ISSN: 2456-1878

International Journal of Environment Agriculture and Biotechnology

(IJEAB)

An open access Peer-Reviewed InternationalJournal

DOI: 10.22161/ijeab.96

Vol.- 9 | Issue - 6 | Nov-Dec 2024

editor.ijeab@gmail.com | editor@ijeab.com | https://www.ijeab.com/

International Journal of Environment, Agriculture and Biotechnology

(ISSN: 2456-1878)

DOI: 10.22161/ijeab

Vol-9, Issue-6

November - December, 2024

Editor in Chief

Dr. Pietro Paolo Falciglia

Publisher

Infogain Publication

Email: editor.ijeab@gmail.com ; editor@ijeab.com

Web: www.ijeab.com

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.

Sincerely,
Editor-in-Chief
International Journal of Environment, Agriculture and Biotechnology (IJEAB)
NAAS Score Journal
www.ijeab.com

International Editorial Board/ Reviewer Board

Vol-9, Issue-6, November - December 2024

(DOI: 10.22161/ijeab.96)

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Analysis of Spatial-Temporal Changes of Land Use in Zhenjiang City, Jiangsu Province, from 2000 to 2020 Using GIS

Jinzhao Liang, Ruei-Yuan Wang*

School of Sciences, Guangdong University of Petrochem Technology (GDUPT), Maoming 525000, China
*Corresponding Author

Received: 23 Sep 2024; Received in revised form: 20 Oct 2024; Accepted: 27 Oct 2024; Available online: 01 Nov 2024

Abstract— *With the rapid growth of the economy and the acceleration of urbanization, the scarcity of land resources has become increasingly prominent, and changes in land use types have become a hot research topic. This study takes Zhenjiang City in Jiangsu Province as an example, using land use data from 2000, 2010, and 2020, and combining ArcGIS with three methods: land use transfer matrix, dynamic degree, and standard deviation ellipse, to analyze the spatiotemporal changes and transfer amounts of land use types in the past two decades. The results indicate that firstly, the land use types in Zhenjiang are cropland, construction land, forests, and water bodies, with the specific area being cropland>construction land>forests>water bodies>wetlands>grasslands. Secondly, forests are distributed in the southwest and northwest of Zhenjiang; wetlands are distributed in the north; water bodies are distributed in the north and central western regions; and construction land is distributed in the north and central regions. Thirdly, in the past two decades, the single land use dynamic degree of construction land has been the highest, at 17.27%, indicating the largest change in area and rapid urban extension in Zhenjiang. The center of gravity of construction land has undergone significant changes, showing a shift from northeast to southwest.*

Keywords— ***Spatiotemporal Changes of Land Use, Transition Matrix (TM), Zhenjiang City, Dynamic Degree, Standard Deviation Ellipse (SDE)***

I. INTRODUCTION

Land is an important component of ecosystems, carrying various biological communities including plants, animals, and microorganisms [1]. The health and stability of land play a crucial role in maintaining ecological balance, protecting biodiversity, and addressing climate change. Research shows that the spatiotemporal changes in land use are one of the main causes of environmental change on Earth [2]. It not only affects the sustainable development of human society but also profoundly impacts the balance of the natural environment and ecosystems. In addition, it also has a profound impact on the structure and function of ecosystems. Therefore, reasonable land use planning is necessary to protect natural ecosystems, maintain ecological balance, and prevent the loss of biodiversity.

In recent years, many scholars at home and abroad have analyzed and studied land use change. For example, Appiah (2015) and other scholars used GIS and RS technologies to analyze the characteristics of land use/cover change (LUCC) in the suburban fringe of Ghana [3]. Enaruvbe (2015) used a combination of supervised and unsupervised classification methods to analyze the patterns and rates of spatiotemporal changes in land cover [4]. In relevant research in China, many scholars choose spatial analysis indicators for land use, such as land use dynamics, standard deviation ellipse models, partial correlation methods, etc., to study the spatiotemporal characteristics of land use changes from the perspectives of land use type transfer, change amount, and change rate. Among them, Wang (2024) and other scholars used partial correlation methods to study the spatiotemporal changes of land use and vegetation cover in arid areas [5]. Research has shown that regions with a significant decrease in Fractional Vegetation Coverage (FVC) ($P<0.1$) are mainly characterized by the transfer of grassland to bare land, while regions with an upward trend are characterized by the transfer of bare land to grassland and grassland to cultivated land. There are more regions with a positive correlation between FVC and precipitation, with a larger proportion of grassland area and a smaller proportion of bare land. Tang (2024) and other scholars used methods such as standard deviation ellipse and land use dynamics to analyze the spatiotemporal changes of land use in the Changjizhou Plain area [6]. The study showed that the transformation between different land types in the study area was most evident in the dynamic changes and center of gravity migration of cultivated land, while the dynamic changes and center of gravity migration of other land types were not significant. Scholars such as Luo (2024) conducted a study on the changes in land use landscape patterns in Qinzhou City from 2000 to 2020 using ArcGIS 10.8 and Fragstats4.2 software [7]. Research has shown that PD, SHDI, and SHEI in the study area continue to decrease, while CONTAG and AI continue to rise. The overall landscape fragmentation in Qinzhou City deepens, land use is abundant, and different landscapes tend to become more complex, with a uniform distribution of types.

Since the reform and opening up, Chinese cities have developed rapidly, with significant improvements in both quantity and scale. Especially in the eastern and southern cities near the coast, their development speed and scale are better than other cities. As an important prefecture-level city in Jiangsu Province, Zhenjiang is a crucial pillar of the province's economic development. Due to the rapid advancement of urbanization, rapid socio-economic development, and the implementation of a series of national planning policies, the demand for construction land continues to increase, and the changes in land use types are increasingly influenced by human activities [8]. Therefore, this study uses ArcGIS software to analyze the land use changes in Zhenjiang City from 2000 to 2020, explore the changes in its spatial pattern, and provide specific targeted measures for land use changes, attempting to provide a scientific basis for regional ecological environment protection and land use planning.

II. RESEARCH AREA

Zhenjiang City is a prefecture-level city under the jurisdiction of Jiangsu Province, China. It is located in the southwest, at the western end of the Yangtze River Delta region, at 31° 37′~32° 19′ N latitude and 118° 58′~119° 58′E longitude [9] (Figure 1). It belongs to the subtropical monsoon climate with distinct four seasons, warm and humid, and has three major water systems: Huxi, Yanjiang, and Qinhuai River. The city has undulating terrain and diverse landforms. Among them, the plain area accounts for 15.5% of the total area, hilly and mountainous areas account for 51.1%, water areas account for 13.7%, and polder areas account for 19.7%. This terrain condition provides abundant natural resources and diverse ecological environments for the development of Zhenjiang City.

The permanent population of Zhenjiang continues to grow. According to statistical data, from the end of 2023 to the beginning of 2024, the permanent population will reach 3.226 million, including 2.6034 million urban populations, with an urbanization rate of as high as 80.7% [10]. In addition, the population structure is constantly changing, and the proportion of the elderly population is increasing year by year. In terms of economy, the municipal government actively promotes the green and low-carbon transformation of industries and cultivates and develops new quality productive forces [11]. In recent years, with the gradual improvement of the green manufacturing system, a group of high-quality green manufacturing units have emerged. At the same time, the installed capacity of renewable energy continues to expand, and various types of energy storage development are actively promoted, injecting new vitality into the economic and social development of Zhenjiang.

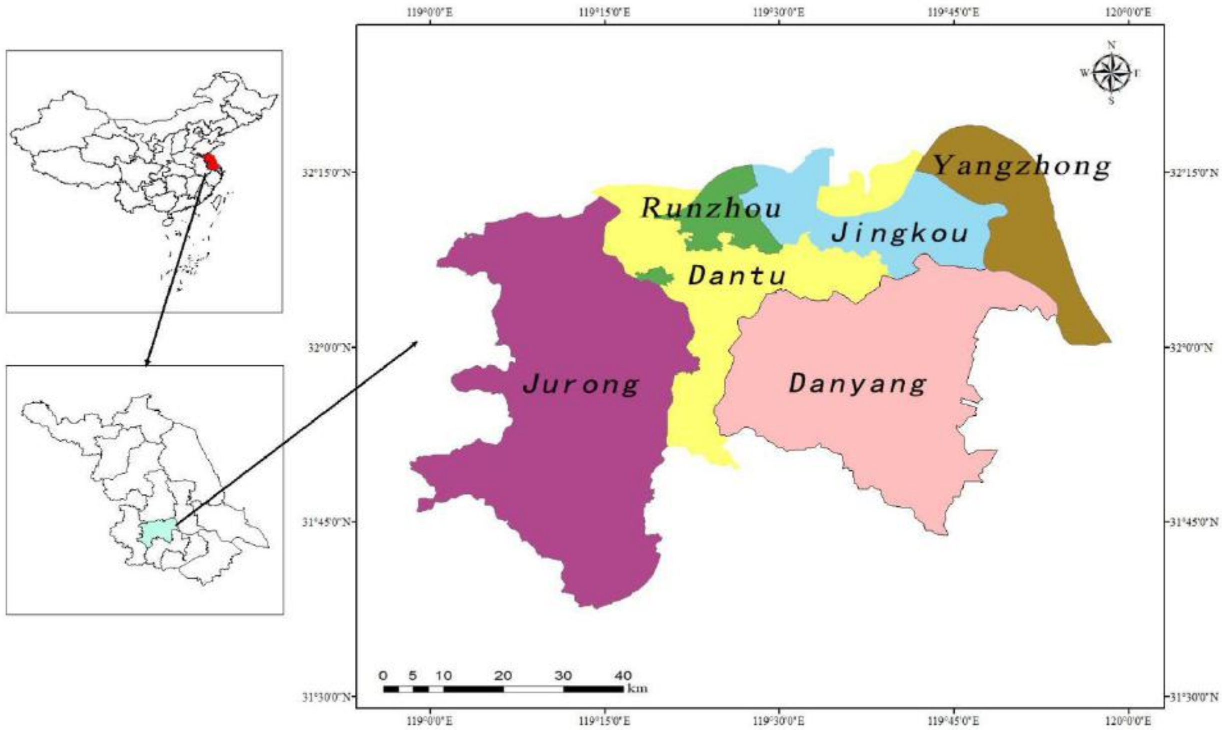


Fig.1 Administrative Region Map of Zhenjiang City

III. DATA SOURCES AND ANALYSIS METHODS

3.1 Data Sources

The research data selected in this article is mainly divided into raster data and vector data. Among them, the raster data includes elevation models (DEM) and land use data of Zhenjiang City in 2000, 2010, and 2020, with a spatial resolution of 30 m. Vector data includes the administrative boundaries of Jiangsu Province and Zhenjiang City. DEM data comes from geospatial data clouds, while land use data comes from global land cover data (https://www.globeland30.org/). The vector data comes from the Alibaba Cloud visualization platform (https://datav.aliyun.com/portal/school/atlas/area_selecter). The conversion of vector data comes from the OSM data sharing platform (https://mapshaper.org/). In addition, referring to the existing land classification system in China [12] and combining with the actual situation of land use types in Zhenjiang City, land use types are divided into six categories: cultivated land, forest land, grassland, wetland, and construction land (Table 1).

Table 1 Required Data Source

Data requirements	Data sources	Purpose
Land use data	Globeland30 (https://www.globeland30.org/)	Identify and classify different types of land
30m DEM	Geospatial Data Cloud (https://www.gscloud.cn/)	Plot analysis
Vector data of Jiangsu Province and Zhenjiang City	1.Alibaba Cloud Visualization Platform (https://datav.aliyun.com/portal/school/atlas/area_selector) 2.OSM Data Sharing Platform (https://mapshaper.org/)	Create the administrative scope of Zhenjiang City

3.2 Analysis Methods

The methods used in this study include data collection, calculation of the transfer matrix, calculation of land use dynamics, and calculation of the standard deviation ellipse (Figure 2). Describe as follows:

1. Data collection: Download land use data from the Global Land Cover Data website for the three periods of 2000, 2010, and 2020, and extract them according to masks. 2. Calculate the transfer matrix: First, use ArcGIS to calculate the transferred land area based on the collected data, and then calculate the total area of various land use types. Then, calculate the change characteristics of land use, including the inflow and outflow, based on the transfer matrix formula. 3. Calculate the dynamic degree of land use: Obtain the land use transfer function through the ArcGIS grid to calculate the transfer amount of the fused land use type area. 4. Calculate the standard deviation ellipse: Use ArcGIS statistical analysis tools to select the field and perform descriptive statistics to obtain the standard deviation result.

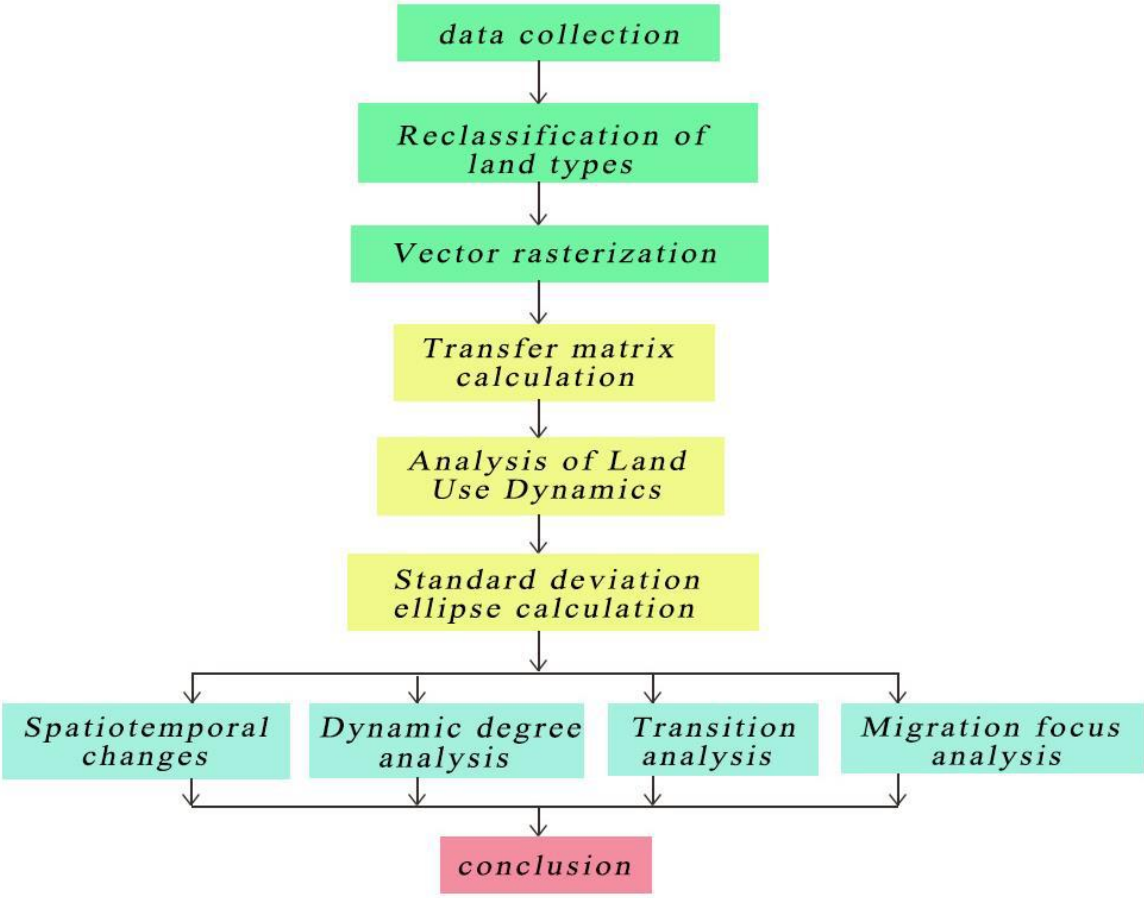


Fig.2 Technical Roadmap Flowchart

3.2.1 Land Use Transfer Matrix

The land use transfer matrix is the application of the Markov model in land use change, which can quantitatively illustrate the mutual transformation between land use types. This study is based on six types of land use data in Zhenjiang from 2000 to 2020. ArcGIS 10.8 software was used to superimpose and process this land use type data [13], calculating the area of transfer in and out of these six types of land use data in different years, and then obtaining the land use type transfer matrix. The formula is as follows:

$$S_{ij}=\begin{vmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ S_{21} & S_{22} & \cdots & S_{2n} \\ & & & \\ S_{n1} & S_{n2} & \cdots & S_{nn} \end{vmatrix} \quad (1)$$

In formula (1), n represents the land use types before and after the land transfer, S represents the land area, and i and j represent the land use types before and after the transfer, respectively (the values of i and j can be 1, 2,..., n).

3.2.2 Dynamic Analysis of Land Use

This study aims to analyze the dynamic changes, degree, and speed of land use types. A land use dynamic change model is used, and the transfer matrix method is combined to process land use data. The single land use dynamic degree [14] reflects the indicator of the speed and magnitude of changes in different land use types over a certain period of time. The formula is as follows:

$$K=\frac{(U_b-U_a)}{U_a}\times\frac{1}{T}\times 100\% \quad (2)$$

In formula (2), K is the dynamic degree of land use type, Ua and Ub are the areas of a certain type of land in the early and late stages of research, respectively, and T represents the time period of research [15].

3.2.3 Standard Deviation Ellipse (SDE) Method

The Standard Deviation Ellipse (SDE) is a method of generating elliptical shapes by calculating the mean and standard deviation of a set of data points. The main parameters include centroid coordinates, azimuth angles, etc., which can intuitively describe the distribution pattern and direction of data points. This study used this method to calculate the centroid coordinates, major and minor axes, and azimuth angles of land use types in Zhenjiang City from 2000 to 2020 and analyzed the spatial distribution characteristics and changing trends of land use in the region. The calculation formula for the center of gravity coordinates is as follows [16]:

$$\bar{X}_w=\frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i},\quad \bar{Y}_w=\frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i} \quad (3)$$

Where is the centroid coordinate, representing the relative position of geographic elements distributed in two-dimensional space; Wi is the weight value; (xi, yi) is the geometric center coordinate of the region.

IV. RESULT ANALYSIS

4. Spatial-temporal Variation Characteristics of Land Use Types

4.1.1 Time Variation of Land Use Area

Analysis shows that cropland, forests, water bodies, and construction land account for 64.30% -77.12%, 7.09% -8.00%, 7.46% -7.89%, and 7.24% -19.74% of the total land area, respectively, while grasslands and wetlands account for 0.09% -0.15% and 0.13% -0.25% of the total area (Table 2). From 2000 to 2020, the change in cropland area showed a decreasing trend year by year, from 2963.17 km^2 to 2470.52 km^2. The forest area showed a trend of first decreasing and then increasing, decreasing from 301.65km^2 to 272.44 km^2, and then increasing to 307.54 km^2. The grassland area has been increasing year by year, from 3.34 km^2 to 5.59 km^2. The trend of wetland area change shows a decreasing and then increasing trend, with 9.49 km^2 first decreasing to 5.13 km^2, and then increasing to 7.23 km^2. The change in water area shows a trend of first increasing and then decreasing, from 286.64 km^2 to 303.32 km^2, and then decreasing to 293.19 km^2. The change in construction land area has been increasing year by year, from 278.13 km^2 to 758.33 km^2.

Table 2 Changes in Land Use Type Area in Zhenjiang City from 2000 to 2020

Land-use type	2000		2010		2020	
	Area/ km^2	Ratio/%	Area/ km^2	Ratio/%	Area/ km^2	Ratio/%
Cropland	2963.17	77.12%	2893.81	75.31%	2470.52	64.30%
Forest	301.65	7.85%	272.44	7.09%	307.54	8.00%
Grassland	3.34	0.09%	4.35	0.11%	5.59	0.15%
Wetland	9.49	0.25%	5.13	0.13%	7.23	0.19%
Water body	286.64	7.46%	303.32	7.89%	293.19	7.63%
Construction land	278.13	7.24%	363.35	9.46%	758.33	19.74%

4.1.2 Spatial Changes in Land Use Types

Analysis shows that the cropland area in Zhenjiang has been continuously decreasing from 2000 to 2020. The area of northern forests decreased between 2000 and 2010, but increased in the following decade. Wetlands are concentrated in Dantu District of Zhenjiang and the western part of Jurong City. The wetland area showed a decreasing trend from 2000 to 2010, but an increasing trend from 2010 to 2020. The water bodies are in the form of rivers, distributed in the northern parts of Zhenrunzhou District, Jingkou District, and Yangzhong City, with no significant changes in area. The proportion of construction land continues to expand, mainly concentrated in the northern parts of Danyang City, Runzhou District, and Jingkou District (Figure 3).

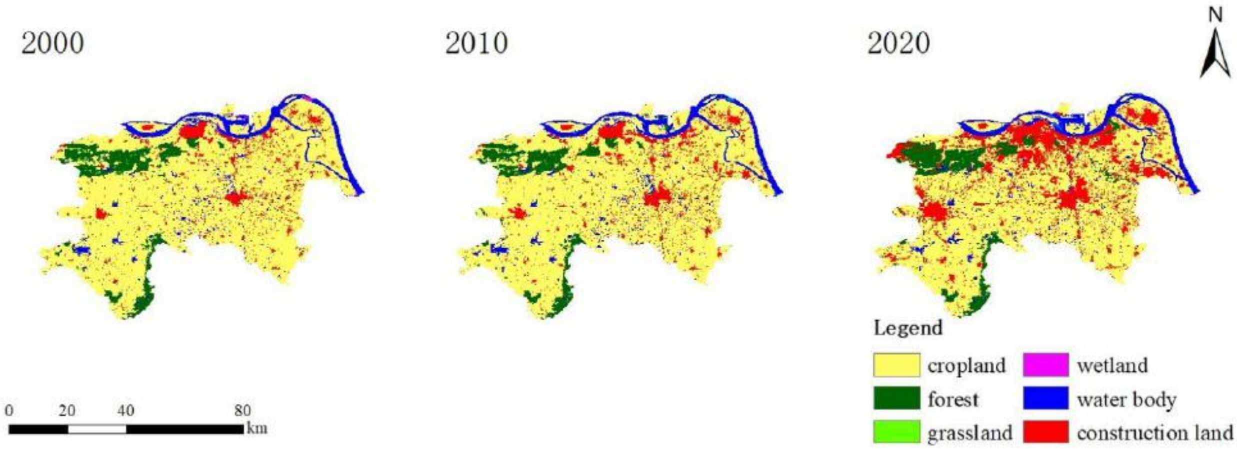


Fig.3 Land Use Changes in Zhenjiang City in the Past Two Decades

4.2 Analysis of Land Use Transfer

Analysis shows that from 2000 to 2010, the grassland was stable, with relatively low levels of outflow and inflow. The main transfer of cropland is construction land, forests, and water bodies, with specific transfer amounts of 117.73 km^2, 22.22 km^2, and 30.2 km^2, respectively. The construction land is transferred from cropland, with an area of 117.73 km^2. The main transfer of forests is cropland and water bodies, with specific transfer amounts of 39.92 km^2 and 12.91 km^2, respectively. Wetlands are also quite stable, with relatively small inflows and outflows. The water bodies are transferred from cropland and forests, with transfer amounts of 30.2 km^2 and 12.91 km^2, respectively (Table 3).

