious, gluten-free option	Shah et al., 2023
Millet Porridge	Boiling or steaming	Traditional breakfast dish	Shah et al., 2023
Millet Pasta	Extrusion	Pasta shapes, high protein	Palavecino et al., 2020
Millet Snack Bars	Extrusion and drying	Convenient, on-the-go snack	Bhattacharya, 2022
Millet Noodles	Cold extrusion	Long strands, quick cooking	Palavecino et al., 2020
Millet Cookies	Baking (conventional or artisanal)	Sweet treat, crunchy texture	Shah et al., 2023
Millet Crackers	Baking or frying	Crispy, savory snack	Shah et al., 2023

X. MACHINERIES USED FOR MILLET PROCESSING:

Millets, being low-value and small-seeded crops, are often improperly cleaned, graded, and dried before sale, resulting in low market prices and posing storage challenges. The broad acceptance and consumption of millet crops and their products are hindered by factors such as hard pericarp, dark color, presence of antinutrients, and limited availability of secondary processing equipment. Developing simple primary millet processing technologies could reduce drudgery associated with millet processing. Primary millet processing involves activities such as dehulling, destoning, cleaning, grading, milling, and sifting.

1. **Destoner for Millet:** This equipment effectively removes stones and contaminants from millet grains. It includes a 450 × 800 mm perforated dimple sheet deck for fluidization and separation, an aspirator with a centrifugal blower to remove lightweight impurities, and an oscillating sieve box made of wood (700 × 1000 mm) to hold two sieves with sieve-changing provisions (Kalse *et al.*, 2022).
2. **Millet Mill:** This device, powered by a single-phase electric motor, removes the outer husk from little millets using two adjustable abrasive rollers. Unhusked millets are fed through a hopper and fall between abrasive plates due to centrifugal force. Dehulled grains are collected through a bottom outlet, and a cyclone separator gathers dust and husk particles (Balasubramanian *et al.*, 2020).
3. **Grain Polisher:** Millets are dehusked and polished using a cone polisher, centrifugal rice sheller, or rice polisher. Barnyard millet can be polished using a rice polisher. The optimal degree of polishing is achieved with 10% (db) moisture content for 3 minutes of milling, though polishing reduces protein, fat, ash, and fiber concentrations (Lohani *et al.*, 2012).
4. **Grinder/Pulverizer:** Hammer mills, burr mills, or plate/disc mills are used to grind small millets. Minor millets typically undergo semi-wet or dry milling processes. Hammer mills are cost-effective for reducing decorticated grain particle size but can lead to flour caking and reduced process throughput due to overheating and moisture (Kalse *et al.*, 2022).
5. **Flour Shifter:** Grounded flour is sieved into two grades using a flour sifter equipped with stainless steel mesh (40-micron mesh size) and provisions for easy sieve removal and fastening. The outlet for fine and coarse materials is set at the proper height (Kalse *et al.*, 2022).

Table 6: The evolution of millet processing machinery over time

Stage	Machinery Used for Millet Processing
Ancient Times	• Stone querns and mortars for grinding and dehulling millets • Hand-operated tools for winnowing and sorting millet grains • Traditional wooden pestles and mortars for grain pounding • Sieves made from woven materials for grain cleaning and sorting
Present	• Mechanical dehullers and grain cleaners for millet processing • Roller mills and abrasive decorticators for millet grain milling • Modern centrifugal separators for grain separation and cleaning
Future	• Automated millet processing lines with integrated sorting systems • Precision milling and sorting using advanced robotic technologies • Nanotechnology-enabled nutrient extraction and preservation

XI. CHALLENGES OF MILLET PROCESSING

Challenges associated with millet processing encompass various aspects that hinder efficient production and utilization of millets. One primary challenge is the lack of modern processing technologies tailored specifically for millets, which leads to inefficient and labour-intensive processing methods. Limited infrastructure and inadequate facilities for storage, transportation, and processing contribute to post-harvest losses and affect the quality of millet-based products. Millet processing faces several challenges, including expensive equipment, limited infrastructure in rural areas, inadequate supply chain logistics, and competition from subsidized grains like wheat and maize. Consistent quality control is challenging due to susceptibility to pests, moisture damage, and fungal contamination. Additionally, outdated technology may hinder large-scale production of high-quality millet products. Consumer familiarity, sensory characteristics, cost, and gestational cycle further contribute to processing limitations (Shah *et al.*, 2023).

XII. CONCLUSION

Technologies for value addition and post-harvest processing have advanced, allowing the creation of processed millet products that appeal to both urban and rural consumers. Millet processing has been integral to product development, showing positive trends in terms of quality and nutrition. Despite its recognized health benefits and potential as a cereal substitute, the full scope and applications of millets have yet to be fully explored. Further research employing advanced methods and diverse cooking techniques is necessary to evaluate the bioavailability of micronutrients such as minerals. The consumption of millets can contribute significantly to a balanced diet and help address global malnutrition challenges. Therefore, promoting millet consumption and improving processing technologies can play a crucial role in enhancing the overall health and nutrition of the population.

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Tea Nutraceuticals: Unveiling Health Benefits and Bioactive Components a Review

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***Abstract*— Nutraceuticals are medicinal foods that plays an important role in maintaining well-being, enhancing health, modulating immunity and thus preventing and treating specific diseases. Nutraceuticals can be defined as substances that have physiological benefits or protection against chronic diseases. Nutrients can be used to improve health, slow the aging process, prevent chronic disease, increase life expectancy, and support body structure and function. Camellia sinensis plant provides different types of tea including black, green, oolong, yellow, brick and white tea. Tea is one of the main beverages consumed around the world, but it is only successfully enjoyed with water for fitness and enjoyment. This review article discusses the analysis of tea nutrients and important bioactive compounds. It also describes the important health benefits of tea consumption. Important bioactive compounds in tea include antioxidants that have been shown to manage diabetes and prevent heart health and digestive diseases and polyphenols are known to reduce inflammation and the growth of cancer cells. In addition to the many known facts, future research will include further investigation into the molecular interactions and other therapeutic benefits of its bioactive compounds, so that everyone can better understand its importance.*

Keywords*— Nutraceuticals, Tea, Bioactive components, Polyphenols, Antioxidants, Caffeine, Dietary supplements.

I. INTRODUCTION

Approximately 2500 years ago, Hippocrates (460–377 BC), the father of modern medicine, conceptualized the relationship between the use of appropriate health foods and their therapeutic benefits and quoted, “Let food be thy medicine, and medicine be thy food” (Bagchi, 2014). In the past five years, the world has witnessed the explosive growth of the multi-billion-dollar industry known as nutraceuticals. The term “nutraceutical” combines the word “nutrient” (a nutritious food or food component) with the word “pharmaceutical” (medicinal preparation) (Kumar & Kumar, 2015). “Nutraceutical” is a term coined in 1979 by Stephen De Felice, which is defined as “food or parts of food that provide therapeutic or health benefits, including the prevention and treatment of disease” (Rajat *et al.,* 2012). Nutraceuticals are defined as food products, extracts, or food derivatives, such as vitamins, herbs, amino acids, minerals, and enzymes, that may potentially exhibit pharmaceutical benefits in addition to their nutritional value (Santini *et al.,* 2017). They are also commonly referred to as dietary supplements or functional foods and, from a nutritional point of view, they are a source of both nutrients (carbohydrates, proteins, fats, vitamins, minerals) and non-nutrients (e.g. enzyme regulators) (Bergamin *et al.,* 2019).

Nutrients are biologically active substances that can be present in functional foods or individual foods and have beneficial effects on human health through participation in metabolic processes (Morris *et al.,* 2004). Espin *et al.,* (2007) believe that nutraceuticals include pharmaceutical preparations containing first-class dietary phytochemicals as active ingredients. Nutrients as food additives in the United States also have other terms such as therapeutic foods, phytochemicals, prophylactics, medicinal foods (pharmaceuticals), and functional foods (Błecha and Wawer, 2011 and Morris *et al.,* 2004). The difference between drugs and dietary supplements is a matter of debate among scientists and health officials. It is generally accepted that dietary supplements should only contain lower doses than pharmaceutical products and show a higher level of safety in use (especially long-term) than conventional pharmaceutical products (http://www.nutrition.org.uk). Globally, the use of dietary supplements varies, with more than 50% of adults in some Western countries taking dietary supplements regularly (Burnett *et al.,* 2017 & Binns *et al.,* 2018).

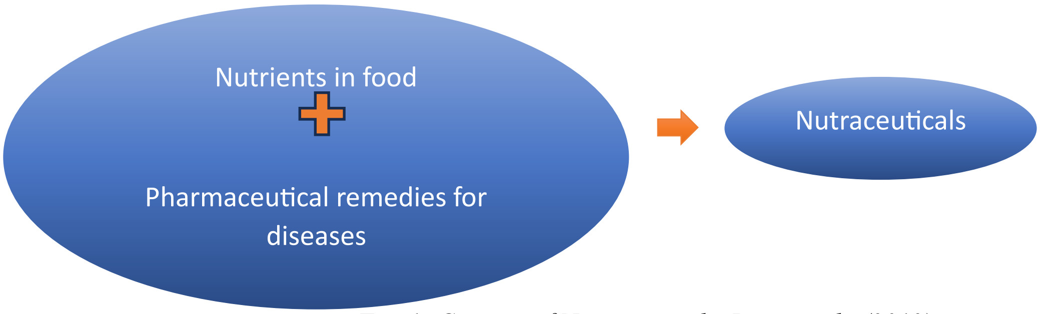

Fig. 1: Concept of Nutraceuticals. Rajat et al., (2012)

Tea, a beverage made from the leaves of the Camellia sinensis plant, originated in ancient China and has become increasingly popular worldwide in recent decades (Guo *et al.,* 2017). Tea derived from the Camellia sinensis plant is one of the most popular and widely consumed beverages worldwide. As it is rich in bioactive compounds, it has many health benefits.

II. HISTORY OF TEA

In Chinese legend, the story of tea begins with Emperor Shen Nong (2737-2697 BC), also known as the Divine Healer, Divine Husband, and Divine Cultivator. To protect the health of his people, the emperor ordered that water should be boiled before drinking. One day while he was boiling water, a leaf blown by the wind fell into the pot. When Shen tasted the finished product, he was not only satisfied with the taste, but also felt energized. Its leaves come from the plant we know today as Camellia sinensis. Shen ordered widespread cultivation and recommended its infusion to his subjects, declaring that "it energises the body, satisfies the mind, and sets the goal" (Saberi, 2010).

PRODUCTON & STATUS OF TEA

With an annual value of USD 9.5 billion, the world's tea trade is valued at USD 9.5 billion, surpassing USD 17 billion in global tea production. This represents a substantial source of export revenue for emerging and low-income economies (FAO, 2022a). The demand for tea has increased by 2.5% per capita over the past ten years, mostly in East Asia, Africa, Latin America and the Caribbean, and the Near East, offsetting declining consumption in Europe, the United States, Canada, and the Russian Federation. Research estimates that global tea production will grow at a compound annual growth rate (CAGR) of 5.7% from 2021 to 2026 (Caro, 2020; Mordor Intelligence, 2023a). The FAO reports that from growing 5 million hectares, tea production increased from approximately 4.3 million tonnes (Mt) in 2008 to 6.3 Mt in 2020 (FAO, 2022a; FAOSTAT, 2021). Over the past decade, tea output has stayed relatively stable, with a CAGR of 2.31% from 2014 to 2020, down from 3.32% from 2008 to 2020. The global tea market is expected to increase at a compound annual growth rate (CAGR) of 7.09% from USD 49.53 billion in 2023 to USD 98.29 billion by 2033, according to a research analysis published by Spherical Insights & Consulting.

Table. 1: Global production of tea from 2004 to 2020

Year	Tea Production (in million metric tons)
2004	3624.61
2006	3845.56
2008	4256.47
2010	4610.75
2012	5025.69
2014	5493.99
2016	6108.84
2018	6650.6
2020	7024.04

Source: M. Ridder (2022)

CONSUMPTION

The global consumption of tea continues to increase in 2013. Total tea consumption increased by nearly

5 percent to 4.84 million tons in 2013, supported by rapid growth in per capita income levels, particularly in China and India and other emerging countries. The demand growth was particularly significant in China. Consumption in recent years shows a significant increase of more than 8% annually, and the total consumption in 2013 reached 1.61 million tons, which increased by 9% compared to the previous year, making it the largest consumption in the world. In India, consumption increased by 2.4% in 2009 and 6.6% in 2013, reaching 1 million tons (Chang, 2015). In 2016, Turkey was the largest tea-consuming country in the world, with a per capita tea consumption of approximately 6.96 pounds per year. In contrast, China had an annual consumption of 1.25 pounds per person. In 2022, global consumption of tea amounted to about 6.7 billion kilograms and is estimated to reach to 7.4 billion kilograms by 2025 (Published by Statista Research Department, Aug 29, 2023). Tea volume "is seeing annual growth of 2.8% and is expected to be higher in the future (Bolton, 2018).

Table. 2: Global Tea consumption from 2013 to 2021

Year	Consumption (Billion litres)
2013	234
2014	242
2015	250
2016	258
2017	266
2018	273
2019	281
2020	289
2021	297

Source: Bolton, (2018)

TYPES OF TEA

According to different processing techniques, there are different types of tea, such as green tea, yellow tea, white tea, black tea, oolong tea, and orange tea (Yang & Kong, 2016). Among these different types of tea, the most consumed tea products are black tea and green tea.

Green tea:

Unfermented and pale green liquor. It is also popular in Japan and China. Although green tea naturally contains caffeine, the content is usually lower than that found in oolong tea, and most of the caffeine content can be removed by decaffeination (Amaresh *et al.,* 2011).

Black tea:

It is known as a fully fermented brown liqueur. It is widely used in Western countries. It is naturally caffeinated and can be decaffeinated to remove most of the caffeine content (Amaresh *et al.,* 2011).

Oolong tea:

Oolong tea is a semi-fermented tea that has characteristics between black tea and green tea. It naturally contains caffeine, usually in lower amounts than black tea, and can be consumed decaffeinated to remove most of the caffeine content (Amaresh *et al.,* 2011).

Table 3: Properties of green tea & black tea.

Properties	Green tea	Black tea
Processing	Involves fixation, rolling & drying processes (Cabrera *et al.,* 2006)	Involves a withering, rolling, fermentation & drying process (Sharma & Rao 2009)
Origin	China (Sinija and Mishra 2008)	Asia and Europe (Skotnicka *et al.,* 2011)
Taste	Bitter (Soni *et al.,* 2015)	Distinct taste (Soni *et al.,* 2015)
Colour	Green or yellow (Soni *et al.,* 2015)	Red to black (Soni *et al.,* 2015)
Nutrients	Epigallocatechin gallate (EGCG)	Theaflavins
Antioxidant	More Polyphenols	More Flavonoids
Caffeine	Less than black tea	More than green tea
Health benefits	- **Heart Health**: Both protect heart health by reducing LDL cholesterol and blood pressure. - **Brain Function**: Caffeine and L-theanine enhance alertness and mood. - **Cancer Prevention**: EGCG in green tea may inhibit cancer cell growth.	- **Heart Health**: Improves blood vessel function in coronary artery disease. - **Bone and Teeth Health**: Provides fluoride for stronger teeth and bones.

Health hazards	- **Caffeine Sensitivity**: Green tea has less caffeine. - **Gastric Issues**: Not recommended for those with gastric problems. - **Pregnancy and Breastfeeding**: Avoid excessive consumption.	- **Caffeine Intake**: Moderate consumption to prevent side effects. - **Hypertension**: Caution for those with high blood pressure. - **Insomnia**: Avoid excessive intake.
Best time to drink	Drink green tea during 10 am to 11 am or evening. Drinking during this time will increase your metabolism.	It's alright to take tea in morning or evening but it is good to avoid taking tea in breakfast or with proper meal.
Quality	Better in fresh	Depend on produced location

Source: Chaudhary, (2023), Sharangi, (2009).

Table 4: Major chemical constituents and their composition in tea

Constituent	Green tea (%)	Black tea (%)
Catechins	30	9
Amino acids	4-5	3
Proteins	15	15
Lipids	3	3
Caffeine	3	3
Organic acids	2	2
Methylxznthines	7-9	8-11
Minerals	6-8	5

Source: Mohanpuria *et al.,* (2010) & Harbowy et al., (1997).

SCOPE

Nutraceuticals play a significant role in modifying and maintaining normal physiological function that maintains healthy human beings (Prajapati & Kumar, 2020). The philosophy behind nutraceuticals focuses on prevention. Most of the time, it can be used in the field of dietary supplements and functional foods (Nwosu & Ubaoji, 2020). The food products used as nutraceuticals can be categorized as dietary fiber, prebiotics, probiotics, polyunsaturated fatty acids, antioxidants, and other different types of herbal natural foods. A dietary supplement is a food or substance in food that has medical or health benefits. They can be used not only because of their nutritional value, but also as medicine. When it comes to tea, the range of uses as a dietary supplement is fascinating, including antioxidant properties, digestive health, cardiovascular benefits, and general health support.

III. CLASSIFICATION OF NUTRACEUTICALS

The food industry consists of three main sectors including functional foods, dietary supplements and herbal/natural products (Błecha and Wawer, 2011).

Functional foods

As defined by the United States of America Institute of Medicine's Food and Nutrition Board, a functional food is "a food or nutrient that has the potential to provide health benefits beyond traditional nutrients." The concept of functional foods is "foods that, when consumed as part of the daily diet, have beneficial effects beyond their basic nutritional functions." Functional foods contain bioactive substances obtained from plant or animal sources (Ernst, 2001 and Nwosu & Ubaoji, 2020).

Dietary supplements

Dietary supplements are products taken in addition to regular meals to provide additional health-promoting nutrients. According to the Dietary Supplement Health Education Act (DSHEA), dietary supplements are products intended to supplement the diet. It contains food components such as vitamins, minerals, amino acids, plants and herbs. It is intended to be taken as a tablet, capsule, pill, or liquid. and labelled as a food supplement (ODS 2011, Ronis *et al.,* 2018, and Hassan *et al.,* 2020). Although dietary supplements are not intended to cure or cure diseases, dietary supplements are more focused on the expected results of these products, such as prevention or treatment of diseases (Nwosu & Ubaoji, 2020).

Herbal products

Medicinal plants are as old as human civilization and have provided a complete stock of therapeutic agents for the treatment of acute and chronic diseases. As herbal knowledge has accumulated over thousands of years, today we have many effective tools to ensure health care (Kumar and Kumar, 2015). Nutrients have great potential to improve health and prevent chronic diseases with the help of plants (Singh & Sinha, 2012). Plants play an important role in maintaining the quality of human life through rich sources of biological components. Plant bioactive compounds are an essential category of food supplements that, in addition to minerals, vitamins and other active compounds, have health-enhancing medicinal properties. Plants contain a wide range of active phytochemicals including flavonoids, terpenoids, saponins and polyphenols. These plant bioactive substances are commonly used as dietary supplements by people seeking conventional health care (Nwosu & Ubaoji, 2020).

IV. HEALTH FUNCTIONS OF TEA

Antioxidation

Antioxidants are substances that slow or inhibit the oxidation of substrates caused by free radicals. They act as free radical scavengers. Free radicals are molecules or chemical species that contain one or more unpaired electrons and can exist independently and can cause degenerative diseases (Parihar *et al.,* 2022). Antioxidants are known to reduce free radicals that limit the risk of oxidative stress (OS) and related diseases. At the cellular and molecular level, they inhibit or delay oxidative processes by inactivating reactive oxygen species (ROS) and interrupting the radical chain reaction of lipid peroxidation under certain low concentrations (Prakash and Gupta, 2009). Tea has long been of interest as a medicine and health drink, but recently the potent antioxidant effects of tea polyphenols have gained attention. Oxidative stress has been shown to play a role in the development of many diseases, including cancer (Feng *et al.,* 2001, Embola *et al.,* 2002, and Cabrera *et al.,* 2003).

Anti-inflammation

Inflammation is a reflex marker against harmful pathogens and stimuli that disrupt the immune system. Pain, redness, heat and swelling in the infected or damaged area are signs of inflammation. Steroidal and non-steroidal anti-inflammatory drugs are used to treat inflammatory effects. The remarkable anti-inflammatory activity of tea and its bioactive components has been demonstrated with insights into multiple mechanisms of action, suggesting potential in the treatment and management of inflammation-related diseases (Hamer, 2007).

Anticancer

Cancer is a manifestation of malignancy, which results from step-by-step processes that are distinguished by progressively accumulating mutations (Butt & Sultan, 2009). According to the GLOBOCAN 2018 database, there were an estimated 18.1 million new cancer cases and 9.6 million cancer deaths worldwide in 2018, and new cases will reach 20 million globally by 2025 (Ferlay *et al.,* 2019, 2015). Bioactive dietary components rich in nutraceuticals have the potential to prevent cancer (Avrelija & Walter 2010). One of the benefits of drinking green tea is that carcinogenesis in the digestive tract is inhibited by ECGC as expressed in cells. Polyphenols from tea inhibited the growth and lysis of the human gastric cancer cell line KATO III, and also inhibited the release of tumour necrosis factor-a (TNF-a) from the cells (Okabe *et al.,* 1999). It was reported that green tea consumption (5 × 1 cup/day, four weeks) alters oral bacteria, which may be related to oral carcinogenesis (Adami *et al.,* 2018).

Cardiovascular protection

Improper lifestyle, diet, age and many other external factors can lead to the onset of cardiovascular diseases. Tea and its bioactive compounds are capable of showing positive effects on promoting good health. The antioxidants present in tea leaves are known to reduce the amount of oxidative radicals that otherwise damage the heart and vessels connected to the heart. This is also known to increase oxidative stress which subsequently results in heart failure over time (Zhang *et al.,* 2014).

Anti-diabetes

Diabetes is caused by an imbalance in metabolism, where our body is either unable to produce insulin or completely consumes insulin. Many anti-diabetic drugs are expensive and have been reported to cause other types of side effects. Hence, switching to food items with nutraceutical values is a better option. Tea has been discovered as an alternative to prevent the onset of diabetes. Green tea is traditionally used to control blood sugar levels. Animal studies suggest that green tea may help prevent the development of diabetes (type-1) and slow its progression once it has developed (Ratnani and Malik, 2022). Herbal dietary supplements containing nutraceuticals have been proven to provide therapeutic benefits on type 2 diabetes (Rajat *et al.,* 2012).

Anti-obesity

Obesity is a medical condition characterized by the accumulation of excess body fat. Nutraceuticals like conjugated linoleic acid, capsaicin, xylem have excellent anti-obesity properties. Herbal nutraceuticals like chitosan, caffeine, fenugreek, vitamin C, green tea, curcumin, black gram, bottle guard reduce body weight (Rajat *et al.,* 2012). Recent studies have suggested an anti-obesity effect of tea and its components, by improving energy expenditure, lipid metabolism and lipid accumulation (Tang *et al.,* 2019). Tea extracts and their constituents, including polyphenols, caffeine and polysaccharides, have shown anti-obesity effects, including regulation of glycolipid digestion, absorption and metabolism, improvement of energy expenditure, inhibition of lipid accumulation and deposition, and ultimately increase and decrease in body weight. can lean mass (Tang *et al.,* 2019).

Hepato-protection

Tea has shown beneficial effects on dietary- and chemical-induced disorders in the liver, including oxidative stress damage to the liver, inflammation, steatosis, and fibrosis (Weeravatnakorn, 2015, Braud *et al.,* 2017, Rangi *et al.,* 2018, and Tang *et al.,* 2019). Population-based studies show that those who drink more than 10 cups of green tea per day are less likely to develop liver problems. Green tea also protects the liver from the damaging effects of toxic substances such as alcohol (Yin *et al.,* 2015). Results from several animal and human studies suggest that catechins may help treat viral hepatitis, liver inflammation (Ratnani and Malik, 2022).

Gastrointestinal protection

The beneficial effects of tea on the digestive system may be related to tea polyphenols (TPs, which consist mainly of catechins). Studies have shown that epigallocatechin-3-gallate (EGCG), a catechin, can help regulate the digestive system as it reduces inflammation in the gastrointestinal tract and colitis models (Oz *et al.,* 2013).

Anti-microbe

The presence of phenolic compounds and epigallocatechin-3-gallate in tea is responsible for the antimicrobial nature. The anti-microbes include anti-bacteria, anti-fungal and anti-virus. Tea may modulate gut microbiota composition (increase beneficial microorganisms and decrease harmful microorganisms) and may be beneficial for individuals at risk for obesity, metabolic syndrome, hyperlipidemia, and cardiovascular diseases (Lu et al., 2019, Liu et al., 2019, Zhang et al., 2018, Chen et al., 2018, Zhou et al., 2018, Chen et al., 2018, Ma et al., 2019 & Tang et al., 2019).

BIOACTIVE COMPONENTS

Many bioactive components have been identified in tea and its brews, including polyphenols, pigments, polysaccharides, alkaloids, free amino acids and saponins, and the amount of these compounds can be quite different in different tea varieties (Bi *et al.,* 2016, Guo *et al.,* 2017, Pan *et al.,* 2017 and Wang *et al.,* 2017). Tea contains polyphenolic compounds (catechins and epicatechins), theaflavins, flavanol glycosides, L-theanine, caffeine, theobromine and volatile organic compounds. These bioactive components are responsible for tea's astringency, taste, aroma and flavour as well as its health beneficial effects (Samanta, 2022).

Polyphenols

White, green and yellow teas are rich in polyphenols, especially catechins and their derivatives, including catechin, epicatechin (EC), gallocatechin (GC), epigallocatechin (EGC), catechin gallate (CG), epicatechin gallate (ECG), gallocatechin Contains gallate (GCG), and epigallocatechin gallate (EGCG) (Tang *et al.,* 2019, Zhao *et al.,* 2019, Luca *et al.,* 2016, Satoh *et al.,* 2016, Yang *et al.,* 2018 and Tang *et al.,* 2019). In addition, other polyphenols such as gallic acid, chlorogenic acid, ellagic acid, galloylquinic acid, kaempferol-3-O-glucoside (kaempferol-3-G) and various flavonoids are also found in tea (Tang *et al.,* 2019, Zhao *et al.,* 2019, Bai *et al.,* 2017, Chen *et al.,* 2015, Zielinski *et al.,* 2015 and Tang *et al.,* 2019). In particular, tea polyphenols are one of the most important natural antioxidants (Luca *et al.,* 2016 and Tang *et al.,* 2019).