Table 3 Land Transfer Matrix of Zhenjiang City from 2000 to 2010(km^2)

Land-use type	Grassland	Cropland	Construction	Forest	Wetland	Water body
Grassland	2.54	0.3	0.03	0.27	0.05	0.16
Cropland	0.97	2791.41	117.73	22.22	0.64	30.2
Construction	0.07	33.13	243.3	0.26	0.01	1.37
Forest	0.27	39.92	0.34	248.2	0	12.91
Wetland	0.34	3.48	0.29	0.3	2.82	2.26
Water body	0.17	25.57	1.66	1.19	1.62	256.44

Analysis shows that from 2010 to 2020, the amount of grassland transfer was relatively small (Table 4), mainly from cropland, with a transfer amount of 2.17 km^2. The main transfer of cropland is construction land, forests, and water bodies, with specific transfer amounts of 408.76 km^2, 57.88 km^2, and 36.14 km^2. The amount of forest transfer is relatively small, mainly from cultivated land, with a transfer volume of 57.88 km^2. The outflow and inflow of wetlands are relatively small, and the amount of wetland conversion into grassland, construction land, and forest, as well as the amount of grassland, construction land, and forest conversion into wetlands, are all zero. The main transfer of water bodies is cropland, with a specific transfer volume of 45.01 km^2.

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available:https://ijeab.com/
Journal DOI:10.22161/ijeab

Table 4 Land Use Transfer Matrix of Zhenjiang City from 2010 to 2020 (km^2)

Land-use type	Grassland	Cropland	Construction	Forest	Wetland	Water body
Grassland	1.84	0.83	0.55	0.61	0	0.52
Cropland	2.17	2383.75	408.76	57.88	4.1	36.14
Construction	0.79	30.16	329.49	1.22	0	1.64
Forest	0.55	8.93	13.22	246.23	0	3.28
Wetland	0	0.85	0	0	0.7	3.57
Water body	0.25	45.01	6.2	1.38	2.41	247.35

Analysis shows that there were a total of 29 types of land use changes in Zhenjiang from 2000 to 2010, mainly consisting of cropland, construction land, and forests. The proportion of conversion between various land uses was relatively small, forming a point-like distribution. The concentrated areas of conversion are Dantu District, Danzhou City, Jingkou District, and Jurong City, mainly for the conversion of cropland to construction land, forests to cropland, and cropland to water bodies. These areas have vast cropland areas and relatively developed agriculture [17], which are greatly affected by human activities (Figure 4, Figure 6).

According to the supporting data, the Land and Resources Bureau of Yangzhong City agreed to relinquish a state-owned land use right of Yangzhong Sanmao Electrical Materials Co., Ltd. in 2010. The land was originally a water body but was later approved by the Provincial People's Government to be expropriated as state-owned construction land [18], indicating that some of the land use transfer in the area came from such human activities, thus presenting as water bodies being converted into construction land. In addition, the northwest of Zhenjiang is characterized by low mountains and hills. These areas have fertile soil and good drainage, providing favorable site conditions for forest growth. Therefore, there are a large number of forests distributed, such as Baohua Mountain National Forest Park, which has rich biodiversity and unique natural landscapes [19]. It is an important area for forest protection in the northwest of Jurong City. With the acceleration of urbanization in Jurong City, the demand for urban construction land continues to increase, and some forests have been transformed into urban construction land, such as residential and commercial areas.

Analysis shows that there were a total of 25 types of land use changes in Zhenjiang from 2010 to 2020, mainly construction land, cropland, and forests. The conversion between each type of land use was relatively frequent, with larger changes compared to the previous decade, showing a distribution pattern of patchy and dotted. The main manifestation is the conversion of cropland to construction land, forests, and water bodies, and the conversion of forests to construction land. The concentrated areas of conversion are Jurong City, Runzhou District, Danyang City, and Jingkou District. Among them, with the acceleration of urbanization, the demand for urban construction land in Runzhou District continues to increase. To meet this demand, some cropland has been requisitioned and converted into urban construction land, including different types of urban construction land for residential, commercial, industrial, etc. [20]. The northeastern part of Jingkou District has sufficient precipitation, suitable temperature, and fertile soil, which makes it easier for cropland in the area to be converted into forests (Figure 5, Figure 6).

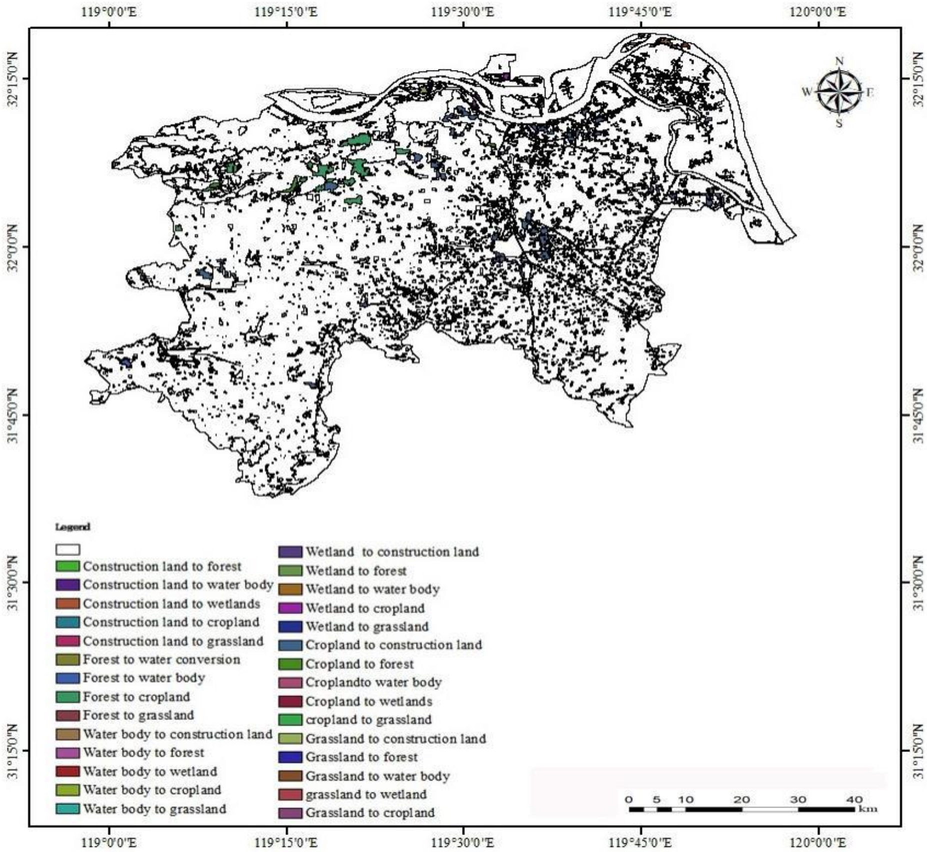


Fig .4 Transfer Maps of Different Land Use Types from 2000 to 2010

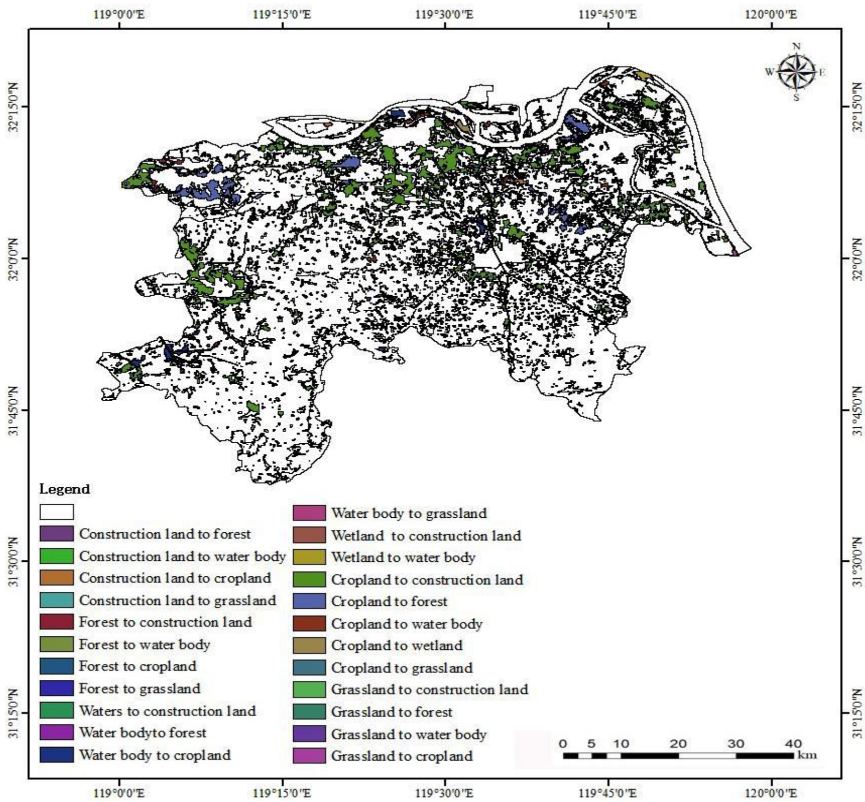


Fig.5 Transfer Map of Different Land Use Types from 2010 to 2020

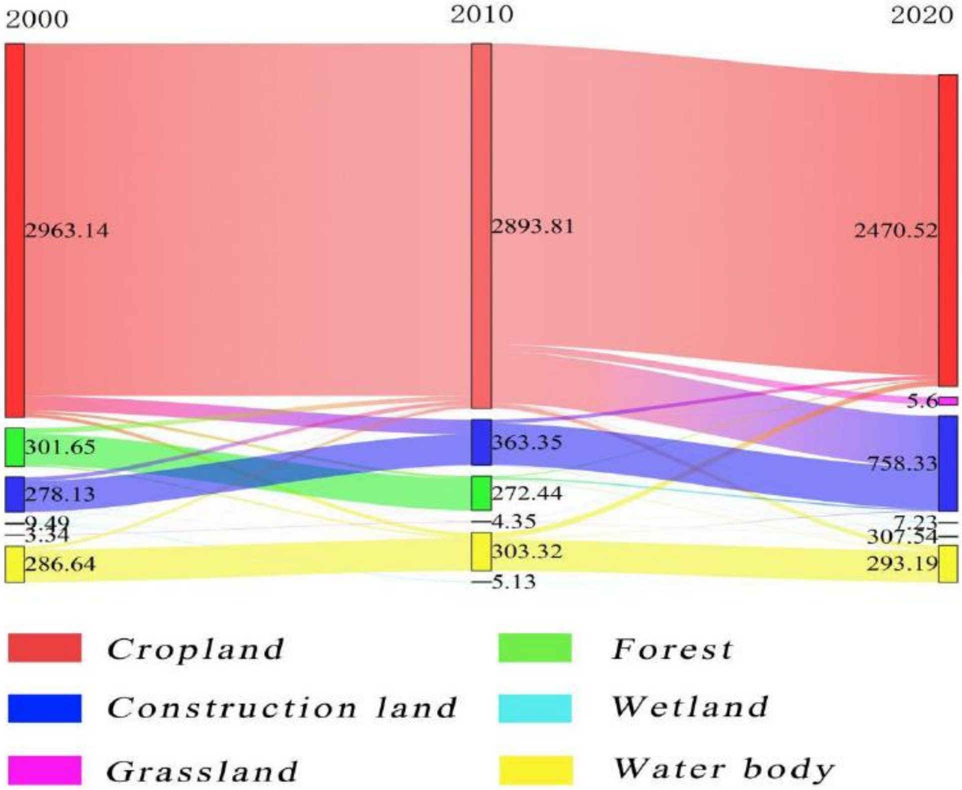


Fig.6: Sankey Map of Land Use Transfer from 2000 to 2020

4.3 Dynamic Degree Analysis

There are significant differences in the dynamic degree of single land use in Zhenjiang (Table 5, Figure 7). From 2000 to 2010, the areas of cropland, forests, and wetlands decreased, with dynamic degrees of -0.23%, -0.97%, and -4.59%, respectively. The dynamic degrees of grassland, water bodies, and construction land are all positive, at 3.02%, 0.58%, and 3.06%, respectively, indicating an increase in the area of these three land uses.

From 2010 to 2020, the expansion of construction land area was relatively large, with a dynamic attitude value of 10.87%, indicating that the urban development of Zhenjiang has been rapid during this decade, with significant improvements in both scale and speed. The dynamic degrees of cropland and water bodies are negative, with values of -1.46% and -0.33%, respectively. The dynamic degrees of forests, grasslands, and wetlands are positive, with values of 1.29%, 2.85%, and 4.09%, respectively.

Overall, from 2000 to 2020, the dynamic degree of construction land was 17.27%, forests were 0.20%, grasslands were 6.74%, water bodies were 0.23%, and cropland and wetlands were both negative values, at -1.66% and -2.38%, respectively.

Table 5 Comparison of Dynamic Degree of Single Land Use in Different Periods

Type		2000-2010	2010-2020	2000-2020
Dynamic degree of single land use/%	Cropland	-0.23	-1.46	-1.66
	Forest	-0.97	1.29	0.20
	Grassland	3.02	2.85	6.74
	Wetland	-4.59	4.09	-2.38
	Waters	0.58	-0.33	0.23
	Construction	3.06	10.87	17.27

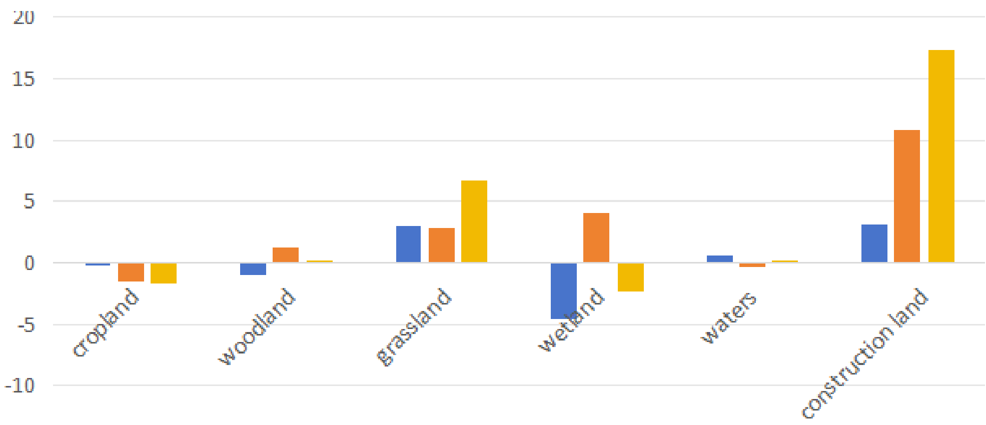


Fig.7 Comparison of Dynamic Degree of Single Land Use in Different Periods

In addition, based on the comprehensive dynamic degree of land use in Zhenjiang from 2000 to 2020 (Table 6, Figure 8), the comprehensive dynamic degree of land use in the first ten years was 0.27%, the second ten years was 1.13%, and the overall annual comprehensive dynamic degree was 1.29%. Analysis shows that the degree of land use was relatively low from 2000 to 2010. There is a clear trend of change in the last decade compared to the previous decade. Overall, the comprehensive dynamic degree of land use from 2000 to 2020 has gradually increased, and the changes have shown a clear upward trend.

Table 6 Comprehensive Dynamic Degree of Land Use in Different Time Periods

Serial Number	Time	Comprehensive dynamic diagram/%
1	2000-2010	0.27
2	2010-2020	1.13
3	2000-2020	1.29

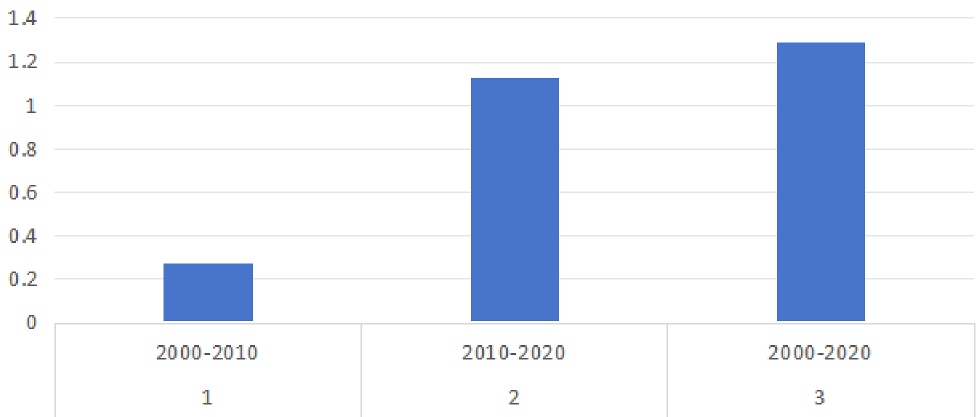


Fig.8 Comprehensive Dynamic Degree of Land Use in Different Periods

4.4 Standard Deviation Elliptical Analysis

To explore the changes in the spatial pattern of land use, the standard deviation and center of gravity migration trajectory of construction land ellipses in different periods of the study area were plotted, and the changes in the spatial pattern of construction land from 2000 to 2020 were analyzed (Figure 9, Table 7).

From the center of gravity coordinates, the distribution of the center of gravity of construction land from 2000 to 2020 was between (119° 33′ 32.48" to 119° 38′ 14.75", 32° 00 ′ 30.47" to 32° 09′ 19.15"), located in the northeast direction of Zhenjiang, indicating that there have been significant changes in construction land in the east and north in the past two decades.

From the perspective of the direction of center of gravity migration, the center of gravity of construction land shifted towards the northeast from 2000 to 2010 and towards the southwest from 2010 to 2020. Overall, in the past two decades, the focus of construction land has shifted from northeast to southwest, mainly in the central area of Dantu District.

From the perspective of the long axis direction, the construction land decreased from 28.29km in 2000 to 25.04km in 2010, and then increased to 27.59km in 2020, showing a trend of first decreasing and then increasing. This indicates that during this period, the construction land showed a phenomenon of first diverging and then converging in the "northeast southwest" direction, and the construction land area showed a trend of first decreasing and then increasing in the "northeast southwest" direction.

From the perspective of the short axis, the construction land increased from 17.81km in 2000 to 18.20km in 2020, showing an increasing trend. This indicates that the construction land during this period diverged in the "northeast southwest" direction, and the construction land area showed an increasing trend.

From the perspective of azimuth changes, there has been a trend of first decreasing and then increasing in the past two decades, decreasing from 61.25° in 2000 to 57.71° in 2010, and then increasing to 70.36° in 2020. This indicates that the construction land area in Zhenjiang has been decreasing before 2010 and has increased between 2010 and 2020.

Table 7 SDE Parameters of Construction Land from 2000 to 2020

Year	Barycentric coordinate		Long axis/km	Short axis/km	Azimuth angle/°
	Longitude	Latitude			
2000	119°33′32.48"	32°08′57.36"	28.29	17.81	61.29
2010	119°38′14.75"	32°09′19.15"	25.04	17.09	57.71
2020	119°35′32.24"	32°00′30.47"	27.59	18.2	70.36

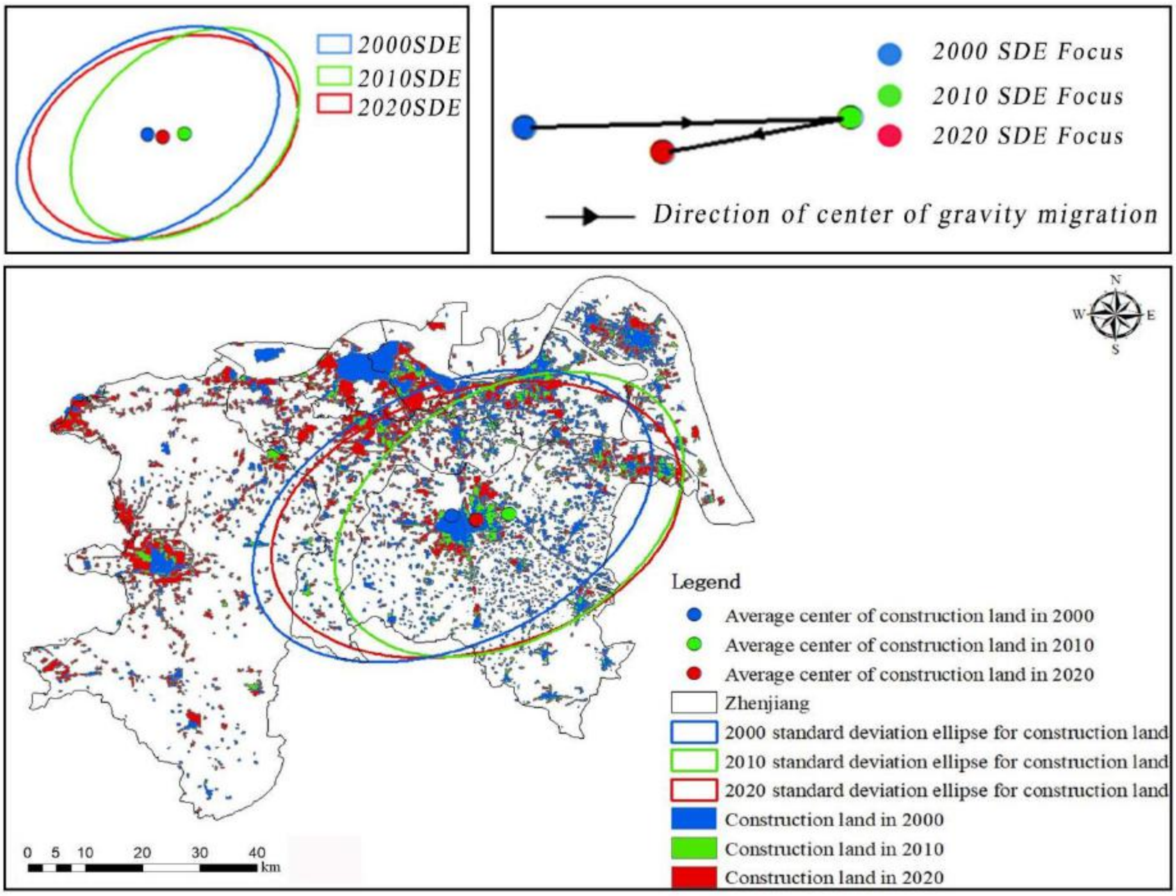


Fig.9 SDE and Center of Gravity Migration Trajectory of Construction Land from 2000 to 2010

V. CONCLUSION

This study uses the land use data of Zhenjiang City in 2000, 2010, and 2020 as the benchmark and adopts the methods of transition matrix, dynamic degree analysis, and SDE to analyze the spatiotemporal changes of land types from 2000 to 2020. The results indicate that land use types are divided into cropland, forests, grasslands, wetlands, water bodies, and construction land. Among them, cropland, construction land, forests, and water bodies are the main areas, while grasslands and wetlands account for a relatively small proportion. Their specific areas are cropland>construction land>forests>water bodies>wetlands>grasslands.