Table 5: Health benefits of polyphenol content in tea

polyphenol content	Tea	Health benefits
Epicatechin (EC)	Green tea	Anti-hyperlipidemic, Anti-inflammatory, Antioxidative, Anticarcinogenic, Cytoprotective
Epigallocatechin (EGC)		Reducing risks of diabetes mellitus and cardiovascular diseases
Epicatechin gallate (ECG)		Anti-hyperlipidemic, Anti-inflammatory, Antioxidative, Anticarcinogenic, Cytoprotective
Epigallocatechin gallate (EGCG)		Anticarcinogenic, Anti-inflammatory, Antioxidant, Metabolic regulation
Theaflavin (TF1)	Black tea	Antioxidant, Cardiovascular health
Theaflavin-3-monogallate (TF2a)		
Theaflavin-3’-monogallate (TF2b)		
Theaflavin-3,3’-digallate (TF3)		

Source: Musial *et al.,* (2020).

Pigments

Tea catechins are oxidized during fermentation, to theflavins, therubigins and thebrownins, therefore, oolong, black and dark tea are rich in pigments (Lv *et al.,* 2017, Koch *et al.,* 2017, Tang *et al.,* 2018 and Tang *et al.,* 2019). The structures of theflavins, which have been identified with 4 isomers, including theflavin, theflavin-3-gallate, theflavin-30-gallate, and theflavin-3,30-gallate, are simpler than therubigins and thebrownins, which are complex mixtures. polyphenols and their polymers (Sakakibara *et al.,* 2003, Bhattacharya *et al.,* 2011 and Tang *et al.,* 2019). Tea pigments have also been shown to be important bioactive components responsible for the health functions of tea, such as anti-inflammatory, anticancer and hepato-protective effects, although their antioxidant activity may be low when compared to tea catechins (Pan *et al.,* 2017, Ramadan *et al.,* 2017, Weeravatnakorn *et al.,* 2015 and Tang *et al.,* 2019).

Polysaccharides

Tea polysaccharide (TPS) is a non-starch protein-free acidic polysaccharide containing 44.2% neutral sugars, 43.1% glyoxylic acid and 3.5% protein. TPS mainly contains glucose (Glc), galactose (Gal), arabinose (Ara), rhamnose (Rha), xylose (Xyl), galactronic acid (GalA), mannose (Man), ribose (Rib), glucuronide, etc. sugars (GulA) (Lv *et al.,* 2009 and Yao *et al.,* 2022). TPS is another important bioactive component of tea apart from polyphenols. The content of polysaccharides in tea can increase with the maturation of raw tea leaves, which is completely different from the pattern of tea polyphenols (Xiao and Jiang 2015 and Tang *et al.,* 2019).

Alkaloids

Tea is one of the most important sources of alkaloids, usually purine alkaloids (such as caffeine, theobromine, theophylline), which can be converted into flavoalkaloids (Bi *et al.,* 2016 and Li *et al.,* 2018). A possible pathway for deamination of L-theanine, decarboxylation, spontaneous cyclization, and attachment of the product to EGCG to form the flavoalkaloid has been proposed (Li *et al.,* 2018). Caffeine is the most abundant alkaloid among all six types of tea (Bi *et al.,* 2016). The antioxidant, antidiabetic and ant obesity effects of tea alkaloids have been reported in several studies (Luca *et al.,* 2016, Xu *et al.,* 2015, Li *et al.,* 2018, and Tang *et al.,* 2019).

Free amino acids

Amino acids play an important role in creating tea aroma during black tea processing. Meanwhile, aspartic acid, glutamic acid, serine, glutamine, tyrosine, valine, phenylalanine, leucine, isoleucine and luteanine are the main amino acids found in tea leaves, and asparagine is formed from it. L-theanine (γ-ethylamino-L-glutamic acid) is a unique neuroactive amino acid found naturally in tea. It is a free (non-protein) amino acid found almost exclusively in the tea plant (Camellia spp.) and constitutes 1-2% of the dry weight of tea leaves and approximately 50% of the total free amino acids (Juneja *et al.,* 1999).

Flavonol glycosides

Flavonoids have anti-cancer properties by acting as antioxidants. These are found in citrus fruits, soy foods, which are unique dietary sources of isoflavones, green tea, which is rich in epigallocatechin gallate, and curcuma longa, which is rich in curcumin (Neha *et al.,* 2011). The effects of flavonol supplementation on cardiometabolic risk factors showed a significant decrease in triglycerides, total cholesterol, low-density lipoproteins, fasting plasma glucose levels and blood pressure, and a significant increase in high-density lipoproteins (Menezes e*t al.,* 2017 and Rha *et al.,* 2019). The antioxidant effect of flavonol glycosides is weaker than flavonol aglycones (Plumb *et al.,* 1999 and Rha *et al.,* 2019).

L-theanine

L-theanine (γ-glutamylethylamide) is a non-protein amino acid found abundantly in tea. This compound was first isolated by Sakado in the late 1940s. A standard 200 ml cup of black tea contains on average about 25 mg of L-theanine, while typical green tea leaves contain 0.2-2.4% (w/w) (Deb *et al.,* 2019). L-theanine has been shown to contribute to the production of volatile compounds in tea, which may be the main reason for the rice-like crisp aroma and chestnut freshness (Guo *et al.,* 2019, Zhang *et al.,* 2020, Li *et al.,* 2022). L-theanine has antioxidant, anti-inflammatory, neuroprotective, anti-cancer, metabolic regulator, cardiovascular, liver and kidney protection, immunity, and protection of the reproductive system and intestines (Li *et al.,* 2022).

Caffeine

Of the approximately 50,000 known secondary metabolites produced by plants, more than 12,000 are alkaloids. The most common secondary metabolites are anthocyanins, flavonoids, quinine, lignin, steroids and terpenoids. Caffeine is a common purine alkaloid and is found in more than 60 different plant species, including coffee, tea, kola nut, guarana berry, yerba mate, and cocoa beans (Ashihara & Crozier, 1999 & Mohanpuria *et al.,* 2010). Caffeine acts as an adenosine antagonist, thereby reducing the natural decrease in noradrenaline concentration. Caffeine inhibits phosphodiesterases and increases protein kinases. Catechins also inhibit pancreatic and gastric lipase, weakening fat emulsification and thereby reducing fat absorption (Dulloo *et al.,* 2000).

V. FUTURE

Dietary supplements play a big role in food and nowadays humans support quality and healthy food, so until humans do not exist in this world, there is no place to use dietary supplements in the future. The future range of tea nutritional supplements has enormous potential as we continue to discover the health benefits inherent in these delicate tea leaves. Powdered tea containing various bioactive ingredients offers exciting possibilities for nutritional supplements. As science advances, we can expect innovative formulations that take advantage of the properties of tea to promote health.

VI. CONCLUSION

Nutraceuticals have health and disease prevention benefits and should be consumed in recommended and acceptable amounts (Prajapati & Kumar, 2020). People are now focused on changing their normal lifestyle in a healthier direction, so dietary supplements play a very important role in this regard. Advanced research has been done on the use of tea to find its value as a dietary supplement, and researchers are now working on ways to manage many common ailments and restore the ancient value of tea as a better alternative.

In conclusion, polyphenols, pigments, polysaccharides, alkaloids, free amino acids, flavonol glycosides, L-theanine and caffeine in tea can be the main bioactive components involved in the diverse health functions of tea. These bioactive components protect our body against various health conditions and have the ability to protect us against many chronic diseases. Even though tea has all these benefits, more attention should also be paid to its safety, including contamination with heavy metals, pesticides, and mycotoxins, as well as the possible adverse effects of high doses of tea bioactives. Overall, tea is a promising dietary component and its consumption has shown many health functions (Tang et al., 2019).

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Assessment of the Ability to Seal the Apex Using Gutta-Percha Combined with Bio-C Sealer, Activ GP with Bio-C Sealer, and Activ GP with Activ GP Sealer as Materials for Root Canal Filling: A Stereomicroscopic Study conducted in vitro

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Abstract— *Fifty freshly extracted human permanent mandibular single-rooted premolar teeth were utilized in this study. The anatomical crowns of the chosen teeth were removed with a diamond disc, and pulp tissue was eliminated using barbed broaches. The working length was established by subtracting 0.5mm from the length determined with the tip of the trial file just visible at the apical foramen of each root canal in all specimens. Biomechanical preparation was conducted in all specimens using the crown-down technique with the ProTaper Next rotary file system. The master apical file was set to X4 (Size 40 and 6% Taper). The specimens were randomly assigned to five groups, each comprising 10 specimens. Group 1 utilized Master Gutta-percha points coated with Bio-C sealer, Group 2 used Master Activ GP points coated with Bio-C sealer, and Group 3 employed Master Activ GP points coated with Activ GP sealer as obturation materials with a single-cone technique. Group 4 served as the Negative control, with root canals left unobturated, while Group 5 served as the Positive control, using Master Gutta-percha points without any root canal sealer as the obturation material. All canal orifices were sealed with restorative Glass ionomer cement. Subsequently, specimens were double-coated with nail varnish, except for the apical 3mm of roots, and immersed in petri dishes containing Indian ink dye for 48 hours. After dye removal, nail varnish was completely eliminated, and specimens were longitudinally sectioned with a diamond disk. For each specimen, the half containing the most visible part of the entire root canal was selected, and the extent of linear dye penetration was measured using a Stereomicroscope following Escobar's criteria. The measurements were recorded, tabulated, and statistically analyzed using One Way ANOVA and Tukey's Post-hoc tests. Gutta-percha coated with Bio-C sealer as a root canal obturation material exhibited the highest apical sealing ability compared to Activ GP with Bio-C sealer and Activ GP with Activ GP sealer. Activ GP with Activ GP sealer displayed the lowest or poorest apical sealing ability.*

Keywords— ***Premolar teeth, Crown-down technique, ProTaper Next, Bio-C sealer, Stereomicroscope***

I. INTRODUCTION

The primary objectives of root canal therapy are to thoroughly clean, shape, and fully fill the root canal system in three dimensions, ensuring a fluid-tight seal. This seal is crucial for preventing the ingress of microorganisms and their by-products from peri-radicular tissues into the root canal system. Approximately 60% of endodontic failures stem from incomplete obturation of the root canal space. Microleakage, often resulting from gaps within the root filling or between the filling and dentin walls, is a common cause of treatment failure, allowing bacteria and toxins to infiltrate the canal. Thus, achieving a fluid-tight apical seal is essential for preventing reinfection.

Gutta-percha (GP) is widely regarded as the gold standard obturation material due to its biocompatibility, non-staining properties, and radiopacity. However, despite its advantages, gutta-percha alone does not provide a complete dentinal seal, leaving potential unfilled spaces that can lead to leakage. Therefore, the ability of a root canal sealer to bond effectively to both dentinal walls and obturation material is crucial for treatment success.

In recent years, there has been growing concern about the inadequate sealing properties of conventional root canal filling materials. To address this, there has been a shift towards developing obturation materials capable of bonding to dentin walls to eliminate interfacial gaps, drawing on dentin adhesive technology from restorative dentistry.

Activ GP is a novel Glass-Ionomer (GI)-based obturation system designed to address these concerns. It features a 2 µm coating of GI particles on its surface and within the cone body to enhance bonding with gutta-percha and dentinal walls. These cones are precisely sized by laser to ensure a precise fit and are used with GI sealer to improve bonding.

Bio-C (Ceramic) is a calcium silicate-based root canal sealer composed of various materials including zirconium oxide, dicalcium silicate, and calcium hydroxide. It is insoluble, radiopaque, and aluminum-free, requiring water to set and harden. Developed for single cone as well as lateral condensation techniques, Bio-C offers a working time of 4 hours at room temperature.

This in-vitro study aims to assess the apical sealing ability of Gutta-percha with Bio-C sealer, Activ GP with Bio-C sealer, and Activ GP with Activ GP sealer through stereomicroscopic analysis.

II. MATERIALS AND METHODS

Fifty freshly extracted human permanent mandibular single-rooted premolar teeth were obtained from Triveni Institute of Dental Sciences, Hospital, and Research Centre, Bilaspur, India. Inclusion criteria specified non-carious, non-fractured, unrestored matured teeth with closed root apices, single roots, single canals, and the absence of calcifications, resorptive defects, or other anatomical anomalies.

Teeth extracted solely for orthodontic reasons or those compromised by periodontal issues were considered for inclusion in this study. Criteria for exclusion encompassed teeth with caries, fractures, restorations, open root apices, multi-rootedness, or multiple canals. Initial preparation involved cleaning teeth of surface debris, calculus, and residual tissue using ultrasonic instruments, followed by immersion in a 3% sodium hypochlorite solution for disinfection, rinsing with tap water, and storage in 0.5% thymol at room temperature until use.

The anatomical crowns of selected teeth were sectioned using a diamond disc attached to a low-speed contra-angled handpiece to achieve a standard root length of up to 16 mm, perpendicular to the cemento-enamel junction. Subsequently, pulp tissue was removed with barbed broaches and K-files, ensuring patency to the apical foramen. Working length was determined by subtracting 0.5 mm from the length indicated by the trial file's tip visible at the apical foramen. Biomechanical preparation employed the ProTaper Next rotary file system in a crown-down technique as per the manufacturer's instructions, with the master apical file set to X4 (Size 40 and Taper 0.06), using 17% EDTA and 3% sodium hypochlorite solutions as irrigants. Following instrumentation, root canals were flushed with distilled water and dried with sterile paper points.

Subsequently, specimens were randomly assigned to five groups, each comprising ten specimens.

Group 1: A Master Gutta-percha point (Size 40, Taper 6%) from Dentsply Maillefer (Ballaigues, Switzerland) was uniformly coated with Bio-C sealer (Brasseler, USA). It was then slowly inserted into the root canal until the predetermined working length was reached, verified for tugback, and filled using the single-cone technique.

Group 2: A Master Activ GP point (Size 40, Taper 6%) from Brasseler (USA) was uniformly coated with Bio-C sealer. It was slowly inserted into the root canal until the predetermined working length was reached, checked for tug back, and filled using the single-cone technique.

Group 3: A Master Activ GP point (Size 40, Taper 6%) was uniformly coated with Activ GP sealer. It was slowly inserted into the root canal until the predetermined working length was reached, verified for tug back, and filled using the single-cone technique.

Group 4 (Negative control): Root canals were left unobturated; neither obturation material nor root canal sealers were used.

Group 5 (Positive control): A Master Gutta-percha point (Size 40, Taper 6%) was slowly inserted into the root canal until the predetermined working length was reached, verified for tug back, and filled using the single-cone technique, without the use of any root canal sealer.

Both Bio-C and Activ GP sealers were handled following their respective manufacturer’s instructions. Once the root canals were filled, Gutta-percha and Activ GP cones were positioned accordingly.

The root apices were seared off 2mm below the canal orifices and sealed with Glass ionomer restorative cement (GC Corporation, Tokyo, Japan).

Following the completion of root canal filling, radiographs were taken of all specimens to evaluate the quality of obturation. The specimens were then stored at 37°C in 100% relative humidity for 10 days. Subsequently, they were double-coated with nail varnish, excluding the apical 3mm of roots. Each layer of nail varnish was allowed to dry completely before the next layer was applied. The specimens from each group were then individually placed in separate petri dishes and immersed passively in Indian ink dye (Himedia Laboratories Pvt. Ltd. Mumbai, India) for 48 hours at 37°C.

After removal from the dye, the teeth underwent a thorough rinse under running tap water for 10 minutes, and the nail varnish was completely removed using a scalpel blade. Each root was then longitudinally sectioned bucco-lingually with a diamond disk (0.3 mm in thickness) using a low-speed handpiece. The root was carefully split into two halves by wedging a fine chisel into the groove and gently twisting the chisel. For each specimen, the half containing the most visible part of the entire root canal (from root apex to the orifice) was selected, and the other half was discarded.

Root canal instrumentation and handling of all specimens among the five groups were performed by a single endodontist to minimize inter-operator variability, and the endodontist was not blind to the groups.

The extent of linear dye penetration was measured to the nearest millimeter from the root apex to the coronal extent of each sectioned specimen using a Stereomicroscope (Labline, India) at 20X magnification. Escobar's criteria were utilized to analyze the extent of apical dye penetration/leakage in this in-vitro study. All specimens were analyzed by one examiner who specialized in Endodontics, and the data were recorded.

- Score 0: Infiltration loss (dye penetration 0–<1.5 mm).
- Score 1: Simple infiltration (dye penetration 1.5–3 mm).
- Score 2: Medium infiltration (dye penetration > 3 mm).

III. RESULTS

The observed measurements of apical dye penetration/leakage for all specimens were organized into a table and subjected to statistical analysis using Statistical Package for Social Sciences (SPSS) version 24, employing Analysis of Variance (One Way ANOVA) and Tukey's Post hoc test.

Analysis of Variance examines the equality of three or more means simultaneously by assessing variances. One Way ANOVA revealed a statistically significant disparity in the mean values of apical dye leakage among the groups, indicated by a P (Probability) value of < 0.05.

GROUPS	No. of Specimens	Mean ± SD*	*P value
Group 1 (Gutta-percha[GP] with Bio-C sealer)	10	0.4 ± 0.5	P < 0.05
Group 2 (Activ GP with Bio-C sealer)	10	1.0 ± 0.67	
Group 3 (Activ GP with Activ GP sealer)	10	1.5 ± 0.52	
Group 4 (Negative control)	10	2.0 ± 0.2	
Group 5 (Positive control)	10	1.8 ± 0.48	

IV. DISCUSSION

The primary goal of root canal obturation is to prevent recontamination of the root canal system by impeding the ingress of microorganisms and fluids. Various methods have been employed to assess the apical sealing ability of root canal filling materials, including dye penetration, dye extraction, and fluid infiltration. In this in-vitro study, the dye penetration method was chosen due to its simplicity, speed, and cost-effectiveness, making it a widely accepted indicator of potential leakage. A passive dye penetration method was adopted, with the positive control group specimens validating the reliability of this approach based on the extent of dye penetration observed.

It is widely acknowledged that gutta-percha alone does not establish ideal bonding with root canal dentin, leading to investigations into alternative materials capable of creating a tight and durable apical seal. When gutta-percha is used with conventional root canal sealers, gaps often exist between the gutta-percha, sealer, and root canal dentin, facilitating the passage of bacteria and fluids.

Bioceramic materials, encompassing bioinert, bioactive, or biodegradable categories based on their interaction with surrounding tissues, have emerged as promising alternatives. Bio-C sealer, a calcium silicate-based bioceramic sealer, undergoes a setting reaction resulting in calcium phosphate precipitation, promoting bioactivity and tissue growth. The setting mechanism involves a reaction with water, either from tissue fluids or in humid conditions, leading to the formation of a hydraulic seal.

In this study, Group 1 specimens, obturated with gutta-percha coated with Bio-C sealer using a single-cone technique, exhibited superior apical sealing ability with minimal dye penetration (mean value 0.4) compared to Group 2 (Activ GP with Bio-C sealer) and Group 3 (Activ GP with Activ GP sealer). This can be attributed to the properties of Bio-C sealer, including tubular diffusion of sealer particles into dentinal tubules and formation of a mineral infiltration zone, enhancing sealing efficacy.

Efforts have been made to develop new obturation materials such as Activ GP, aiming for a "Monoblock" seal that adheres and bonds to root canal dentin. Group 2 specimens, obturated with Activ GP coated with Bio-C sealer, demonstrated optimal apical sealing ability with moderate dye penetration (mean value 1.0), although a statistically significant difference in dye leakage was noted compared to Group 1. Conversely, Group 3 specimens, obturated with Activ GP coated with Activ GP sealer, exhibited poor apical sealing ability with greater dye penetration (mean value 1.5).

In endodontics, the use of adhesive systems within the root canal remains controversial due to challenges in bonding to radicular dentin. Factors such as irregular canal anatomy, decreasing dentinal tubules in the apical area, and calcified apical canal walls pose obstacles to resin bonding. Additionally, resin bond durability may be compromised over time due to functional forces or incomplete resin infiltration into demineralized dentin, leading to fluid movement between the hybrid layer and unaffected dentin.

The increased dye leakage observed with the Activ GP system (Activ GP with Activ GP sealer) highlights the need for further research into enhancing the sealing properties of obturation materials, particularly in challenging clinical scenarios characterized by irregular canal anatomy and calcified canal walls.

Using Activ GP sealer as the obturation material in our study aligns with the findings of Horsted-Bindslev et al., who similarly linked the failure of the Activ GP system in preventing dye leakage to the polymerization shrinkage of the glass ionomer sealer (Activ GP sealer) and the inadequate bonding of the Activ GP cone with its sealer due to non-uniform coating of fillers on the cones.

The Activ GP - Sealer system employs a single-cone technique, where the master cone closely matches the geometry of NiTi rotary files used for canal instrumentation. Consequently, there may be a thicker layer of sealer at the interfacial area between root canal dentin and Activ GP. Research has demonstrated that a thicker layer of root canal sealer can compromise sealing ability, leading to voids caused by shrinkage during the setting reaction.

Data regarding the sealing ability of the Activ GP system as an obturation material have been contradictory. While Monticelli et al. found no difference in leakage between teeth obturated with Gutta-percha/AH Plus sealer and Activ GP/GI sealer (Activ GP sealer) using a fluid filtration model, bacterial leakage studies using S. mutans revealed significantly more leakage with single-cone obturation using Activ GP/GI sealer (Activ GP sealer) compared to GP/AH Plus sealer. Within the scope of our in-vitro study, none of the tested root canal obturation systems achieved a complete seal.

V. CONCLUSION

Within the limitations of our study, Gutta-percha coated with Bio-C sealer exhibited superior apical sealing ability compared to Activ GP with Bio-C sealer and Activ GP with Activ GP sealer. Activ GP with Activ GP sealer demonstrated the least effective apical sealing ability. However, further in-vivo studies are warranted to validate and correlate our in-vitro findings with clinical outcomes.

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Ecological Sensitivity Assessment of Xinyi City in Guangdong Province Based on GIS and AHP

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Abstract— *Ecological sensitivity analysis is an important basis for urban planning and layout. This article selects six ecological evaluation factors, including altitude, slope, aspect, water environment, vegetation NDVI, and land use, to construct an ecological sensitivity evaluation system for Xinyi City. Using the spatial analysis techniques of GIS and the Analytic Hierarchy Process (AHP), a comprehensive evaluation was conducted on six ecological evaluation factors. Meanwhile, the natural breakpoint method was used to divide the results into five levels: extremely sensitive area, high sensitive area, medium sensitive area, low sensitive area, and non-sensitive area. The results indicate that the ecological sensitivity of Xinyi City is generally high, and land use type, vegetation coverage, and water environment are the main factors affecting ecological sensitivity. The five sensitive areas, from non-sensitive to extremely sensitive, account for 0.71%, 18.44%, 38.88%, 33.01%, and 8.96% of the total area of the city, respectively. The highly sensitive areas of Xinyi City are distributed in the northeast, while the non-sensitive areas are distributed in the southwest. The comprehensive evaluation of ecological sensitivity and spatial layout in this article can provide a basis for land use construction planning and ecological environment protection in Xinyi City.*

Keywords— ***Ecological sensitivity assessment; Geographic Information Systems (GIS); Analytic Hierarchy Process (AHP); Xinyi City***

I. INTRODUCTION

With the development of society and the advancement of technology, the scope and intensity of human impact on the natural environment are constantly increasing, leading to the expansion and intensification of regional ecological and environmental problems such as desertification, salinization, soil erosion, and acid rain. These regional ecological and environmental problems are seriously threatening the atmosphere, land, and water resources that humans rely on for survival, resulting in significant direct and indirect economic losses every year. A good ecological environment is an important foundation for human survival and sustainable development; therefore, protecting the ecological environment and conducting ecological environment assessments are particularly important [2, 3].

Ecological sensitivity refers to the degree to which an ecosystem reflects human behavior, interference, and changes in environmental conditions, indicating the likelihood of ecological environmental problems occurring in a region. It refers to the ability of ecological factors to adapt to external changes or pressures without endangering environmental quality. If various ecological factors in a region are difficult to recover after being damaged, then the ecological sensitivity of the region is strong; on the contrary, it is weaker [5]. The essence of ecological sensitivity assessment is to clearly identify potential ecological problems in the current natural environment and implement them in specific spatial areas. This type of research began in the late 20th century and was defined by the academic community as the self-recovery ability of ecosystems to resist external adverse effects under specific spatiotemporal conditions. Through ecological sensitivity evaluation, it can reflect national or regional ecological changes and spatial differentiation patterns, laying the foundation for land and resource utilization and ecological environment protection [7, 8].

Ecological sensitivity assessment (ESA) is currently a research hotspot, and many scholars have conducted relevant research. Through a review of domestic literature, it was found that ecological sensitivity assessment has a wide range of research fields and diverse research scales. Among them, research areas include watersheds, cities, wetlands, nature reserves, etc. The research scale extends from national, geographical region and provincial levels to cities and counties. In addition, research methods mainly use traditional weight determination methods, such as principal component analysis (PCA), the analytic hierarchy process (AHP), the expert scoring method, and the maximum value method [9]. There are currently three main research directions. One is ecological sensitivity research targeting certain ecological and environmental issues. For example, Mo et al. conducted sensitivity analysis on flood disasters in Guangxi, providing countermeasures for disaster prevention and reduction [10]; Wang et al. analyzed sensitive areas of soil erosion in China and proposed zoning plans [11]. The second is to conduct ecological sensitivity analysis on the ecological value of cultural landscapes. Zhong et al. conducted an ecological sensitivity analysis on the tourism landscape of Qinghai Province, providing reference for the sustainable development of ecotourism [12]; Li et al. conducted an ecological sensitivity analysis on the upper reaches of the Yangtze River from the perspective of spatial pattern [13]. The third is to analyze the sensitivity of urban ecology. Yan et al. used indicators such as soil erosion, river water quantity, and quality as evaluation factors to conduct ecological sensitivity analysis in Beijing [14]. Gan et al. analyzed the trend of ecological sensitivity changes in the Guangdong-Hong Kong-Macao Greater Bay Area over the past 20 years [15], providing a scientific basis for green and sustainable development and environmental management in the Guangdong-Hong Kong-Macao Greater Bay Area.

Xinyi City, as the only national key ecological functional area in western Guangdong, is an important ecological barrier and water source conservation area in the coastal area of western Guangdong, ensuring the ecological security and water resource supply of the coastal area. With the booming development of emerging economies and tourism, human activities have a series of negative impacts on the ecological environment, such as resource scarcity, severe environmental pollution, and ecosystem degradation. Therefore, a comprehensive evaluation of the ecological sensitivity of Xinyi City is of great significance for its urban planning and industrial layout.

This article takes Xinyi City as the research area, analyzes its ecological sensitivity, explores its spatial layout, and provides a decision-making basis for land use planning, environmental restoration, and sustainable development in Xinyi City. The main approach is to use spatial analysis of GIS and AHP to conduct single factor analysis on six ecological evaluation factors and to comprehensively analyze multiple factors by weighted superposition, which can provide a scientific basis for the future economic development, construction, and ecological environment protection of Xinyi City.

II. STUDY AREAS

Xinyi City, a county-level city under the jurisdiction of Guangdong Province, is managed by Maoming City. Located in the southwest of Guangdong Province, in the northern part of Maoming City, between latitude 22 ° 11 Å 10.2 "to 22 ° 42 Å 25.2" north and longitude 110 ° 40 Å 36.1 "to 111 ° 40 Å 29.4" east, the city is 57.656 kilometers wide from north to south and 102.719 kilometers long from east to west. It borders Yangchun to the east, Gaozhou to the south, Beiliu and Rongxian in Guangxi to the west, and Luoding and Cenxi in Guangxi to the north. National Highway 207 runs through the entire area from north to south, making it one of the sub-central cities connecting the southwestern and central southern regions of Guangdong. The total area of the city is 3101.7 square kilometers, accounting for 1.75% of the total area of Guangdong Province. Under its jurisdiction are 18 towns, including Zhenlong, Shuikou, Beijie, Jindong, Dingbao, Chidong, Baishi, Dacheng, Huaixiang, Hongguan, Chashan, Cinnabar, Guizi, Pingtang, Qianpai, Heshui, Xinbao, and Sihe, as well as 2 street offices, including Dongzhen Street Office and Yudu Street Office. The Municipal Government's Office is on Dongzhen Street. (Figure 1).

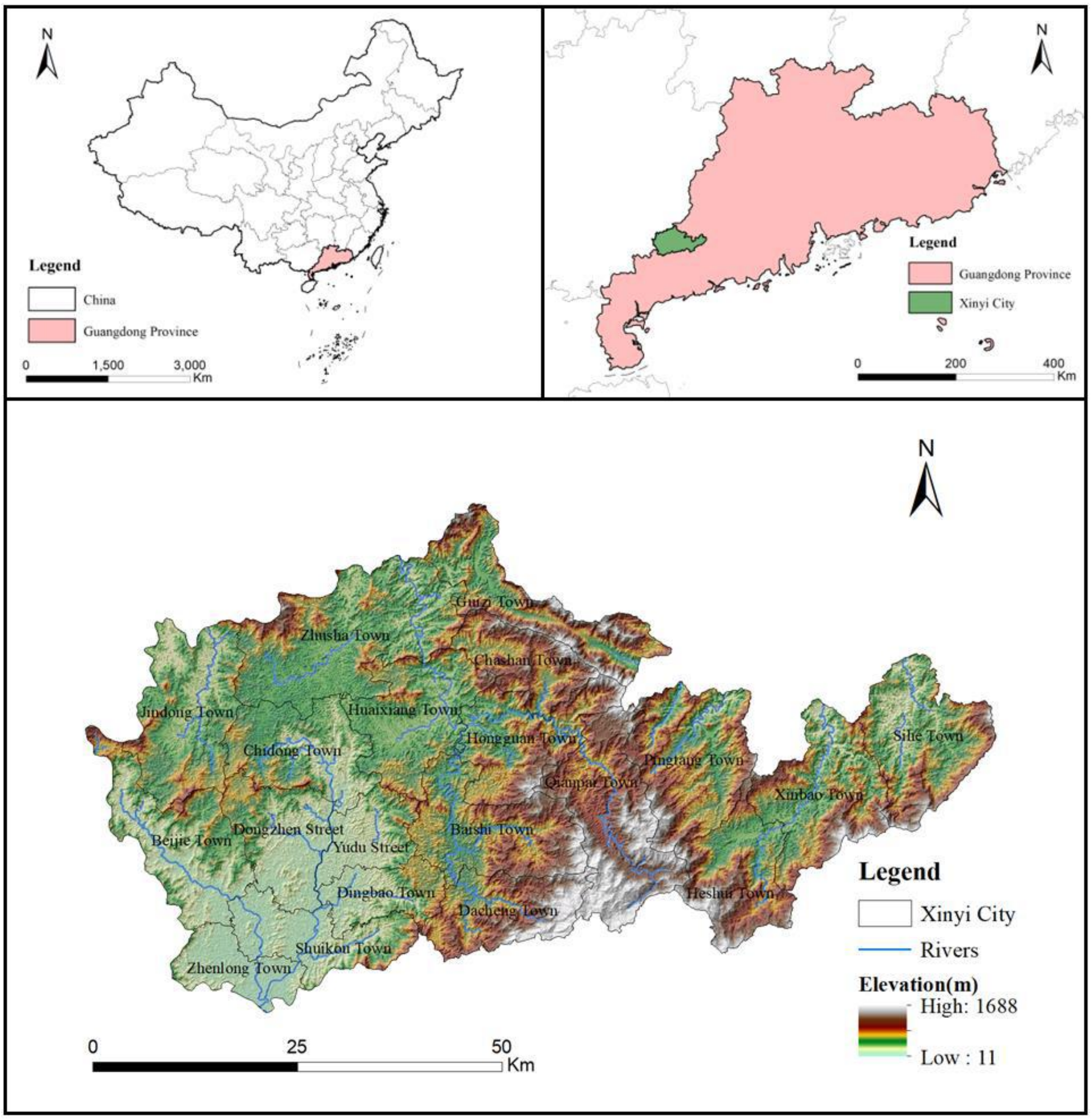

Fig.1 Geographical Location and Overview of Xinyi City

The terrain is high in the northeast and low in the southwest. Within the territory, there are steep mountains and rivers crisscrossing, with elevations ranging from 50 meters to 1704 meters. The eastern part is mainly composed of Zhongshan with elevations above 800 meters, while the western part is mainly composed of low mountains and hills with elevations below 800 meters. There are 80 mountains with an elevation of over 1000 meters and 371 peaks with an elevation of over 500 meters. The highest point is Datianding, with an altitude of 1704 meters, which is the highest peak in western Guangdong. There are five soil types within the territory, including yellow soil, red soil, lateritic red soil, paddy soil, and tidal sand soil.

The river is divided into the Pearl River basin and the Jianjiang basin. There are 12 rivers with a catchment area of over 100 km^2 in the city, including Dongjiang River (the upstream main stream of Jianjiang River), Beijie River, Xiaoshui River, Baishi River, Shadi River, Qianpai River, Guizi River, Zhusha River, Bailong River, Shazi River, Sihe River, and Jindong River. There are 9 roads between 50 and 100 km^2 and 28 roads between 15 and 50 km^2. The total storage capacity of lakes in Xinyi City is 59.705 million m^3, with 2 medium-sized reservoirs and 39 small reservoirs.

Belonging to the South Asian tropical monsoon climate, the climate is warm, with sufficient sunlight and abundant rainfall. The rain is hot in the same season, with hot summers and cool winters. The frost-free period is long, with cold damage in spring, easy flooding in summer, and occasional typhoons in autumn. The average annual temperature in the city is 19.6~23.2 °C, and the average annual rainfall is 1543.1~2233.2 millimeters. The hottest month of the year is July, with an average temperature of 28.6 °C. The coldest period is from January to February, with an average temperature of 12.9 °C.

III. DATA AND METHODS

3.1 Data Sources

The data used in this study includes administrative boundary maps of the study area and 30 m of digital elevation model (DEM) data (sourced from the geospatial data cloud, https://www.gscloud.cn/search). River water system data in Guangdong Province, 2022 GlobeLand30 surface cover data, and the 2022 1 km Normalized Vegetation Index (NDVI). We are using ArcGIS software to mask and crop data, extract slope and aspect factors using DEM, and use a unified coordinate system and projection system.

3.2 Study Methods

After collecting data, six single ecological evaluation factors were selected based on the characteristics of Xinyi City, namely elevation, slope, aspect, water environment, normalized difference vegetation index (NDVI), and land use. Grade single factors and draw an ecological sensitivity factor analysis chart. Then, the Analytic Hierarchy Process (AHP) is used to establish weight values for analysis and evaluate the grading level. Finally, the comprehensive analysis results of ecological sensitivity were obtained (Figure 2), and relevant data such as spatial distribution and area proportion were analyzed and evaluated.

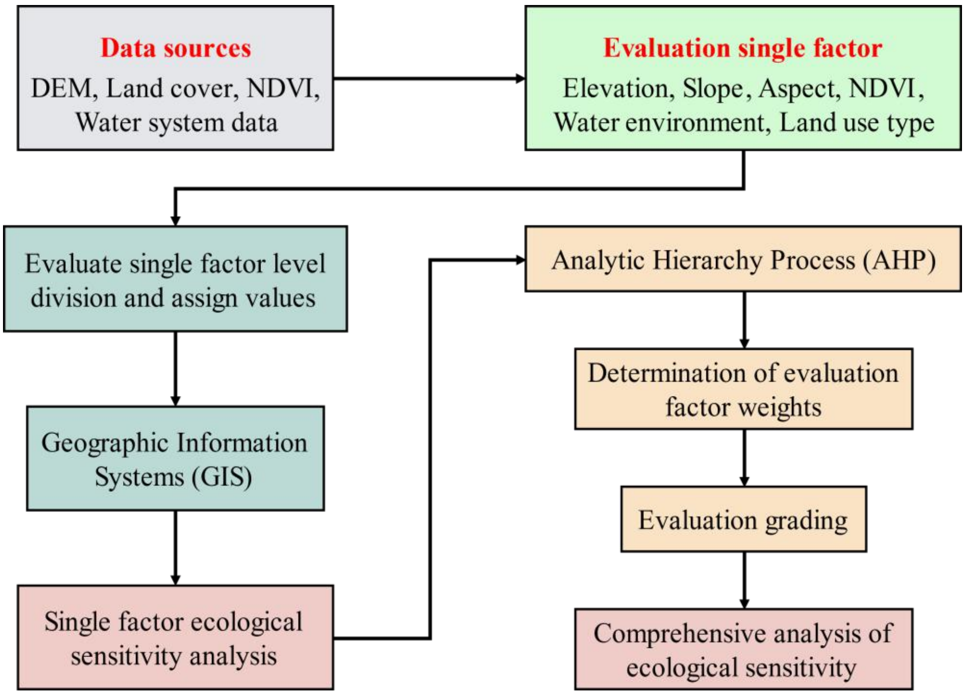

Fig.2 Technical Roadmap

3.3 Ecological Sensitivity Assessment

This article will use GIS and AHP to evaluate the ecological sensitivity of Xinyi City [16]. Ecological sensitivity refers to the scientific method of analyzing the adaptability of various factors in the ecosystem within a study area to external disturbances, mainly through reasonable numerical analysis of multiple data points. It can accurately reflect the adaptability of the study area to external disturbances under the influence of various factors [17]. It is worth noting that the factors affecting ecological sensitivity are very complex, with diverse causes and manifestations [7]. The size of the research scale, the ecological environment status of the study area, and the level of socio-economic development all affect the selection of evaluation indicators [18]. The ecological sensitivity factors vary in different regions, and there is no unified standard for selecting factors. Thus, it is necessary to select representative sensitive factors of the main environmental characteristics based on the inherent mechanisms of ecological environmental issues and the environmental conditions of the research area.

This study uses ecological sensitivity evaluation methods to select appropriate evaluation factors, analyze and grade relevant data, and ultimately generate comprehensive evaluation results as a reasonable basis for urban ecological planning. This evaluation method avoids the lack of scientific data guidance in the planning process and also avoids planning decision-makers leaning towards personal subjectivity, thereby reducing the negative impact on the ecological environment.

3.4 Selection of Evaluation Indicators and System Construction

AHP refers to a decision-making method that decomposes elements related to decision-making into levels such as goals, criteria, and plans and conducts qualitative and quantitative analysis on this basis. This method is a hierarchical weight decision analysis method proposed by American operations researcher Professor Satie from the University of Pittsburgh in the early 1970s, applying network system theory and multi-objective comprehensive evaluation methods. This method can easily solve complex factor-sorting problems. In addition, the GIS is an important tool for ecological sensitivity research, which collects and integrates massive geographic data over a certain period of time based on geographical conceptual space. After data analysis combined with GIS, visualization can be achieved, and spatial analysis and related data calculation and extraction can be carried out.

3.4.1 Selection of Evaluation Factors and Classification of Sensitive areas

To study the single-factor impact, this article refers to relevant papers on regional ecological sensitivity evaluation. Based on the research objectives, the comprehensive characteristics of the ecological environment in Xinyi City, as well as the principles of ecological sensitivity and data availability, ecological evaluation factors with characteristics of the study area [5] were selected, including elevation, slope, aspect, NDVI, water environment, and land use. Assign ecological sensitivity values of 9, 7, 5, 3, and 1 to each individual factor, representing extremely important, very important, quite important, somewhat important, and unimportant. At the same time, based on the strength of ecological sensitivity, it is divided into five different levels of ecologically sensitive areas, namely extremely high sensitive areas, high sensitive areas, medium sensitive areas, low sensitive areas, and non-sensitive areas. (Table 1)

Extremely sensitive area: It is most sensitive to human activities for development and construction. If there is interference or destruction, it will not only affect the area but also lead to devastating damage to the ecosystem of the research area. For this purpose, the protection zoning plan should list the area as the most in need of key protection. We must strictly protect the natural ecological environment, and urban construction must not occupy land arbitrarily. At the same time, we must do a good job of ecological restoration. Plan the construction of nature reserves and forest parks, and establish natural and environmental education bases without affecting the environment.

High sensitivity area: It is highly sensitive to human activities and development, making ecological restoration difficult. It plays a very important role in protecting the ecosystem and its functions in extremely sensitive areas. In protection zoning planning, this type of area can be regarded as a secondary key ecological protection area.

Medium sensitive area: It can withstand a certain intensity of human activities, but excessive development and construction can also damage the natural ecological environment in the area, resulting in slow ecological restoration and difficulty in ecological restoration. Therefore, reasonable protection measures need to be considered in the planning of protection zones.

Low sensitivity zone: capable of withstanding a significant amount of human development and construction activities but also prone to natural disasters such as soil erosion when severely affected, resulting in slow ecological restoration. In protection zoning planning, these areas can be considered general-level protection areas.

Non sensitive area: capable of withstanding large-scale human development and construction activities with diverse land use methods. In protection zoning planning, this area can be considered to have the lowest level of protection. We should vigorously carry out economic construction on the basis of ensuring ecological system security while paying attention to the reasonable layout of production space, living space, and ecological space. We should be guided by the harmonious coexistence between humans and nature, pay attention to creating green spaces, pay attention to ecological benefits, and build a modern city that is livable and suitable for business, promoting sustainable development of the city.

According to different levels, areas with higher ecological sensitivity indicate greater sensitivity to human development and construction activities, higher ecological value, and should be listed as key protected areas. Regions with lower ecological sensitivity mean that they can withstand a certain level of human development and construction activities, and their land can be used for multiple purposes with relatively low protection levels.

Table 1 Classification Criteria for Single Factor Ecological Sensitivity

Sensitivity level	Evaluation factors					
	Slope	Elevation	Slope aspect	Water enviro-nment	NDVI	Land use
extremely sensitive（Score9）	>55	>1700	North	50<	>0.8	Water bodies
high sensitive（Score7）	40-55	1300-1700	Northeast Northwest	50-200	0.6-0.8	Forest and cropland
medium sensitive（Score5)	25-40	900-1300	East and West	200-500	0.4-0.6	Grassland and shrubs
low sensitive（Score3）	10-25	500-900	Southeast Southwest	500-800	0.2-0.4	Bare land
non-sensitive（Score1）	0-10	<500	South	>800	<0.2	Construction land

3.4.2 Determination of Ecological Factor Weights

Use the AHP method to distinguish between the target layer and the indicator layer. The target layer is comprehensive ecological sensitivity, while the indicator layer refers to the six ecological evaluation factors mentioned above. Based on the actual situation of the research area, the weight calculation method of relevant literature is cited for comprehensive evaluation, which includes experts scoring each factor, establishing a factor judgment matrix, and calculating the weight values of each factor based on the specific scores of each ecologically sensitive factor. The weight values between each factor cited in this article are shown in Table 2 [2, 7]. To verify the validity of the weight results, a consistency test is conducted using the consistency ratio as follows:

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (1)$$

$$CR = \frac{CI}{RI} \quad (2)$$

The calculation results of the AHP show that the maximum eigenvalue λ_{max} is 6.3548, and the CI value is 0.0710. According to Table 3, the corresponding RI value is 1.26. According to the formula CR=CI/RI=0.0563<0.1, through a one-time test, it is shown that the result of single factor weighting is acceptable [23].

Table 2 Single Factor Ecological Sensitivity Weights

Evaluation factors	Elevation	Slope	Slope aspect	Water environment	NDVI	Land use
Elevation	1	1/2	1/2	1/3	1/4	1/5
Slope	2	1	1/2	1/2	1/3	1/4
Slope aspect	2	2	1	1/2	1/3	1/5
Water environment	3	2	2	1	1/2	1/3
NDVI	4	3	3	2	1	1/2
Land use	5	4	5	3	2	1
Weight	0.0531	0.0780	0.0947	0.1487	0.2407	0.3847

Table 3 Judgment Matrix RI Standard Values

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49

IV. ANALYSIS AND RESULTS

After selecting six ecologically sensitive factors, establish a single factor sensitivity grading standard, including extremely high sensitivity, high sensitivity, medium sensitivity, low sensitivity, and insensitivity. Visualize and analyze through GIS, calculate its area and proportion (Table 4), and conduct spatial analysis and subsequent exploration.

Table 4 Summary of Single Factor Ecological Sensitivity Grading Area and Proportion

Evaluation factors	Unit	Non sensitive	low sensitive	medium sensitive	high sensitive	extremely sensitive
Elevation	Area/km^2	2566.16	849.63	163.2	25.87	—
	Proportion /%	71.19	23.57	4.53	0.72	—
Slope	Area/km^2	771.06	1958.76	798.51	62.79	1
	Proportion /%	21.47	54.53	22.23	1.75	0.03
Slope aspect	Area/km^2	442.58	916.65	864.89	915.46	452.58
	Proportion /%	12.32	25.52	24.08	25.49	12.60
Water environment	Area/km^2	2825.53	244.32	292.8	189.1	53.07
	Proportion /%	78.38	6.78	8.12	5.25	1.47
NDVI	Area/km^2	—	0.28	19.53	971.93	2613.08
	Proportion /%	—	0.01	0.54	26.96	72.49
Land use	Area/km^2	25.74	0.02	3	3569.89	6.17
	Proportion /%	0.71	0.001	0.08	99.03	0.17

4.1 Elevation Factor

The highest altitude in Xinyi City is 1688 meters. The terrain is mainly mountainous and hilly, with higher terrain in the northeast and lower terrain in the southwest. According to the analysis of the results, the ecological sensitivity of the elevation factor is relatively low, and the proportion of non-sensitive areas is relatively high. The high sensitivity area, medium sensitivity area, and low sensitivity area account for 0.72%, 4.53%, and 23.57%, respectively, with a total area of 1038.7 km², distributed in the central and eastern regions, such as Dacheng Town, Qianpai Town, Heshui Town, Chashan Town, Guizi Town, etc.; the non-sensitive area covers an area of 2566.16 km², accounting for 71.19% of the total area, distributed in the west and northeast (Figure 3).

4.2 Slope Factor

Slope can indicate the steep terrain of a region, which is closely related to soil erosion, soil moisture content, and soil fertility and can affect the development and utilization of land and the layout of urban construction. Under the same conditions, the larger the slope, the poorer the ecological carrying capacity of the region, the greater the degree of interference from various factors, the more fragile the ecosystem, and the higher the sensitivity of the region. The results show that the natural terrain of Xinyi City is relatively steep, and the ecological sensitivity of slope factors is mainly low and medium. It is widely distributed in the study area, with an area of 2757.18km², accounting for 76.76% of the total area. Next is the non-sensitive area, with an area of 771.06km², accounting for 21.47% of the total area, mainly distributed along river banks. The high sensitivity area and extremely high sensitivity area with a slope greater than 40 ° account for 1.75% and 0.03%, respectively, with an area of 62.79 km² and 1 km², concentrated in Guizi Town, Qianpai Town, and Dacheng Town, with a relatively small footprint (Figure 4).

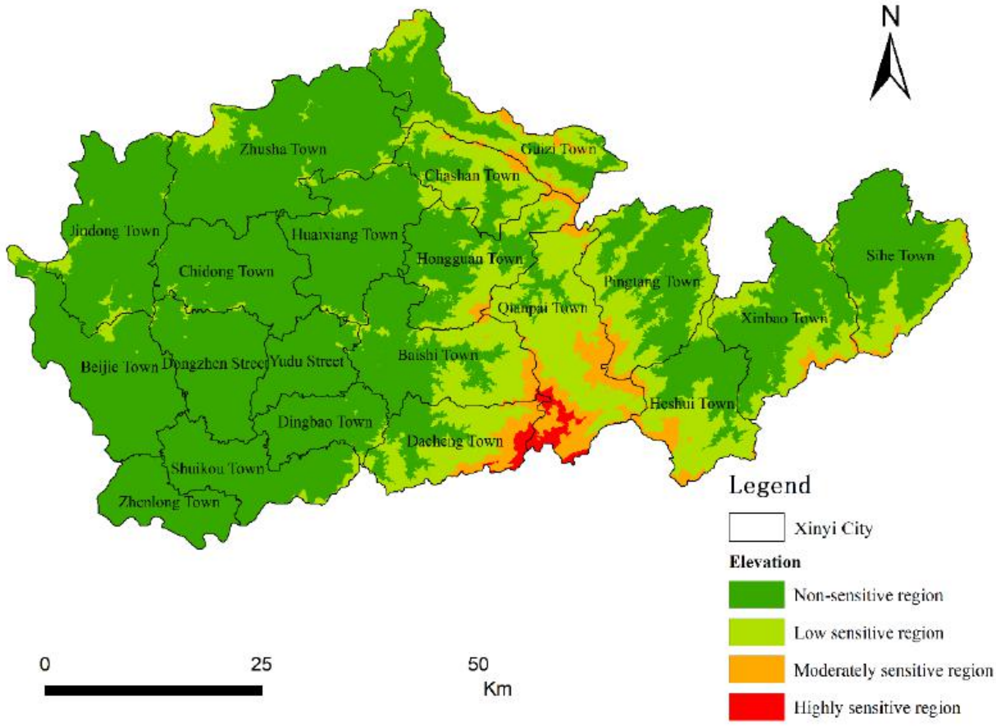

Fig.3 Analyses of Elevation Factors

4.3 Slope Aspect Factor

The terrain of Xinyi City is complex and diverse, with numerous mountains and hills, rivers, lakes, and mountains crisscrossing each other. The overall ecological sensitivity of slope factors is relatively uniform. Among them, the non-sensitive and low-sensitive areas account for 37.84% of the total area, with an area of 1359.23 Km², facing south, southeast, southwest, and east in four directions. The medium sensitive area, high sensitive area, and extremely sensitive area account for 24.08%, 25.49%, and 12.60%, respectively, with an area of 864.89km², 915.46km², and 452.58km², are facing east, west, northeast, northwest, and north directions. In summary, in the future development and construction process of Xinyi City, regional land use planning should be done in advance. Under complex terrain conditions, achieving the coexistence of ecological environment protection and socio-economic development promotes regional sustainable development (Figure 5).