In terms of changes, the decrease in cropland area is the most significant, while the increase in construction land is the largest, indicating that the urban development of Zhenjiang is rapid, and its development speed and scale have greatly improved [21]. On the other hand, it indicates that during this period, the land in Zhenjiang has been greatly affected by human activities, and the ecological environment quality has been greatly impacted, posing significant challenges and pressures to the environment. In terms of spatial changes, the expansion of construction land is concentrated in the northern and central regions, indicating that the northern and central regions of Zhenjiang are in an accelerated stage of urbanization. Urban infrastructure, public service facilities, etc. are constantly improving, attracting more population and enterprises to settle in, thereby promoting the expansion of construction land. In addition, the continuous decrease in cropland area in the past two decades indicates that with the economic development of Zhenjiang and the acceleration of urbanization and industrialization processes, the demand for construction land is constantly increasing. This has led to the conversion of some cropland into urban construction land, industrial land, etc., resulting in a continuous decrease in cropland area. The area of wetlands and forests first decreased and then increased, indicating that from 2000 to 2010, due to a lack of sufficient ecological protection awareness and to meet the needs of economic development and population growth, the wetland resources in Zhenjiang were damaged and occupied to a certain extent during the acceleration of urbanization, industrialization, and other processes. Some wetlands were converted into construction land or other uses. The expansion of land in the process of urbanization has also led to the occupation of some forests, thereby reducing the forest area.

In terms of land use transfer, the area of cropland transferred to construction land was the largest from 2000 to 2010, indicating that with the rapid development of Zhenjiang's economy, higher requirements have been put forward for the utilization of land resources, and the occupation and impact of cropland are the most severe. The water bodies are transferred from cropland, indicating that Zhenjiang has increased its efforts to protect and restore water resources. By implementing a series of ecological protection measures, such as establishing wetland protection areas and restoring damaged water ecosystems, the water area has been effectively increased. From 2010 to 2020, the main circulation of cropland was forests and water bodies, indicating that Zhenjiang increased its efforts to protect the ecological environment and water resources during this period, and implemented a series of greening projects. These projects include returning farmland to forests, afforestation, etc., aimed at increasing forest coverage and improving the ecological environment.

In terms of land use dynamics, the comprehensive land use dynamics showed an increasing trend from 2000 to 2020, reaching a maximum value of 1.13% from 2010 to 2020, indicating that the transformation of land use types was most intense from 2010 to 2020. This indicates that there has been frequent conversion between land use types during this period, and significant changes have occurred in land use patterns due to factors such as economic development and population growth. Among them, the single land use dynamics of wetlands and construction land were the highest during this period, reaching peak values of 4.09% and 10.87%, respectively. On the one hand, it indicates that wetlands have suffered severe degradation during this period due to excessive development and utilization of wetland resources caused by human activities such as urbanization and industrialization. On the other hand, it indicates that with the growth of population and economic development, the demand for construction land in cities continues to increase, leading to the continuous expansion of construction land area.

In the past two decades, the center of gravity of construction land has undergone significant changes, shifting from northeast to southwest. On the one hand, it indicates that the economic vitality and development potential of the Southwest region are gradually increasing, attracting more investment and population inflows, and thereby promoting the expansion of construction land in the region. On the other hand, it also reflects the continuous optimization of urban spatial layout in the process of urbanization in Zhenjiang in order to meet the new needs of economic and social development and promote the city's development towards a more balanced and sustainable direction.

ACKNOWLEDGEMENTS

The author is grateful for the research grants given to Ruei-Yuan Wang from GDUPT Talents Recruitment, Peoples R China under Grant No.2019rc098, and Academic Affairs in GDUPT for Goal Problem-Oriented Teaching Innovation and Practice Project Grant No.701-234660.

REFERENCES

[1] Sun, X., Li, G., Ren, X., Zhang, M, Wang, J., Zhao, Q., and Li, P. Land use change and its ecological environment effects under urban expansion in Anhui Province. Environmental Science, 2024, (10): 1-17.

[2] Jie, K., and Liao, W. Research on the spatiotemporal characteristics and driving forces of land use changes in Yumen City based on geographical monitoring data. Land and Natural Resources Research, 2024, (06): 26-31.

[3] Appiah, O. D., Schröder, D., Forkuo, K. E., and Bugri, T.J. Application of Geo-Information Techniques in Land Use and Land Cover Change Analysis in a Peri-Urban District of Ghana. ISPRS International Journal of Geo-Information, 2015,4(3):1265-1289.

[4] Enaruvbe, G.O., and Atedhor, G.O. Spatial analysis of agricultural land use change in asaba. Ife Journal of Science, 2015,17(1):65-74.

[5] Wang, J., Zhang, F., Cai, J., and Li, Y. Spatial and temporal changes in land use and vegetation cover in arid areas and their correlation analysis. Grassland Science, 2024, (10): 1-15.

[6] Kang, P., Wu, B., Gao, F., Du, M., Wang, C., and Cao, W. Analysis of spatiotemporal changes and driving factors of land use in the plain area of Changji Prefecture. People's Yangtze River, 2024, 55 (08): 59-68.

[7] Luo, X., Wu, H., and Zhao, S. Research on Changes in Land Use Landscape Pattern in Qinzhou City from 2000 to 2020. Surveying and Spatial Geographic Information, 2024, 47 (08): 85-88.

[8] Wang, S., Tang, G., Wu, D., and Xiang, J. Land Ecological Environment Status and Main Ecological Environment Problems in Beihu District. Modern Agriculture, 2008, (04): 60-61.

[9] Geng, B., and Huang, C. Research on Regional Development Planning of Zhenjiang City. Urban Architecture, 2024, 21 (05): 137-141+168.

[10] Fang, K. Preliminary exploration of urban renewal planning strategies under the background of the stock era: taking the urban renewal planning of the southern area of Jiangsu University in Zhenjiang City as an example. Jushe, 2024, (04): 115-118.

[11] Sun, Z., Gao, L., and He, Y. Reflections on Promoting Ecological Civilization Construction through Green Development: A Case Study of Zhenjiang City. Environmental Protection and Circular Economy, 2020, 40 (06): 1-3.

[12] Ou, D., Zhang, Q., Qin, J., Gong, S., Wu Y., Zheng, Z., and Gao, X. Construction of a County Land Spatial Classification System Based on the Dynamic Coupling of Land Use and Its Functions. Journal of Agricultural Engineering, 2021, 37 (24): 284-296.

[13] Jia, J., Su, X., Zhang, J., Zhang, M., Li, X., and Wei, W. Spatial and temporal changes in land use damaged by landslides in the loess area of Tianshui City from 1985 to 2020. Journal of Soil and Water Conservation, 2023, 37 (04): 195-204.

[14] Li, Y., Gao, C., Chen, H., Liu, Y., Li, J., and Guo, Z. Spatial and temporal evolution analysis of land use in Duyun City from 2000 to 2020 based on GlobeLand30. China Resources Comprehensive Utilization, 2022, 40 (09): 71-76.

[15] Huang, Y., Yang, R., and Feng, Y. Spatial study of urban fringe area in Gongyi City based on comprehensive land use dynamic changes from 1990 to 2020. Forestry Survey and Planning, 2024, 49 (02): 6-12.

[16] Wang, Y., and Huang, L. Spatial and Temporal

Characteristics Analysis of Land Use Dynamic Changes in Chenggong District, Kunming City from 2003 to 2018. Science, Technology and Engineering, 2019,19 (28): 42-49.

[17] Deng, W., Zhao, L., Wang, W., and Lu, G. Construction and Evaluation of Agricultural Sustainable Development Index System in Zhenjiang City. Sichuan Environment, 2004, (06): 31-34.

[18] Zhang, X. Problems and Improvement Countermeasures in the Quality Assessment of Supplementary Farmland in Yangzhong City. Modern Agricultural Science and Technology, 2015, (04): 348-349+352.

[19] Yin, Y., Zhang, W., and Li, L. Dynamic changes and transformation strategies of forest phase in Zhenjiang Nanshan National Forest Park. Jiangsu Forestry Science and Technology, 2011, 38 (02): 54-56.

[20] Zhao, B., Zhuang, R., and Wang, S. Strategies for the Transformation and Optimization of Administrative Divisions in Jiangsu Province Based on Spatial Field Energy. Economic Geography, 2016, 36 (06): 8-17.

[21] Li, Q. Research on New Driving Forces of Industrial Economic Growth: A Case Study of Zhenjiang City. China Collective Economy, 2019, (32): 18-19.

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Physiological and biochemical characterization cellulolytic bacteria

S. D. Bharambe[1,*], Kunvar Gyanendra Kumar[2], R. P. Singh[3], A. S. Pawar[4]

[1]Ph.D. Scholar, Dept. Agriculture Biotechnology, Bhagwant University, Rajasthan, India.
[2]Faculty of Agriculture, Bhagwant University, Rajasthan, India
[3]Dean of Agriculture, Bhagwant University, Rajasthan, India
[4]Research Scholar, Dept. Agriculture Biotechnology, Bhagwant University (Rajasthan), India.
Corresponding author: surekhapatil08@gmail.com

Received: 22 Sep 2024; Received in revised form: 19 Oct 2024; Accepted: 25 Oct 2024; Available online: 01 Nov 2024

***Abstract*— *Several efficient cellulase producing microorganisms were isolated. The purpose was to identify and characterize those isolates displaying the greatest cellulase activity for the possible use in the large scale biorefining. Cellulases are inducible enzymes that are synthesized by a large number of microorganisms during their growth on cellulosic materials. Cellulases have attracted much interest because of the diversity of their applications. Cellulases are used in the various industrial process, including textile and laundry, food, feed, leather, pulp and paper. The biochemical characterizations of the isolated Bacterial strains from termite gut. .Isolated strains are efficient namely TG I and TG II. Indicate that they may play a role in cellulose digestion in termite gut.*

***Keywords*— Bacteria, Cellulase, Termites, Biochemical study and Enzyme**

I. INTRODUCTION

Bacteria has high growth rate as compared to fungi has good potential to be used in cellulose production. Some bacterial species viz., *Cellulomonas species*, *Pseudomonas species*, *Bacillus species* and Micrococas have cellulolytic property [15]. Large number of bacteria are capable of degrading cellulose, but only a few of them produce significant quantities of cell-free bioactive compounds capable of completely hydrolyzing crystalline cellulose in-vitro [16]. Cellulolytic bacteria have been isolated from diverse habitats like soil, compost, and water [8] .Common classification separates different pretreatments into physical, chemical, physicochemical, and biological treatments [18]. Enzymatic hydrolysis, pre-treatment of cellulosic material is utmost importance to obtain glucose which can be further converted into bioethanol by microbes [2, 11, 17, and 22]. Bacteria are now being widely explored for cellulase production because of their extremely high natural diversity and the capability to produce stable enzymes that can be applied in industries [3, 9].

II. MATERIAL AND METHODS

A. Sample collection: Termite Sample was collected from sites which includes cellulose feeding organisms, such as termite residing on woody western ghat region Maharashtra state. Sample dissect in 0.9% saline solution under sterile condition. 1.0 gram of each sample is placed in 9 ml of 0.9% saline, mixed it rapidly and Serial dilution techniques was followed and the dilutions selected for further studies.

B. Isolation cellulolytic Bacteria`: The mixture was mixed by vortex for 2-3 mins for removal of microorganisms. One ml of this sample was plated by serial dilution (up to 10^{4-} (technique amended with CMC agar and incubated at 37°c for 24 -48 hours. Bacterial cultures grown on CMC slants were cultured on basal mineral salt medium (BSM) as shown Fig 01.

C. Culture and Biochemical Characteristics

I. Morphology

Test \ Sample	TG I	TG II
Shape	Cocci	Cocci
Gram strain	Positive	Positive
Motility	Motile	Motile

II. Colony Characteristics

Test \ Sample	TG I	TG II
Colour	Dirty white	Dirty white
Elevation	Convex	Convex
Density	Opaque	Opaque
Opti. Temp	30^0C	30^0C
Opti. pH	7	7

III. Biochemical Test

Test \ Sample	TG I	TG II
I) Starch hydrolysis	+	-
II) Carbohydrate fermentation		
Arabinose	+	-
Maltose	+	+
Lactose	+	-
Mannitol	-	+
Starch	+	-
Cellulose	+	+
Glucose	-	+
III)H2S production	- (Alkaline)	- (acidic)
IV)Simmon citrate	+	+
V)Caseic hydrolysis	+	-
VI) Catalase	+	+

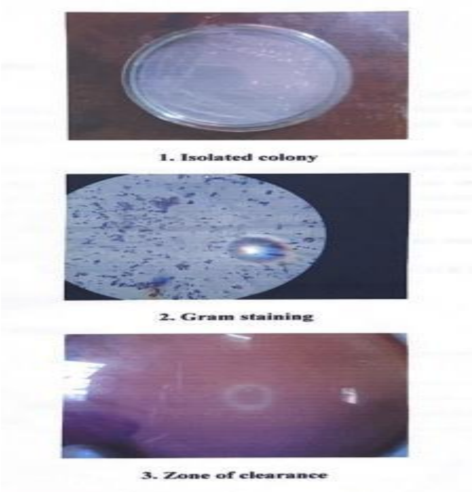


Fig.1 Isolated Bacteria.

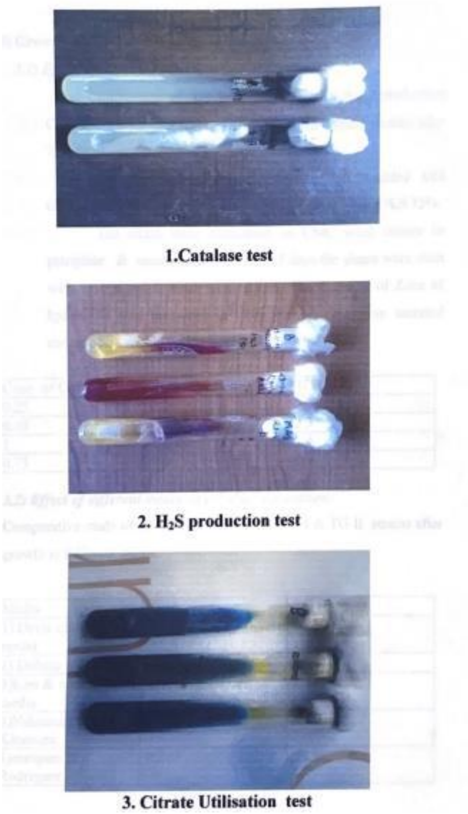


Fig.2 - Biochemical Test

III. RESULTS AND DISCUSSION

Gram stain was an empirical method of distinguishing bacterial species into two large groups (Gram-positive and Gram-negative) based on the presence of chemicals, primarily the presence of high levels of peptidoglycan and physical properties of their cell walls. A number of cellulolytic bacterial colonies were isolated from Termite gut. The colony morphology was studied in detail and the results are presented in Tabulation with heading also followed by biochemical tests performed for the isolated microorganisms.as shown fig 02. Clear zone producing bacterial isolates were then subjected to various biochemical test.

IV. CONCLUSIONS

With the help of biochemical tests) we could conclude that bacterial isolate belongs to genus belongs to genus Bacillus. A potential cellulose degrading enzyme from B. subtilis was characterized and studied for its possible hydrolyzing capability for disintegrating the cellulosic biomass residues.

ACKNOWLEDGEMENT

The authors are thankful to all Faculty Bhagwant university.

REFERENCES

[1] Acharya, A. Joshi, D. Shrestha, K. Bhatta, D. (2012). Isolation and screening of thermophilic cellulolytic bacteria from compost piles. Scientific world.10: 43-6.

[2] Arora, S. Khajuria, R and Kaur, L. (2015). Non Alcoholic, Naturally-Carbonated Beverage from Daucus carota Using Saccharomyces cerevisae Isolate. Carpathian Journal of Food Science & Technology, 7(2).

[3] Ashjaran, A and Sheybani S. (2019).Drug Release of Bacterial Cellulose as Antibacterial Nano Wound Dressing. International Journal of Pharmaceutical Research and Allied Sciences. 8(3):137-143.

[4] Chilana, H. Arora, S. Khajuria, R and Kaur, L. (2015). Non-Alcoholic, Naturally-Carbonated Beverage from Vitis Vinifera Using Saccharomyces cerevisae Isolated from Cheese Whey. Online Journal of Biological Sciences, 15(3): 184.

[5] Davinder, A. Kumar, A. Singh, R. Pratap, S and Singh, B. (2017). Impact of zinc and boron on growth, yield and quality of Kinnow (Citrus deliciosa x Citrus nobilis) in sub-tropical conditions of Punjab. Journal of Pure and Applied Microbiology, 11(2): 1135-1139.

[6] Faridha, B. Meignanalaksmi, S and Pandima, D. (2013).Isolation and Characterization of Cellulase Producing Paracoccus Pantotrophus fmr19 (jx012237) from Goat Rumen Fluid and Its Effects on pH, Temperature and Carbon Sources. International Journal of Advanced Biotechnology and Research. 4: 384-390.

[7] Ge, X. Chang, C. Zhang, L .Cui, S. Luo, X. Hu, S. Qin, Y and Li, Y. (2018). Conversion of lignocellulosic biomass into platform chemicals for biobased polyurethane application. ―In: Li Y & Ge X. (eds.), Advances in Bioenergy, Vol 3, Elsevier, pp.161-213.

[8] Gupta, P. Samant, K and Sahu, A. (2012): Isolation of cellulose-degrading bacteria and determination of their cellulolytic potential, International journal of microbiology, 2012.

[9] Haakana, H. Mittinen-Oinonen, A. Joutsjoki, V. Mantyla, A. Souminen, P and Vahmaanpera J.(2004) Cloning of cellulase from Melanocarpus albomyces and their efficient expression in Trichoderma reesei. Enzyme Microbial Technology. 34:159-167.

[10] Heptinstall, J. Stewart, J. and Seras, M. (1986). Fluorimetric estimation of exocellobiohydrolase and β-d-glucosidase activities in cellulase from Aspergillus fumigatus Fresenius. Enzyme Microb. Technol. 8, 70–74. doi: 10.1016/0141- 0229(86)90073-6.

[11] Kaur, J. Kumar, V. Goyal, A.. Tanwar, B. Gat, Y. Prasad, R and Suri, S. (2019). Energy drinks: health effects and consumer safety. Nutrition & Food Science.

[12] Kuhad, R.Gupta, R and Singh, A. (2011) Microbial cellulases and their industrial applications. Enzyme Res.vol.2011, pp.1–10,

[13] Kumar, A. Joshi, V and Kumar, V. (2020). Systematic investigation on production and quality evaluation of lugdi: a traditional alcoholic beverage of Himachal Pradesh, India. Journal of Microbiology, Biotechnology and Food Sciences, 9(4): 1307-1311.

[14] Li, X and Gao, P. (2008) Isolation and partial properties of cellulose-decomposing strain of Cytophaga sp. LX-7 from the soil. J. Appl. Microbiol. 82: 73-80.

[15] Nakamura, K and Kappamura K. (1982). Isolation and identification of crystalline cellulose hydrolyzing bacterium and its enzymatic properties. J Ferment Technol, 60 (4): 343-8.

[16] Patagundi, B. Shivasharan, C and Kaliwal, B. (2014). Isolation and Characterization of Cellulase producing bacteria from Soil. International Journal of Current Microbiology and Applied Science, 3(5): 59-69.

[17] Pramanik, T and Maji, P. (2015). Microwave assisted green synthesis of pharmaceutically important dihydropyrimidinones in fruit juice medium. Int J Pharm Pharm Sci, 7, 376-9. Pramanik, T.; & Padan, S. K. (2016a). Microwave irradiated "green biginelli reaction" employing apple, pomegranate and grape juice as eco-friendly reaction medium. Pharmacology, 1, 4.

[18] Ravindran, R and Jaiswal A. (2016). A Comprehensive Review on Pre-treatment Strategy for Lignocellulosic Food Industry Waste: Challenges and Opportunities. *Bioresour. Techn.* 199, 92–102.

[19] Sangma, C. Kumar, V. Suri, S. Gat, Y. Kaushal, M and Kumar, A. (2019). Preservation and evaluation of spiced chayote juice using hurdle technology. Brazilian Journal of Food Technology, 22.

[20] Soares, F. Melo, I. Dias, A and Andreote, F. (2012). Cellulolytic bacteria from soils in harsh environments. World J. Microbiol. Biotechnol. 28, 2195–2203. doi: 10.1007/s11274-012-1025-2.