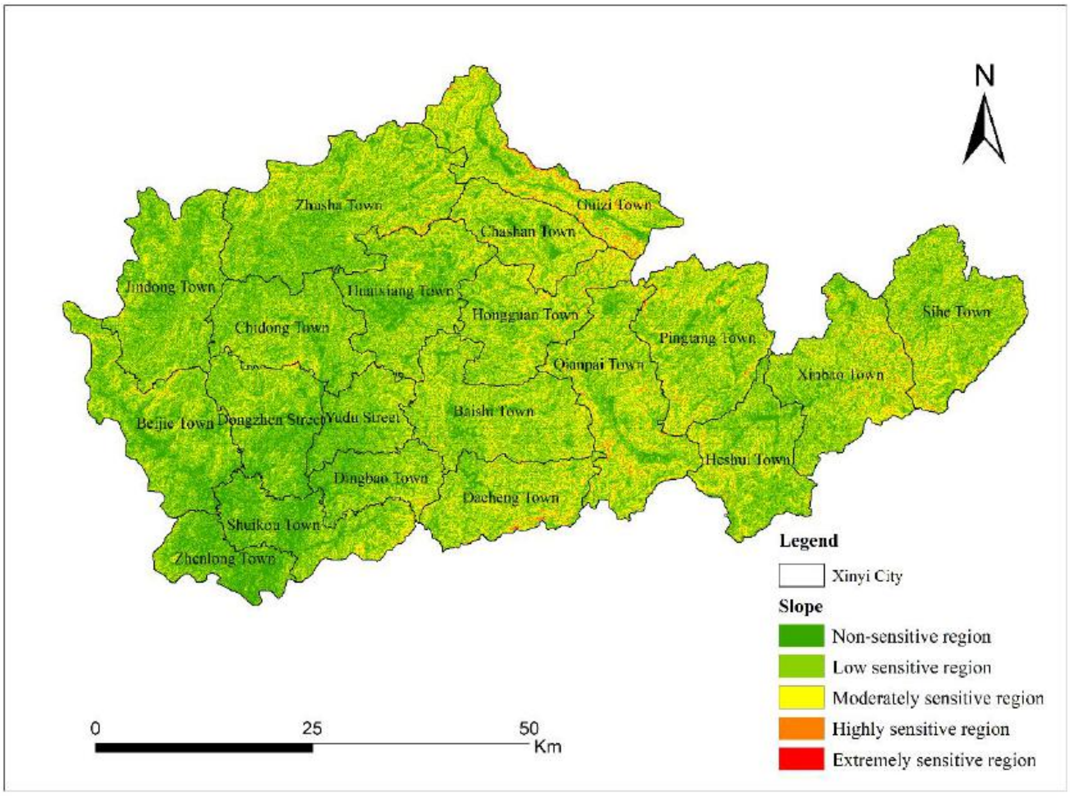

Fig.4 Slope Factor Analyses

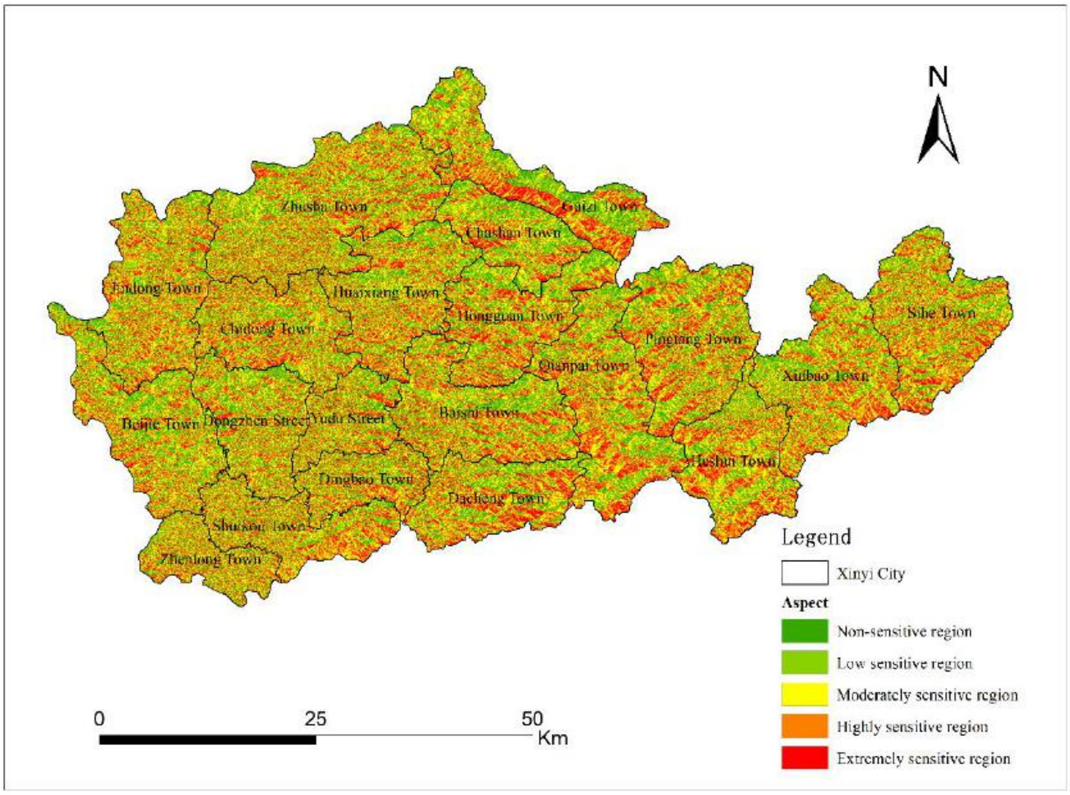

Fig.5 Slope Factor Analyses

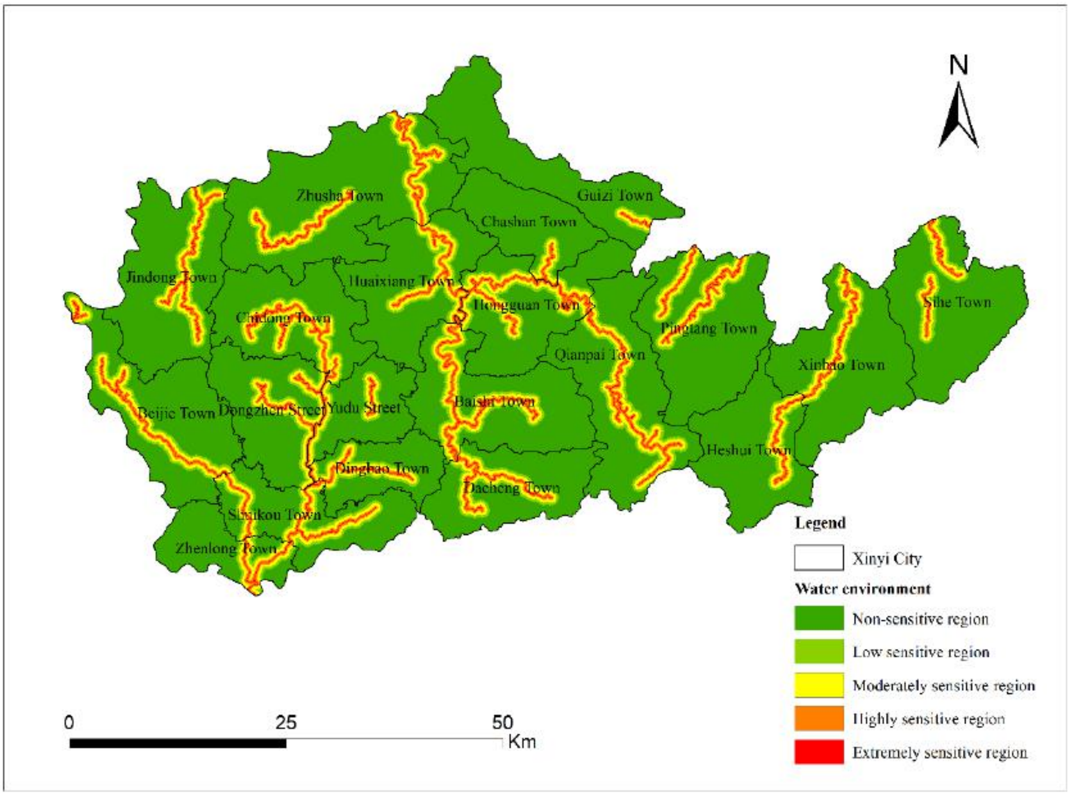

Fig.6 Analysis of Water Environment Factors

4.4 Water Environmental Factors

Through the buffer analysis of GIS, the water environment data of Xinyi City was analyzed, and it was found that the closer to the water environment, the higher the ecological sensitivity, while the further away from the water environment, the lower the sensitivity. Xinyi City has a small water area and a sparse surface river network. The overall ecological sensitivity of water environmental factors is low, with extremely sensitive areas and highly sensitive areas accounting for 6.74% of the total area of the city, with a total area of 242.17 km². The water environment in this area is easily affected by human activities, making it highly ecologically sensitive. Secondly, non-sensitive areas account for 78.38% of the total area of the city, with an area of 2825.53 km². The water environment in this area is not easily affected by human activities (Figure 6).

4.5 NDVI Factors

Xinyi City has a forest area of 212200 hectares, a forest coverage rate of 68.28%, and a forest volume of 16.9444 million m^3, ranking among the top in the province. It is a national ecological protection and construction demonstration zone and a national key ecological function zone. The ecological sensitivity of NDVI factors in Xinyi City shows a characteristic of high in the northeast and low in the southwest, with the lowest being at the junction of Dongzhen Street and Yudu Street. Result analysis shows that the ecological sensitivity of NDVI factors in Xinyi City is generally high, with extremely sensitive and highly sensitive areas accounting for 72.49% and 26.96%, respectively, covering an area of 2613.08km² and 971.93km². The medium-sensitive area accounts for 0.54%, with an area of 19.53km². The low-sensitivity area accounts for 0.01%, with an area of 0.28km² respectively (Figure 7).

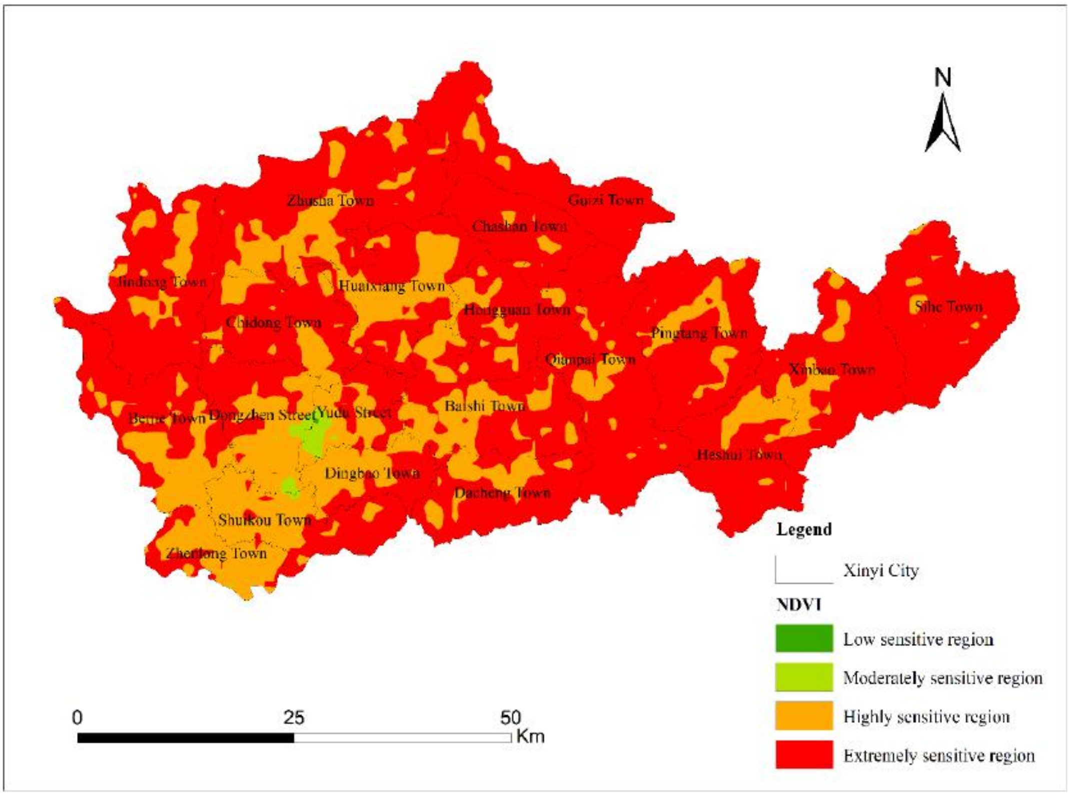

Fig.7 NDVI Factor Analyses

4.6 Land Use Factors

According to the current land use situation in Xinyi City, land use types are divided into 5 categories: water bodies, forest land and arable land, grassland and shrubs, bare land, and construction land. The area of the medium-sensitive area is 3km², accounting for 0.08% of the total area. The area of the high sensitivity zone is 3569.89km², accounting for 99.03% of the total area. The extremely sensitive area covers an area of 6.17km², accounting for 0.17% of the total area. The results indicate that the ecological sensitivity of land use factors in Xinyi City, except for the areas along the Jinjiang River in the urban area, is mainly high sensitivity, distributed in the east, north, and west, with a large forest area. Among them, the ecological function of forests plays an extremely important role in protecting the ecological environment of Xinyi City and promoting regional sustainable development. Secondly, the construction land in Xinyi City is mainly concentrated in the urban area, with an area of 25.74km², accounting for 0.71%, while the area of bare land in the city is relatively small, accounting for only 0.001% (Figure 8). Therefore, scientific and rigorous construction planning must be carried out in the process of development and utilization to reduce damage to the ecological environment. For different types of land use, reasonable development should be carried out to achieve sustainable development in Xinyi City.

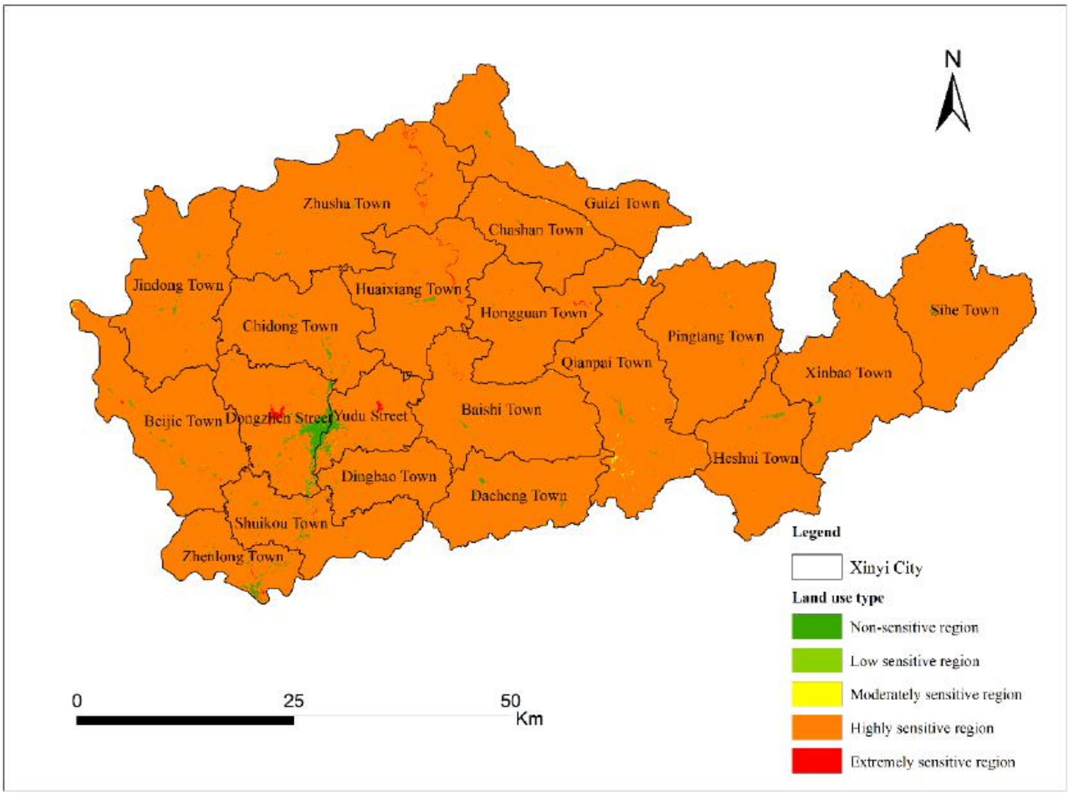

Fig.8 Analysis of Land Use Factors in Xinyi City

4.7 Comprehensive Analysis of Ecological Sensitivity

This article selects six ecological evaluation factors: elevation, slope, aspect, water environment, vegetation NDVI, and land use type. By using GIS and AHP to perform weighted superposition analysis on various evaluation factors, a comprehensive evaluation map of ecological sensitivity in Xinyi City (Figure 9), a statistical table for comprehensive analysis of ecological sensitivity in Xinyi City (Table 5), and an ecological sensitivity table for each town (street) in Xinyi City (Table 6) were obtained.

The overall ecological sensitivity of Xinyi City is relatively high, showing a decreasing pattern from northeast to southwest. The proportion of extremely sensitive areas and high sensitive areas is 8.96% and 33.01%, respectively, with a total area of 1506.07 km². They are mainly distributed in river and riverbank areas, which are mostly crisscrossed by mountains and rivers, with large undulations and steep slopes. Therefore, in the process of construction and utilization, special attention needs to be paid to the protection of the ecological environment in these areas. The medium-sensitive area and low sensitive area are 1395.36km² and 661.65km², respectively, accounting for 38.88% and 18.44%, respectively, mainly for human production and living areas outside the city center, with a certain scale of construction land. The non-sensitive areas are concentrated in the central and southern parts of Xinyi City, accounting for 0.71% of the city's area with a total area of 25.37km². The area has a high degree of urbanization, a large scale of construction land, high transportation accessibility, and convenient production and life for the people. However, in the process of economic and social development, ecological security still needs to be valued and maintained to achieve sustainable development.

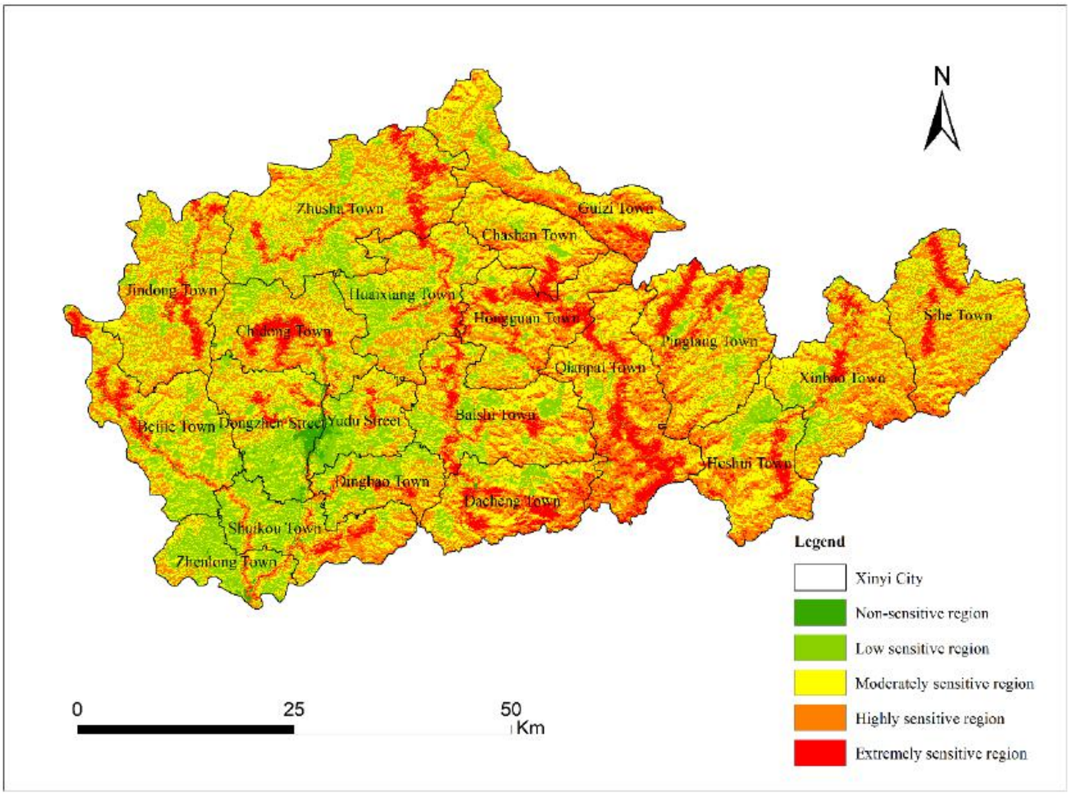

Fig.9 Comprehensive Evaluation of Ecological Sensitivity

Table 5 Comprehensive Analysis and Statistics of Ecological Sensitivity in Xinyi City

Ecological sensitivity evaluation	Comprehensive evaluation index	Area /km^2	Proportion /%
Non sensitive	(1.96,4.25]	25.37	0.71
low sensitive	(4.25,5.45]	661.65	18.44
medium sensitive	(5.45,5.88]	1395.36	38.88
high sensitive	(5.88,6.34]	1184.55	33.01
extremely sensitive	(6.34,8.11]	321.53	8.96

Table 6 Ecological Sensitivity Table of Each Town (Street) in Xinyi City

District	Unit	Non sensitive	low sensitive	medium sensitive	high sensitive	extremely sensitive
Dongzhen Street	Area/km^2	9.95	54.40	53.84	25.64	5.38
	Proportion /%	6.67	36.46	36.08	17.18	3.61
Yudu Street	Area/km^2	3.91	35.28	33.98	18.31	2.50
	Proportion /%	4.16	37.54	36.15	19.48	2.66
Baishi Town	Area/km^2	0.32	40.11	82.35	66.61	20.12
	Proportion /%	0.15	19.15	39.31	31.79	9.60
Beijie Town	Area/km^2	1.23	59.80	83.84	50.47	14.19
	Proportion /%	0.59	28.54	40.01	24.09	6.77
Chashan	Area/km^2	0.11	9.07	59.82	39.00	9.66

District	Unit	Non sensitive	low sensitive	medium sensitive	high sensitive	extremely sensitive
Town	Proportion /%	0.09	7.71	50.84	33.15	8.21
Chidong Town	Area/km^2	1.01	35.04	65.23	53.54	18.50
	Proportion /%	0.58	20.22	37.64	30.89	10.67
Dacheng Town	Area/km^2	0.56	17.65	50.16	59.11	23.84
	Proportion /%	0.37	11.66	33.15	39.06	15.75
Dingbao Town	Area/km^2	0.72	31.52	33.30	25.01	4.38
	Proportion /%	0.76	33.20	35.08	26.35	4.62
Guizi Town	Area/km^2	0.32	16.70	76.72	74.59	15.44
	Proportion /%	0.18	9.09	41.75	40.59	8.40
Heshui Town	Area/km^2	0.66	20.01	63.66	64.80	15.92
	Proportion /%	0.40	12.12	38.57	39.26	9.65
Hongguan Town	Area/km^2	0.13	15.48	66.50	65.91	25.01
	Proportion /%	0.08	8.94	38.43	38.09	14.46
Huaixiang Town	Area/km^2	0.53	52.46	78.17	51.11	8.21
	Proportion /%	0.28	27.54	41.04	26.83	4.31
Jindong Town	Area/km^2	0.73	37.59	92.74	77.06	14.65
	Proportion /%	0.33	16.87	41.63	34.59	6.58
Pingtang Town	Area/km^2	0.30	24.02	89.51	84.51	25.85
	Proportion /%	0.13	10.71	39.93	37.70	11.53
Qianpai Town	Area/km^2	0.20	11.32	77.96	99.22	50.05
	Proportion /%	0.08	4.74	32.65	41.56	20.96
Shuikou Town	Area/km^2	1.29	46.96	47.20	41.07	9.13
	Proportion /%	0.88	32.24	32.41	28.20	6.27
Sihe Town	Area/km^2	0.25	17.41	83.69	88.87	18.11
	Proportion /%	0.12	8.36	40.17	42.66	8.69
Xinbao Town	Area/km^2	0.53	26.00	85.94	85.10	14.66
	Proportion /%	0.25	12.25	40.49	40.10	6.91
Zhenlong Town	Area/km^2	2.12	45.45	30.27	13.25	2.00
	Proportion /%	2.28	48.83	32.52	14.23	2.15
Zhusha Town	Area/km^2	0.49	65.27	139.85	100.72	23.80
	Proportion /%	0.15	19.77	42.36	30.51	7.21
Baishi Town	Area/km^2	0.32	40.11	82.35	66.61	20.12
	Proportion /%	0.15	19.15	39.31	31.79	9.60
Beijie Town	Area/km^2	1.23	59.80	83.84	50.47	14.19
	Proportion /%	0.59	28.54	40.01	24.09	6.77

V. CONCLUSION

The advent of the industrial and information age has brought about rapid urbanization and development for people. People should not only enjoy the convenience of production and life but also be vigilant for danger, dialectically view the urban prosperity and ecological damage brought about by development, and correctly view and solve various ecological and environmental problems that have already emerged. With the rapid development of urbanization, Xinyi City inevitably causes damage to the ecological environment. To protect the ecological environment and maintain ecological balance, this study provides some references for the future development of Xinyi City. This article selects six ecological evaluation factors, including elevation, slope, aspect, water environment, vegetation NDVI, and land use, to establish an ecological sensitivity evaluation system. The conclusions drawn from this study are as follows:

(1) The sensitive areas in Xinyi City are composed of high- and medium sensitive areas with overall high ecological sensitivity. Among them, the areas with relatively small ecological damage are located in the southwest of Xinyi City.

(2) The main factors affecting the ecological sensitivity of Xinyi City are land use type, vegetation coverage, and water environment.

(3) The spatial distribution of ecological sensitivity in Xinyi City shows a decreasing pattern from northeast to southwest. The extremely sensitive and highly sensitive areas are distributed in areas with high terrain, complex terrain, and close to rivers and lakes in Xinyi City. The extremely sensitive areas must strictly protect the natural ecological environment and cannot be occupied arbitrarily. High-sensitivity areas can be used to construct nature reserves and develop ecotourism in a reasonable manner. The non-sensitive areas are mainly concentrated in the urban center of the southwest of Xinyi City. The terrain is flat, suitable for human production and life, and the construction land is large. These areas have a stable ecological structure and strong anti-interference ability and can be developed and constructed reasonably on the basis of protecting the ecology. Low- and medium-sensitive areas are mainly distributed in human residential areas outside the central urban area. The construction land in these areas is relatively large, and these areas can be moderately developed, but natural resource protection needs to be strengthened. Urban ecological sensitivity assessment helps to understand the ecological security status and development potential of cities, guide urban planning, promote ecosystem stability, optimize ecological patterns, and build modern cities that are livable and business-friendly.

(4) Qianpai Town, Dacheng Town, Hongguan Town, Sihe Town, Pingtang Town, Guizi Town, Heshui Town, and Xinbao Town have the highest ecological sensitivity, and special attention should be paid to their future urban development and land use, and scientific and rigorous decision-making and planning should be formulated.

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Yield gap among coconut growers in Tumkur district of Karnataka

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Abstract— *Plantation crops are a vital section of our agrarian economy. They are important for the growth and development of farming sectors in many Indian states. Coconut is one important plantation crop which not only contributes significantly to foreign exchange earnings but also provides significant direct and indirect employment opportunities. So, coconut plantation's impact on the socio-economic development of farming sector is profound and immense. The present study on Yield gap among the randomly selected 120 coconut growers from Tiptur, Turuvekere, Chikkanayakanahalli and Sira taluks of Tumkur district was conducted during the year 2022-23. The research objective was to assess the yield gap among coconut growers. The yield gap analysis showed that there existed an overall yield gap of about 28.90 per cent where Sira taluk had the highest yield gap of about 34.34 per cent among other taluks followed by Chikkanayakanahalli taluk showing 30.54 per cent yield gap followed by the Tiptur taluk with 26.70 per cent yield gap and then followed by Turuvekere taluk with 24.04 per cent of yield gap. Among the overall coconut growers more than two-fifth of coconut growers (46.67 %) fall under medium level of yield gap followed by high level of yield gap (27.50 %) and then by low level of yield gap (25.83 %). The Kruskal-wallis one-way Anova to know the significant difference in the yield gap among the taluks, disclosed that there is a significant difference in the yield gap among taluks with H-value of 15.03 significant at one per cent level.*

Keywords— ***Coconut growers, Karnataka, Kruskal-wallis one-way Anova, Tumkur, Yield gap***

I. INTRODUCTION

Agriculture is a vital part of India's economy and among the various agricultural sectors, Plantation crops contribute immensely to our agricultural economy, significantly driving growth and development in numerous Indian states. This sector contributes substantially to foreign exchange earnings and provides extensive direct and indirect employment, making it essential for overall socio-economic development of the Indian farming community. 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.

India is amongst the largest coconut producing countries in the world with around 31% share of global production (Coconut Development Board, 2021)[1]. In the Indian scenario, coconut cultivation holds particular importance, especially in Karnataka state, which has become one of the leading hubs for coconut production. Tumkur district in Karnataka state, often hailed as 'Kalpatharu Nadu' or the 'Land of Coconuts' plays a pivotal role in strengthening the state's coconut yield. Tumkur district alone contributes around 29% of the total coconut cultivation area and nearly 30% of production in the state (Coconut Development Board 2021-22)[2].

Now a days we can say that developing new technologies is not a major challenge in our nation, as agricultural scientists possess the capability to innovate as needed. The primary concern lies in the widespread adoption and utilization of modern farm technologies by coconut growers. If coconut growers do not adopt such improved technologies from time to time, it may become difficult for the coconut growers to harness the potential yield as expected. Here, Extension institutes come handy to deliver support to coconut farmers through the dissemination of knowledge, provision of technical expertise, promotion of best practices and technologies to ensure the success and advancement of coconut farming in the country.

Despite such efforts by the research and extension functionaries, there exists a notable disparity between expected potential yield and the actual yield obtained at the field level in coconut production. This disparity suggests that there is untapped potential and opportunities for improvement within coconut farming practices to reduce the yield gap. So, studying the yield gap in the coconut production and the areas which are needed to be focused becomes imperative in light of coconut sector's significant role in the Indian agrarian economy. Also, maximizing productivity becomes crucial for enhancing the economic growth and sustainability considering the substantial contribution of the coconut crop to India's GDP and export revenue.

Addressing the yield gap can lead to increased output which in turn could boost earnings of the coconut growers and strengthen the country's position in the global coconut market. In essence, studying the yield gap in coconut production is essential for leveraging India's position as a key player in the global coconut industry, maximizing economic returns and promoting sustainable agricultural practices among coconut growers. With this backdrop, this research paper seeks to study the yield gap among coconut growers in Tumkur district there by inform policy formulation, guide extension services and facilitate stakeholder interventions aimed at promoting sustainable agricultural development in the region.

II. MATERIALS AND METHODS

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

Yield gap refers to the difference between the potential yield of the coconut palm obtained at the research station and coconut grower's actual yield. The index developed by Nagaraj (1999)[3] for Yield gap was used which refers to the percentage of the yield potential realized:

$$\text{(1)}\quad \text{Yield gap Index} = \frac{\text{Potential yield} - \text{Actual yield}}{\text{Potential yield}} \times 100$$

Potential yield refers to the maximum yield obtained in the coconut growers environment or research station. The potential coconut yields were arrived based on the yields mentioned in package of practices of University of Horticultural sciences, Bagalkot. The potential yield of coconut is 100 nuts/palm.

Actual yield refers to the actual coconut yield per plant obtained by the coconut growers (respondents) in the study area. It was used to compute the Yield gap index. Then the categorization of the coconut growers into three categories was done using mean and standard deviation as a means of check.

Yield gap category	Criteria
Low	Less than (Mean - 1/2SD)
Medium	Between (Mean ± 1/2 SD)
High	More than (Mean + 1/2 SD)

III. RESULTS AND DISCUSSION

3.1 Yield gap among coconut growers

According to data from Table 1 about the yield gap analysis, there was an overall yield gap of about 28.90 per cent between the potential farm yield and the actual farm yield of coconuts obtained in the current study. Among chosen taluks, Sira had the highest yield gap of about 34.34 per cent followed by Chikkanayakanahalli with a yield gap of 30.54 per cent, Tiptur with a yield gap of

26.70 per cent and then Turuvekere with a yield gap of 24.04 per cent. The potential yield of coconut was 100 nuts per palm, as shown in the table while Tiptur coconut growers actual farm yield was only 73.30 nuts per palm leaving an average yield gap of 26.70 nuts per palm. There was an average yield gap of 24.04 nuts per palm where Turuvekere coconut growers actual yield was 75.96 nuts per palm. With an average yield gap of 30.54 nuts per palm, Chikkanayakanahalli coconut growers produced 69.46 nuts per palm actual farm yield. According to the actual farm yield of Sira coconut growers, the average yield was found to be 65.66 nuts per palm leaving a yield gap of about 34.34 nuts per palm. The probable reason might be that Turuvekere and Tiptur taluks considered to have good irrigation sources, whereas the Chikkanayakanahalli and Sira taluks are considered dry or rainfed tract. So, we can say that untapped potential and scope is there for improving the yield in coconut production.

Table 1: Yield gap among coconut growers (n=120)

Sl. No	Taluks	Potential Yield (nuts/palm)	Actual Yield (nuts/palm)	Yield gap (nuts/palm)	% gap	Overall Actual yield (nuts/palm)	% gap
1	Tiptur	100	73.30	26.70	26.70	71.10	28.90
2	Turuvekere		75.96	24.04	24.04		
3	Chikkanayakanahalli		69.46	30.54	30.54		
4	Sira		65.66	34.34	34.34		

% = Percentage

3.2 Overall yield gap among coconut growers

As depicted in the Table 2, study revealed that in case of Tiptur taluk, significant number of coconut growers (46.67 %) were found to come under medium level of yield gap followed by low level of yield gap (36.66 %) and then by high level of yield gap (16.67 %). While in Turuvekere taluk, half of the coconut growers (50.00 %) come under the medium level of yield gap followed by low level of yield gap (36.67 %) and then by high level of yield gap (13.33 %). Whereas looking in to the case of Chikkanayakanahalli taluk, significant number of coconut growers (43.33 %) were found to come under the medium level of yield gap followed by high level of yield gap (40.00 %) and then followed by low level of yield gap (16.67 %). From Studying the case of the Sira taluk, significant number of coconut growers (46.67 %) come under the medium level of yield gap followed by high level of yield gap (40.00 %) and then followed by low level of yield gap (13.33 %). Thus, among the overall coconut growers more than two-fifth of coconut growers (46.67 %) fall under medium level of yield gap followed by high level of yield gap (27.50 %) and then by low level of yield gap (25.83 %). This may be the result of low technological expertise, a lack of desire to use good agricultural practices and a shortage of resources among coconut growers. The findings of Vikas (2020)[4] are in agreement with this trend.

Table 2: Overall yield gap among coconut growers (n=120)

Level of yield gap	Tiptur (n_1=30)		Turuvekere (n_2=30)		Chikkanayakanahalli (n_3=30)		Sira (n_4=30)		Total (n=120)	
	f	%	*f*	%	*f*	%	*f*	%	*f*	%
Low < (29.72 – 10.97)	11.00	36.66	11.00	36.67	5.0	16.67	4.00	13.33	31.00	25.83
Medium (29.72 ± 10.97)	14.00	46.67	15.00	50.00	13.0	43.33	14.00	46.67	56.00	46.67
High > (29.72 + 10.97)	5.00	16.67	4.00	13.33	12.0	40.0	12.00	40.00	33.00	27.50
Mean=29.72 SD=21.95										

f = Frequency and **%** = Percentage

3.3 Comparison of yield gap among coconut growers with Kruskal-Wallis One-way ANOVA

The Table 3 showing the Kruskal-wallis one-way ANOVA to know the significant difference in the yield gap among the taluks, showed that there is a significant difference in the yield gap among taluks with H-value of 15.03 significant at one per cent level. Where Turuvekere taluk performed better with 47.38 mean rank then followed by the Tiptur taluk with mean rank of 49.28 then by the Chikkanayakanahalli taluk with mean rank of 70.60 then by the Sira taluk with mean rank of 74.73 where it implies that as the mean rank value is less/decreased the yield gap is also less/decreased and vice versa.

Table 3: Comparison of yield gap among coconut growers with Kruskal-Wallis One-way ANOVA (n=120)

Sl. No	Taluks	Sample size	Mean rank	H-Value
1	Tiptur	$n_1 = 30$	49.28	15.03**
2	Turuvekere	$n_2 = 30$	47.38	
3	Chikkanayakanahalli	$n_3 = 30$	70.60	
4	Sira	$n_4 = 30$	74.73	

**Significant at one per cent level

IV. CONCLUSION

In conclusion, studying the yield gap among coconut growers holds immense importance for the sustainable development of coconut farming sector in Tumkur district and beyond. By identifying the factors contributing to this gap, policymakers, agricultural extension services and stakeholders can develop targeted interventions to address the challenges effectively. Closing the yield gap not only enhances the livelihoods of coconut farmers but also strengthens the resilience of the agricultural sector, fosters economic growth and ensures food security. Moreover, it can contribute to the overall prosperity and well-being of coconut-growing communities, thus laying the foundation for a successful socio-economic growth and development of coconut growers.

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A Study on Marketing of Mushroom (Oyster Mushroom) in Gaya District of Bihar

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Abstract**—** *This study investigates the marketing channels for mushrooms in Gaya district, Bihar, focusing on two primary channels: direct sales from producers to consumers (Channel I) and sales through retailers (Channel II). The research employs a multistage sampling procedure to collect primary data from producers and retailers. Channel I, where producers sell directly to consumers, exhibits a higher marketing efficiency of 36.70% and a producer share of 97.28% in the consumer's rupee. In contrast, Channel II, involving retailers, results in a significantly lower marketing efficiency of 17.23% and a producer share of 81.76%, due to higher intermediary costs and retailer margins. The study highlights the benefits of direct marketing channels in enhancing producer profitability and efficiency, suggesting that reducing intermediary involvement can substantially improve economic returns for mushroom growers. These findings provide valuable insights for policymakers and stakeholders aiming to optimize agricultural marketing strategies and support sustainable mushroom cultivation in the region.*

Keywords**— *Marketing channels, Mushroom producers, Direct sales, Marketing efficiency, Producer profitability***

I. INTRODUCTION

Mushroom cultivation has emerged as a significant agricultural activity, particularly in regions like Gaya district of Bihar, where it contributes to the livelihoods of many small and marginal farmers. The efficiency of marketing channels is crucial in determining the profitability and sustainability of mushroom production. This study aims to analyze the marketing channels for mushrooms, focusing on direct sales from producers to consumers (Channel I) and sales through retailers (Channel II), to identify the most efficient and beneficial methods for farmers.

India has seen a substantial increase in mushroom production over the years due to its high nutritional value and increasing consumer demand. According to the ***National Horticulture Board (2019),*** India produces approximately 1.35 lakh metric tons of mushrooms annually, with a significant portion coming from small-scale farmers in states like Bihar. Gaya district, in particular, has been identified as a prominent area for mushroom cultivation due to its favorable climate and the presence of a large number of small and marginal farmers engaged in this activity ***(Bora et al., 2017).***

Marketing is a critical component of agricultural enterprises, affecting the income and sustainability of farmers. Efficient marketing channels ensure that producers receive a fair share of the consumer's rupee while minimizing costs and losses. Previous studies have highlighted the importance of direct marketing channels in improving profitability for small-scale farmers. For instance, ***Sharma et al. (2018)*** found that direct sales to consumers significantly increased the net returns for vegetable farmers in Himachal Pradesh. Similarly, ***Singh and Kaur (2019)*** noted that direct marketing reduced intermediary costs and increased the producer's share in the consumer's price in Punjab's fruit markets.

However, the role of intermediaries in agricultural marketing cannot be entirely overlooked. Retailers and other intermediaries often provide essential services such as storage, transportation, and market access, which can be beneficial for producers, especially those with limited resources ***(Patil and Bhagat, 2020).*** Therefore, understanding the trade-offs between direct and intermediary-involved marketing channels is essential for developing strategies that enhance farmer incomes and market efficiency.

In Gaya district, two primary marketing channels for mushrooms have been identified: Channel I, where producers sell directly to consumers, and Channel II, where producers sell to retailers who then sell to consumers. This study aims to compare these channels in terms of marketing costs, margins, price spread, producer's share in the consumer's rupee, and overall marketing efficiency. By doing so, it seeks to provide actionable insights for policymakers and agricultural stakeholders to optimize mushroom marketing strategies in the region.

Data for this study were collected using a multistage sampling procedure. Primary data were gathered from producers and retailers through personal interviews and surveys, while secondary data were obtained from various sources, including government reports, academic journals, and relevant literature. The analysis focuses on key metrics such as marketing costs, price spreads, and the producer's share in the consumer's price to determine the most efficient marketing channel for mushroom growers in Gaya district.

This study aims to provide a comprehensive analysis of mushroom marketing channels in Gaya district, highlighting the benefits and challenges of direct and intermediary-based marketing. The findings will contribute to the development of more efficient and profitable marketing strategies for mushroom growers, ultimately enhancing their economic sustainability and livelihood security.

II. METHODOLOGY

The present study was based on primary data collected from producers and retailers using a multistage sampling procedure. Gaya district in Bihar was purposively selected due to its prominence in mushroom cultivation. Within Gaya district, the Gaya town block was chosen based on the high concentration of mushroom growers. Villages such as Chakand, Dhansir, Ghutiya, Kandi, and Kujapi, known for mushroom production, were included. A list of mushroom growers was compiled, and 10% of these growers were randomly selected as respondents. Farmers were categorized by production levels into small (0-50 kg), medium (50-100 kg), and large (more than 100 kg) producers. Two major mushroom markets, Delha Mandi and Durgabari Sabji Mandi, were selected for their significance in mushroom sales. From these markets, five out of ten mushroom retailers were chosen for the study. Primary data on mushroom production, marketing practices, and related challenges were collected through personal interviews and surveys using well-prepared interview schedules. Secondary data were gathered from literature reviews and various government sources such as the Directorate of Marketing and Agricultural websites and journals.

III. RESULT

Table 1. Marketing Channels of Mushroom

Channel I	Producer > Consumer
Channel II	Producer > Retailer > Consumer

Table 2. Marketing Cost, Marketing Margin and Price Spread in Channel I

SI. No.	Particulars	Rs/Kg
1.	Producer's sale price	120
2.	Cost of packing	0.25
3.	Transport cost	1.75
4.	Cleaning, grading, etc.	1.02
5.	Miscellaneous expenses	0.25
6.	Total expenses	3.27
7.	Net price received by the producer	116.73
8.	Consumer's purchase price	120
9.	Price Spread	3.27
10.	Producers Share in Consumer Rupee	97.28
11.	Marketing Efficiency	36.70

Table 3. Marketing Cost, Marketing Margin and Price Spread

SI. No.	Particulars	Rs/Kg
1.	Producer's sale price	110.00
i.	Expenses borne by the producer	3.27
ii.	Cost of packaging material	0.25
iii.	Cleaning, Grading, filling etc.,	1.02
iv.	Load & transport	1.75
V.	Miscellaneous charges	0.25
2.	Net price received by the farmer	106.73

i.	Expenses borne by the retailer	4.54
ii.	Transportation cost	1.54
iii.	Rent of the shop	2.25
iv.	Loss, wastage and spoilage	0.75
V.	Margin of the retailer	20.00
3.	Retailer's sale price/ consumer's purchase price	134.54
4.	Price spread	24.54
5.	Producers Share in Consumer Rupee	81.76
6.	Marketing Efficiency	17.23

Table 4. Estimation Total Marketing Cost and Marketing Margin

SI. No.	Particulars	Channel I	Channel II
1	Total marketing cost	3.27	7.81
2	Total marketing margins		20.00
3	Price spread	3.27	24.54
4	Producer share in consumer rupee in per cent	97.28	81.76
5	Marketing efficiency in per cent	36.70	17.23

IV. DISCUSSION

The study examines two marketing channels for mushrooms: Channel I, where the producer sells directly to the consumer, and Channel II, where the producer sells to a retailer who then sells to the consumer. The analysis reveals distinct differences in marketing costs, margins, price spreads, and efficiency between the two channels.

In Channel I, the producer's sale price is Rs 120 per kg. After accounting for costs such as packing, transport, and cleaning, the total marketing expense is Rs 3.27 per kg, leaving the producer with a net price of Rs 116.73 per kg. The price spread, or the difference between the consumer's purchase price and the producer's net price, is Rs 3.27. The producer's share in the consumer's rupee is notably high at 97.28%, indicating minimal intermediary costs. Marketing efficiency is also high at 36.70%.

In Channel II, the producer sells at Rs 110 per kg and incurs expenses similar to Channel I, resulting in a net price of Rs 106.73 per kg. However, the retailer incurs additional costs, including transportation, shop rent, and losses due to spoilage, totaling Rs 4.54 per kg. The retailer's margin is Rs 20 per kg, leading to a consumer purchase price of Rs 134.54 per kg. This results in a price spread of Rs 24.54, significantly higher than Channel I. Consequently, the producer's share in the consumer's rupee drops to 81.76%, and marketing efficiency decreases to 17.23%.

Comparing the two channels, Channel I is more efficient with lower marketing costs and higher producer share in the consumer rupee. Channel II, while involving more intermediaries and higher costs, offers retailers a substantial margin but reduces overall marketing efficiency. These findings highlight the trade-offs between direct and indirect marketing channels, emphasizing the benefits of direct sales for producers in terms of higher returns and greater efficiency.

V. CONCLUSION

The study on the marketing channels of mushrooms in Gaya district, Bihar, reveals significant insights into the efficiency and profitability of different marketing strategies. Channel I, where producers sell directly to consumers, demonstrates higher efficiency with a producer share of 97.28% and lower marketing costs. Conversely, Channel II, involving retailers, results in higher marketing costs and lower producer shares at 81.76%. Despite providing retailers with significant margins, Channel II reduces overall marketing efficiency. These findings underscore the advantages of direct marketing channels in maximizing producer returns and efficiency. Policymakers and agricultural stakeholders should consider promoting direct sales and reducing intermediary costs to enhance the economic benefits for mushroom growers. Future research could explore ways to improve marketing infrastructure and support systems to further increase the profitability and sustainability of mushroom cultivation in the region.

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Bioethanol from Sweet Potato Clones at Pruning Age and Yeast Concentrations

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Abstract**—*The use of bioethanol can save premium usage in addition, bioethanol can reduce greenhouse gas emissions by up to 80% from its combustion results so as to decomp additionally greenhouse effects. Raw materials for producing bioethanol from that materials containing glucose, starch, cellulose. The purpose of the study was to find out of tape yeast concentrations on the bioethanol fermentation process of 8 sweet potato clones. The interaction between clone variation and yeast concentration has a noticeable effect on the results of the analysis of starch levels after the fermentation process. Starch levels showed a very significant decrease in the starch levels of fresh raw materials before the fermentation process. The results showed that the interaction between clone variation and yeast concentration had a noticeable effect on the results of the analysis of alcohol levels produced. The highest alcohol content is produced from Sari clones ($_{150\ DAP}$) with a yeast concentration of 15% with a content of 6.59%. The variation of clones and the concentration of yeast interacts manifestly with the results of the analysis of the total sugar content after the fermentation process. The total sugar measured is the total amount of sugar left after the fermentation process. Results showed a significant decrease in total sugar fermentation process by tape yeast showed the absence of starch hydrolysis and a total overhaul of the resulting sugar into alcohol. The concentration of yeast has no effect on the change of pH in the fermentation process, the pH at the end of the fermentation process is in the range of 4.1-6.3.*

Keywords**—*****Bioethanol, fermentation, eco-friendly, sweet potato.***

I. INTRODUCTION

Bioethanol produced from sweet potatoes has advantages compared to petroleum fuels because the source is renewable and has a high octane value so that the combustion process becomes more complete with CO_2 emission levels of 40-80% lower and is environmentally friendly. This potential is quite large to be used as a substitute for gasoline and diesel fuel because it has more potential than cassava. Starch in sweet potatoes can be hydrolyzed into carbohydrate monomer units and can be used by microorganisms in the fermentation process. According to Jena & Kumar Kar (2019) that the production of bioethanol used as biofuel is an important choice that is more environmentally friendly than fossil fuels. In addition, the raw materials used to produce bioethanol are cheaper than fossil products (Bušić et al., 2018). This type of renewable energy can reduce dependence on external oil sources and effectively reduce greenhouse gas emissions (Li et al., 2014). Renewable energy development is a key strategy to sustain economic growth and to improve the environment. Biomass is an alternative renewable fuel for gasoline (Khoo et al., 2013).

Renewable energy is very important and needed by many parties. Alternative energy sources have several advantages, namely renewable and environmentally friendly because they have low CO^2 emissions (Kartini & Dhokhikah, 2018). Conversion efficiency increased significantly during sweet potato ripening, where the highest value was reached 25 days after harvest. Among the heating methods, the conventional one is slightly superior in terms of conversion efficiency (9% higher at 25 days) and has better results regarding cost analysis (Schweinberger et al., 2016).

Alternative sources of raw materials that are very important and have the potential to be developed are sweet potato plants which are perennial plants, can thrive in tropical and sub-tropical regions. Able to adapt to adverse environmental conditions, such as drought and infertile soil as well as tolerance to pests and diseases, produce well with low inputs such as fertilizer and water (Lestari et al., 2019). Production of bioethanol made from carbohydrates is generally carried out in several stages which are not simultaneous in separate reactors such as extraction, hydrolysis and fermentation processes using *Sacharomyces cereviceae*.

The development of sweet potatoes as a source of food and feed is important for the development of Bio-industry Concept Agriculture. Clones that are suitable for the benefit of agricultural development with the concept of bio-industry are dual-purpose type clones. Research on 17 sweet potato clones has been successfully classified (Indawan, Lestari, & Thiasari, 2018). Into forage type (3 cultivars), low dual-purpose (3 cultivars), high dual-purpose (7 cultivars), and low root production (4 cultivars) (Lestari & Hapsari, 2015). Described by Indawan et al. (2018), that developed and researched sweet potato clones planted with the addition of biochar as a support for improving soil conditions with the aim of producing optimal sweet potato clones. According to Khaidir et al. (2016), that the concentration of tape yeast affects the pH and levels of the resulting bioethanol, but does not have a significant effect on the yield and density of bioethanol.

II. MATERIAL AND METHODS

The research was carried out in November 2018 - January 2019, at the Laborotory Industrial Microbiology, Chemical Engineering of Tribhuwana Tungga Dewi University, and Malang State Polytechnic. The test components include: Chemical components of fresh ingredients (starch content, total sugar content, pH). Fermented chemical components (ethanol content, starch content, total sugar content and pH).

The first factor of the tuber samples tested was from harvests treated with stover pruning at 80 DAP, 90 DAP, 120 DAP and 150 DAP, namely: Kuningan Putih ($_{80\ DAP}$), Beta-2 (80 DAP), Kuningan Merah ($_{90\ DAP}$), BIS OP-61 ($_{90\ DAP}$), 73-OP-5 ($_{120\ DAP}$), Beta 2-♀-29 ($_{120\ DAP}$), BIS OP 61-OP 22 ($_{150\ DAP}$), Sari ($_{150\ DAP}$). Second factor: Variation of tape yeast concentration consisted of 3 levels: B_1: Yeast concentration 5% (w/w), B_2: Yeast concentration 10% (w/w), B_3: Yeast concentration 15% (w/w). The test was repeated 3 times to obtain 72 experimental units.

Making bioethanol using a simple anaerobic fermenter with a volume of 500 mL. Each treatment uses 100 g of fresh sweet potato which is mashed using a blender by steaming first. Tape yeast was added to the fermenter with a concentration of 5%, 10%, and 15% (w/w), then 300 ml of sterile distilled water was added. Fermentation was carried out for 10 days at room temperature. Measurement of ethanol content using a Gas Chromatography (GC-14B) Shimadzu FID system. Flame Lonization Detector (FID) is a detector that has maximum reproducibility for various applications. The temperature used is 40-160ºC and the gas used as the carrier gas is Nitrogen (N_2). Starch and total sugar content were tested using methods based on AOAC.

The type of acid catalyst used is sulfuric acid (H_2SO_4). Saccharomyces cereviseae to convert glucose into ethanol. One of the ways to produce ethanol is by fermenting glucose syrup with microorganisms. Yeast is tolerant to quite high alcohol (12-18% v/v), resistant to high sugar content and remains active in fermenting at 4-32ºC. Analysis procedure (1). Measurement of ethanol content, (2). Measurement of total sugar, (3). Reducing sugar levels. The Somogyi-Nelson method determines glucose levels based on spectrophotometry. Data analysis used Analysis of Variance (ANOVA) with a significant level of 5%.

III. RESULT AND DISCUSSION

Starch content, total sugar and pH

Results of analysis of starch content, total sugar, initial pH, alcohol content and fermented starch content, correlation between alcohol content, starch and total sugar, pH fermented from 8 sweet potato clones, can be seen in Table 1 - Table 7 below.

There is instability in the nature of a clone not because of genetic factors, but because of differences between planting locations. Making bioethanol with sweet potato as the basic ingredient is through three stages of process, namely hydrolysis, fermentation and distillation processes. The hydrolysis process is carried out to break down starch into reducing sugars so that it can be fermented into bioethanol. The fermentation process converts glucose into ethanol with the help of the bacterium *Saccharomyces cereviceae*.

Ethanol is a colorless liquid with a characteristic odor. The specific gravity at 15ºC is 0.7937 and the boiling point is 78.32ºC at a pressure of 76 mmHg, the heat of combustion is 328 Kcal. The highest starch content was 23.05% in Kuningan Putih clone (80 DAP) and the lowest was 7.73% in BETA 2-♀-29 clone (120 DAP). The highest total sugar was in clone 73-OP-5 (120 DAP) and the lowest was in Kuningan Merah (90 DAP) of 2.26% (Table 1).

The process of producing bioethanol from materials with the main component of starch will involve saccharification and fermentation processes. Changes in chemical components in the manufacture of bioethanol are relatively the same as the process of making tape from cassava by utilizing inoculums from a succession of microorganisms. Fermentation factors that need to be considered to achieve good and correct process conditions include inoculum concentration, temperature, humidity, and aeration.

Table 1. Results of analysis of starch content, total sugar and pH of 8 fresh sweet potato clones.

No.	Clones	Starch content (%)	Sugar total (%)	pH initial
1.	Kuningan Putih (80 DAP)	23.05	3.79	4.8
2.	Beta 2 (80 DAP)	18.95	4.69	5.8
3.	Kuningan Merah (90 DAP)	7.98	2.26	5.4
4.	BIS OP-61 (90 DAP)	21.93	5.33	4.4
5.	73-OP-5 (120 DAP)	16.31	6.13	5.5
6.	BETA 2-♀-29 (120 DAP)	7.73	2.07	5.9
7.	BIS OP 61-OP 22 (150 DAP)	18.67	4.78	4.4
8.	Sari (150 DAP)	18.63	3.89	4.8

Note: DAP = day after planting.

Table 2. Alcohol content of fermented 8 sweet potato clones with 3 variations of tape yeast concentration.