[21] Mijena, D., Getiso, A., & Felecho, J. (2024). Assessing Artificial Insemination Service Effectiveness and Evaluation of Semen Quality in West Arsi Zone of Oromia Region, Ethiopia. In International Journal of Forest, Animal And Fisheries Research (Vol. 8, Issue 3, pp. 01–18). https://doi.org/10.22161/ijfaf.8.2.1

[22] Teather, R. and Wood, P. (1982). Use of Congo red Polysaccharide Interactions in Enumeration and Characterization of Cellulolytic Bacteria from the Bovine Rumen. Applied and Environmental Microbiology, 43(4):777-780.

[23] Shyamsunder, B., Menon, Dr. S., Walia, Dr. U. S., Prasanna, T., Raju, G. S. K., & Nawabpet, P. (2024). Effect of intercropping wheat (triticum aestivum.L.) with mustard (brassica juncea) on yield and economics under organic system of cultivation. In International Journal of Environment, Agriculture and Biotechnology (Vol. 9, Issue 2, pp. 218–223). https://doi.org/10.22161/ijeab.92.24

[24] Nyanyoh, B. B., & Wanie, C. M. (2024). Categorisation of Rural Development Stakeholders in Bui Division, North

West Region of Cameroon. In International Journal of Rural Development, Environment and Health Research (Vol. 8, Issue 2, pp. 44–53). https://doi.org/10.22161/ijreh.8.2.5

[25] Ranjbaranghaleh, A. (2024). Policy and Regulatory Frameworks Addressing Methane Emissions in Dairy Farming. In International Journal of Horticulture, Agriculture and Food science (Vol. 8, Issue 3, pp. 53–56). https://doi.org/10.22161/ijhaf.8.3.7

[26] Zhang, H. Huang, S. Wei, W. Zhang, J and Xie, J. (2019): Investigation of alkaline hydrogen peroxide pretreatment and Tween 80 to enhance enzymatic hydrolysis of sugarcane bagasse, Biotechnology for biofuels, 12(1): 107.

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available:https://ijeab.com/
Journal DOI:10.22161/ijeab

Assessing the Environmental Impact of Compostable Bioplastic Bags

Tapsi Jain, Yashika Grover, Shreya Jain, Hyma Yadav

Department of Science, Delhi Public School Ghaziabad, Meerut Road, India
Email: hmsec.mrd@dpsgs.org
Department of Science, Delhi Public School Ghaziabad, Meerut Road, India
Email: yashikag.mrd@dpsgs.org
Department of Science, Delhi Public School Ghaziabad, Meerut Road, India
Email: Dr.charuagarwal@gmail.com
Department of Science, Delhi Public School Ghaziabad, Meerut Road, India
Email: yadava.anurag@gmail.com

Received: 19 Sep 2024; Received in revised form: 20 Oct 2024; Accepted: 28 Oct 2024; Available online: 04 Nov 2024

Abstract— *Plastics made from fossil fuels contribute to pollution and disrupt ecosystems. While bioplastics and compostable bags that are made from renewable materials offer promising alternatives, they can also have severe effects such as eutrophication. Bioplastics can increase the soil nutrients like nitrogen (under certain conditions). A huge impact has been made by bioplastic additives on soil's physical, chemical, and biological properties, land, human health, flora and fauna, and the environment in general.*

Keywords— ***Bioplastics, Biomass, Compostable bags, Plastic pollution, Soil health.***

I. INTRODUCTION

Alternative to traditional plastic bags are compostable bags. Compostable bags are made from renewable resources and degrade more easily, making them better for our planet. Compostable bags are an eco-friendly alternative to conventional plastic bags. They are made from natural materials. These bags play a crucial role in reducing waste in landfills and mitigating climate change. When composted, they turn into three main components: biomass, water, and carbon dioxide. Bioplastics are made from plant-based products making them way better than traditional plastics. However, despite their sustainability, they also have some drawbacks. Feeding a large population is a challenge, and now growing plants for bioplastics will compete with food production and compromise the demands of our population. Also, the fertilizers and pesticides used for biomass production can flow down water bodies and lead to eutrophication. Bioplastics have lower human and terrestrial environmental toxicity and carcinogenic potential than traditional plastics, but they are more harmful to aquatic ecosystems.

Plastic trash bags are the most common method of waste disposal in households. Landfill sites are overflowing with non-biodegradable plastic bags, posing a severe threat to our planet. On the other hand, this research has consistently highlighted the detrimental impact of bioplastic bags on land, human health, and ecosystems. Compostable bags offer a potential solution to this pressing environmental issue.

II. OBJECTIVES

- To compare the environmental impacts of bioplastics and traditional plastic bags, considering factors such as greenhouse gas emissions, and resource consumption.
- To assess the effects of compostable bioplastic bags on soil ecosystems, including their biodegradability, impact on soil fertility, and microbial activity.

- To evaluate the economic and social practicality of transitioning from traditional plastic bags to compostable bioplastic bags, considering their potential impacts on food security and resource competition.

III. RATIONALE OF THE STUDY

The purpose of the study was to find out how bioplastics affect the soil health and the surroundings present in compostable bags. Compostable bags are often seen as a better choice than regular plastic bags, but we need to know more about how they impact the soil. The study is an attempt to investigate how effective are these bioplastics present in compostable bags. This research will bring forth the resultant soil quality when compostable bags are disposed of in the ground and the quality of compost created.

By examining how biodegradable bags break down and influence soil nutrients and organisms, we can determine their overall impact on the environment. This information is crucial for making informed decisions about using compostable bags and promoting sustainable waste management practices.

IV. METHODOLOGY

This research aims to assess the impact of bioplastics on soil health, with a particular focus on compostable bags. Due to the nature of the inquiry, a secondary research approach will be employed. This section details the methodology used to analyse existing research on the subject. A comprehensive search for relevant scientific papers, articles, and reports was conducted using online databases such as Google Scholar, ScienceDirect, and Web of Science. This paper includes details on the type of bioplastic material used, the composition of the compostable bags, soil properties evaluated, and the observed impacts on soil health parameters like nutrient levels or microbial activity.

By following these outlined steps, this research has analysed the data from existing studies to assess the current understanding of how bioplastics, particularly compostable bags, impact soil health.

V. RESULTS AND DISCUSSIONS

5.1 Chemical Composition of Compostable Bags

Bio-compostable bags are made from bioplastics, like PHA (polyhydroxyalkanoate), PBAT (Polybutylene Adipate Terephthalate), and PLA (Polylactic acid), which is generally made from the sugars in corn starch, cassava, or sugarcane. PLA is usually made from cornstarch, cassava, or sugarcane. These bioplastics break down in three to six months, much faster than regular plastics that take hundreds of years to decompose. When they break down, they turn into carbon dioxide, water, biomass, and/or mineral salts when they are exposed to air.

5.2 Degradation of Bioplastics

Some of the plastic can degrade. Amongst them, some take a long time to degrade others do not. Bioplastics are made from plant products, so they can degrade easily. But when bioplastics degrade, they can release methane due to the lack of oxygen. Methane is a greenhouse gas which contributes to climate change.

5.3 Effects of Bioplastics in Soil

Plastic degradation in soil has known adverse effects on soil nutrition and plant growth. However, the breakdown of bioplastics in soil has a different impact. As bioplastics are derived from starch and vegetable oils, their decomposition increases soil nutrient levels by releasing these components into the soil. Moreover, the degradation of bioplastics releases carbon compounds, promoting microbial growth. This process also contributes to the organic matter in the soil, improving its water-holding capacity.

While this is beneficial, it's important to note that microorganisms like bacteria and fungi involved in bioplastic decomposition utilize essential nutrients, like nitrogen and phosphorus to metabolize bioplastics, potentially leading to a shortage of these nutrients in the soil. While bioplastics can release nutrients, the net effect on nutrient availability for plants is complex and depends on factors like microbial activity and the specific type of bioplastic. There will be a shortage of nutrients in soil after bioplastic degradation unless there are prior nutrients present in the soil as microorganisms require nutrients for metabolizing bioplastics.

5.4 Advantages of Bioplastic Degradation

•Increased Soil Fertility

- Organic Matter Contribution: Some types of bioplastics, especially those produced from organic ingredients such as cellulose or starch can decompose into soil-enriching organic matter thus improving fertility and structure.
- Nutrient Release: Bioplastics can disintegrate and release into soil carbon, nitrogen, and other vital elements necessary for the growth of plants and microbial activities.

•Reduction in conventional Plastic Pollution

- Biodegradability: Bioplastics designed to decompose naturally can lessen the build-up of traditional plastic materials in soils that usually last centuries causing environmental degradation.
- Less Microplastic Formation: The risk of microplastic contamination in soil is lower when properly formulated bioplastics are used because they degrade more thoroughly than conventional plastics thereby reducing the possibility of ecological disturbance within soils' ecosystems through entry into food chains.

Decreased Ecotoxicity

- Reduced Chemical Additives: Unlike common types of plastics, a lot of bioplastics have reduced toxic additives which implies that the danger of poisonous substances leaching to the ground is minimized hence promoting beneficial organisms living in it and maintaining soil health.
- Safer Decomposition: At times, breakdown products originating from decomposition processes involving bioplastic may be less toxic to soil organisms; therefore encouraging healthier and more balanced.

5.5 Disadvantages of Bioplastic Degradation

•Misleading biodegradation information: Not all bioplastics degrade completely in the natural environment. Some require composting technologies with specific conditions (high temperature, humidity) that are not always handled in natural soil. As a result, these bioplastics can persist in the environment, causing pollution like conventional plastics.

•Microplastic formation: As bioplastics degrade, they may break down into microplastics instead of disappearing altogether. These microplastics can accumulate in the soil, causing long-term pollution.

•Physical degradation: Bioplastics can interfere with soil structure by altering soil porosity and water-holding capacity, and can affect plant root systems and microbial communities

•Effects on soil organisms: Bioplastics in soil can adversely affect soil organisms such as earthworms and microorganisms that play an important role in maintaining soil health and fertility

•Residual toxins: Some bioplastics contain chemical additives (such as plasticizers, stabilizers, and colorants) that can leach into the soil during decomposition These chemicals can be toxic to soil bacteria, plants, and groundwater, and it has destroyed the ecosystem.

•Accumulation of heavy metals: Some bioplastics, especially those produced from agricultural residues or industrial by-products, may produce small amounts of heavy metals and as these bioplastics degrade, the metals can accumulate in the soil, which can cause toxicity issues.

•Agricultural Applications: The production of bioplastics is heavily dependent on crops such as maize, sugarcane, and potatoes, which need large amounts of water and fertilizers.

VI. CONCLUSION

Bioplastics are derived from renewable resources, such as cornstarch, sugarcane, or potato starch. These materials offer environmental benefits by **reducing reliance on fossil fuels and decreasing the carbon footprint**.

Bioplastics also break down more rapidly than conventional plastics, especially in composting conditions. Bioplastics have the potential to provide a sustainable and eco-friendly alternative to traditional plastics by reducing non-renewable energy consumption and greenhouse gas emissions.

However, they also have a negative impact on soil health and surroundings. All bioplastics do not fully degrade naturally. Some require industrial composting facilities with specific conditions (high temperature, humidity) that are not always met in natural soils. Additionally, when bioplastics degrade, they may break down into microplastics rather than completely disappearing. These harmful microplastics can accumulate in the soil, leading to long-term contamination.

Microplastics resulting from bioplastic degradation can accumulate in soils and negatively affect agricultural productivity. Proper plastic waste management is crucial to mitigate these harmful effects. However, their environmental impacts, particularly with regard to eutrophication, acidification, and ozone depletion, must be considered. Bioplastics have a high degradation rate due to their material composition; their high degradation rate solves a major problem which is soil contamination. Bioplastics have the potential to transform our world into a cleaner and better place.

REFERENCES

[1] Sintim, H. Y., Bandopadhyay, S., English, M. E., Bary, A. I., DeBruyn, J. M., Schaeffer, S. M., Miles, C. A., Reganold, J. P., & Flury, M. (2019). Impacts of biodegradable plastic mulches on soil health. *Agriculture, Ecosystems & Environment*, *273*, 36-49. https://doi.org/10.1016/j.agee.2018.12.002

[2] Maji, P., & Mistri, B. (2021). Assessment on the impact of plastic-contaminated fertilizers on agricultural soil health: A case study in Memari II C.D. Block, Purba Bardhaman, West Bengal, India. In P. K. Shit, P. P. Adhikary, & D. Sengupta (Eds.), *Spatial Modeling and Assessment of Environmental Contaminants* (pp. 1–16). Springer. https://doi.org/10.1007/978-981-16-2373-6_12

[3] Grover, Y., & Goel, S. (2016). Feasibility of compostable bags for disposal of solid waste in urban households. *International Journal of Environment, Agriculture and Biotechnology*. https://ijeab.com/detail/feasibility-of-compostable-bags-for-disposal-of-solid-waste-in-urban-households/ (Accessed: 27 June 2024)

[4] Sustainability for All. (n.d.). What are bioplastics? https://www.activesustainability.com/environment/what-are-bioplastics/?_adin=02021864894 (Accessed: 28 June 2024)

[5] Zhang, X., Abt, M., Bahaji, A., Blennow, A., Cheng, Y., Dier, M., Du, X., Geilfus, C., Guo, K., Hu, W., Kong, X., Liu, L., Li, X., Murata, T., Tang, S., Tao, Z., Tappiban, P., Yu, W., Zahoor, R., Zhang, W., Zhou, T., Zhu, D., Zörb, C., Ahmad, A., Ai, Y., Balet, S., Beckles, D., Bertoft, E., & Bhatia, S. (2019). Starch biosynthesis and degradation in terrestrial plants. *Environmental Science & Technology*, *53*(9), 4637–4650. https://doi.org/10.1021/acs.est.9b01339

[6] de Souza Machado, A. A., Lau, C. W., Till, J., Kloas, W., Lehmann, A., Becker, R., & Rillig, M. C. (2018). Microplastics in agricultural soils: Sources, pathways, and risks. *Environmental Science & Technology*, *52*(17), 9656-9665. https://doi.org/10.1021/acs.est.8b02212

[7] Liwarska-Bizukojc, E. (2019). Bioplastics and their environmental impact. *Environmental Technology & Innovation*, *14*, 100354. https://doi.org/10.1016/j.eti.2019.100354

[8] Adhikari, D., Mukai, M., Kubota, K., Kai, T., Kaneko, N., Araki, K. S., & Kubo, M. (2016). Degradation of bioplastics in soil and their degradation effects on environmental microorganisms. *Journal of Environmental Science*, *28*, 1-10. https://www.scirp.org/journal/paperinformation?paperid=64039

[9] State of the Planet. (2017). The truth about bioplastics. https://news.climate.columbia.edu/2017/12/13/the-truth-about-bioplastics/ (Accessed: 28 June 2024)

[10] Accinelli, C., Adhikari, K., Adhikari, R., Ali, S., Balaguer, M., Barbale, M., Brennecke, D., Brizga, J., Brodhagen, M., Bronick, C., Calabria, L., Castronuovo, D., Černá, T., Chae, Y., Chen, H., Colares, G., & Gryze, S. D. (2019). Bioplastics and their applications in agriculture: Opportunities and challenges. *Environmental Science & Technology*, *53*(10), 6044–6052. https://doi.org/10.1021/acs.est.9b01339

[11] Richard, S. (2022). Bioplastics and their impact on the environment. *Research & Reviews: Journal of Medicinal & Organic Chemistry*. https://www.rroij.com/open-access/bioplastics-and-their-impact-on-environment.php (Accessed: 28 June 2024)

[12] INNOV. (2024). Beyond plastic: Can bioplastics help us deal with plastic pollution? https://innovation.eurasia.undp.org/beyond-plastic-can-bioplastics-help-us-deal-with-plastic-pollution/ (Accessed: 28 June 2024)

[13] Bethanis, J., & Golia, E. E. (2023). Revealing the combined effects of microplastics, Zn, and Cd on soil properties and metal accumulation by leafy vegetables: A preliminary investigation by a laboratory experiment. *Soil Systems*, *7*(3), 65. https://doi.org/10.3390/soilsystems7030065

[14] de Souza Machado, A. A., Lau, C. W., Kloas, W., Bergmann, J., Bachelier, J. B., Faltin, E., Becker, R., & Rillig, M. C. (2019). Impact of microplastics on agricultural soils: A review. *Environmental Science & Technology*, *53*(10), 6044–6052. https://doi.org/10.1021/acs.est.9b01339

[15] Sa'adu, I., & Farsang, A. (2023). Microplastics and their effects on soil ecosystems. *Environmental Sciences Europe*, *35*(1), 10–20. https://doi.org/10.1186/s12302-023-00720-9

[16] Narancic, T., Cerrone, F., Beagan, N., & O'Connor, K. E. (2020). Recent advances in bioplastics: Application and biodegradation. *Polymers*, *12*(1), 1-14. https://doi.org/10.3390/polym12010120

[17] Camu, B. (2019). Using fertilizer? Think twice before you do. *Leaf & Limb*. https://www.leaflimb.com/Traditional-Fertilizers-Cause-More-Harm-Than-Good/ (Accessed: 6 August 2024)

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Impact of *Prosopis cineraria* on Soil organic carbon: Implication for arid agroforestry with a case study of Sardarshahar, Rajasthan

Laxmi Pareek[1], Vinod Kumar Yadav[2], Suman Lata Tripathi[1] and Shilpa Yadav[1]*

[1]Department of Botany, Government Dungar College, Bikaner, Rajasthan, India
[2]ICAR-National Research Centre on Camel, Bikaner Rajasthan, India
*Corresponding author: yadavshilpa14@gmail.com

Received: 20 Sep 2024; Received in revised form: 18 Oct 2024; Accepted: 25 Oct 2024; Available online: 04 Nov 2024

***Abstract*— *Prosopis cineraria (P. cineraria), commonly known as Khejri, plays a significant role in enhancing soil health, particularly in arid and semi-arid regions. This study investigates the impact of Prosopis cineraria on soil organic carbon (SOC) levels in the context of agroforestry systems in Sardarshahar, Rajasthan. The analysis reveals that the presence of this species positively influences SOC concentrations, contributing to improved soil fertility and structure. The deep root system and high biomass production of P. cineraria facilitate the accumulation of organic matter in the soil, leading to higher carbon sequestration potential compared to non-forested areas. Additionally, the integration of this species into arid agroforestry systems can support sustainable agricultural practices in these challenging environments. This case study highlights the ecological benefits of P. cineraria in maintaining soil health in arid regions and discusses about the dynamics of SOC along seasons and soil depth. The findings advocate the importance of incorporating native tree species like Prosopis cineraria into agroforestry practices to enhance soil organic carbon stocks and promote sustainable land management in Rajasthan and similar arid landscapes.*

Keywords*— Soil organic carbon; Prosopis cineraria; Arid; agroforestry; soil fertility

I. INTRODUCTION

Agroforestry, the practice of integrating trees and shrubs into agricultural landscapes, has gained considerable attention as a sustainable land-use strategy, particularly in arid and semi-arid regions (Ntawuruhunga *et al.*, 2023). The incorporation of native tree species into these systems not only enhances biodiversity but also plays a crucial role in improving soil quality, increasing productivity, and mitigating the adverse effects of climate change (Gomes *et al.*, 2020). In this context, soil organic carbon (SOC) is a key indicator of soil health, directly influencing soil fertility, water retention, and nutrient cycling (Solanki *et al.*, 2024). Enhancing SOC levels in arid regions is a significant challenge due to low biomass production and the harsh environmental conditions that limit organic matter accumulation (Visconti *et al.*, 2024).

Prosopis cineraria, commonly known as Khejri, is a drought-resistant tree species native to the Indian subcontinent, particularly prevalent in the arid and semi-arid regions of Rajasthan (Verma *et al.*, 2010). It is widely recognized for its ability to thrive in harsh environments, where it provides a range of ecological and economic benefits in the form of ecosystem services (Yadav *et al.*, 2021). *P. cineraria* have deep root systems and a high biomass production capacity, which makes it particularly effective in stabilizing soils and improving their structure. Additionally, the species is known to contribute significantly to SOC levels by adding organic matter through leaf litter, root turnover, and other biological processes (Verma *et al.*, 2010). *P. cineraria* provide good fuelwood and charcoal. The wood is favoured for cooking and domestic heating (Mahoney, 1990). Village people remain dependent on local and nearby trees for fuelwood and fodder (Yadav *et al.*, 2022).

In arid ecosystems, arbuscular mycorrhizal fungi (AMF) are essential components of the rhizosphere microflora. These fungi play a vital role in breaking down soil organic matter, facilitating nutrient mineralization, and recycling nutrients within the soil (Tarafdar and Rao, 1997; Pare *et al.*, 2000). The distribution and diversity of AMF populations are highly variable and are influenced by several factors, including soil properties, environmental conditions, host plant species, and farming practices (Sanders, 1990; McGongle and Miller, 1996).

Despite the acknowledged benefits of *Prosopis cineraria in* agroforestry, its specific impact on SOC dynamics in arid environments like those found in Rajasthan remains underexplored. Understanding how *P. cineraria* influence SOC in these regions can provide valuable insights into sustainable land management practices and carbon sequestration strategies, which are critical in the face of climate change (Gomes *et al.*, 2020). By promoting *P. cineraria*, land managers can enhance soil fertility, biodiversity, and ecosystem resilience (Yadav and Yadav, 2023).

This study focuses on Sardarshahar, an arid region in Rajasthan, to evaluate the impact of *Prosopis cineraria on* soil organic carbon levels. By comparing SOC concentrations in soils under *P. cineraria* with those in non-vegetated areas, the research aims to elucidate the role of this species in enhancing soil fertility and promoting sustainable agroforestry practices. The findings of this study will help to inform strategies for integrating native tree species into agroforestry systems to optimize soil health and carbon storage in arid landscapes.

II. MATERIAL AND METHODS

Study area

The study was conducted in Sardarshahar, a town located in the Churu district of Rajasthan, India (Figure: 1). Sardarshahar is situated in the northwestern part of the state and falls within the arid region of the Thar Desert (Wikipedia contributors, 2024). The geographical coordinates of the study area are approximately 28.44° N latitude and 74.49° E longitude, with an average elevation of about 312 meters above sea level. The region experiences extreme climatic conditions characterized by high temperatures, low and erratic rainfall, and significant variations in day and night temperatures (Wikipedia contributors, 2024).