No.	Clones	Concentration yeast (%)		
		5%	10%	15%
1.	Kuningan Putih (80 DAP)	5.96	5.45	6.20
2.	Beta 2 (80 DAP)	2.87	3.70	3.61
3.	Kuningan Merah (90 DAP)	0.70	0.37	0.94
4.	BIS OP-61 (90 DAP)	1.55	1.46	3.15
5.	73-OP-5 (120 DAP)	4.68	5.16	5.04
6.	BETA 2-♀-29 (120 DAP)	2.41	2.45	2.39
7.	BIS OP 61-OP- 22 (150 DAP)	3.16	2.90	3.53
8.	Sari (150 DAP)	5.84	6.11	6.59

Note: DAP = day after planting.

Table 3. Starch content from the fermentation of 8 sweet potato clones with 3 variations of tape yeast concentration.

No.	Clones	Concentration yeast (%)		
		5%	10%	15%
1.	Kuningan Putih (80 DAP)	0.27	0.62	0.66
2.	Beta 2 (80 DAP)	0.25	0.38	0.29
3.	Kuningan Merah (90 DAP)	0.09	0.28	0.41
4.	BIS OP-61 (90 DAP)	0.37	0.41	0.60
5.	73-OP-5 (120 DAP)	0.05	0.07	0.21
6.	BETA 2-♀-29 (120 DAP)	0.21	0.22	0.72
7.	BIS OP 61-OP-22 (150 DAP)	0.63	0.70	0.67
8.	Sari (150 DAP)	0.64	0.65	0.74

Note: DAP = day after planting.

Correlation between alcohol content and starch content

Starch content (0.64%, 0.65%, 0.74%) successively at concentrations of 5%, 10%, 15% in the Sari clone (150 DAP) (Table 3). The highest fermented total sugar (1.40%, 1.54%, 1.44%) at different concentration levels (5%, 10%, 15%) was in the BIS OP 61-OP-22 clone (150 DAP), while the lowest total fermented sugar (0.26%, 0.25%, 0.28%) at different concentration levels (5%, 10%, 15%) in the Kuningan Merah clone (90 DAP) (Table 5).

Table 4. Correlation between alcohol content and starch content from the fermentation of 8 sweet potato clones with 3 variations of tape yeast concentration.

	Alcohol content	Starch content	
Alcohol content	1		
Starch content	0.285482273	1	Weak correlation

Table 5. Total sugar content of fermented 8 sweet potato clones with 3 variations of tape yeast concentration.

No.	Clones	Concentration yeast (%)		
		5%	10%	15%
1.	Kuningan Putih (80 DAP)	0.34	0.31	0.30
2.	Beta 2 (80 DAP)	0.39	0.35	0.28
3.	Kuningan Merah (90 DAP)	0.26	0.25	0.28
4.	BIS OP-61 (90 DAP)	0.73	0.74	0.44
5.	73-OP-5 (120 DAP)	0.54	0.45	0.39
6.	BETA 2-♀-29 (120 DAP)	0.39	0.38	0.44
7.	BIS OP 61-OP-22 (150 DAP)	1.40	1.54	1.44
8.	Sari (150 DAP)	1.13	0.86	0.63

Note: DAP = day after planting.

Correlation between alcohol content and total sugar

The core stage of bioethanol production is the fermentation of sugar, either in the form of glucose, sucrose or fructose by yeast, especially *Saccharomyces* sp or *zymomonas mobillis* bacteria. Produced from the raw material starch or starch $(C_6H_{10}O_5)n$ which is hydrolyzed into glucose and then fermented with the microorganism *Saccharomyces cerevisiae* at a temperature of ± 27-30ºC. Fermented products can contain ethanol up to ± 18%.

There is an interaction effect between the concentration of tape yeast and the length of time of fermentation on the pH and levels of bioethanol produced from the red sweet potato fermentation process. The highest total sugar was 6.13% in clone 73-OP-5 (120 DAP) and the lowest was 2.07% in BETA 2-♀-29 clone (120 DAP). The alcohol content was 5.66% at a concentration of 5% in the Kuningan Putih clone (80 DAP), 6.11% and 6.59% at a concentration of 10% and a concentration of 15% in the Sari clone (150 DAP). Correlation of alcohol content and starch content is weakly correlated. The correlation between alcohol content and total sugar content is very weak, meaning that the variables of sugar content and starch content do not show a linear relationship.

Table 6. Correlation between alcohol content and total sugar resulting from the fermentation of 8 sweet potato clones with 3 variations of tape yeast concentration.

	Alcohol content	Total sugar content	
Alcohol content	1		
Starch content	0.092503483	1	Very weak correlation

pH

The length of time of fermentation has an effect on the pH and content of the bioethanol produced, but has no significant effect on the yield and density of bioethanol produced by fermented red sweet potato. The difference in starch and sugar content between fresh sweet potato and flour is due to the high variability in raw material composition. Total sugar expressed glucose equivalents were similar for the two ingredients: 75.0% and 77.0% w/w dry matter, for fresh sweet potato and flour respectively (Lareo et al., 2013). Described by Ramasamy et al. (2014), that starch is the most valuable component in sweet potato, changes in starch content during storage time directly affect the development of the sweet potato industry. Biodiesel synthesis using bioethanol of different grades showed that the yield and product purity increased with the grade of ethanol used, with values ranging from 63 to 83 wt%, and 50 to 94 wt%, respectively. High alcohol values are needed to make biodiesel and bioethanol production (Jhonprimen et al., 2012). Concentrations of 5%, 10%, 15% showed the highest pH showed a value of 6.3 in the BIS OP 61-OP-22 clone (150 DAP) from the initial pH of 4.4, meaning that there was an increase in the pH value, while the lowest pH value was 4.1 in the Beta 2 clone (80 DAP) from the initial pH: 5.8 there was a decrease in the pH value (Table 7).

Table 7. The pH of the fermented 8 sweet potato clones with 3 variations of tape yeast concentration.

No.	Clones	Yeast concentration (%)		
		5%	10%	15%
1.	Kuningan Putih (80 DAP)	5.4	5.1	5.1
2.	Beta 2 (80 DAP)	4.1	4.8	4.8
3.	Kuningan Merah (90 DAP)	5.0	5.0	5.1
4.	BIS OP-61 (90 DAP))	5.1	5.2	5.2
5.	73-OP-5 (120 DAP)	5.0	5.0	5.0
6.	BETA 2-♀-29 (120 DAP)	5.0	5.0	5.1
7.	BIS OP 61-OP-22 (150 DAP)	6.3	6.3	6.3
8.	Sari (150 DAP)	5.5	5.4	5.5

Note: DAP = day after planting.

The results showed that starch content was weakly correlated with other ingredients, indicating that starch content did not have a linear relationship, while the percentage of dry content and fermentable sugar content was closely correlated with starch content. The percentage of dry content significantly and positively correlated with fermentable flour and sugar content. Confirmed by Laude et al. (2011), that CO_2 emissions decreased by 115% by carbon capture and storage during ethanol production. According to Koga et al. (2013), bioethanol production is the final expression of the quality of fermentation in sweet potato tubers. During the storage and fermentation process, there are many factors that cause changes in the yield of bioethanol from sweet potato genotypes that are different from the storage time. The interaction between clone variation and yeast concentration had a significant effect on the results of analysis of starch content after the fermentation process.

Starch content showed a very significant decrease compared to the starch content of fresh raw materials before the fermentation process. The alcohol content is still relatively low because the purification process has not been carried out. To increase the purity, it is necessary to carry out a distillation process because tape yeast is a mixed inoculum, so it is necessary to pay attention to the conversion of starch and sugar in sweet potatoes into products other than ethanol.

The SFS process from sweet potato hydrolyzate occurs at a temperature of 35ºC with a pH of 4.5 which produces an ethanol concentration of 5.32% (v/v) with an ethanol formation efficiency of 35.79%, a fermentation efficiency of 70.16% and a yield of 11.79%. The SFS process lasts for 48-72 hours at 55-60ºC. The substrate concentration and processing time of SFS in the manufacture of ethanol from sweet potato hydrolyzate was 20% (w/v) with a processing time of 48-72 hours. SSF was performed using fresh sweet potato and flour for different ratios of dry matter to water (w/v). The ratios are 1:2 (according to fresh sweet potato without adding water), 1:5 and 1:8 for fresh sweet potato, and 1:2, 1:3, 1:5 and 1:8 for sweet potato flour. Characterization of ethanol is done by determining some of the physical properties of the selected ethanol and the values obtained are compared with standard data on the physical properties of ethanol.

These properties include Density, Viscosity, and Boiling Point, are as follows: 0.825 g/cm³, 0.00143 Pa.s, and 78.40℃. Showed that ethanol can be produced from starch-containing staple foods through fermentation (Anaele et al., 2020). concluded that the concentration of the amyloglucosidase enzyme 1.2 ml/kg of substrate (3000 U/ml) with a concentration of Sacharomyces ceriviceae 10% (v/v) was the best treatment with a concentration of bioethanol produced 7.48% (v/v), yield 19.89%, product formation efficiency by substrate 47.37%, fermentation efficiency 92.88%, and substrate consumption concentration 15.78 g/L (Zhang et al., 2011). Starch hydrolysis with an acid catalyst requires high temperatures, namely 120ºC-160ºC. The acid will break down the starch molecules randomly and the resulting sugars are mostly reducing sugars. The type of acid catalyst used is sulfuric acid (H_2SO_4), and Saccharomyces cereviseae to convert glucose into ethanol. One way to produce ethanol is by fermenting glucose with the microorganism *Saccharomyces cerevisiae.*

Saccharomyces cerevisiae is a yeast that is tolerant to fairly high alcohol (12-18% v/v), resistant to high sugar levels and remains active in fermenting at 4-32ºC. As stated by Ayoola et al., (2017) that the dry matter content which was higher than fresh sweet potato did not increase the final ethanol concentration. The availability of ethanol tolerant yeast can improve performance, can be obtained up to 4800 L of ethanol per hectare. Three bioethanol production models were selected to evaluate the life-cycle energy efficiency and environmental impact of sweet potato-based bioethanol (Isah et al., 2019). Bioethanol is produced primarily by the process of fermenting sugars, although it can be prepared by the chemical reaction of ethylene with steam in the following reaction scheme:

$$_2C_2H_4(g) + H_2O\ (l) \rightarrow C_2H_5OH\ (g)$$

The fermentation process on the other hand involves the enzymatic breakdown of simple sugars like glucose by enzymes known as zymases. The scheme of the reaction is as follows:

$$C_6H_{12}O_6\ (s) \rightarrow 2C_2H_5OH\ (aq) + 2CO_2\ (g)$$

Starchy substrates are often used for the production of bioethanol, used as a substitute for fossil fuels can be produced either by microbial fermentation of sugars or from petrochemical sources, however the production of bioethanol by microbial fermentation of sugars is the most widely used because of its simplicity.

IV. CONCLUSION

The test results concluded that the interaction between clone variation and yeast concentration had an effect on the highest alcohol content analysis results from the Sari clone $_{(150\ DAP)}$ with a yeast concentration of 15% with a concentration of 6.59%. Clone variation and yeast concentration interacted with the results of analysis of total sugar content after the fermentation process. The total sugar measured was the total sugar content remaining after the fermentation process, indicating a significant decrease in total sugar content. Yeast concentration had no effect on changes in pH during the fermentation process, the pH at the end of the fermentation process was in the range 4.1-6.3 (clone Beta-2 $_{(150\ DAP)}$ and clone BIS OP-61-OP-22 $_{(150\ DAP)}$.

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Study on Marketing of Jowar (Sorghum) in Bareilly District of Uttar Pradesh

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Abstract— *This research paper examines the marketing channels for Jowar (Sorghum) in Bareilly District, Uttar Pradesh, focusing on the cost, margin, efficiency, and price spread associated with each channel. The study identifies three primary marketing pathways: direct producer-to-consumer sales (Channel I), sales through village merchants or retailers (Channel II), and sales involving commission agents and wholesalers (Channel III). The research utilizes a systematic multi-stage stratified random sampling technique, collecting primary data through personal interviews and secondary data from relevant sources. The results reveal that Channel I, the direct marketing route, is the most efficient with the lowest marketing costs and a high efficiency of 48.81. Channels II and III, incorporating intermediaries, exhibit significantly lower efficiencies (5.87 and 5.15 respectively) and higher price spreads, indicating greater economic burdens for producers and consumers. These findings highlight the detrimental impact of intermediaries on market dynamics. The study advocates for reducing intermediary involvement to enhance marketing efficiency, improve producer profitability, and ensure fair pricing for consumers. This strategy promises to empower local farmers and promote sustainable agricultural practices.*

Keywords*— *Marketing channels, Jowar (Sorghum), Efficiency, Price spread, Producer profitability

I. INTRODUCTION

The marketing of agricultural products is crucial for the economic empowerment of farmers and the overall development of rural areas. In India, Jowar (Sorghum) is a significant crop, particularly in regions like Uttar Pradesh, where it contributes to both food security and income generation. This research focuses on the marketing channels for Jowar in Bareilly District, a key hub for Jowar production and marketing. Effective marketing strategies can significantly impact the profitability and sustainability of agricultural practices, as highlighted by ***Pingali and Traxler (2002) and Acharya and Agarwal (2011).***

The study aims to analyze the cost, margin, efficiency, and price spread across different marketing channels, employing a multi-stage stratified random sampling technique to ensure comprehensive data collection. Previous studies have emphasized the importance of efficient marketing systems for improving farmer incomes and reducing post-harvest losses ***(Joshi et al., 2004; Singh and Joshi, 2009).*** In this context, the role of intermediaries in agricultural marketing has been a critical area of investigation, with findings indicating that excessive intermediary involvement often leads to inflated consumer prices and reduced producer profits ***(Gandhi et al., 2001; Murthy et al., 2007).***

The research builds on these insights by providing a detailed examination of the marketing channels in Bareilly District. By understanding the dynamics and efficiency of each channel, this study aims to identify strategies that can enhance market access, reduce costs, and increase profitability for Jowar producers. The findings have significant implications for policy-making and the design of agricultural marketing interventions, contributing to the broader goal of sustainable agricultural development in India ***(Chand and Kumar, 2004; Birthal et al., 2005).***

II. METHODOLOGY

The research methodology employed for this study involves a systematic multi-stage stratified random sampling technique to thoroughly investigate the marketing mechanisms of Jowar in Bareilly District, Uttar Pradesh. The first stage involved the purposeful selection of Bareilly district due to its significant role as a key hub for Jowar production and marketing. Bareilly's extensive engagement in Jowar cultivation aligns perfectly with the study's objectives to explore the economic advantages and empowerment derived from Jowar-related activities. In the second stage, Shergarh block, which comprises 121 villages, was specifically chosen for its highest concentration of Jowar cultivation and marketing groups. For the third stage, a list of villages in the selected block was obtained, and 5% were randomly selected, resulting in six villages: Bhaunta, Jagat, Nagla, Rohali, Bisalpur, and Lakha. In the fourth stage, 10% of respondents from each village were randomly selected based on their land holdings, totalling 100 respondents.

To gain an in-depth perspective on the Jowar market's structure, market functionaries including retailers like Sakar Daily Need Mart and Raashan Express, and wholesalers such as Rama Pansari and Deva Foods, were selected. Data collection comprised both primary and secondary methods. Primary data was gathered through personal interviews with respondents using a well-structured, pre-tested schedule, while secondary data supplemented the study and was sourced from block and district offices, relevant organizations, and the internet. This comprehensive methodological approach ensures detailed investigation into the economic impacts and empowerment associated with Jowar marketing, cultivation techniques, market accessibility, and profitability among local farmers.

III. RESULT

Channels of Marketing for Sorgum

Table 1 Different marketing channels involved in the marketing of Jowar

Channel I	**Producer > Consumers**
Channel II	**Producer > Village Merchant/Retailer > Consumers**
Channel III	**Producer > Commission Agent > Wholesaler > Consumers**

Marketing cost, marketing margin, marketing efficiency and price spread in the marketing of Jowar

Table 2 Price Distribution of Jowar in Channel I

S.No.	Particulars	Value in INR/quintal
1.	Producer Sale Price	2,500
	Cost Incurred by Producer:	
i.	Packaging Cost	5
ii.	Packing material cost	7.5
iii.	Transportation Cost	20
iv.	Market cost	8
v.	Labour cost	5
vi.	Loading and unloading charges	10
vii.	Weighing charges	5
viii.	Miscellaneous charges	3
ix	Producer additional profit	436.5
	Total Marketing Cost (i-vi)	63.5
2.	Sale Price to Consumers	3000
A.	**Total Marketing Cost**	500
B.	**Total Market Margin**	-
C.	**Marketing Efficiency**	48.81
D.	**Price Spread**	500

Table 3 Price Distribution of Jowar in Channel II

S.No.	Particulars	Value in INR/quintal
1.	Producer Sale Price	2,500
2	**Cost Incurred by Producer:**	
i.	Packaging Cost	5
ii.	Packing material cost	7.5
iii.	Transportation Cost	20
iv.	Market cost	8
v.	Labour cost	5
vi.	Loading and unloading charges	10
vii.	Weighing charges	5
viii.	Miscellaneous charges	3
	Total Cost	**63.5**
3	Net price received by producer	2466.5
4	Sale price of producer to Merchant/Retailer	3100

5	**Cost incurred by the Village Merchant/Retailer**	
	Loading and unloading charges	10
	Packing cost	5
	Market fee	8
	Losses & Miscellaneous charges	5
	Total Cost	60
	Margin of Retailer	500
2.	Sale Price to Consumers	3660
A.	**Total Marketing Cost**	123.5
B.	**Total Market Margin**	500
C.	**Marketing Efficiency**	5.87
D.	**Price Spread**	1160

Table 4 Price Distribution of Jowar in Channel III

S.No.	Particulars	Value in INR/quintal
1.	Producer Sale Price	2,500
2	**Cost Incurred by Producer:**	
i.	Packaging Cost	5
ii.	Packing material cost	7.5
iii.	Transportation Cost	20
iv.	Market cost	8
v.	Labour cost	5
vi.	Loading and unloading charges	10
vii.	Weighing charges	5
viii.	Miscellaneous charges	3
	Total Cost	**63.5**
3	Net price received by the producer	2466.5
4	Sale price of producer to Commission Agent	3100
5	**Cost incurred by the commission agent**	
	Loading and unloading charges	10
	Packing cost	5
	Market fee	8
	Commission of trader	-
	Losses & Miscellaneous charges	5
	Total cost(i-v)	58
6	Margin of commission agent	280
7	Sale price of commission agent to wholesaler	3438
8	**Cost incurred by wholesaler**	
	Weighing charges	5
	Loading and unloading charges	10
	Town charges	25
	Carriage up to shop	15
	Miscellaneous charges	5
	Total cost	60
9	Wholesalers Margin	270
10.	Sale Price to Consumers	3,768
A.	**Total Marketing Cost**	181.5
B.	**Total Market Margin**	550
C.	**Marketing Efficiency**	5.15
D.	**Price Spread**	1268

IV. DISCUSSION

The research on marketing channels for Jowar reveals three primary pathways: Channel I (Producer > Consumers), Channel II (Producer > Village Merchant/Retailer > Consumers), and Channel III (Producer > Commission Agent > Wholesaler > Consumers). Each channel exhibits distinct characteristics in terms of marketing cost, margin, efficiency, and price spread.

In Channel I, the direct sale from producer to consumer involves minimal intermediary costs, resulting in a producer sale price of INR 2,500 and a consumer sale price of INR 3,000. The total marketing cost incurred by the producer is INR 63.5, yielding a marketing efficiency of 48.81 and a price spread of INR 500.

Channel II introduces a village merchant/retailer into the chain. The producer still receives INR 2,500, but after deducting their marketing costs (INR 63.5), the net price is INR 2,466.5. The retailer then incurs additional costs (INR 60) and adds a margin of INR 500, selling the Jowar to consumers at INR 3,660. This channel results in a significantly lower marketing efficiency of 5.87 and a wider price spread of INR 1,160.

Channel III, which involves a commission agent and a wholesaler, shows even more complexity. The producer's initial sale price remains INR 2,500, with a net price of INR 2,466.5 after costs. The commission agent incurs costs (INR 58) and earns a margin of INR 280, selling to the wholesaler at INR 3,438. The wholesaler adds further costs (INR 60) and a margin of INR 270, leading to a final consumer price of INR 3,768. This channel has the lowest marketing efficiency at 5.15 and the highest price spread of INR 1,268.

These findings indicate that the direct marketing channel (Channel I) is the most efficient, with the lowest costs and highest efficiency, benefiting both producers and consumers. Conversely, the involvement of multiple intermediaries in Channels II and III significantly increases the price spread and reduces marketing efficiency, highlighting the impact of intermediary costs and margins on the overall market dynamics of Jowar.

V. CONCLUSION

The research on Jowar marketing channels in Bareilly District highlights significant disparities in marketing efficiency, cost, and price spread across different channels. Channel I, involving direct sales from producers to consumers, emerges as the most efficient with minimal costs and a high marketing efficiency of 48.81. Conversely, Channels II and III, which include intermediaries such as village merchants, retailers, commission agents, and wholesalers, demonstrate substantially lower efficiencies (5.87 and 5.15 respectively) and broader price spreads. These findings underscore the economic burden imposed by intermediary involvement, which inflates consumer prices and reduces producer profits. The study advocates for strategies that minimize intermediaries to enhance marketing efficiency, ensuring better returns for producers and fair prices for consumers. This approach could significantly empower local farmers, improve market accessibility, and foster sustainable agricultural practices in the region.

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Farmer's Producer Organization (FPOS): Doubling the Farmers Income

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***Abstract*— *Even though it still accounts for roughly 55% of all employment, the agriculture sector currently contributes only 14% of the GDP (GoI, 2014). According to the Agricultural Census of 2020, there were more than 138 million farm holdings in India. Of these, approximately 24.8 million were small farm holdings with individual operational land holding dimensions of less than 2 hectares, and approximately 92.8 million were marginal farm holdings, defined as having a man or woman operational landholding of less than 1 hectare. Though they will encounter many difficulties, small and marginal farmers in India will undoubtedly remain for a very long time. As a result, what happens to them has a significant impact on the entire financial system as well as the agricultural zone in particular. Consequently, their actions have a significant impact on the agricultural region in particular and the financial system as a whole, both of which affect people's ability to make a living. The current challenge is to bring these smallholders together and alter their economic outlook. The aforementioned circumstances necessitate radical measures and crucial structural changes aimed at reviving Indian agriculture. The most beneficial way for Farmer Producer Organisation (FPO) to fulfil the wishes of farmers at the local level is through the Farmer Producer Company (FPC) instrument, which is registered under the Companies Act. Encouraging small farmers in particular to join member-owned producer organisations, tripling their income, and boosting the nation's agricultural sector's output, productivity, and profitability are all crucial objectives.*

Keywords*— *Farmers Producer Organization, Small and Marginal Farmers

INTRODUCTION

Agriculture in India is predominantly production-oriented restrained in giant quantity of fragmented smallholdings and plays a pivotal function in the Indian economy. It provides employment to around 56 percent of the Indian workforce, contributes to

the overall boom of the financial system and reduces poverty via offering employment and food security to the majority of the population. However, due to rather fragmented, scattered and heterogeneous landholding, the rising value of cultivation and restrained get admission to of small/marginal farmers (SF/MF) to public sources and markets, the small maintaining based agriculture has gradually become unviable. The lack of production quantities, resources, fantastic inputs, credit facility, contemporary technologies, etc., and normal crop failures, lack of certain market, earnings safety, and the poorly developed supply chain has resulted in high dependency of farmers on the exploitative Small and marginal farmers constitute around 85% of the whole land protecting and keep around 44% of the land below cultivation (Ereneus K Marbaniang 2019).

The above situation calls for essential structural reforms and transformational initiatives towards the revitalization of Indian agriculture both, by using way of stepping up investments for productiveness enhancement as also reforms in agricultural advertising and marketing and post-harvest agri logistics for boosting agricultural growth. In this context, a the sustainable answer lies in the collectivization of agricultural produce and price addition marketing by using achieving the economy of scale and creating commodity-specific agri value chains with the participation of agri entrepreneurs and predominant producers on the equitable terms. With all given circumstances, governments are banking upon FPOs to acquire their target of "Doubling Farmers' Income". Government, NBFCs, civil societies, and different monetary establishments have invested in FPOs, looking at its future position in rural development.

FPOs have possible to act as a catalyst of change in the economic system of our country. FPOs can function as expected, only when their management systems, governance and capital shape are strong. Other external elements like infrastructure development, market, and economic accessibility, deposit affordability, environment-friendly commodity pricing mechanism, etc. need to be managed through authorities at an equitable pace. Here are a few steps which can make a distinction in the medium to long term (Agyeya Tripathi 2020)

Objectives

1. To highlight the role of FPOs in doubling the farmer's incomes.

2. To describe the aim, services, and steps to establishing an FPO.

Methodology

The present paper is based on secondary data which is collected from books, journals, newspapers, websites, the internet, etc. to study the role of FPOs.

Meaning of FPO

FPO stands for Farmer Producer Organizations. FPO is an organization, where the members are farmers itself. Farmers Producers Organization provides end-to-end assistance and offerings to the small farmers, and covers technical services, marketing, processing, and others aspects of cultivation inputs (Kanika 2021).

Main aim of FPO

The important goal of the Farmer Producer Organization is to make sure higher profits for the producers through an organization of their own. Small producers do now not have the extent in my view to get the gain of economies of scale. In agricultural marketing, there is a chain of intermediaries, who regularly work non-transparently main to the situation, where the producer receives only a small section of the value, which the final consumer pays. This will be eliminated. Through accumulation, the essential producers can avail the gain of the economies of scale. Farmers Producers have better bargaining electricity in the structure of bulk consumers of produce and bulk suppliers of inputs (Department of Agriculture and Cooperation 2013).

Services of FPO

(i) Supply satisfactory manufacturing inputs like seed, fertilizer, pesticides, and such other inputs at reasonably decrease wholesale rates.

(ii) Make available need-based totally manufacturing and post-production machinery and gear like cultivator, tiller, sprinkler set, combine harvester and such different machinery and gear on custom hiring groundwork for members to limit the per-unit manufacturing cost.

(iii) Make reachable value addition like cleaning, assaying, sorting, grading, packing, and additionally farm level processing amenities at consumer cost basis on a fairly less expensive rate. Storage and transportation amenities may also be made available.