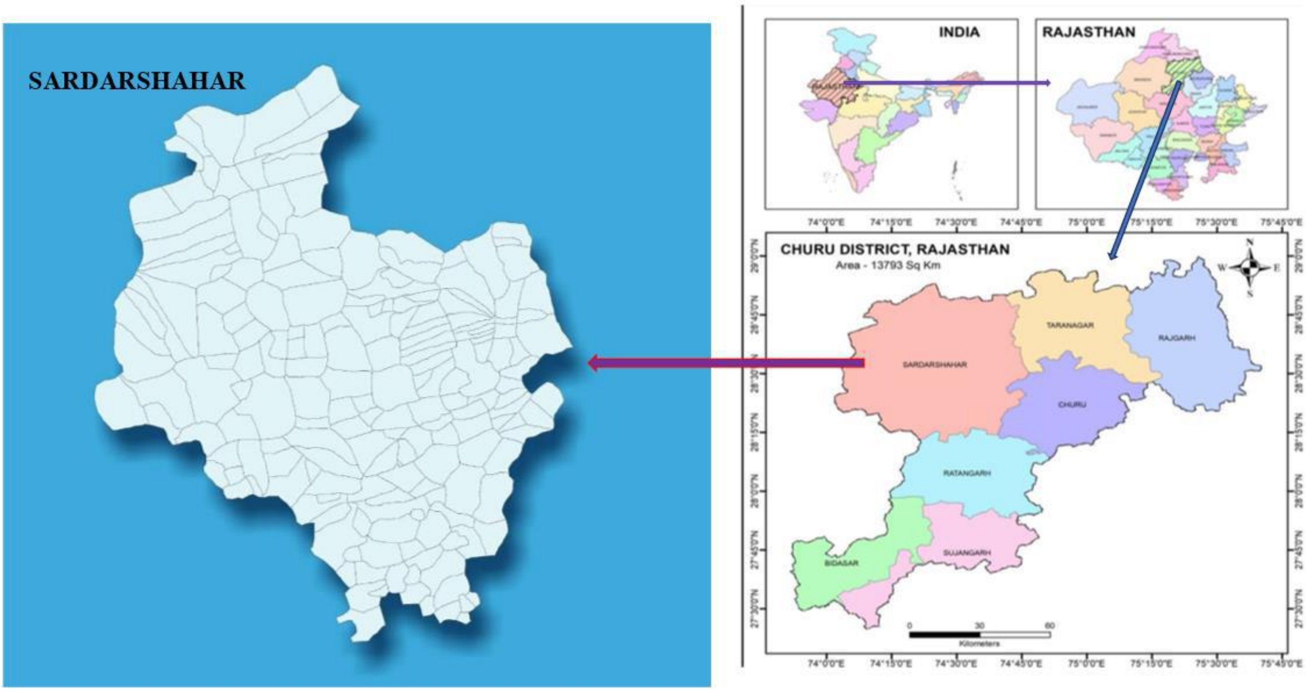


Fig.1: Map of SARDARSHAHAR (Not to scale)

The climate of Sardarshahar is typically arid, with an average annual rainfall of around 250-300 mm, most of which is received during the monsoon months of July to September. The temperatures in the region can soar as high as 48°C during the summer and drop to as low as 2°C in the winter, reflecting the high thermal amplitude typical of desert climates (Ground water department, 2013). The soils in this area are predominantly sandy, with low organic matter content, poor fertility, and limited water-holding capacity, which pose significant challenges to agricultural productivity.

Despite these harsh conditions, the presence of native species like *Prosopis cineraria has* enabled the development of traditional agroforestry systems that support local livelihoods. *Prosopis cineraria,* also known as Khejri, is well adapted to the arid climate and sandy soils of Sardarshahar, making it a vital component of the region's agricultural and ecological landscape (Samadia *et al.*, 2021). This tree species plays a crucial role in sustaining local agroecosystems by providing shade, reducing soil erosion, enhancing soil fertility, and serving as a source of fodder, fuelwood, and other non-timber products.

The choice of Sardarshahar as the study area is particularly relevant due to its representative conditions of Rajasthan's arid regions, where soil degradation and declining soil organic carbon levels are critical concerns. Understanding the impact of *P. cineraria* on soil organic carbon in this context is essential for developing sustainable agroforestry practices that can enhance soil health and agricultural productivity in similar arid and semi-arid landscapes. The study sites were selected to include areas under the influence of *P. cineraria* as well as adjacent non-vegetated plots for comparative analysis of soil organic carbon levels.

Site selection

Soil samples were collected from two distinct sites within Sardarshahar:

- **Site A**: Areas with established *Prosopis cineraria* plantations, representing agroforestry systems.
- **Site B**: Adjacent non-vegetated or open agricultural lands without *Prosopis cineraria* presence, serving as control plots.

The selection criteria included similar soil types, land-use practices, and environmental conditions to minimize variability that could influence SOC measurements.

Soil Sampling

Soil samples were collected from both study sites quarterly during December (winter), march (spring), June (summer) and September (rainy) to capture baseline SOC levels. The following procedures were followed:

- **Sampling Depth**: Soil samples were taken from two depth ranges: 0-15 cm (topsoil) and 15-30 cm (subsoil) to assess the vertical distribution of SOC.
- **Sampling Technique**: A systematic sampling approach was employed. Five soil cores were collected randomly from each depth range at each site, using a soil auger. The cores were mixed to form a composite sample for each depth range, resulting in a total of four samples per site (two depths per site).

Soil Preparation and Analysis

The collected soil samples were processed in the laboratory following these steps:

- **Air-Drying**: The samples were air-dried and sieved through a 2 mm mesh to remove debris and aggregate clumps.
- **Soil Organic Carbon Determination**: SOC were assessed using core sampler technique (Blake and Hartge, 1986) and modified Walkley and Black (1934) which involves oxidizing organic matter with potassium dichromate in sulfuric acid. The SOC content was calculated based on the amount of dichromate reduced during the reaction. Data were subjected to statistical analysis to assess the differences in SOC levels between the two sites.

Statistical Analysis: SPSS and MS Excel were used for statistical analysis.

III. RESULTS AND DISCUSSION

The average SOC at top soil (0-15cm depth) under the *P. cineraria* canopy was observed 0.20% compared to 0.11% at control area where as at sub soil depth 15-30cm depth under the *P. cineraria* was observed 0.18% with compared to 0.11% at control area (Table-1 and Figure- 2).

Table:1- Annual average SOC under Agroforestry of P. cineraria with control area

Condition	**Soil depth**	**Average SOC± SE (in percent)**
***P.cineraria* (Site A)**	0-15cm	0.2 ± 0.03
	15-30cm	0.18 ± 0.02
Control (Site B)	0-15cm	0.11 ± 0.03
	15-30cm	0.11 ± 0.02

Abbreviation: SE- Standard error

The variations in soil organic carbon (SOC) concentrations for different depths and conditions are highlighting the significant impact of *Prosopis cineraria* in enhancing SOC levels compared to control plots across all seasons (Table-2). The presence of *Prosopis cineraria* substantially increases SOC concentrations in both topsoil and subsoil compared to control plots, across all seasons.

Table:2: Soil organic carbon along soil depth and season in percent

Condition	soil depth	Spring	Summer	Rainy	Winter
P. cineraria	**Top soil**	0.2	0.18	0.17	0.24
	Sub soil	0.17	0.2	0.19	0.17
Control	**Top soil**	0.1	0.09	0.08	0.15
	Sub soil	0.09	0.12	0.11	0.13

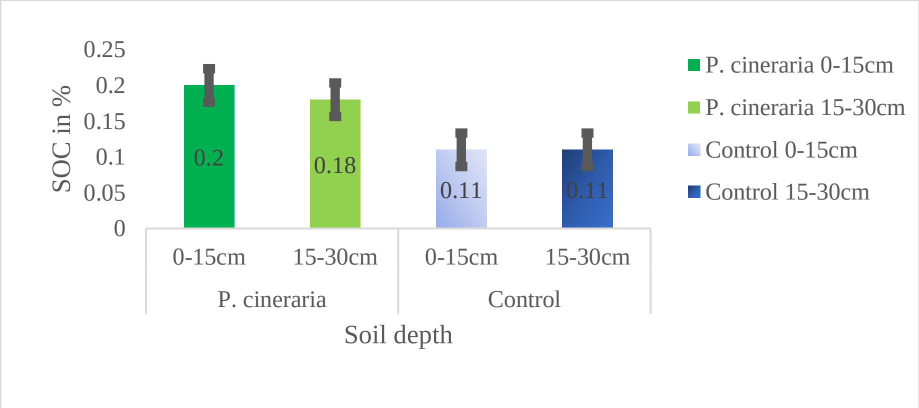


Fig.2- Annual average SOC under P. cineraria agroforestry along soil depths

Seasonal fluctuations were more pronounced in soils under *Prosopis cineraria*, with the highest SOC levels observed during the winter season in the topsoil (0.24%) followed by during spring (0.20%), Summer (0.18%) and least was during rainy season (0.17%) in top soil, whereas in sub soil maximum soc was observed during summer season (0.20%) which may be due to biodegradations of biomass during this season's favourable environmental condition at sub soil depth. In summer and rainy season SOC was observed higher in subsoil than top soil whereas in Spring and winter SOC was observed higher in top soil (Fig.-3).

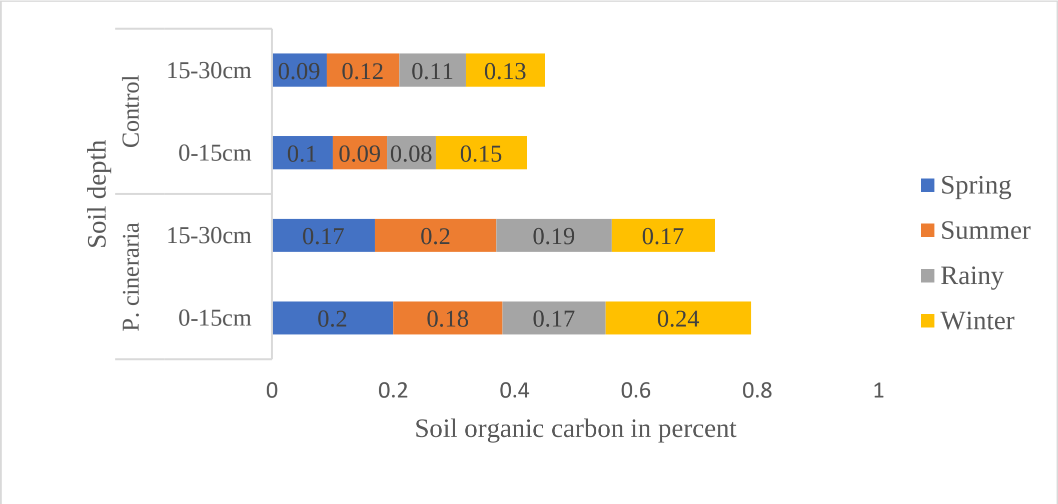


Fig.3- SOC (in %) along soil depth and season under the canopy of P. cineraria

The SOC concentration at lower depths declined with increasing soil depth, and was unaffected by changes in land use from fields without plantations to fields with tree plantations (Yuefeng *et al.*, 2014). In contrast, the control plots showed consistently lower SOC levels with minimal seasonal variations, underscoring the limited natural input of organic carbon without the influence of vegetation like *Prosopis cineraria*.

The trend line shows (figure 4) the dynamics of SOC retention in top soil under the *P. cineraria* canopy with the R^2 value of 0.91 and figure 5 shows the trend line of SOC retention at sub soil with R^2 value of 0.93. The trend line reveals that when top soil has higher SOC than sub soil has lower SOC (Spring and winter seasons) whereas when top soil has lower SOC than subsoil have higher SOC (summer and rainy).

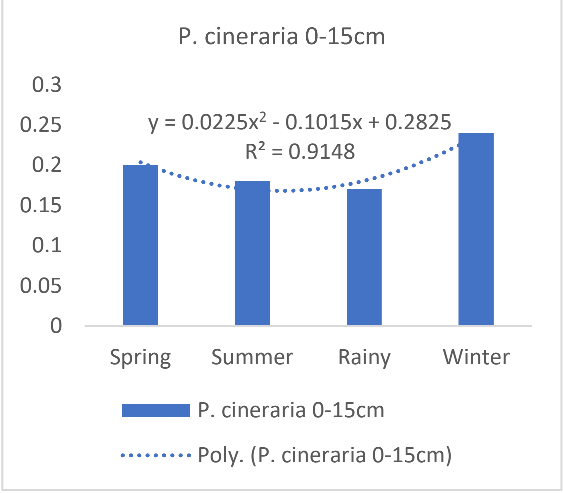


Fig :4- SOC trend in top soil

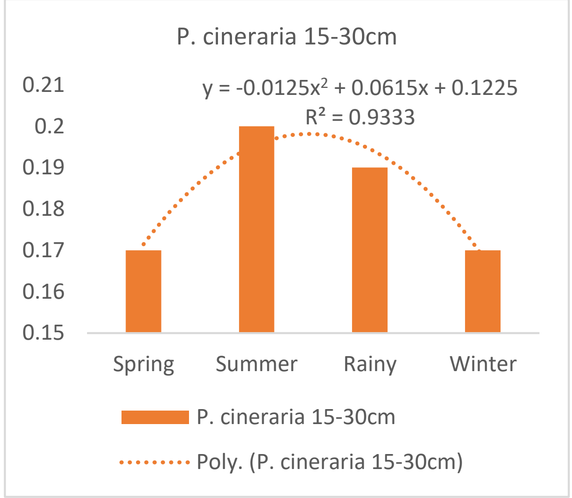


Fig :5- SOC trend in subsoil

A two-way Analysis of Variance (ANOVA) was performed to assess the significance of the differences in SOC levels between *Prosopis cineraria* and control plots across the different seasons. The ANOVA results yielded a p-value of **7.98×10^{-6}**, indicating a highly significant difference in SOC levels between areas under *Prosopis cineraria* and the control plots. The significantly lower p-value suggests that the presence of *Prosopis cineraria* has a statistically significant effect on increasing SOC levels compared to the control plots across all seasons. Seasonal variations in SOC levels are more pronounced in areas with *Prosopis cineraria*, with winter showing the highest levels of SOC in the topsoil. This analysis highlights the substantial influence of *Prosopis cineraria* in enhancing soil organic carbon levels, contributing to improved soil health in arid regions like Sardarshahar, Rajasthan.

Seasonal variations in land management, along with biological and climatic conditions, primarily influence the structure of the soil at the surface of agricultural soils (Parvin *et al.*, 2021). The present findings are partial in line with the findings of Raina (2003), Singh *et al.* (2007), and Singh and Gill (2014). Changes in soil organic carbon (SOC) are primarily influenced by inputs of organic matter, favorable temperature and moisture conditions, the amount of litter fall, and the chemical composition of tree roots and litter fall under varying climate and soil conditions (Saha *et al.*, 2007; Yuefeng *et al.*, 2014),). Lower temperatures in winter can slow down the decomposition of organic matter, allowing more carbon to accumulate in the soil. *P. cineraria* might also reduce soil temperatures by providing shade, further contributing to higher SOC retention. During the winter, *P. cineraria* shed more leaves, leading to increased organic inputs into the soil. This additional leaf litter provides a continuous supply of carbon, enhancing soil organic matter levels during the colder months. Seasonal differences in root growth and microbial activity under *P. cineraria* may also play a role in SOC dynamics, with more root biomass and associated microbial interactions leading to enhanced carbon stabilization in the soil.

The significantly higher SOC levels under *P. cineraria* compared to the control plots underscore the tree's role in enhancing soil fertility. The tree's deep-rooting system, extensive leaf litter production, and ability to fix atmospheric nitrogen are likely key factors contributing to the higher SOC concentrations observed. The leaf litter from *P. cineraria* decomposes, enriching the soil with organic matter, which not only increases carbon content but also improves the soil's structure and nutrient-holding capacity (Alrajhi *et al.*, 2024).

In contrast, the consistently low SOC levels in control plots suggest a lack of organic matter inputs, highlighting the importance of *P. cineraria* in promoting carbon sequestration in soils where natural vegetation is sparse. This supports the idea that integrating *P. cineraria* into arid agroforestry systems can significantly enhance soil quality and productivity.

The results of this study have important implications for land management and agroforestry practices in arid regions. Incorporating *P. cineraria* into farming systems could serve as a practical approach to improving soil health and combating soil degradation in such environments. The enhanced SOC levels under *P. cineraria* not only improve soil fertility but also contribute to greater soil moisture retention, nutrient cycling, and resilience against erosion.

The ability of *P. cineraria* to stabilize SOC levels across different soil depths and seasons indicates its potential to maintain soil productivity even under adverse climatic conditions. This is particularly relevant in arid regions like Sardarshahar, where soil organic matter is naturally low, and the risk of desertification is high. The tree's contribution to carbon sequestration also aligns with broader global goals of mitigating climate change by enhancing terrestrial carbon sinks (Yadav *et al.*, 2021).

IV. LIMITATIONS OF THE STUDY

While this study provides valuable insights into the role of *P. cineraria* in enhancing SOC, it is limited by its focus on a single location and a specific set of soil depths. Future research should consider exploring the effects of *P. cineraria* across a broader range of soil types and climatic conditions to better understand its potential for wider-scale applications in agroforestry. Additionally, investigating the long-term impact of *P. cineraria* on soil microbial communities and nutrient dynamics would help elucidate the mechanisms driving SOC accumulation. Such studies could provide a more comprehensive understanding of how to optimize the use of *P. cineraria* for sustainable soil management and carbon sequestration in arid and semi-arid regions.

V. CONCLUSION

The study demonstrates that *Prosopis cineraria* plays a critical role in enhancing soil organic carbon levels, particularly in arid agroforestry systems. Its ability to significantly increase SOC concentrations in both the topsoil and subsoil, along with its impact on seasonal carbon dynamics, makes it a valuable species for improving soil health and promoting sustainable land use in regions prone to soil degradation. Integrating *P. cineraria* into agroforestry practices can provide a practical strategy for soil restoration, increased carbon storage, and enhanced agricultural productivity in dryland areas like Sardarshahar, Rajasthan.

REFERENCES

[1] Alrajhi, K., Bibi, S., & Abu-Dieyeh, M. (2024). Diversity, Distribution, and applications of arbuscular mycorrhizal fungi in the Arabian Peninsula. *Saudi Journal of Biological Sciences*, *31*(2), 103911. https://doi.org/10.1016/j.sjbs.2023.103911

[2] Blake GR, Hartge KH (1986) Methods of soil analysis. American Society of Agronomy. Inc., Publisher, Madison, USA

[3] Gomes, L., Bianchi, F., Cardoso, I., Fernandes, R., Filho, E. F., and Schulte, R. (2020). Agroforestry systems can mitigate the impacts of climate change on coffee production: A spatially explicit assessment in Brazil. Agriculture Ecosystems & Environment, 294, 106858. https://doi.org/10.1016/j.agee.2020.106858

[4] Ground water department (2013). Hydrogeological Atlas of Rajasthan Churu District. https://phedwater.rajasthan.gov.in/content/dam/doitassets/water/Ground%20Water/Pdf/PublicReports/Groundwater_Atlas/Districts/Districtwise%20Atlas%20-%20Churu.pdf

[5] Mahoney, D. (1990). Trees of Somalia - A field guide for development workers. Oxfam/HDRA, Oxford pp. 133-136.

[6] McGonigle, T. P., Miller, M. N. (1996). Development of fungi below ground in association with plants growing in disturbed and undisturbed sorts. Soil Bio. Biochem. 28: 263-269.

[7] Ntawuruhunga, D. Ngowi, E.E. Mangi, H.O. Salanga, R.J. and Shikuku, K.M. (2023). Climate-Smart Agroforestry Systems and Practices: A Systematic Review of What Works, What Doesn't Work, and Why. For. Policy Econ., 150, 102937.

[8] Pare, T., Gregorich, E. G., and Nelson, S. D. (2000). Mineralization of nitrogen from crop residues and N recovery by maize inoculated with vesicular arbuscular mycorrhizal fungi. Plant and Soil 218: 11-20

[9] Parvin, N., Sandin, M., and Larsbo, M. 2021. Seedbed consolidation and surface sealing for soils of different texture and soil organic carbon contents. Soil & Tillage Research 206 (2021) 104849

[10] Raina, P. (2003). Effect of tree plantation on soil fertility in arid regions of Rajasthan. In: Pratap Narain, S. Katju, Amal Kar, M. P. Singh and Praveen Kumar (eds). *Human Impacts on Desert Environment*. Arid Zone Research Association of India and Scientific Publishers, Jodhpur. pp. 189-194.

[11] Saha R., Tomar J.M.S. and Ghosh P.K. (2007). Evaluation and selection of multipurpose tree for improving soil hydro-physical behavior under hilly ecosystem of north-east India. *Agroforestry Systems* 69: 239-248.

[12] Samadia, D., Haldhar, S., Verma, A., Gurjar, P., Berwal, M., Gora, J., Kumar, R., and Ram, H. (2021). Khejri (*Prosopis cineraria*) research for horticultural harnessing and environmental services: an appraisal. *Journal of Agriculture and Ecology*, *12*(2), 1–26. https://doi.org/10.53911/jae.2021.12201

[13] Sanders, I. R. (1990). Seasonal patterns of vesicular-arbuscular mycorrhizal occurrence in grasslands. Symbio. 9: 315-320.

[14] Singh, B. and Gill, R.I.S. (2014). Carbon sequestration and nutrient removal by some tree species in agri-silviculture systems in Punjab, India. *Range Management and Agroforestry* 35: 107-114.

[15] Singh, B., Gill, R.I.S. and Kaur, N. (2007). Litter fall and nutrient return in poplar plantation varying in row direction and spacing. *Indian Journal of Agroforestry* 9: 33-37.

[16] Solanki, A. C., Gurjar, N. S., Sharma, S., Wang, Z., Kumar, A., Solanki, M. K., Divvela, P. K., Yadav, K., and Kashyap, B. K. (2024). Decoding seasonal changes: soil parameters and microbial communities in tropical dry deciduous forests. *Frontiers in Microbiology*, *15*. https://doi.org/10.3389/fmicb.2024.1258934

[17] Tarafdar, J. C., and Rao, A. V. (1997). Response of arid legumes to VAM fungal inoculation. Sym. 22: 265-274

[18] Verma, N., Tarafdar, J. C. and Srivastava K. K (2010). Periodic changes in *Prosopis cineraria* associated AM population at different soil depth and its relationship with organic carbon and soil moisture. *African Journal of Microbiology Research*, 4(1) pp. 115-121

[19] Visconti, F., López, R., and Olego, M. A. (2024). The Health of Vineyard soils: Towards a SustainableViticulture. *Horticulturae*, *10*(2),154. https://doi.org/10.3390/horticulturae10020154

[20] Walkley, A., and Black, I. A. (1934) An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci 37:29–38

[21] Wikipedia contributors. (2024, July 24). *Sardarshahar*. Wikipedia. https://en.wikipedia.org/wiki/Sardarshahar

[22] Yadav, S and Yadav V. K. 2023. Green Economy Challenges and Feasible Opportunities of the Mountainous state Uttrakhand in India. IJAEB: 16(02): 73-76, DOI: 10.30954/0974-1712.02.2023.3

[23] Yadav, V. K., Yadav, S., Adhikari, B. S. and Rawat, L. (2022). Forest Provisioning Services Use Pattern: A Case Study from Renuka Forest Division, Western Himalaya. *Small-scale Forestry,* 21: 55–70.

[24] Yadav, V.K., Yadav, S., Rawat, L. and Adhikari, B.S. (2021). Food Provision Indicators of Renuka Forest Division, Himachal Pradesh, Western Himalaya. Indian Forester, 147(4): 395-399

[25] Yuefeng, Guo, Fucang, Qin, Yuefeng Yao and Wei, Qi. (2014). Effect of land use changes on soil organic carbon and soil microbial biomass carbon in low hills of North Yanshan Mountains. *Range Management and Agroforestry* 35: 15-21.

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Substitution of Inorganic Fertilizer and Biofertilizer Application on Wetland Rice (*Oryza sativa*) Varieties Inpari 32

Marvita Akhiri Rimbasari, Setyono Yudo Tyasmoro*, Karuniawan Puji Wicaksono, Didik Hariyono*

Faculty of Agriculture, Brawijaya University, Indonesia
*Corresponding author: marvitaakhiri@student.ub.ac.id

Received: 15 Sep 2024; Received in revised form: 14 Oct 2024; Accepted: 23 Oct 2024; Available online: 05 Nov 2024

***Abstract*— *This research aims to determine the substitution of inorganic fertilizers using organic fertilizers and biofertilizers (PGPR) in an effort to reduce farmers' dependence on inorganic fertilizers and reduce subsidized fertilizers by the government. The research method used in this research is a factorial experiment with 2 factors with 6 treatment combinations. The first factor is biofertilizer (PGPR), R0 = without PGPR, R10 = 10 liters ha-1 PGPR and the second factor is P0 (farmers' habitual fertilization (400 kg ha^{-1} urea + 400 kg ha^{-1} NPK), P1 (100% inorganic (275 kg ha^{-1} urea + 250 kg ha^{-1} NPK)), P2 (75% inorganic (206.25 kg ha^{-1} urea + 187,5 kg ha^{-1} NPK) + 25% organic (1,25 ton ha^{-1})) , P3 (50% inorganic (137,5 kg h^{-1} Urea + 125 kg ha^{-1} NPK) + 50% organic (2,5 ton ha^{-1})), P4 (25% inorganic (68,75 kg ha^{-1}) 1 Urea + 62,5 kg ha^{-1} NPK) + 75% organic (3,75 ton ha^{-1})), P5 (100% organic fertilizer (5 ton ha^{-1})). Variables observed were plant length, number of tillers, grain contents per hill, weight of 1000 seeds, productivity, leaf chlorophyll content and R/C ratio. The result shows that organic fertilizer and PGPR can be used to substitute inorganic fertilizer at 25% to 50% of the recommended dose, especially in its effect on yield. Meanwhile, substitution of 75% and 100% still not shows the effective substitution.*

***Keywords*— biofertilizer, inorganic fertilizer, organic fertilizer, rice**

I. INTRODUCTION

Rice is a key food ingredient and a vital commodity for food sustainability in Indonesia. As a contributor to the highest yield, the yield in East Java has declined from the previous year, from 56.68 kha ha-1 in 2020 to 56.47 kha-ha-1 in 2021 (BPS, 2022). The cause of the decline in yields in Eastern Java needs serious attention. One of the factors that greatly affects the productivity of rice is fertilization. Padi cultivation practices are heavily dependent on government-subsidized inputs of inorganic fertilizers. Modern agriculture with uncontrolled inputs of chemical fertilizers can reduce soil fertility which ultimately reduces grain productivity. (Zhang et al., 2020).

Organic fertilizers can be used to improve the efficiency of the use of inorganic fertilisers. Organic fertilizers can improve soil physical and chemical properties and increase soil productivity. According to Atmaja et al., (2019), organic fertilizers derived from animal debris contain both macro and micro nutrients namely N, P, K, Ca, Mg, and others. Besides containing macro nutrients and micro-organic fertilisers also contain organic acids such as humic acid, fulvatic, organic and also enzymes that are not found in inorganic nutrients.

The continuous use of chemical fertilizers also affects the soil's biological properties, i.e. the presence of microorganisms that are beneficial to soil and plants. Therefore, it is necessary to add fertilizer that is capable of improving soil biology. PGPR is one of the groups of microbes that are beneficial as the best biokontrol agents to avoid the harmful effects of chemicals and help plant health (Ansari et al., 2019). In addition to being a biofertilizer, the use of PGPR aims to accelerate the transformation of organic material into the nutrient available to plants. Bacteria provide nutrients to plants dissolving organic matter, transforming N air into available forms (Widiyawati et al., 2014). Previous studies have stated that replacing 50% or more of the inorganic fertilizer content with PGPR is sufficient to maintain normal growth and development of plants. The use of PGPR can be combined with conventional grape cultivation methods without reducing harvest yields. (Kobua et al., 2021).

Fertilization technology combining inorganic and organic fertilizer and PGPR is expected to be a solution to fertilization problems and able to restore soil fertility so that grain productivity can be improved.

The introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

II. MATERIAL AND METHODES

The research was conducted between October 2022 and February 2023. The research site is in Jatimulyo experimental land, Brawijaya University Agricultural Faculty in Jatimulyo, Lowokwaru district, Malang city. The tools used in this study are Leaf area meter (LAM), SPAD, oven, analytical scales and cameras. The materials used are grain seeds varieties inpari 32, inorganic fertiliser, organic fertilizer and PGPR "MUPUS" manufactured by HPT University of Brawijaya Laboratory. The inorganic fertilizer used are urea and NPK, and the organic material used is a composite of four organic substances, namely, straw, husks, corn stover and corn cobs that have gone through a compositing process.

This study is a factorial experiment with two factors, the first factor is the aplication of PGPR while the second factor is the substitution of inorganic fertilizer. The research was carried out using a split plot design consisting of a main and a sub plots. The research method used in this study is a factorial experiment with 2 factors with 6 combinations of treatments. The first factor is R0 = without PGPR, R10 = 10 litres of ha^{-1} PGPR and the second factor is P0 (farmers' habitual fertilization (400 kg ha^{-1} urea + 400 kg ha^{-1} NPK), P1 (100% inorganic (275 kg ha^{-1} Urea + 250 kg ha^{-1} NPK)), P2 (75% anorganic (206,25 kg ha^{-1} Urea & 187.5 kg ha^{-1} NPK) + 25% organic (1,25 tons ha^{-1})), P3 (50% in organic (137,5 kg h^{-1} Urea and 125 kg ha^{-1}, NPK) + 50% organic (2,5 tonnes ha^{-1})), P4 (25% inorganic (68.75 kgha^{-1} Uria & 62.5 kg ha1^{-1} N PK) + 75% organic (3,75 tons ha^{-1})), P5 (100% organic fertilizer (5 tons ha^{-1})). The variables observed are plant length, number of leaves, leaf size, number, dry weight, content per pile, weight of 1000 seeds, productivity, chlorophyll level, plant absorption, and R/C ratio analysis.

III. RESULTS AND DISCUSSION

PGPR treatment and fertilizer substitution, both factors did not show any interaction on the parameters of plant length, number of tillers and leaf chlorophyll content (Table 1). PGPR application did not significantly affect the parameters of plant length and chlorophyll content, but significantly affected the number of tillers, while fertilizer substitution application significantly affected the three parameters.

The results of observations of plant length showed no interaction between PGPR treatment and inorganic fertilizer substitution, likewise there was no significant effect between plant length in the treatment without PGPR and with PGPR application. This is because the bacteria in PGPR in order to provide a direct or indirect impact on plant growth require the formation of colonies in the soil that are dynamic (Khoso et al., 2024). Fertilization treatment produced a significant difference in the inorganic fertilizer substitution treatment of 50%, 75% and 100% organic on plant length in the treatment of farmer's habitual fertilizer doses and recommendations from the Ministry of Agriculture, while the 25% fertilizer substitution showed no significant difference. The use of inorganic fertilizers can be replaced by 25% organic fertilizers, because organic fertilizers contain macronutrients (N, P, K) and micronutrients needed by plants (Haruna et al., 2020).

Plant production is greatly influenced by the number of tillers because of its effect on the number of panicles produced (Deng et al., 2014). The results of observations showed that the application of PGPR significantly increased the number of tillers in rice plants, however, there was no interaction between the use of PGPR and the application of different doses of fertilizer (inorganic fertilizer substitution). Kobua et al (2021) stated that plants treated with PGPR have a better chance of withstanding external pressure, thus ensuring survival and increasing productivity. Plants given a certain amount of PGPR can form tough cells and have better metabolism throughout the stem area (Gray and Smith, 2005). The number of tillers in the fertilizer dose treatment (inorganic fertilizer substitution) was significantly different in the 100% organic treatment compared to other treatments. In the inorganic fertilizer substitution of up to 75%, it was not significantly different from the recommended dose of the Ministry of Agriculture, and the highest number of tillers was in the farmer's habitual fertilization. This shows that the availability of nutrients greatly influences the formation of tillers. The number of tillers will increase the amount of grain formed on the panicle, this will increase the weight of grain per plot. Seeds come from the results of photosynthate and assimilates that are translocated for seed formation, so that the more photosynthate and assimilates produced, the more seeds will be produced. The number of tillers formed will increase the amount of grain formed on the panicle, thus causing an increase in the weight of grain per plot (Widiyawati et al., 2014).

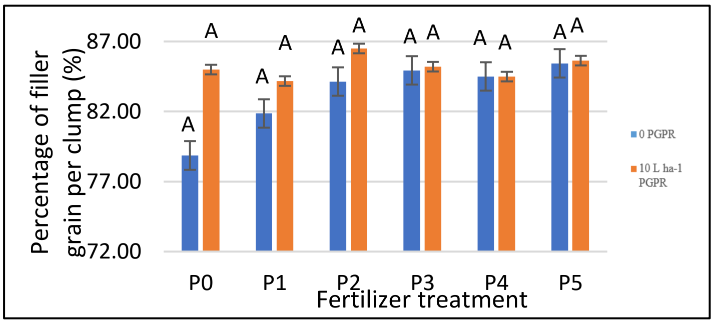
Table 1. Effect of PGPR and inorganic fertilizer substitution on vegetative growth

Substitusi pupuk anorganik dan PGPR)	Plant length per clump (cm)	Number of tillers	Chlorophyll index (mg g^{-1})
R0	90,77	14,3 a	30,1
R10	92,33	17,4 b	26,8
HSD 5%	ns	2,5	ns
P0	97,83 d	18,8 c	32,4 b
P1	96,83 d	17,8 bc	32,2 b
P2	93,17 cd	17,2 bc	32 b
P3	91,17 bc	16 bc	30,1 ab
P4	87,67 ab	14,8 b	29,2 a
P5	82,67 a	11 a	28 a
HSD 5%	5,39	2,1	2,7

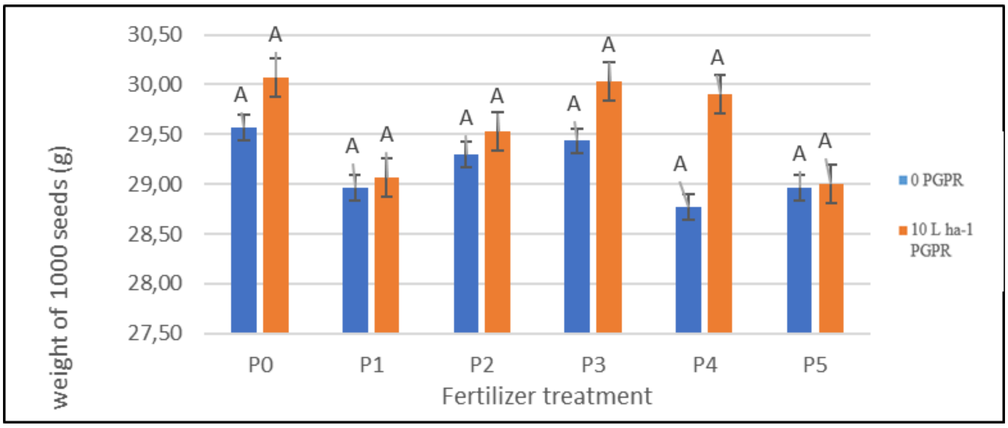
Description: The numbers in the table followed by the same letter do not show significant differences based on the 5% HSD test, HST = Days After Transplanting, HSD = Honestly Significant Difference, tn = not significant. R0 = Without PGPR, R10 = PGPR 10 Lha-1, P0 = farmer's fertilizer dose, P1 = recommended dose of the Indonesian Ministry of Agriculture, P2 = 25% inorganic fertilizer substitution, P3 = 50% inorganic fertilizer substitution, P4 = 75% inorganic fertilizer substitution, P5 = 100% inorganic fertilizer substitution (100% organic)

Leaf chlorophyll levels in plants that were given PGPR applications and those that were not showed no significant difference. Chlorophyll levels in the treatment of farmer's customary fertilizers and the Ministry of Agriculture's recommendations were the highest. This is in accordance with the high nutrient content, especially the higher N content compared to other treatments, likewise the leaf chlorophyll levels in the organic fertilizer treatment alone were the lowest. This difference in chlorophyll levels will certainly have an impact on the difference in the formation of photosynthates produced, thus affecting both vegetative and generative growth. Chlorophyll in leaves affects the reflection of infrared light which is one of the factors in increasing plant production (Mukhlisin and Soemarno, 2020). Research reveals a direct positive correlation between N fertilizer and total leaf chlorophyll content. Nitrogen is an important component of protein and nucleic acids for cell formation and the function of chlorophyll in carbohydrate synthesis (Mondal et al., 2023).

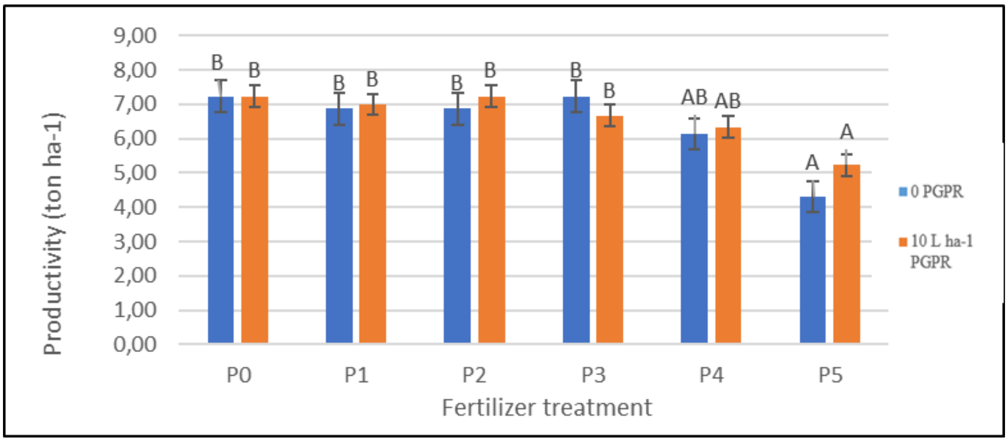
Interaction on the percentage of filled grain per hill (%) parameter did not occur between PGPR and fertilizer substitution treatments. There was no significant difference between PGPR and no PGPR treatments on the percentage of filled grain per hill. Likewise, in the fertilizer substitution treatment, the percentage of filled grain per hill ranged from 81.9% - 85.5%. The percentage of filled grain per hill above 80% indicates the ability of plants to provide assimilates which is certainly influenced by several factors.



(A)



(B)



(C)

Fig.1. Effect of fertilizer treatment and PGPR administration on yield parameters including percentage of filled grain per hill (%), weight of 1000 seeds (g) and productivity. (A) Effect of fertilizer treatment and PGPR administration on percentage of filled grain per hill (%). (B) Effect of fertilizer treatment and PGPR administration on weight of 1000 seeds (g). (C) Effect of fertilizer treatment and PGPR administration on rice productivity (ton ha-1). P0 (farmers' habitual fertilization (400 kg ha^{-1} urea + 400 kg ha^{-1} NPK), P1 (100% inorganic (275 kg ha^{-1} Urea + 250 kg ha^{-1} NPK), P2 (75% inorganic (206.25 kg ha^{-1} Urea + 187.5 kg ha^{-1} NPK) + 25% organic (1.25 ton ha^{-1}), P3 (50% inorganic ik (137.5 kg ha^{-1} Urea + 125 kg ha^{-1} NPK) + 50% organic (2.5 tons ha^{-1}), P4 (25% inorganic (68.75 kg ha^{-1} Urea + 62.5 kg ha^{-1} NPK) + 75% organic (3.75 tons ha^{-1}), P5 (100% organic fertilizer (5 tons ha^{-1}).

In the 1000 seed weight parameter, there was no interaction between PGPR treatment and fertilizer substitution (Table 2). The weight of 1000 seeds in the PGPR treatment and without PGPR was not significantly different, namely 29.2 g in the treatment without PGPR and 29.5 g in the treatment with PGPR. Likewise, in the fertilizer substitution treatment, there was no significant difference in the results of the 1000 seed weight. The 1000 seed weight parameter describes the physical quality of the seeds produced by rice plants. The weight of 1000 seeds of Inpari 32 rice is 27.1 (Wahyuningrum et al., 2022). The results of the study on the weight of 1000 seeds showed no significant difference between the fertilizer substitution treatment and the PGPR treatment and all showed results above 27.1 g, namely in the range above 29 g, which means that the physical quality of the seeds produced is very good. Factors of the rice grain filling process and genetics (palea and lemma size) cause the fertilizer dose to have no effect on the weight of 1000 seeds (Widiyawati et al., 2014).

Fertilization treatment significantly affected productivity, but PGPR administration and its interaction did not significantly affect the variable (Figure 2.). Fertilization treatment affected plant productivity, but was not significantly different. Reducing chemical fertilizers by 75% did not reduce rice plant productivity.

Table 2. Farming business analysis

No.	Treatment	Total Cost (IDR)	Revenue (IDR)	R/C
1.	Farmer's fertilizer dose	25.900.000	49.920.000	1,92
2.	Recommended dosage	25.234.750	47.840.000	1,89
3.	25% Inorganic fertilizer substitution	26.182.812	49.270.000	1,88
4.	50% Inorganic fertilizer substitution	27.156.250	48.490.000	1,72
5.	75% Inorganic fertilizer substitution	28.060.937	43.030.000	1,53
6.	100% organic	29.000.000	33.280.000	1,14
7.	100% organic (sold as organic rice)	29.000.000	61.440.000	2,11

* According to BPS (Indonesian Central Statistics Agency) data in 2018, the conversion of dry grain harvest to ground dry grain was 83.17%, while ground dry grain to rice was 64.10%, with the calculation of the price of medium quality rice being IDR 13,000.00.

R/C ratio analysis is a comparison of profits and costs used to determine business feasibility. The input-output data observed consists of the quantity and price of production inputs and the quantity and price of rice produced (Arianti et al., 2022). The calculation of the R/C value in this study was carried out without adding PGPR costs considering that there was no significant difference between treatments using PGPR and those that did not. From Table 3. Above, the highest R/C value was obtained in the treatment of farmer's habitual fertilizer, which was 1.92, then the treatment of the recommended fertilizer dose from the Indonesian Ministry of Agriculture was 1.89. Substitution of inorganic fertilizers of 25%, 50% and 75% resulted in R/C values of 1.88; 1.72; and 1.53. The lowest R/C value was in the organic fertilizer treatment, which was 1.14. Overall, all fertilization treatments are still feasible because they have an R/C value> 1.

The first paragraph under each heading or subheading should be flush left, and subsequent paragraphs should have a five-space indentation. A colon is inserted before an equation is presented, but there is no punctuation following the equation. All equations are numbered and referred to in the text solely by a number enclosed in a round bracket (i.e., (3) reads as "equation 3"). Ensure that any miscellaneous numbering system you use in your paper cannot be confused with a reference [4] or an equation (3) designation.

IV. CONCLUSION

The results of the study showed that organic fertilizer and PGPR can be used to substitute inorganic fertilizer 25% to 50% of the recommended dose, especially its effect on yield. While 75% and 100% organic fertilizer are not effective in substituting inorganic fertilizer.

ACKNOWLEDGEMENTS

This research completed for requirement master degree program at Brawijaya University. The authors say many thanks for research advisor and lecturer from the Faculty of Agriculture, University of Brawijaya, who has supported this research.

REFERENCES

[1] Zhang, Z., S. Gao, and C. Chu. 2020. Improvement of nutrient use efficiency in rice: current toolbox and future perspectives. Theor. Appl. Genet. 133(5): 1365–1384. doi: 10.1007/s00122-019-03527-6.