(iv) Undertake higher income-generating things to do like seed production, beekeeping, mushroom cultivation, etc.

(v) Undertake aggregation of smaller loads of farmer-members produce; add cost to make them greater marketable.

(vi) Facilitate market statistics about the produce for really apt decisions in manufacturing and marketing.

(vii) Facilitate logistics services such as storage, transportation, loading/unloading, etc. on a shared price basis.

(viii) Market the aggregated produce with higher negotiation energy to the buyers and in the advertising channels supplying better and remunerative prices. (Operational Guidelines, GOI 2020)

Steps to establishing an FPO

Cluster identification

Cluster areas are to be selected by way of the RI in session with the respective State Government departments. However, it must be ensured that a cluster of 8,000-10,000 farmers should be formulated, inside one or two blocks, identifying eighty to a hundred and twenty contiguous villages of a particular district.

Diagnostic study

A Diagnostic Study is to be carried out by the RI in the chosen cluster area. The Diagnostic Study is conducted to verify the preliminary situation of the farmers and degree of agriculture in the area. The find out about will also assist in figuring out the viable interventions required and apprehend the unique undertaking implementation context.

Feasibility analysis

Feasibility Analysis for the formation of FPCs be carried out by using RIs and then appraised by hired external specialists in a variety of technical areas. A normal feasibility study should cover factors such as financial, technical, legal, political, socio-cultural, environmental, financial and useful resource feasibility.

Baseline assessment

Baseline Assessment, to be carried out by RI, will assist in producing information associated to the modern prevailing state of affairs of farming and small, marginal and tenant farmers. Baseline assessment will cowl a range of elements to perceive the manageable interventions, to sketch development and business plans and to establish the base figures based totally on future consequence symptoms that can be measured to recognize the exchange contribution.

Business planning

Business Planning will be carried out through RIs with the assist of chosen farmers' representatives. Business planning is a system through which the strategic and operational orientation of an emerging FPO is shaped. While baseline evaluation figures will be necessary inputs to apprehend the stage from which merchandise and services for farmers' members should be developed, greater important will be the collective visualisation of the future of the FPO. Using a variety of tools and systematic collective reflections, a commercial enterprise layout with perfect projections on more than a few elements wishes to be developed.

Mobilisation of farmers

Once a strong case has been set up with the aid of SHT with the help of a pick out group of farmers thru the commercial enterprise planning process, it is time to mobilise farmers into FIGs and ultimately as farmer-members of FPOs. Mobilisation of farmers be completed with a range of conversation aids like – pamphlets, documentary movies, posters, regular village-level meetings, desirable vision improvement of promoter farmer-members. Promoter farmer-members are these who are eager to shape a FPO on voluntary basis, having understood the importance and attainable benefits of forming FPOs, got thru training programmes and publicity furnished by SHT of RIs.

Organising and formalising

FIGs in an aggregated cluster together structure FPOs. Typically, around 50-70 FIGs can come collectively to shape a FPO. FPOs can be registered under the Producer Company provision beneath the Companies Act.

Resource mobilisation

Before initiating the operations of a FPO all required assets be mobilised by the RI with the help of FPO representatives and board of directors. Financial, human (staff), technical and bodily resources have to be developed for the duration of this specific step. Based on the business format the RI should liaise with a range of financing businesses and mobilise assets for hiring/purchasing and growing a number resources.

Management structures improvement

RIs must facilitate the development of management structures in the FPO. Guidelines for administration systems have to be capable to tackle all necessities associated to monetary services, input and output management services. Systems related to management of finance, human resources, stock and inventory, procurement and pleasant management, marketing, internal audit, inner struggle resolution and other necessary practical areas be developed. Standard running tactics for the same must be established.

Business operations

Business operations is the commencement of procurement, production, processing, marketing and financial carrier activities of a FPO. RIs ought to carefully train each the governing and operational structures of the FPO in order to ensure clean functioning of enterprise operations. The whole value-chain related to a range of agriculture and allied merchandise and commodities wants to be managed.

Assessment and audit

RIs should facilitate the steady evaluation of the overall performance of a range of stakeholders like farmer members, governing board of directors, and service providers. They also assist FPOs to replicate using Institutional Maturity Index to understand areas of improvement.

CONCLUSION

It can be assessed by the above discussion that the very existence of FPOs for to doubling the farmers income with help of the government policies and procedures. Recognizing the problems of small and marginal farmers in India, the government is actively promoting Farmers Producer Organisation (FPO). The aggregation of small, marginal, and landless farmers in FPOs has helped enhance the farmers' economic strength and market linkages for improving their income.

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Study on Rainfall Effects on Corn (*Zea mays* L.) Productivity in Ngawi Regency

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Abstract— *The demand for corn in Indonesia is currently quite high, in line with the growing population and the increasing need for corn to meet the feed industry. Corn productivity has increased due to the expansion of land area and has not yet reached its yield potential due to climate change. Climate is a determining factor for the success of crop cultivation, thus it is necessary to study the relationship between climate elements and their effects on corn productivity in Ngawi Regency. The study was conducted from September to November 2022 using the survey method. The location was determined using purposive sampling technique directly determined by the researchers based on the corn production centers in Ngawi Regency. The chosen research locations were Pitu, Bringin, and Kendal Subdistricts. The climate classification in Pitu Subdistrict, Bringin Subdistrict, and Kendal Subdistrict has climate types D, C, and C, respectively. Correlation test results show that in Pitu Subdistrict, there is no significant correlation between rainfall intensity, rainy days, wet months, and dry months with corn productivity. Rainy days show a significant positive correlation with corn productivity in Bringin Subdistrict, while in Kendal Subdistrict, rainfall intensity and rainy days show a significant negative correlation with corn productivity.*

***Keywords*— rainy days, rainfall intensity, corn, climate change.**

I. INTRODUCTION

Corn is a strategic and economically valuable commodity as a primary source of carbohydrates and protein after rice. Corn also serves as raw material for the feed and household industries. Corn is a strategic crop to be cultivated in various regions. As a primary food source, corn has become a major commodity after rice (Ginting, Kuswardani, and Azwana 2012). The demand for corn in Indonesia is currently quite high, in line with the growing population and the increasing need for corn to meet the feed industry. National corn production in Indonesia has been continuously increasing every year.

This increase is due to the expansion of land area, thus corn productivity increases with the expansion of land area. However, the increase in corn productivity has not yet reached its optimal productivity potential of 10 – 11 tons ha^{-1}, while corn productivity in Indonesia is only 5 – 6 tons ha^{-1} (Nurdin et al. 2021). Factors affecting crop productivity can be broadly categorized into internal and external factors. External factors can be caused by rainfall, temperature, sunlight intensity, and air humidity. These climate factors often change due to global warming (Naura and Riana 2018).

Lack of information about climate change can cause corn production to decline or even result in crop failure. Climate change can affect corn productivity. One of the impacts of climate change is the change in rainfall intensity. Rainfall plays a role in water supply, especially in rainfed and dry lands. Excessive rainfall can increase the amount of surface water, which can affect plant growth (Herlina and Prasetyorini 2020). Therefore, research is needed on the relationship between climate elements and their impact on corn productivity, especially in Ngawi Regency, which has not been widely studied.

II. MATERIALS AND METHODS

The study was conducted from September to November 2022 in several corn production centers in Ngawi Regency. The study used a survey method by collecting field observation data and secondary data on corn production in Ngawi Regency and climate elements data consisting of rainfall intensity, rainy days, wet months, and dry months. The research location was determined by purposive sampling based on the corn production centers in Ngawi Regency. The chosen research locations were Pitu Subdistrict, Kendal Subdistrict, and Bringin Subdistrict. The data used included land area data, production data, rainfall intensity, rainy days, wet months, and dry months in the research area over the past 10 years, from 2011 to 2020. The data obtained were then analyzed for correlation to determine the relationship between the climate elements studied and corn productivity. The correlation analysis results will yield a correlation coefficient (r) value between -1 or 1. Interpretation of the correlation coefficient value is as follows:

0.00 – 0.199 = very low

0.20 – 0.399 = low

0.40 – 0.599 = moderate

0.60 – 0.799 = strong

0.80 – 1.000 = very strong

Multiple regression analysis was also performed to determine the effect of rainfall intensity, rainy days, wet months, and dry months on corn productivity in the three subdistricts of Ngawi Regency. The multiple linear regression equation generally used is based on Mulyani et al. (2019), which is:

Y=A+B1X1+B2X2+B3X3+B4X4

Explanation:

Y = dependent variable (corn production)

X1 = variable rainfall intensity

X2 = variable rainy days

X3 = variable wet months

X4 = variable dry months

A = constant

B1 = coefficient of rainfall intensity variable

B2 = coefficient of rainy days variable

B3 = coefficient of wet months variable

B4 = coefficient of dry months variable

III. RESULTS AND DISCUSSION

Corn Productivity

Corn productivity in Pitu Subdistrict was highest in 2016 at 7901 kw ha-1, while the lowest productivity occurred in 2011 at 5684 kw ha^{-1} (Table 1). Corn productivity in Bringin Subdistrict was highest in 2015 at 7990 kw ha^{-1}, while the lowest productivity occurred in 2011 at 4947 kw ha^{-1} (Table 2). Corn productivity in Kendal Subdistrict was highest in 2015 at 8936 kw ha^{-1}, while the lowest productivity occurred in 2011 at 5667 kw ha^{-1} (Table 3).

Rainfall Intensity

The highest rainfall intensity in Pitu Subdistrict occurred in 2013, amounting to 2560 mm year-1, while the lowest rainfall intensity occurred in 2019, amounting to 1107 mm year-1 (Table 1). The highest rainfall intensity in Bringin Subdistrict occurred in 2016, amounting to 2665 mm year-1, while the lowest rainfall intensity occurred in 2018, amounting to 1476 mm year-1 (Table 2). The highest rainfall intensity in Kendal Subdistrict occurred in 2011, amounting to 5288 mm year^{-1}, while the lowest rainfall intensity occurred in 2014, amounting to 1807 mm year^{-1} (Table 3).

Rainy Days

The highest number of rainy days in Pitu Subdistrict occurred in 2016, amounting to 159 days year^{-1}, while the lowest number of rainy days occurred in 2011, amounting to 81 days year^{-1} (Table 1). The highest number of rainy days in Bringin Subdistrict occurred in 2017, amounting to 140 days year^{-1}, while the lowest number of rainy days occurred in 2013, amounting to 84 days year^{-1} (Table 2). The highest number of rainy days in Kendal Subdistrict occurred in 2011, amounting to 207 days year^{-1}, while the lowest number of rainy days occurred in 2013, amounting to 110 days year^{-1} (Table 3).

Wet Months

The highest number of wet months in Pitu Subdistrict occurred in 2013, amounting to 9 months, while the lowest number of wet months occurred in 2018, amounting to 3 months (Table 1). The highest number of wet months in Bringin Subdistrict occurred in 2016, amounting to 10 months, while the lowest number of wet months occurred in 2018, amounting to 5 months (Table 2). The highest number of wet months in Kendal Subdistrict occurred in 2011 and 2016, amounting to 12 months, while the lowest number of wet months occurred in 2019, amounting to 5 months (Table 3).

Dry Months

The highest number of dry months in Pitu Subdistrict occurred in 2014, 2015, and 2019, amounting to 6 months, while the lowest number of dry months occurred in 2013 and 2017, amounting to 2 months (Table 1). The highest number of dry months in Bringin Subdistrict occurred in 2018, amounting to 7 months, while the lowest number of dry months occurred in 2016, amounting to 2 months (Table 2). The highest number of dry months in Kendal Subdistrict occurred in 2018 and 2019, amounting to 6 months, while the lowest number of dry months occurred in 2011 and 2016, with no dry months recorded (Table 3).

Table 1. Data on corn productivity and climate elements in Pitu Subdistrict, Ngawi Regency, 2011 – 2020

Year	Productivity (kw ha^{-1})	Rainfall Intensity (mm)	Rainy Days (days)	Wet Months (months)	Dry Months (months)
2011	56.84	1781	81	6	3
2012	62.58	1702	99	7	4
2013	58.48	2560	129	9	2
2014	61.62	1349	96	6	6
2015	75.33	1550	95	5	6
2016	79.01	1458	159	7	3
2017	77.69	1814	124	8	2
2018	73.26	1304	101	3	7
2019	72.38	1107	100	4	6
2020	70.02	1759	122	7	3

Source: BPS Ngawi (2020) and BMKG Jatim (2020)

Table 2. Data on corn productivity and climate elements in Bringin Subdistrict, Ngawi Regency, 2011 – 2020

Year	Productivity (kw ha^{-1})	Rainfall Intensity (mm)	Rainy Days (days)	Wet Months (months)	Dry Months (months)
2011	49.47	1603	87	7	5
2012	66.11	1763	96	7	5
2013	56.68	2388	84	8	4
2014	77.03	2319	101	7	4
2015	79.90	2087	133	8	3
2016	79.27	2665	115	10	2
2017	74.92	2097	140	8	3
2018	72.72	1476	103	5	7
2019	77.81	1860	120	6	5
2020	71.88	2507	138	8	3

Source: BPS Ngawi (2020) and BMKG East Java (2020)

Table 3. Data on corn productivity and climate elements in Kendal Subdistrict, Ngawi Regency, 2011 – 2020

Year	Productivity (kw ha^{-1})	Rainfall Intensity (mm)	Rainy Days (days)	Wet Months (months)	Dry Months (months)
2011	56,67	5288	207	12	0
2012	64,79	2223	175	6	5
2013	58,31	3469	172	9	3
2014	87,34	1807	121	9	3
2015	89,36	2694	137	7	4
2016	78,79	3645	189	12	0
2017	76,35	2622	143	7	4
2018	72,14	2063	121	6	6
2019	72,47	1857	110	5	6
2020	70,79	2661	144	8	4

Source: BPS Ngawi (2020) and BMKG East Java (2020)

Table 4. Correlation coefficients (r) of rainfall intensity, rainy days, wet months, and dry months with corn productivity in three subdistricts of Ngawi Regency

Corn Productivity in Subdistricts	Rainfall Intensity	Rainy Days	Wet Months	Dry Months
Pitu	-0.464	0.470	-0.262	0.166
Bringin	0.319	0.702*	0.126	-0.332
Kendal	-0.535	-0.574	-0.177	0.144

Note: * = significant correlation

Table 5. R^2 values of the effect of rainfall intensity, rainy days, wet months, and dry months on corn productivity in three subdistricts of Ngawi Regency

Subdistrict	R^2 Value
Pitu	0.62
Bringin	0.57
Kendal	0.80

Correlation of Corn Productivity and Climate Elements

Rainfall intensity and rainy days in Pitu Subdistrict have a moderate relationship with corn productivity, with values of r = -0.464 and r = 0.470. Wet months and dry months have a low relationship with values of r = -0.262 and r = 0.166. Rainfall intensity and dry months in Bringin Subdistrict have a low relationship with corn productivity, with values of r = 0.319 and r = -0.332, while wet months have a very low relationship with a value of r = 0.126. Rainy days, however, have a strong relationship with a value of r = 0.702. Rainfall intensity and rainy days in Kendal Subdistrict have a strong relationship with corn productivity, with values of r = -0.535 and r = -0.574. Wet months and dry months have a low relationship with values of r = -0.177 and r = 0.144 (Table 4).

A negative correlation means that the climate element decreases corn productivity, while a positive correlation means that the climate element increases corn productivity. Rainfall intensity decreases corn productivity in Pitu and Kendal Subdistricts but increases corn productivity in Bringin Subdistrict. This is possibly due to excessive water availability causing waterlogging, which affects nutrient leaching, while increased production indicates sufficient water availability and good soil conditions. This aligns with Suciantini (2015), who stated that increased rainfall intensity in a region can potentially cause floods that trigger erosion and nutrient leaching. Conversely, a decrease in rainfall intensity can potentially cause drought, affecting plant growth (Wokanubun, Ririhena, and Wattimena 2020). Besides drought, another impact of climate change is prolonged rainfall, which can disrupt corn plant growth. Corn is not tolerant of waterlogging as it interferes with plant aeration and respiration (Hermawan et al. 2014).

Corn does not require much water and can be planted in various seasons. Water availability in the field must be adjusted to the plant's needs to avoid excess or deficiency. This aligns with Rusastra et al. (2004), who stated that corn is a plant that absorbs water in small amounts and can be planted during the dry season. Corn has a high ability to absorb water in the soil, balancing the amount of evaporated water (Chagwiza et al. 2020). Moreover, corn requires rainfall ranging from 85 to 200 mm per month (Asriani and Ma'Mun 2019). If the rainfall in a region meets the corn plant's needs, corn planting can be done 2 to 3 times a year (Hikami, Arifianto, and Giarno 2023).

Regression Analysis of Corn Productivity with Climate Elements

The R2 value indicates the influence of rainfall intensity, rainy days, wet months, and dry months on corn productivity in the research area (Table 5). The R2 value in Pitu Subdistrict is 0.62, indicating that 62% of corn productivity is influenced by climate elements. In Bringin Subdistrict, the R2 value is 0.57, indicating that 57% of corn productivity is influenced by climate elements. In Kendal Subdistrict, the R2 value is 0.80, indicating that 80% of corn productivity is influenced by climate elements.

The regression analysis results for rainfall on corn productivity in Pitu Subdistrict yield the equation: $Y=7035-0.008\ \text{Rainfall Intensity} + 0.026\text{Rainy Days} - 2.24\text{Wet Months} - 0.83\text{Dry Months}$, This equation shows that an increase in rainfall intensity by 1 mm per year will decrease corn productivity by 0.008 quintals, an increase in rainy days by 1 day will increase corn productivity by 0.026 quintals, an increase in wet months by 1 month will decrease corn productivity by 2.24 quintals, and an increase in dry months by 1 month will decrease corn productivity by 0.83 quintals.The regression analysis results for rainfall intensity and rainy days on corn productivity in Bringin Subdistrict yield the equation: $Y=-0.34 + 0.001\text{Rainfall Intensity} + 0.038\text{Rainy Days} - 1.51\text{Wet Months} + 2.49\text{Dry Month}$, This equation shows that an increase in rainfall intensity by 1 mm per year will increase corn productivity by 0.001 quintals, an increase in rainy days by 1 day per year will increase corn productivity by 0.038 quintals, an increase in wet months by 1 month will decrease corn productivity by 1.51 quintals, and an increase in dry months by 1 month will increase corn productivity by 2.49 quintals in Bringin Subdistrict.

The regression analysis results for rainfall intensity on corn productivity in Kendal Subdistrict yield the equation: $Y = 25764 - 0.008\text{Rainfall Intensity} - 0.29\text{Rainy Days} - 8.09\text{Wet Months} - 15.06\text{Dry Months}$, This equation shows that an increase in rainfall intensity by 1 mm per year will decrease corn productivity by 0.008 quintals, an increase in rainy days by 1 day per year will decrease corn productivity by 0.29 quintals, an increase in wet months by 1 month will decrease corn productivity by 8.09 quintals, and an increase in dry months by 1 month will decrease corn productivity by 15.06 quintals in Kendal Subdistrict.

An increase in rainfall intensity in Pitu and Kendal Subdistricts can decrease corn productivity, while an increase in rainfall intensity in Bringin Subdistrict can increase corn productivity. This is likely influenced by soil conditions, elevation, variety used, cultivation techniques, and planting time differences among farmers, indicating other factors affecting corn productivity. This aligns with Nurdin et al. (2021), who stated that water deficit or excess in corn can reduce yield, especially during the grain-filling phase. Planting time needs to be considered, especially during the rainy or dry season, to meet the corn plant's needs. Increased rainfall intensity increases the amount of water received by the soil surface, potentially causing waterlogged soil, affecting soil aeration. This aligns with Santoso and Layli (2011), who stated that high rainfall can cause floods, making the soil waterlogged, leading to root rot. This can cause an earlier harvest time to avoid crop failure.

IV. CONCLUSIONS

Climate elements affect corn productivity in the three subdistricts of Ngawi Regency. Increased rainfall intensity can decrease corn productivity in Pitu and Kendal Subdistricts, while a decrease in rainy days can increase corn productivity in Bringin Subdistrict. The number of wet and dry months does not affect corn productivity in the three subdistricts of Ngawi Regency.

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Operations Management in Farmer Producer Organizations: A Case Study of Bagma Agri-Producer Company Ltd., Tripura

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***Abstract*— *This study elucidated the efficacy and challenges of Farmer Producer Organizations (FPOs) in India, focusing on the Bagma Agri-Producer's Company Ltd. (BAPC Ltd.) in Tripura. Through a rigorous analysis of primary data collected from 32 randomly selected members out of 250 registered participants, the research delineated the multifaceted operations and organizational dynamics of BAPC Ltd. The study employed Ordinal Logistic Regression to elucidate the correlation between socio-economic variables and member satisfaction, revealing a statistically significant positive relationship ($p \leq 0.10$) for most factors, excluding gender and non-farm income. A comprehensive SWOT analysis underscored BAPC Ltd.'s strategic advantages, including its multi-product approach and robust institutional linkages, while also highlighting areas for amelioration such as limited value-addition infrastructure. The organization's involvement in eight diverse projects, ranging from dairy to apiculture, exemplified its adaptability to the region's mixed farming landscape. However, the research also uncovered potential threats to long-term sustainability, including competition from nascent FPOs and persistent intermediary influence in supply chains. This nuanced examination of BAPC Ltd. provided invaluable insights into the potential of FPOs as catalysts for agricultural transformation, while simultaneously emphasizing the imperative for sustained support and strategic interventions to optimize their impact on smallholder agriculture in India.*

Keywords*— *Farmers Producer's Organization (FPO), Ordinal Linear Regression, Smallholder Agriculture, Rural Development, Agribusiness Management

I. INTRODUCTION

Northeast India, a predominantly agrarian region, is renowned for its diverse cultural heritage and rich biodiversity. Endowed with abundant natural resources, including fertile land, water bodies, dense forests, high rainfall (ranging from 1500 mm to 12000 mm), and a mega-diverse flora and fauna, the region possesses unique and unparalleled features (Deka et al., 2020; Debnath, 2022). However, despite these ample natural and human resources, the Northeast region of India lags behind many other states in terms of development.

Tripura, like other states in the Northeast, has an agriculture-based economy, with approximately 42% of its population dependent on agriculture and allied activities (DoE & S, 2018). Rice is the major crop cultivated in the state, and the climate is suitable for a variety of horticultural and plantation crops, including pineapple, jackfruit, tea, rubber, and bamboo. A section of the indigenous population practices the traditional slash-and-burn (*jhum*) method of cultivation. One of the main obstacles in the agriculture sector of the state is the shortage of cultivable land, as two-thirds of the total geographical area is hilly, and only about 27% of the land is cultivable, compared to the national average of 43%.

The better performance of the agriculture sector has a direct and multiplier effect across the economy. Interestingly, about 96% of agriculturists in Tripura are marginal and small farmers, with very few large landholders specializing in specific crops. A common pattern observed in the state is the same farmer dealing with multiple crops, vegetables, livestock, fish, and other agricultural activities. However, studies have shown that farmers face significant challenges in adopting modern practices. For instance, Debnath et al. (2017) found that lack of financial support, low-cost feed, and quality fish seed were the main barriers to the adoption of recommended fish farming technologies in fishery sector in South Tripura.

Tripura's industrial backwardness can be attributed to its geographical isolation and poor road and railway connectivity with the mainland of India. Low availability of infrastructure has made the process of economic development and decentralization extremely difficult in the state. The adoption of best practices and innovation in agriculture, animal husbandry, fisheries, horticulture, as well as small and micro-level entrepreneurial units, including information technology, can boost employment opportunities and improve productivity, thereby reducing rural poverty to a large extent in the state.

Producer companies can play a crucial role in helping smallholder farmers participate in emerging high-value markets, such as the export market and the unfolding modern retail sector in India. Theory and experience suggest that Producer Organizations (POs) offer a means by which the constraints faced by smallholder farmers can be reduced, thereby enhancing their participation in agricultural markets (Stockbridge et al., 2003). POs have played a significant role in agricultural and rural development, and in recent years, their strengthening has gained increasing donor attention owing to their importance in promoting the commercialization of smallholder agriculture in response to structural adjustment policies, economic liberalization, and globalization.

By setting the target of doubling farmers' income by 2022, the Indian government signaled a significant policy shift, shifting focus from food production to farmers' welfare. Toward this goal, several schemes are in place, with the promotion of farmer producer organizations (FPOs) being a prominent one, particularly important due to the small and fragmenting landholdings in the country (85 percent of farms are less than 2 hectares, and 67 percent are less than 1-hectare holdings (GOI 2015)). Small farm size is associated with limited marketable surplus and lower access to inputs like seeds, fertilizers, credit, information, and extension services. Small and marginal farmers also have poor access to public goods, such as public irrigation and government subsidies. Poor transportation and communication networks restrict farmers from accessing remunerative markets and result in opportunities for rent-seeking by local traders. The lack of adequate local markets and the costlier transport for small quantities force farmers to sell to local traders at low prices (Hegde 2010). Without large volumes, small farmers face low bargaining power in input procurement and output sale (Kirsten and Sartorius 2002). With the formation of FPOs, the role of middlemen is significantly reduced (Fafchamps and Hill 2005). Hence, farmer organizations can create opportunities for small and marginal farmers to participate more effectively in markets (Stockbridge et al., 2003).

The Indian government, with economic liberalization, not only aims to initiate new organizational forms in agricultural production and marketing to integrate large firms but also encourages groups of small-scale primary producers to connect with corporate buyers. With the amendment of the Companies Act 1956 in 2002, the Indian government introduced the concept of 'producer companies,' which constitute an attempt to establish basic business principles within farming communities, bring industry and agriculture closer together, and boost rural development (Kumar, 2008). Farmer producer companies can be seen as hybrids between private companies and cooperative societies. The producer-company concept aims to combine the efficiency of a company with the 'spirit' of traditional cooperatives. These companies aim to integrate smallholders into modern supply networks, minimizing transaction and coordination costs while benefiting from economies of scale (Lanting, 2005). They are run and owned by farmers, financially facilitated by the government or donor agencies, and managed by professionals.

Against this backdrop, this research paper aims to explore the innovative ideas of value-chain governance and collective-action organizational structure of a producer company in Tripura. Through a case study of a specific producer company, Bagma Agri-Producer's Company Ltd. (BAPC Ltd.), which produces and markets multiple agricultural products, the paper discusses the potential benefits for rural communities and the re-empowering effect of this form of farmer organization. The general intention is to analyze the potential of the producer-company model as a bottom-up approach for smallholder participation in emerging markets of Tripura.