[2] Ansari, R.A., and I. Mahmood. 2019. Plant health under biotic stress. In Plant Health Under Biotic Stress: Vol. 2 : Microb. https://doi.org/10.1007/978-981-13-6043-5

[3] Widiyawati, I., A. Junaedi, dan Rahayu Widyastuti. 2014. Peran Bakteri Penambat Nitrogen untuk Mengurangi Dosis Pupuk Nitrogen Anorganik pada Padi Sawah The Role of Nitrogen-Fixing Bacteria to Reduce the Rate of Inorganic Nitrogen Fertilizer on Lowland Rice. J. Agron. Indones. 42(2): 96–102.

[4] Kobua, C.K., Y.T. Jou, and Y.M. Wang. 2021. Advantages of amending chemical fertilizer with plant-growth-promoting rhizobacteria under alternate wetting drying rice cultivation. Agric. 11(7). doi: 10.3390/agriculture11070605.

[5] Haruna, Y., A. Muhammad, A. Umar Birnin-Yauri, A. Rabo Sanda, and O. Oladoja Olutayo. 2020. Effect of Organic Fertilizer Produced from Agricultural Wastes on the Growth Rate and Yield of Maize. Am. J. Appl. Chem. 8(5): 126. doi: 10.11648/j.ajac.20200805.12.

[6] Deng, F., L. Wang, W. Ren, X. Mei, and S. Li. 2014. Soil & Tillage Research Optimized nitrogen managements and polyaspartic acid urea improved dry matter production and yield of indica hybrid rice. 145: 1–9.

[7] Gray, E.J., and D.L. Smith. 2005. Intracellular and extracellular PGPR: Commonalities and distinctions in the plant-bacterium signaling processes. Soil Biol. Biochem. 37(3): 395–412. doi: 10.1016/j.soilbio.2004.08.030.

[8] Mukhlisin, A., and S. Soemarno. 2020. Estimasi kandungan klorofil tanaman kopi robusta (Coffea canephora var. Robusta) menggunakan Normalized Difference Vegetation Index (NDVI) di Bangelan, Wonosari, Malang. J. Tanah dan Sumberd. Lahan 7(2): 329–339. doi: 10.21776/ub.jtsl.2020.007.2.18.

[9] Mondal, S., R. Kumar, J.S. Mishra, A. Dass, S. Kumar, et al. 2023. Grain nitrogen content and productivity of rice and maize under variable doses of fertilizer nitrogen. Heliyon 9(6). doi: 10.1016/j.heliyon.2023.e17321.

[10] Wahyuningrum, A; Zamzami, A; Agusta, H. 2022. 1 , 2 1,2. Bul.Agrohorti 10(3): 321–330.

[11] Arianti, F.D., M.D. Pertiwi, J. Triastono, H. Purwaningsih, S. Minarsih, et al. 2022. Study of Organic Fertilizers and Rice Varieties on Rice Production and Methane Emissions in Nutrient-Poor Irrigated Rice Fields. Sustainability 14,5919. doi: doi.org/10.3390/su14105919.

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available:https://ijeab.com/
Journal DOI:10.22161/ijeab

Impact of foliar spray of micronutrients and plant growth regulators on growth and yield of Guava (*Psidium guajava* L.) cv. L-49

Sonam Meena[1], Sanjay Kumar[1], Rajesh Kumar Meena[1], Nikita Divaker[1], Kriparam Meena[1], Rakesh Meena[2]

[1]Department of Horticulture, School of Agricultural Sciences & Technology, Babasaheb Bhimrao Ambedkar University (A Central University), Lucknow, Uttar Pradesh, India.
[2]Department of Fruit Science, College of Horticulture and Forestry, Jhalawar, Agriculture University, Kota, Rajasthan

Received: 27 Sep 2024; Received in revised form: 24 Oct 2024; Accepted: 01 Nov 2024; Available online: 08 Nov 2024

***Abstract*— *Guava (Psidium guajava L.), Botanically, guava belongs to the family Myrtaceae. Its basic chromosome number is 11 (2n 2x = 22), foliar application is based on the principle that the nutrients are quickly absorbed by leaves and transported to different parts of the plant to fulfil the functional requirement of nutrition. Experiment was carried out at the Horticultural Research Farm-1, Department of Horticulture, Babasaheb Bhimrao Ambedkar University (A Central University), Vidya Vihar, Rae Bareli Road, Lucknow-226025 (U.P.), India during the year 2020-2021, to study the impact of foliar spray of micronutrients and plant growth regulators on guava fruit performance. Observations are recorded fruit set, fruit retention, fruit length, fruit width, fruit weight, fruit volume and fruit yield, applications of foliar spray with Borax 0.5%+GA_3 40 ppm is most effective in performance of guava fruits viz, fruit set (70.28 %), fruit retention (61.35 %), fruit length (8.68 cm), fruit width (7.83 cm), fruit weight (139.96 g) fruit volume (125.80 ml) and fruit yield (64.85 kg/tree).*

***Keywords*— Guava (Psidium guajava L.), Micronutrients, PGR.**

I. INTRODUCTION

Guava (*Psidium guajava* L.), Botanically, guava belongs to the family Myrtaceae. Its basic chromosome number is 11 (2n 2x = 22) also known as “apple of the tropics” and poor man’s apple, is the most important, highly productive, delicious and nutritious fruit, grown commercially throughout tropical and subtropical regions of India. Its fruits are available throughout the year except during the summer season. It occupies a pride place amongst the important fruits grown in the country and claims to be the fourth most important fruit in area and production after mango, banana and citrus. It is cultivated in India since early 17th century. Due to its wider adaptability in diverse soils and agro-climatic regions, low cost of cultivation, prolific bearing and being highly remunerative with nutritive values, it has gained more popularity among the fruit growers (Das *et al*., 1995). This fruit is a native of tropical America and extensively grown in South Asian countries. The leading guava growing states are Uttar Pradesh, Bihar, Madhya Pradesh and Maharashtra. The important of guava is due to fact that it is hardy fruit and which can be grown in poor alkaline soil or poorly drained soil. It can be grown in soil with pH ranging 4.5-8.5 withoutany irrigation. It can stand above 46^0C temperature. Guava does equally well under tropical and sub-tropical climatic conditions (Gaur *et al*., 2014a). However, guava crop has three distinct periods of flowering and fruiting. The three distinct flowering periods are Ambe (February-March), Mrig (June-July) and Hastabahar (October-November) and fruiting periods for these bahar are July-August, October-December and February-April, respectively (Shukla *et al*., 2009). Foliar application is based on the principle that the nutrients are quickly absorbed by leaves and transported to different parts of the plant to fulfil the functional requirement of nutrition. This method is highly helpful for the correction of element deficiencies to restore disrupted nutrient supply, overcome stress factors limiting their availability and it plays important role in improving fruit set, productivity and quality of fruits and recovery of nutritional and physiological disorders in fruit trees.

Zinc is the important constitute of several enzyme systems which regulate various metabolic reaction associated with water relation in the plant. Zinc is essential for auxin and protein synthesis, seed production and proper maturity. It also increases fruit size as well as yield. Zinc is essential for improving the vegetative growth of guava trees obtained in terms of terminal shoots, shoot diameter and number of leaves per shoot (Price *et al*., 1972) Among them, NAA induces more fruiting, promotes flowering, whereas, GA_3 increases fruit retention. Ethrel a ripening hormone induces early and uniform ripening (Jensen *et al*., 1975). It has been seen that different nutrients in association of plant growth regulators increase economic yield facilitating harvesting (Pandey *et al*., 1988). It is therefore, necessary to standardize the most effective combination to increase yield of quality fruits in guava. NAA is important growth regulator of auxin group, which helps to reduce fruit drop and improve fruit set and quality specially TSS. By the application of NAA, TSS and ascorbic – acid content of fruit is increased and acidity reduce. NAA reduce the number of seed of the fruits. It also induces heavier fruiting and promoting flowering (Sharma and Tiwari 2015). Maximum yield during winter season due to heavy defoliation and deblossoming in the rainy season crop. It might be due to phytotoxic influence of higher concentrations of NAA on the guava foliage which caused burning and defoliation thereby resulting in low accumulation of photosynthates responsible for the fruit growth.

II. MATERIAL AND METHODS

The present investigation was carried out at the Horticultural Research Farm-1, Department of Horticulture, Babasaheb Bhimrao Ambedkar University (A Central University), Vidya Vihar, Rae Bareli Road, Lucknow- 226025 (U.P.), India during the year 2020-2021. Climatic conditions: Geographically, Babasaheb Bhimrao Ambedkar University, (A Central University), Vidya Vihar, Rae Bareli Road, Lucknow (U.P.), India situated is situated 123 m above mean sea level (MSL) in the subtropical zone of central Uttar Pradesh at 26 55' North Latitude and 80 59' East longitude The climate of Lucknow is characterized by sub- tropical with hot, dry summer and cool winters. This region received an average annual rainfall of 650-750 mm, which is distributed over a period of more than 100 days with peak period during January-June. The average relative humidity is 60% in different seasons of the year. Experiment was laid out in Randomized Block Design with three replications. The details of the treatments were T_1- Control, T_2- $ZnSO_4$ 0.5%, T_3- Borax 0.5%, T_4- NAA 40 ppm, T_5- GA_3 40 ppm, T_6- $ZnSO_4$ 0.5%+Borax 0.5%, T_7- $ZnSO_4$ 0.5%+NAA 40 ppm, T_8- $ZnSO_4$ 0.5%+GA_3 40 ppm, T_9- Borax 0.5%+NAA 40 ppm, T_{10} - Borax 0.5%+GA_3 40 ppm T_{11} - $ZnSO_4$ 0.5% + Borax 0.5% + NAA 40 ppm, T_{12} - $ZnSO_4$ 0.5% + Borax 0.5% + GA_3 40 ppm. Observations were recorded for fruit set, fruit retention, fruit length, fruit weight, fruit volume, fruit yield. Data were subjected to statistical analysis.

III. RESULT AND DISCUSSION

Applications of Borax 0.5%+GA_3 40 ppm (T_{10}) showed a statistically significant impact on fruit performance. The maximum fruit set was noted in Borax 0.5%+GA_3 40 ppm (T_{10}) followed by was noted in $ZnSO_4$ 0.5%+GA_3 40 ppm (T_8). The plant under control showed minimum fruit set in (T_1). Fruit set by GA_3 spray was due to profuse flowering. It might have increased the fruit set either by improving pollen germination or by helping its receptivity or the style becomes non-functional (Mandal *et al*., 2016). In the present investigation, micronutrients increased fruit set percentage which might be due to the reason that these nutrients play an important role in translocation of carbohydrates and in auxin synthesis to the sink and increase pollen viability and fertilization (Yadav *et al*., 2014). Maximum fruit retention was noticed in Borax 0.5%+GA_3 40 ppm (T_{10}) followed by $ZnSO_4$ 0.5%+GA_3 40 ppm (T_8). The minimum fruit retention was found in control (T_1) Zinc and Boron which proved helpful in maintaining better nutritional status of plants which ultimately led to beneficial effect in hastening fruit retention. These results are in accordance to the findings of Raj Kumar *et al.* (2010), maximum fruit length (8.68 cm) was obtained with the spray of Borax 0.5%+GA_3 40 ppm (T_{10}) followed by (8.46 cm) was noted in $ZnSO_4$ 0.5%+GA_3 40 ppm (T_8). The minimum fruit length (7.16cm) was recorded under control (T_1). Similar result was also found by Rajput and Chand (1976), Singh et al. (2004), and Pal *et al*. (2008) in guava and the maximum fruit width found in application of Borax 0.5%+GA_3 40 ppm (T_{10}) followed by as notedin $ZnSO_4$ 0.5%+GA_3 40 ppm (T_8). The minimum fruit width was recorded under control (T_1). Improvement in quality of fruits due to zinc sulphate found by Rajput and Chand (1976), Singh et al. (2004), and Pal *et al*. (2008) in guava. The maximum fruit weight was obtained with the spray of Borax 0.5%+GA_3 40 ppm (T_{10}) followed by as noted in $ZnSO_4$ 0.5%+GA_3 40 ppm (T_8). The minimum fruit weight was recorded under control (T_1). Similar result was also found by Kumar *et al.*, (2013), average fruit weight, and reduced the seed percent and seed pulp ratio which ultimately increased the yield per tree, maximum fruit volume was obtained with thespray of Borax 0.5%+GA_3 40 ppm (T_{10}) followed by as notedin $ZnSO_4$ 0.5%+GA_3 40 ppm (T_8). While, minimum fruit volume was found in control (T_1). Similar result was also found by Kanpure *et al.*, (2016) as well as the maximum fruit yield was obtained with the spray of Borax 0.5%+GA3 40 ppm (T_{10}) followed by as noted in ZnSO4 0.5%+GA3 40 ppm (T_8). While minimum fruit yield was found in control (T_1). The observations also indicated that all treatments enhanced the yield with greater degree with higher concentrations. Similar result was also found by Balakrishnan (2000).

Table 1: Effect of PGR and micronutrients on fruit set, fruit retention, fruit length, fruit width, fruit volume, fruit yield

Treatments	Fruit set %	Fruit retention (%)	Fruit length(cm)	Fruit width (cm)	Fruit weight(gm)	Fruit volume (ml)	Fruit Yield (kg/plant)
T_1 Control	46.41	39.50	7.16	6.12	104.87	95.07	47.33
T_2 ZnSO4 0.5%	56.74	52.71	7.87	6.19	116.32	107.53	53.14
T_3 Borax 0.5%	57.23	55.07	8.10	6.70	125.40	111.36	57.12
T_4 NAA 40 ppm	59.03	56.21	8.24	6.39	113.60	105.00	54.39
T_5 GA3 40 ppm	55.18	52.06	8.04	6.56	120.66	115.44	53.92
T_6 ZnSO4 0.5%+Borax 0.5%	57.94	58.45	7.93	6.23	129.86	120.55	58.09
T_7 ZnSO4 0.5%+NAA 40 ppm	65.10	56.04	8.06	7.19	128.38	117.67	57.47
T_8 ZnSO4 0.5%+GA3 40 ppm	68.85	57.91	8.46	7.39	133.07	123.03	59.27
T_9 Borax 0.5%+NAA 40 ppm	61.24	53.98	8.11	6.61	119.65	121.12	56.11
T_{10} Borax 0.5%+GA3 40 ppm	70.28	61.35	8.68	7.83	139.96	125.80	64.85
T_{11} ZnSO4 0.5% + Borax 0.5% + NAA 40 ppm	63.39	58.73	8.11	6.3	122.57	119.37	56.29
T_{12} ZnSO4 0.5% + Borax 0.5% + GA3 40 ppm	58.27	52.65	8.30	6.88	130.50	117.50	58.33
S.Em. ±	0.64	0.35	0.42	0.07	0.77	0.40	0.26
C.D. at 5%	1.89	1.05	0.14	0.23	2.27	1.18	0.77

IV. CONCLUSION

Application of foliar spray done with Borax 0.5%+GA_3 40 ppm results revealed that significantly increase in maximum fruit set, fruit retention, fruit length, fruit width, fruit weight, fruit volume, fruit yield per plant (kg/plant) and followed treatment application with $ZnSO_4$ 0.5%+GA_3 40 ppm as compare to control.

REFERENCES

[1] Adugna, D., G., D.-S., & Leta, A. (2024). Yield Response of Chick Pea (Cicer arietinum L.) Varieties to NPS Fertilizer. In International Journal of Horticulture, Agriculture and Food science (Vol. 8, Issue 1, pp. 19–27). https://doi.org/10.22161/ijhaf.8.1.3

[2] Arshad I, Ali W. Effect of foliar application of zinc on growth and yield of guava (*Psidium guajava* L.).Advances in Science, Technology and Engineering Systems Journal. 2016; 1:19-22.

[3] Awasthi P, Lal S. Effect of calcium, boron and zinc foliar sprays on the yield and quality of guava (*Psidium guajava* L.). Pantnagar J. Res. 2009;7(2):223-225.

[4] Balakrishnan K. Foliar spray of zinc, iron, boron and magnesium on vegetative growth, yield and quality of guava. Annals of Plant Physiology. 2000; 14:151-53.

[5] Baranwal D, Tomar S, Singh JP, Maurya JK. Effect of foliar application of zinc and boron on fruit growth, yield and quality of winter season guava (*Psidium guajava* L.). International Journal of Current Microbiology and Applied

Sciences. 2017; 6:1525-29.

[6] Dhakar D, Barholia AK, Jatav R, Singh L, Vasure N. Effect of phosphorus and zinc sulphate on vegetative growth and physiological attributes of guava (*Psidium guajava* L.) cv. Gwalior 27. International Journal of Agriculture Sciences. 2016; 8:2210-13.

[7] Gaur B, Hada TS, Beer K, Kanth N, Syamal MM. Studieson the effect of foliar application of nutrients and GA_3 onyield and reproductive parameters of winter season guava. Trends in Biosciences. 2014b; 7:3386-89.

[8] Jat G, Kacha HL. Response of guava to foliar application of urea and zinc on fruit set, yield and quality. Journal of AgriSearch. 2014; 1:86-91.

[9] Jatav R, Kanpure RN, Tiwari R. Effect of foliar spray of urea and zinc sulphate on morphological, yield and quality attributes of guava (*Psidium guajava* L.) cv. Apple Colour. International Journal of Agriculture Sciences. 2016; 8:3263-68.

[10] Jawed M, Lekhi R, Vasure N, Jatav R, Khan S. Effect of foliar spray of zinc sulphate and gibberellic acid on growth and quality of guava G-27 (*Psidium guajava* L.) Asian j. Hort. 2016;11(1):68-71.

[11] Kanpure RN, Mandloi DS, Anjanawe SR, Kachouli B. Growth and quality of guava (*Psidium guajava* L.). Augmented by foliar application of phosphorus and micronutrients. Eco. Env and Cons. Paper. 2016; 22:7-11.

[12] Kumar J, Kumar R, Rai R, Mishra DS. Response of ‘Pant Prabhat’ guava trees to foliar sprays of zinc, boron, calcium and potassium at different plant growth stages. The Bioscan. 2015; 10:495-98.

[13] Kumar R, Shant Lal, Tiwari JP. Influence of zinc sulphate and boric acid spray on vegetative growth and yield of winter season guava (*Psidium guajava* L.) cv. Pant Prabhat. Pantnagar J. Res. 2010;8(1):135-138.

[14] Mandal, J., Padbhushan, R., Kumar, S., Vimal, B. K., Das, A., Bhowmick, R., & Kumar, A. (2016). Evaluation of different extractants and profile distribution of boron in guava orchard in an Inceptisol of Bihar. *International Journal of Bio-Resource and Stress Management*, *7*(3), 398-405.

[15] Mary, T. (2024). Legal Considerations in the Development and Commercialization of Corporate Intellectual Property. In International Journal of Rural Development, Environment and Health Research (Vol. 8, Issue 3, pp. 01–20). https://doi.org/10.22161/ijreh.8.3.1

[16] Pal A, Pathak RK, Pal K, Singh T. Effect of foliar application of nutrients on yield and quality of guava (*Psidium guajava* L.) fruit cv. Sardar. Progressive Research. 2008; 3:89-90.

[17] Pal Anju, Pathak Rajesh Kumar, Pal Krishan, Singh Tejbir. Effect of foliar application of nutrients on yield and quality of guava (*Psidium guajava* L.) fruits cv. Sardar. Soc. for Sci. Dev. In Agric. and Tech. 2008;3(1):89-90.

[18] Parmar JM, Karetha KM, Rathod PJ. Effect of foliar spray of urea and zinc on growth and flowering attributes of guava (*Psidium guajava* L.) cv. bhavnagar red. ARJCI. 2014;5(2):140-143.

[19] Priyaawasthi, Shantlal. Effect of calcium, boron and zinc foliar sprays on the yield and quality of guava (*Psidium guajava* L.). Pantnagar Journal of Research. 2009; 7:223- 24.

[20] Rajkumar Tiwari JP, Lal S. Influence of zinc sulphate and boric acid spray on vegetative growth and yield of winter season guava (*Psidium guajava* L.) cv. Pant Prabhat. Pantnagar Journal of Research. 2010; 8:135-38.

[21] Sau S, Ghosh B, Sarkar S. Correlation and path analysis studies for growth and yield contributing traits on guava as affected by micronutrients. Annals of Plant and Soil Research. 2016; 18:370-74.

[22] Singh YK, Singh SS, Prasad VM, Singh RK, Yadav A. Assess the effect of different levels of micronutrient on fruit set and yield of guava (*Psidium guajava* L.)” cv. Allahabad Safeda. J. of Pharmacognosy and Phytochemistry. 2017;6(6):1470-1475.

[23] Waskela RS, Kanpure RN, Kumawat BR, Kachouli BK. Effect of foliar spray of micronutrients on growth, yield and quality of guava (*Psidium guajava* L.) cv. Dharidar. International Journal of Agriculture Sciences. 2013; 9:551-56.