II. DATA AND METHODOLOGY

The study was based on primary data and information collected from the Bagma Agri Producer Company Ltd. (BAPC Ltd.) of Tripura State. The author conducted personal discussions with members using a semi-structured interview schedule to gather information about the Farmer Producer Organization (FPO). Additionally, relevant findings from research articles were incorporated as secondary data to complement the analysis. The study utilized cross-sectional information for this case study.

Tabulation and percentage analysis were carried out to highlight the salient features of the data. Tabulation is a systematic way of presenting numerical data in an easily understandable format, providing clear expression and facilitating convenient comparison of related numerical data. The percentage form was used while discussing the study parameters to make the document more reader-friendly.

In the later section of the analysis, Ordinal Logistic Regression (OLR) was employed to assess the level of satisfaction of being a member of the selected FPO against various socioeconomic parameters. Ordinal regression is a member of the regression analysis family, used as a predictive analysis to describe data and explain the relationship between one dependent variable and two or more independent variables. In ordinal regression analysis, the dependent variable is ordinal (statistically, it is 'polytomous' ordinal), and the independent variables are ordinal or continuous-level (ratio or interval).

Linear regression estimates a line to express how a change in the independent variables affects the dependent variables. The independent variables are added linearly as a weighted sum. In this study, the dependent variable was measured on a 5-point Likert scale (1 = 'very poor satisfaction', 2 = 'poor satisfaction', 3 = 'Average satisfaction', 4 = 'high satisfaction', and 5 = 'very high satisfaction').

The independent or explanatory variables considered in the study were:

1. Gender (male or female)

2. Experience in farming (number of years of involvement)

3. Family size

4. Education (number of classes passed)

5. Monthly income from farming activities (in Indian Rupees)

6. Monthly income from non-farming activities (in Indian Rupees)

7. Number of training sessions attended

The analysis aimed to explore the innovative ideas of value-chain governance and collective-action organizational structure of the BAPC Ltd., a producer company in Tripura. Through this case study, the potential benefits for rural communities and the re-empowering effect of this form of farmer organization were discussed.

By examining the level of satisfaction of FPO members against various socioeconomic factors, the study sought to understand the factors influencing the success and potential of the producer-company model as a bottom-up approach for smallholder participation in emerging markets of Tripura.

III. RESULTS AND DISCUSSION

The analysis and discussion section of this paper is organized into three distinct parts. The first section provides a descriptive analysis regarding the background and genesis of the selected Farmer Producer Organization (FPO), Bagma Agri-Producer's Company Ltd. (BAPC Ltd.). The second section offers a critical SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the current state of affairs at BAPC Ltd. The third section attempts to explain the level of satisfaction of members in their participation in BAPC Ltd. against a few selected socio-economic variables as explanatory factors. In the final section, we conclude that producer companies are a promising new model of smallholder organization, but one that requires continued support and further critical analysis to formulate strategic options as per the requirements.

Background and present status of BAPC Ltd.

The Farmer Producer Organization, BAPC Ltd., was initially established under the registration of the Cooperative's Act. However, due to administrative difficulties, the organization shifted its registration to the Companies Act. The Board of Directors and the main implementing body of BAPC Ltd. were involved in activities through a formal farmer's club, namely, Gram Bikash Farmer's Club. Later, the same group of farmers took the initiative to form an FPO under the Companies Act, considering the scope of benefits for a large number of village farmers.

Through years of existence, professionalism, commitment towards the farming community, efficient leadership, and robust networking with other reputed organizations, Bagma Agri-Producer Company has emerged as the leading producer organization in the entire State of Tripura. It started as a vibrant farmer's club supported by NABARD, KVK, and ICAR, later taking the form of a Trust before attaining its current status as a recognized producer organization.

BAPC Ltd. is deeply associated with organizations like NABARD, ICAR, KVKs, and various line Departments of the State Government, including Agriculture, Horticulture, Fisheries, and Animal Resource Development Departments. BAPC Ltd. is rapidly emerging as a credible name in the landscape of Farmer Producer Organizations (FPOs) in Tripura, and much of the credit behind the current growth and development of the organization goes to all the organizations actively supporting its activities targeted towards the welfare of the farming community.

BAPC Ltd. is presently working on eight projects and is in the process of initiating three more projects. BAPC Ltd. has focused on dairy as their core or central activity for supply value chain development, with credit linkage facilities supported by NABARD. Apiculture, the development of Rural Marts, the formation of Joint Liability Groups for marginal farmers, and Seed Production programs (especially for paddy) are among the multi-product-based activities undertaken by BAPC Ltd. Recently, a credit-linked fish farming project was also initialized to diversify the activities of BAPC Ltd. for a large section of farmers.

There are 10 Board of Directors (BoDs) in the company. Two of the BoDs are graduates by qualification, while all the Directors have years of practical experience in agriculture and are considered progressive and innovative farmers in the farming community. Under the able leadership of these BoDs, the day-to-day operational activities are spearheaded by a young and qualified CEO who holds a Post Graduate degree in Rural Development from Tripura University. The CEO is supported by three other permanent staff members.

Currently, the key activities are focused on the supply of inputs like feed, seed, fertilizers, etc., Seed production with the support of technical organizations, Apiculture, Dairy sector activities (supply value chain), assistance for KCC issuing, Rural Marts, Aggregation and collectivization of farmers' produce and marketing, training and capacity building of members, exposure visits, and financial inclusion. Table 1 provides a generalized view of the different types of services offered by BAPC Ltd. against the generalized profile of FPO services available in the literature. It shows a potential scope for development by BAPC Ltd. in different directions.

SWOT Analysis of BAPC Ltd.

I. Strengths:

a. The management or Director's Committee of the FPO is well-known among the farmers' group.

b. It is a multi-product-based FPO, highly relevant for a state like Tripura, where mixed farming category farmers outnumber specialized farmers.

c. Regular contact and support from NABARD.

d. Running a few important projects.

e. A good and efficient team of staff is involved in management.

f. The FPO has its own retail outlet at Matabari, a religiously important spot in Tripura.

g. Location advantage of being located near the district headquarters and connectivity through the national highway and railway.

h. Some members and Directors are already involved in entrepreneurship in their personal capacities.

II. Weaknesses

a. Members are not highly experienced in FPO management and do not have a focused sustainable plan of work to date.

b. Less exposure to many technological advances in farming systems.

c. The FPO is not single-product-based.

d. Lack of entrepreneurship development attitude among farmers.

e. Lacking efficient resource personnel for project preparation or planning.

f. They do not have infrastructure related to value addition, food processing, or storage.

g. Lacking good infrastructure facilities required to run an office.

h. The location of participating Gram Panchayats is widespread.

These challenges are not unique to BAPC Ltd. A study by Debnath et al. (2017) on fish farming in South Tripura found that the main barriers to adopting recommended practices were lack of financial support, unavailability of low-cost feed, and lack of quality fish seed. Their findings align with the weaknesses identified in BAPC Ltd., particularly the lack of exposure to technological advances and the need for infrastructure development.

III. Opportunities

a. Importance towards FPOs as declared by the government.

b. The FPO is comparatively new, with plenty of opportunities for expanding its activities.

c. Farmers are interested and show a positive response towards FPO activities.

d. Vertical integration of the marketing channel.

e. Scope for diversification of crops and related supply-value chain activities.

f. Scope for improving family members' income through economies of scale.

g. Farm mechanization is yet to be adopted.

h. Packaging and value addition for different produce are yet to be explored.

i. Institutional support.

IV: Threats

a. Long-term sustainability.

b. Competition from other recently initiated FPOs.

c. Administrative control.

d. Short-term monetary greed by avoiding the FPO channel by a few members.

e. The involvement of middlemen in the supply value chain is still very active at the village level.

Satisfaction of being a registered member

Altogether, there are 250 registered members under the selected FPO, and as the FPO deals with multiple agricultural commodities, the registered members also have their involvement in farming various agricultural commodities. Table 2 presents the percentage of FPO members who expressed their primary interest in agricultural activities as received through a primary survey of 32 randomly selected members of BAPC Ltd.

The level of satisfaction of being a member of BAPC Ltd. was analyzed using a 5-point Likert scale through Ordinal Linear Regression (OLR), and the results are presented in Table 3.

The model fitting information with a -2 log-likelihood chi-square value of 54.97 was observed at less than a 1% level of significance, and the Goodness of fit using the Pearson chi-squared test also explained a better fit of the model to the data. It was 86.75 (sig. = 0.984), suggesting a good model fit.

Table 3 shows the regression coefficients and significance tests for each of the independent variables in the model. The regression coefficients can be literally interpreted as the predicted change in the log odds of being at a higher level of satisfaction in the form of the dependent variable. Looking at the mathematical sign as it appears in Table 3, we can conclude that all the variables except monthly income from non-farming activities had a positive sign, indicating a positive predictive increase in log odds of higher levels of satisfaction for membership in the FPO. This indicated that higher values of socio-economic variables, except non-farm income, were more likely to indicate higher levels of satisfaction in becoming a member of the FPO. However, for non-farm income, it was the opposite, which might be due to the fact that farmers with higher non-farming income were more likely to have a lower level of satisfaction in being a member of the FPO. But it was not significant.

While observing other independent variables, except gender and income from non-farming income, none showed a significant influence on the level of satisfaction of being a member of BAPC Ltd. The coefficients of other variables were positive and significant at a 10% significance level, indicating a positive influence on the level of satisfaction of being a member.

In summary, the analysis provided insights into the background, present status, strengths, weaknesses, opportunities, and threats of the Bagma Agri-Producer's Company Ltd. (BAPC Ltd.), a prominent Farmer Producer Organization in Tripura. It also examined the level of satisfaction among members of the FPO, considering various socio-economic factors. The findings suggest that producer companies like BAPC Ltd. are a promising new model for smallholder organization in agriculture, particularly in regions like Tripura where mixed farming is prevalent.

The study reveals that BAPC Ltd. has made significant strides since its inception, evolving from a farmer's club to a well-established producer company. Its strong associations with organizations like NABARD, ICAR, KVKs, and various state government departments have contributed to its growth and credibility. The company's focus on multiple agricultural activities, including dairy, apiculture, seed production, and fisheries, demonstrates its adaptability to the diverse needs of farmers in the region.

The SWOT analysis provides valuable insights into the current state of BAPC Ltd. The company's strengths lie in its multi-product approach, strong management team, and strategic location. These factors position it well to serve the needs of mixed farming communities in Tripura. However, the analysis also highlights several weaknesses, such as limited experience in FPO management, lack of value-addition infrastructure, and the need for more focused long-term planning. These areas require attention for the company's continued growth and success.

The opportunities identified for BAPC Ltd. are significant. With the government's increasing focus on FPOs, there is potential for expansion, diversification, and vertical integration of marketing channels. The scope for introducing farm mechanization and exploring value addition processes presents avenues for enhancing farmer incomes and overall productivity. However, the company must also be mindful of the threats it faces, including long-term sustainability challenges, competition from other FPOs, and the persistent influence of middlemen in the supply chain.

The analysis of member satisfaction provides interesting insights into the factors influencing farmers' perceptions of the FPO. The positive correlation between most socio-economic variables and satisfaction levels suggests that BAPC Ltd. is generally meeting the needs of its diverse membership. However, the negative (though not significant) relationship between non-farm income and satisfaction levels indicates a potential area for further investigation. It may be worthwhile for the company to explore strategies to better engage and serve members with higher non-farm incomes, ensuring that the FPO remains relevant and beneficial to all its members regardless of their income sources.

The study's findings have several implications for policy and practice. First, they underscore the importance of continued support for FPOs like BAPC Ltd., both from government agencies and other institutional partners. This support should not only be financial but also include capacity building, technology transfer, and market linkage assistance.

Second, the multi-product approach of BAPC Ltd. appears to be well-suited to the agricultural landscape of Tripura. This model could be considered for replication in other regions with similar mixed farming systems. However, care should be taken to address the challenges associated with managing diverse product lines, such as the need for specialized knowledge and infrastructure for each product category.

Third, the identified weaknesses and threats suggest areas for targeted interventions. For instance, there is a clear need for enhancing the entrepreneurial skills of FPO members, improving infrastructure for value addition and storage, and developing more robust long-term strategic plans. Additionally, measures to counter the influence of middlemen and to ensure the long-term sustainability of the FPO should be prioritized.

Fourth, the satisfaction analysis highlights the importance of considering socio-economic factors in FPO management. Strategies should be developed to enhance the benefits of FPO membership for all farmers, regardless of their farm size, education level, or non-farm income. This might involve tailoring services and interventions to meet the specific needs of different member segments.

Table 1. Services provided by farmers' organizations

Services details (source: Hellin et al, 2009; Markelova et al, 2009; Narrod et al, 2009; Rondot and Collion, 2007)		Pilot survey summary
Services	Activities	Level of adoption by BPAC Ltd.
Organizational services	Organizing farmers, catalyzing collective action, building (strategic) capacities, establishing internal monitoring systems	Fully adopted
Production services	Input supply, facilitation of (collective) production activities	Partially adopted
Marketing services	Transport and storage, output marketing, processing, market information and analysis, branding, certification	Not adopted (partially adopted for dairy sector)
Financial services	Savings, loans, and other forms of credit, financial management	Ongoing
Technology services	Education, extension, research	Not adopted
Education services	Business skills	Not adopted
Welfare services	Health, production health, safety nets	Not adopted
Management of resources	Water, pasture, fisheries, forests, soil conservation etc.	Partially adopted

Table 2: Interest towards different agricultural activities as primary activity of interest among the members of FPO (n=32)

Agricultural Activities	Percentage of farmers showed primary interest
Crop production	25
Vegetables	9.4
Seed production	15.6
Animal rearing	18.8
Apiculture	6.3
Fisheries	18.8
Other agricultural activities	6.3

Table 3: Ordinal Linear regression estimates for level of satisfaction of being member of BAPC Ltd., Tripura, in 2020 (n=32)

Dependent Variables		**Independent variables**				
Level of satisfaction of being member	Marginal percentage	Variable	Measurement	Estimates	+/-	Sig.
Very poor satisfaction	12.5 %	Gender	Male or Female	.026	+	0.981
Poor satisfaction	21.9 %	experience in farming	Number of years of involvement	.278	+	0.020
Average satisfaction	18.8 %	family size	in nos.	.500	+	0.052
High satisfaction	21.9 %	Education	Number of class passed	.336	+	0.077
Very high satisfaction	25 %	Income from farming activities	Rs. per month	.001	+	0.009
Test of parallel lines		income from non-farming activities	Rs. per month	.000	+	0.122
Chi-square = 14.130	Sig. = 0.864	number of training attended	in nos.	.557	+	0.068

Pseudo R-Square (Nagelkerke) = 0.857

IV. CONCLUSION

In conclusion, while BAPC Ltd. and similar producer companies show promise as a model for smallholder organization, they require continued support and critical analysis to reach their full potential. Future research could delve deeper into the factors influencing member satisfaction, explore the long-term economic impacts of FPO membership on farmer incomes, and investigate best practices for managing multi-product FPOs in diverse agricultural settings.

The case of BAPC Ltd. demonstrates that FPOs can play a crucial role in empowering smallholder farmers, improving market access, and promoting agricultural development in regions like Tripura. However, realizing this potential requires a concerted effort from all stakeholders - the FPO management, member farmers, government agencies, and supporting institutions. By addressing the challenges identified in this study and building on the strengths and opportunities, BAPC Ltd. and similar FPOs can contribute significantly to the transformation of smallholder agriculture in India.

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Development of a Rapid and Cost-Effective Method for Estimating Plant Glucose Levels with a Glucometer

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***Abstract*— This work offers a unique glucometer procedure for quick and economical plant glucose determination. The effectiveness of the devised method was demonstrated by its successful application to a variety of plant samples. Tagetes erecta showed the greatest glucose content among the plants studied, while Aegle marmelos showed the lowest. This novel method of measuring plant glucose levels is quicker and less expensive than existing approaches, which gives it a major advantage over others. This approach has the potential to be an effective tool in a number of disciplines, such as agricultural science, ecological research, and plant physiology.*

***Keywords*— Glucometer, glucose estimation, plant glucose, fast and economic method**

I. INTRODUCTION

A basic component of plant life is glucose, a simple sugar. It is the principal energy source and a fundamental constituent of many cellular parts. The widely known process of photosynthesis, in which plants absorb sunlight and transform water and carbon dioxide into carbohydrates, is how they make glucose. Plants use glucose as their main energy source and as a key component of many physiological functions. In plants, glucose plays a pivotal role as a master regulator, impacting several physiological processes during their entire life cycle. These include the ferocious growth phases, the complex dance of nitrogen and carbon metabolism, the germination and development of seeds, and finally, senescence.[1] Understanding plant health, stress responses, and metabolic processes requires monitoring plant glucose levels regularly. Plant glucose is currently estimated using various techniques, such as the enzyme-based test, which makes use of enzymes unique to glucose metabolism. The hexokinase/glucose-6-phosphate dehydrogenase (HK/G6PDH) technique is a typical illustration. After ATP is used by hexokinase to phosphorylate glucose, glucose-6-phosphate is oxidised by G6PDH, which produces NADH. The amount of NADH generated can be determined by measuring its absorbance at 340 nm, which is proportional to the glucose content.[2] In a colorimetric assay, coloured products are produced by interactions between glucose and certain reagents. The glucose oxidase (GOD) technique is a widely used illustration. The oxidation of glucose to gluconic acid and hydrogen peroxide (H2O2) is catalysed by GOD. Then, a chromogenic substrate and H2O2 combine to form a chromogenic horseradish peroxidase (HRP), which produces a coloured product whose intensity correlates with glucose concentration.[3]. Chromatographic procedures can be used to separate and measure the components based on how a mixture's constituents interact with a stationary phase. High-performance liquid chromatography (HPLC) is one method that can be used to quantify and extract glucose from other sugars in a sample.[4].

We suggest a new, less expensive, and more straightforward approach of estimating glucose using a glucometer instead of these time-consuming, expensive, and skill-required methods. Glucometers are compact instruments for determining blood glucose levels. They work based on two well-established principles: electrochemical detection and enzymatic reaction.

II. METHODOLOGY

This methodology combines blood glucose meter calibration with estimating glucose content in a plant leaf extract but with some important modifications.

1. Glucometer Calibration

1.1. Follow the manufacturer's instructions for your specific glucometer model to perform calibration.

1.2. Use the commercially available 100 mg/dL glucose solution for calibration.

1.3. Record the displayed blood glucose reading from the glucometer.

1.4. Calculate the difference between the expected value (100 mg/dL) and the displayed reading. This value represents the calibration error of your glucometer for this specific test.

2. Plant Extract Preparation

2.1. Grind 1 gram of fresh leaves thoroughly using a mortar and pestle.

2.2. Mix 3 mL of 0.9% NaCl solution to the ground plant material.

2.3. Transfer the mixture to a centrifuge tube and centrifuge for 5 minutes at moderate speed (around 3000 rpm) to separate the liquid extract from the solid plant debris.

2.4. Carefully transfer the clear supernatant (liquid extract) to a clean centrifuge tube using a micropipette or by pouring slowly.

3. Glucose Conversion and Measurement (Estimation)

Important Note: This step aims to convert some of the starch present in the leaves to glucose using hydrochloric acid (HCl). However, the efficiency of this conversion and the presence of other sugars in the extract can significantly impact the accuracy of the glucose estimation.

3.1. Add 1 mL of N/10 HCl solution to the collected plant extract in the centrifuge tube.

3.2. **Safety Precaution:** Wear gloves and eye protection while handling hydrochloric acid.

3.3. Mix the solution gently and incubate it at room temperature for 10 minutes (or as recommended in plant starch hydrolysis protocols for your specific plant type). This step converts some of the starch to glucose.

3.4. **Neutralization:** After incubation, carefully neutralize the solution using a weak base like sodium bicarbonate (baking soda) until a neutral pH is reached (around pH 7). This step is crucial to avoid damaging the glucometer.

3.5. Dilute the neutralized extract with distilled water if necessary, following the recommendations in your glucometer's user manual for minimum sample volume.

3.6. Use the glucometer to measure the glucose concentration of the diluted plant extract according to the manufacturer's instructions.

4. Calculation and Interpretation

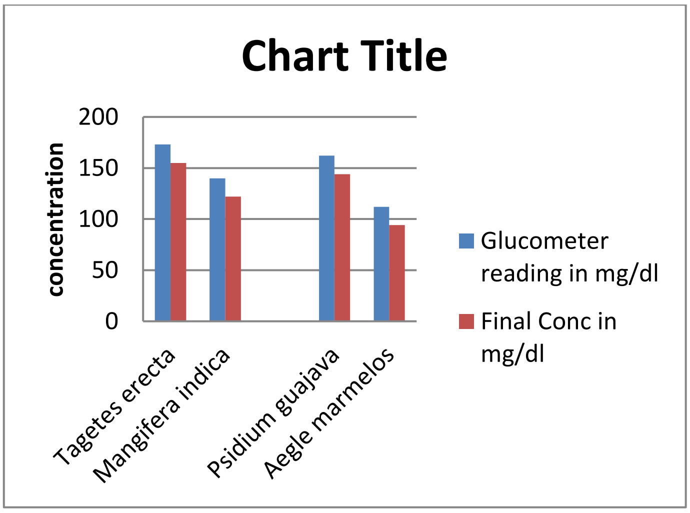
4.1. Since a glucometer is not designed for plant extracts, the displayed reading might not directly represent the leaf glucose concentration.

4.2. Consider the following points for interpretation: Subtract the calibration error (calculated in step 1.4) from the glucometer reading for the plant extract to get a potentially more accurate value. Remember that this method only estimates glucose content by converting some starch and might not account for other sugars present.

III. RESULTS

In this present work, we analyzed four plant leaf samples, which are reflected in the following table.(calibration error = -18)

No	Plant name	Glucometer reading in mg/dl (GR)	Final Conc (GR+CE)
1	*Tagetes erecta*	173	155
2	*Mangifera indica*	140	122
3	*Psidium guajava*	162	144
4	*Aegle marmelos*	112	94



Graph showing a concentration of the different sample

Estimating glucose content of *Tagetes erecta*

IV. CONCLUSION

In conclusion, this study established a new protocol for estimating plant glucose using a glucometer. The findings demonstrated that *Tagetes erecta* exhibited the highest glucose content among the tested plants, while *Aegle marmelos* displayed the lowest. This novel method offers a rapid and cost-effective approach for plant glucose estimation, potentially proving valuable in various fields, including plant physiology, agriculture, and ecological research. This study explored the feasibility of using a glucometer for rapid and economic estimation of plant glucose. The results confirmed that the developed protocol successfully measured glucose levels in various plant samples.

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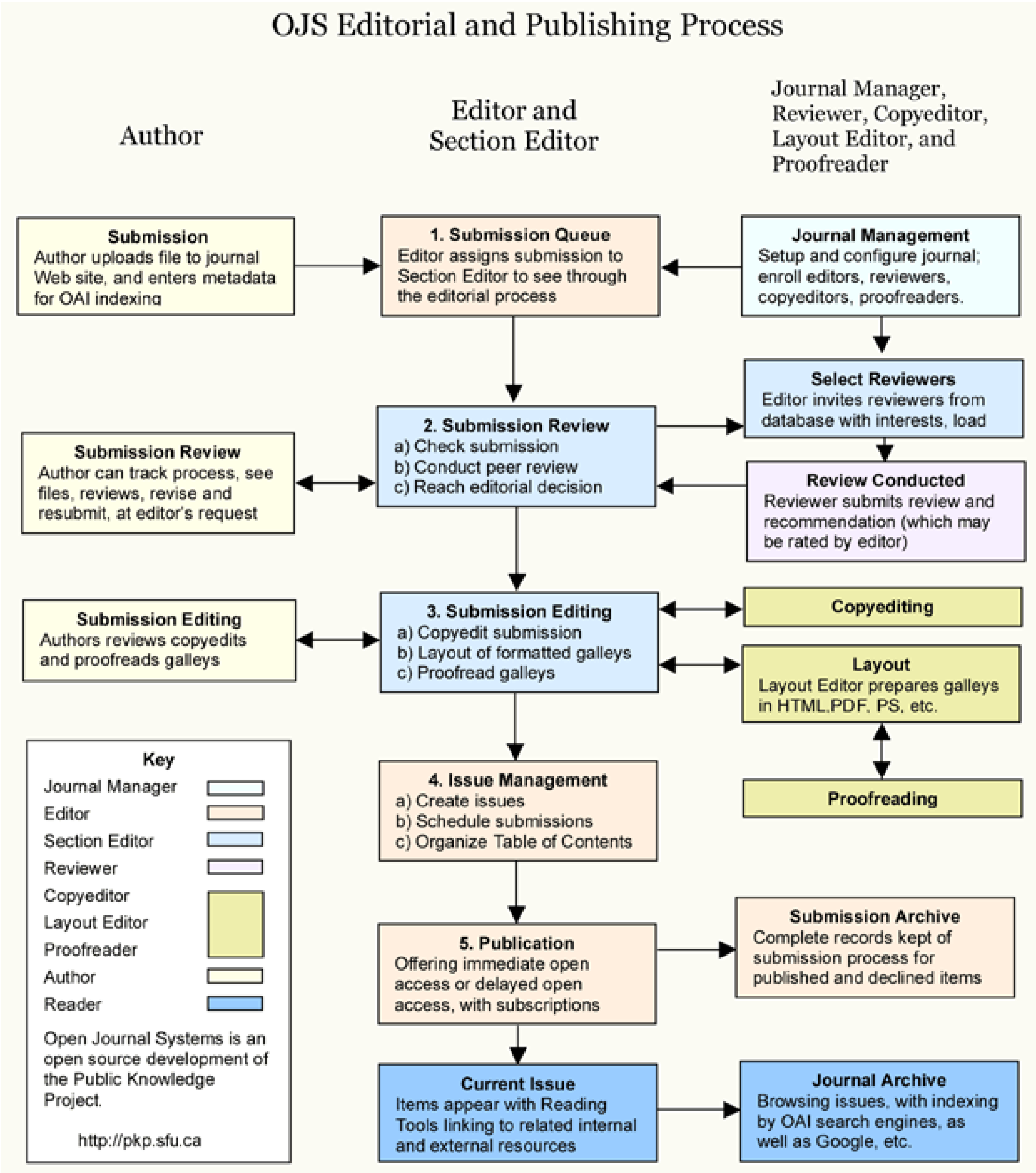

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