[24] Yadav A, Verma RS, Ram RB, Kumar V, Yadav RK. Effect of foliar application of micronutrients on physical parameters of winter season guava (*Psidium guajava* L.) cv. Lalit. Plant Archives. 2017b; 17:

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Institutional Response on Adaptation to the Effects of Climate Change in Selected Parts of Makueni County, Kenya

Faith M. Moses[1], Christopher Oludhe[1], Gilbert Ouma[1], Patrick D. Kisangau[2]

[1]Department of Earth and Climate Sciences; University of Nairobi, Kenya
[2]Department of Biological Sciences; Egerton University, Kenya
Corresponding author email: faythmos@gmail.com

Received: 20 Sep 2024; Received in revised form: 25 Oct 2024; Accepted: 02 Nov 2024; Available online: 08 Nov 2024

***Abstract*— *Climate change has been experienced across the globe, with the most affected being smallholder farmers in least and moderately developed countries. Floods and drought which constitute some of the climatic extreme events have negative impacts on the socio-economic development, with devastating consequences on a country's economy. The main objective of this study was to assess institutional response on adaptation to climate change and variability at the household level, in three agro-ecological zones in Makueni County, Kenya. The study used survey research design. The three agro-ecological sites were selected using stratified sampling, while simple random method was used to select 289 households for interview. Selection of key informants was done through purposive sampling method. Data was collected through administration of semi-structured and open-ended questionnaires to the selected households, and also through interview of key informants, focus group discussions, observation and photography. Findings indicated that there was significant correlation between the climate change and the agro-ecological zones studied (X^2=13.3, df=2, P<0.01). The study established that CBOs were actively engaged in the campaign against climate change across the three agro-ecological zones. Among the reviewed institutional responses, disaster preparedness by the government and training/capacity building among smallholder farmers were found to have significant correlation with climate change and handling of extreme weather events (X^2 =17.557, df=1, sig. 0.00). The study revealed that those who reported to have experienced extreme weather events agreed that there was some level of government mitigation in place, in form of disaster preparedness. The findings revealed that there was no significant correlation between the presence of institutions assisting to mitigate climate change and their distribution across the three agro-ecological zones (p-value > 0.05). The study established that, government disaster preparedness programs were statistically significantly associated with reduced exposure to climate change and extreme weather events.*

***Keywords*— Smallholder farmers, institutional responses, climate change adaptation, Makueni County, Kenya**

I. INTRODUCTION

Climate change has led to adverse effect to every region across the globe, with many irreversible changes, such as the rise of CO_2 concentrations in the atmosphere, increase of the global surface temperatures and also the rise of the global mean sea levels (IPCC, 2021). The continued climate change has threatened food security and livelihoods, as well as disrupting the global movement towards sustainable development (Harvey *et al.,* 2018; FAO, 2015). Evidence of experienced climatic changes across the entire globe of extreme events such as heavy precipitation leading to floods, heatwaves, droughts and tropical cyclones has strengthened and are more likely to reach unbearable threshold for agriculture, health and may also lead to adverse effect to natural water cycle (IPCC, 2021).

In Sub Saharan Africa (SSA), it is frequently accepted that change in climate is on the rise and has a detrimental effect on smallholder farmers, who rely heavily on the rainfall provided by smallholder farmers for their livelihoods (IPCC, 2007; Baudoin *et al.*, 2013; Muema, Mburu, Coulibaly, & Mutune, 2018). The smallholder farmers occupy 80% of land resources for farming which are limited, and they are particularly vulnerable to the effects of climate change (Mbuli *et al.,* 2021). Poverty, limited technology, poor management of natural resources and poor access to support systems and safety nets from the government expose them to high levels of vulnerability for their survival (FAO, 2015; Mbuli *et al.,* 2021).

Kenya has been impacted negatively by climate change due to its nascent economic growth trends. Majority of Kenyan agriculture totally relies on rainfall, with only less than 5% under irrigation, and the sector has suffered from increasing variability in rainfall. Floods and drought which constitute some of the climatic extreme events have negative impacts on the socio-economic development, with devastating consequences on the country's economy (GOK, 2018). Agricultural activities are the main sources of economic growth, livelihood, food security, foreign construction and job creation and foreign exchange earnings for the majority of the population of Kenya (KEPSA, 2014; Ochieng, Kirimi & Mathenge, 2016). Demand for food, fuel wood and forest products have increased tremendously over the years, leading to unprecedented environmental degradation. An estimation of over 57% of Kenyan population lives below poverty line (FAO, 2015) while, most of smallholder farmers (70%), basically rely on climate-sensitive economic activities including agriculture (Simotwo Mikalitsa, & Wambua, 2018; Ylva, Mattias, Emmeline, Johanna, & Ingrid, 2020), therefore, increasing farmers' vulnerability and affecting the Sustainable Development Goal (SDG) 13, Target 13.1, aimed at strengthening adaptability and resilience so as to enable farmers respond to risks associated to climate change and natural calamities (GOK, 2018).

It has been proven that effects of change of climate in Kenya have devastating impacts to smallholder farmers in a situation where adaptation and coping mechanisms present a challenge to them when it comes to their vulnerability. Most of these farmers are constrained by poverty and inappropriate coping mechanisms beyond their immediate ability, even when they are aware of the appropriate climate adaptation measures (Muema *et al.,* 2018).

Makueni county, one of the 47 counties in Kenya, has been a champion in matters climate change actions, led by the county government environmental sector, the county has been able to develop policies, strategies, project governance structures which have been shared across the other departments for implementation. The National government have supported the county, through implementation of projects, which are geared towards climate change adaptation. Other climate actors from the private sector have also actively participated in the same.

The County Government of Makueni leads the implementation of various climate change programmes in collaboration with other national government stakeholders, Non-Governmental Organisations, private, community and faith-based organisations involved in mitigating climate risks in the county. Some of government actors include NDMA and NEMA (MoALF, 2016). There are collaborations between governmental organisations like NEMA and NDMA and Non-Governmental Organisations like USAID, Christian Aid, Alliance for a Green Revolution in Africa (AGRA), Bread for the World, Land O' Lakes International and Transform Aid international (MoALF, 2016). The other NGOs include Business Initiative for Survival and Eradication of Poverty (BISEP), which is involved in capacity building, promotion of selected value chains, identification of gaps in the value chains, farmer linkages to markets and also collaborating with other research organization for dissemination of climate smart technologies. Pathways to Resilience in Semi-Arid Economies (PRISE) is another active organization in the county dealing with research on climate change issues (MoALF, 2016). The institutions have played key roles in helping mitigate the effects of climate change among the farmers. The aim of the present study was therefore to determine the institutional responses to adaptation to climate change at the household level in the study area, Makueni county, Kenya.

II. METHODS

General Study Area

Makueni County is among the 47 counties in Kenya, located in the South Eastern region. The neighbourhood include Kitui County to the East, Kajiado County to West, Machakos County to the North and Taita Taveta County to the south. It has an area of 8,008.7 Km2 and is between Latitude 1º 35 ′ and 3 ° 00 ′ South as well as Longitude 37º10 'and 38º 30 ′ East. The county experience frequent droughts as it is in the Arid and Semi-Aid area. It has six sub-counties including Makueni, Kibwezi East, Kaiti, Mbooni, Kilome and Kibwezi West sub-counties. The county is then sub-divided in to further 30 wards, containing 60 sub-wards (G.O.K, 2013).

The study was done in selected parts of Makueni County which were classified according to agro-ecological zones (Jaetzold, *et al.,* 2006). The agro-ecological zones were classified as Semi Humid zone (upper part) covering Mbooni Sub County area, Semi-Arid areas (middle part) which covered Makueni Sub County and Arid area (lower part) which covered Kibwezi East Sub County.

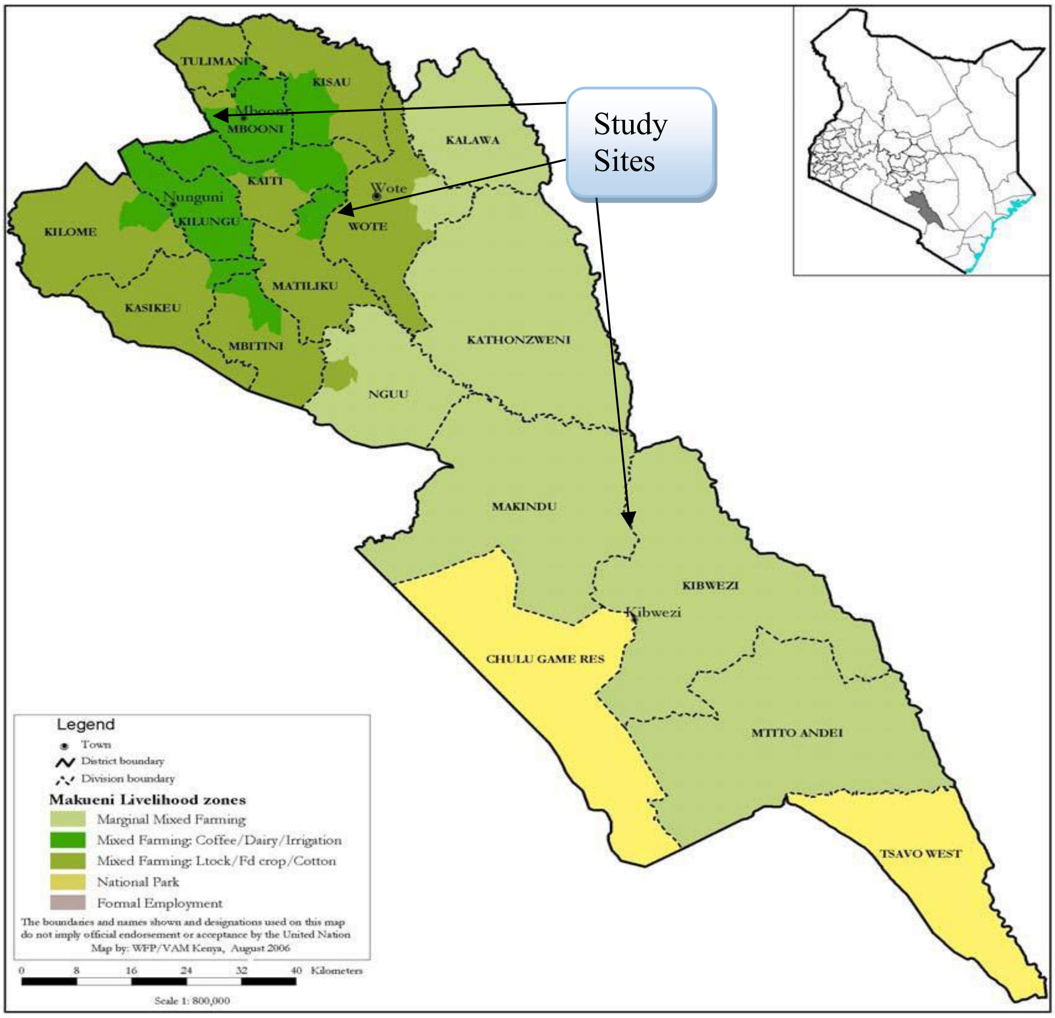


Fig.1: A Map of Makueni Livelihood Zones

Source: Makueni LRA Report, 2013.

Research Design

Descriptive research design was embraced to examine and calculate the susceptibility of smallholder farmers due to changes in climate and variability, including factors that affect their vulnerability. The design was also used to explore their climate change strategies (Asfaw *et al.,* 2021). Mixed methods of both quantitative and qualitative methods were used to collect primary data. Information was collected from family heads regarding socio-economic, biophysical and demographic factors of the study area.

Sample frame and sampling techniques

The sample frame for the study was drawn from farmer beneficiaries from the Kenya Cereals Enhancement Program – Climate Resilient Agricultural Livelihood (KCEP-CRAL). KCEP-CRAL is a national government funded and implemented program in selected counties in Kenya, with Makueni county being a beneficiary. KCEP-CRAL program, which kicked off in 2018 in Makueni, aimed at reducing rural poverty and food insecurity among smallholder farmers in arid and semi-arid lands by developing their economic potential, while improving their natural resource management capacity and resilience to climate change in an increasingly fragile ecosystem. At least 16,000 subsistence farmers benefited from the program through the provision of farm inputs through evoucher system, financial inclusion, post-production management practices and market linkages for targeted value chains, along with other agricultural resources to enhance their resilience. The current study dwelt on three sub-counties selected on the basis of their agro-ecological zone localities and which were beneficiaries of the KCEP-CRAL program.

Table 1: Sampling Frame of Farmer beneficiaries from KCEP-CRAL program

Area (Sub-County)	**KCEP-CRAL Beneficiaries**	**Percentage**
Mbooni Sub-County	140	44.9
Muvau Sub-County	79	25.3
Masongaleni Sub- County	93	29.8
Totals	312	100.0

Source: Ministry of Agriculture Makueni County

The survey research used a randomized multi-stage sampling process to select households (Asfaw *et al.,* 2021).

Sample Size Determination

The following formula was embraced for the study (Asfaw *et al.,* 2021).

$$n = \frac{Z^2 * N * p * q}{e^2(N-1) + Z^2 * p * q} \quad \text{(Eqn. 1)}$$

Where; N represents the total targeted population for smallholder farmers, n is the sample size, and Z is the set standard deviation picked at 95% confidence level, which is 1.96. *P* is the alpha levels of 0.5, showing the estimated proportion present while *q* (1-p)(0.5) represents the estimated proportion of the attribute not present in the population, while *e* is the required accuracy level, usually set as 0.05 (5% of acceptable sample error). From the calculations, the entire sample size was 244 households spread at 140 for Mbooni, 79 for Makueni and 93 for Kibwezi East.

Research Instruments

The study used the following data collection tools; Household questionnaire, Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs). The tools are explained below:

Household Questionnaire: The questionnaire was the main data collection instrument. It was divided into five sections. The first section captured household demographic information. The second section was capturing household general information, while section three was capturing socioeconomic activities and livelihood options. Section four was on adaptations to climate change and variability. The last section was on institutional support. The questions were distributed across the five sections capturing demographics and socio-economic responses, their livelihoods, outcomes and experiences of climate change in agriculture, land use practices related mitigations to climate actions provided by County Government and other climate actors in the study area.

Focus Group Discussion Guide: The guide had open questions on areas on climate change and variability, and the adaptation strategies embraced by farmers. The FGD tool had questions on farming and livestock rearing activities among farmers, identification and observation of climate change and variability indicators, how climate change has affected crop production, livestock rearing, and livelihood options, and the mitigation measures taken. The guide also had questions on mitigation efforts against climate change and variability in Makueni by governmental, non-governmental and individual households.

Data Analysis

The data collected was analyzed by both quantitative and qualitative approaches. The study used Statistical Package for Social Sciences (SPSS) software for analyzing data obtained from the questionnaire and the generated results were presented through frequencies, tables, charts, and statistics. Relevant data from key discussions, FGD notes and policy reviews was processed and analyzed to establish leading themes, trends/patterns, relationships or correlations, and conclusions obtained in line with research objectives (Gray, 2004).

Simple linear regression was used to analyze the correlation between a single quantitative effect and a single descriptive quantity indicator. The method was used to determine and detect the long-term trend as well as variation in weather elements like temperature and rainfall on the annual and monthly time scale.

Multinomial logit regression model was used to analyze factors that contribute to the choices of climate change mitigation strategies embraced by smallholder farmers. The model clarified the association between the probability of selecting a particular adaptation strategy and the descriptive variables.

The significance of relationship between independent variables i.e. demographic and socio-economic characteristics, and existing livelihood actions and dependent variable (implementation of adaptation strategies), was analyzed using chi- square contingency (×2) statistical test. This allowed the establishment of assurance on whether there is a correlation between two indicators in the study population. The chi-square (×2) value was interpreted relative to its associated statistical significance levels taken as $p < 0.05$. In interpretation, a *P* value greater than 0.05 denoted lack of association or relationship between the variables in the population.

Ethical Considerations

The study was guided by research ethics. The six elements of research ethics were considered including informed consent, beneficence, confidentiality, anonymity, no harm and the right to withdraw from the exercise. Farmers, who were the main respondent, were first informed of the intentions and objectives of the study, requesting for their informed consent. Once the informed consent was given, then the other ethical considerations were also worked on. Confidentiality was also considered and adhered to, where information collected from farmers was not shared with third parties. The information collected was also kept confidential, as no farmer details were used to expose them to any unauthorized third party.

III. RESULTS

3.1 Response rate and demographic characteristics of the respondents

A sample of 289 respondents was reached and the target for each specified study area within the three agro-ecological zones is shown in Table 2 below.

Table 2: Distribution and response rate of the respondents

Constituency (Ward)	Targeted sample size	Reached respondents	Percentage reached
Mbooni (Mbooni)	103	105	102
Makueni (Muvau)	66	79	120
Kibwezi East (Masongaleni)	75	105	140
Totals	**244**	**289**	**120**

The study response rate was 120% as six focus group discussions were reached instead of the initially intended five, which meets the threshold for sample size requirement according to Mugenda and Mugenda (2003).

Summary of demographic characteristics

Most of the respondents were drawn from Kibwezi East and Mbooni (Table 3), both sub-counties having a representation of about 36.3%. Makueni had the least representation at 27.4%, in terms of relations to the household head. Majority of the respondents were spouses at 48.1%, while respondents who were the household heads were 38.1%. Further, there were 10.0% and 3.8% of the respondents who identified themselves as children and parents of the household heads. In terms of gender representation, more of the respondents at 64.0% were female, while the other 36% were male. In terms of level of education, majority of the respondents at 56.4% had achieved primary level education, followed by 29.8% who reported to have attained secondary education level. Respondents who had achieved college and university education were 5.5% and 1.4% respectively.

The distributions of respondents in terms of their age, the majority were aged between 26 to 40 years, representing 34.9% of the population. This category was followed by those aged between 41 to 60 years at 33.6%. The study revealed that 20.1% and 11.4% of the respondents were aged above 61 years and below age 25 years respectively. In terms of occupation, majority of the respondents (66.1%) indicated that they were farmers. Those engaged in small scale business and casual laborers were 10.4% and 10.0% respectively. A further 4.2% of the respondents reported to have been engaged with other different occupational roles, while 3.5% of the respondents indicated that they were not engaged in any form of economic activities.

Majority of the respondents in the study area were married in monogamous union at 78.2%. The study established that 12.5% of the respondents were widowed while 5.2% reported to have had orphans in their households. There was a small percentage of respondents (1.7%) who were in polygamous marriage.

Table 3: Summary of Demographic Characteristics

Variable	Category	Frequency	Percentage
Relations to household head	Household head	110	38.1
	Spouse	139	48.1
	Child	29	10.0
	Parent/guardian	11	3.8
Gender	Female	185	64.0
	Male	104	36.0
Education	College	16	5.5
	None	20	6.9
	Primary	163	56.4
	Secondary	86	29.8
	University	4	1.4
Age of respondent	18-25 years	33	11.4
	26-40 years	101	34.9
	41-60 Years	97	33.6
	Above 61 years	58	20.1
Occupation	Students	8	2.8
	Business	30	10.4
	Casual Labourer	29	10.0
	Farmer	191	66.1
	Teacher	9	3.1
	Not employed	10	3.5
	Other roles	12	4.2
Marital Status	Married (Monogamous)	226	78.2
	Married (Polygamous)	5	1.7
	Separated/Divorced	8	2.8
	Single	14	4.8
	Widowed	36	12.5
Type of Household	Dejure female headed (widow, never married, divorced)	13	4.5
	Female headed	32	11.1
	Male headed	242	83.7
	Polygamous	2	0.7
Presence of an orphan	No	274	94.8
	Yes	15	5.2
Sub-county	Kibwezi East	105	36.3
	Makueni	79	27.4
	Mbooni	105	36.3

3.2 Farmer's perception on climate change in the study area

Experience of extreme weather conditions

The study established that 76.8% of the farmers experienced extreme weather conditions, with only 23.2% not experiencing extreme weather conditions. In relation to the agro-ecological zones, more farmers in Kibwezi East and Makueni at 88.6% and 70.9% respectively experienced extreme weather conditions, compared to 69.5% in Mbooni (Table 4). There was significant correlation between the climate change and the agro-ecological zones studied (X^2=13.3, df=2, P<0.01). The Pearson correlation portrayed that the agro-ecological zones studied experienced some form of climate change.

Table 4: Experience of extreme weather conditions

	Sub County Kibwezi East	Makueni	Mbooni	Total	Pearson Chi-Square Value	df	Asymptotic Significance (2-sided)
No	12	23	32	67	13.297a	2	0.001
	11.4%	29.1%	30.5%	23.2%			
Yes	93	56	73	222			
	88.6%	70.9%	69.5%	76.8%			
Total	105	79	105	289			

3.3 Institutional Responses to Adaptation to Climate Change at Household Level

3.3.1 Agricultural Related Services (ARS) from Government

The study revealed that government had offered agriculture related services with, 31.8% who testified they received such services (Table 5). However, a substantial number of the respondents reported that they never got such services. Those who indicated to have received, the various services were fairly distributed across the three agro-ecological zones. In total there were 85 or (92.4%) of the farmers who received agricultural extension services, with majority from Mbooni Sub- County at 51.8%, while the least were from Kibwezi East at 15.3%. Overall, agricultural extension services were not significantly correlated with the sub-counties (X^2 *p value*=0.104). Farmers who received early warning systems were 22.8% across the three agro-ecological zones, with majority from both Mbooni and Makueni (42.9%). Similarly, early warning systems were not significantly correlated with the agro-ecological zones (X^2 *p value*=0.745).

Provision of farm inputs was considered a significant factor that correlated with the sub-counties (X^2 *p value*=0.015), where 26.1% of the farmers received the support from the government, where majority were from Makueni at 58.3%. Financial services were available in Makueni sub-county (1.1%) while insurance services were found in Makueni and Mbooni sub-counties, each at 1.1%. Disease surveillance was common at 14.1% across the three agro-ecological zones, with Mbooni recording the highest at 53.8% (n=7, out of 13).

Table 5: Agricultural related services from Government

Get ARS from government	%	Type of Agricultural Related services	Kibwezi East	Maku-eni	Mboo-ni	Total (n)	Total (%)	Pearson X^2
No (n=197)	68.2	Agricultural extension services	13	28	44	85	92.4%	0.104
Yes (n=92)	31.8	Early warning Information Systems	3	9	9	21	22.8%	0.745
		Farm Inputs, (seeds, implements, & tools)	4	14	6	24	26.1%	0.015
		Financial services	0	1	0	1	1.1%	0.405
		Insurance services	0	1	1	2	2.2%	0.808
		Disease surveillance	1	5	7	13	14.1%	0.716

3.4 Institutions in the community addressing climate change extremities on livelihoods

The study revealed that apart from the government, there were other non-governmental organizations and institutions that addressed climate change extremities across the three agro-ecological zones, (Table 6), though minimal (8.3%, n=24). All the positive responses (n=24) confirmed that the County government/national government line ministry and the private sector had played a major role in addressing climate change, while a frequency of 23 respondents were of the view that both NGOs and CBOs were actively engaged in the campaign against climate change. Church organizations were also deemed helpful in addressing climate change. The study indicated that a significant number of the famers with a frequency of 15 believed that Church organizations have played a major part in addressing climate change.

Table 6: Organizations acting against climate change (n=24)

Are there Institutions handling CC Extremities?	n	%	Organization/Institution	n	%
No	265	91.7	Church Organization	15	5.2
Yes	24	8.3	County government/ministry	24	8.3
			NGOs	23	8.0
			CBOs	23	8.0
			Private sector	24	8.3
			Other entities	19	6.6

3.4.1 Presence of institutions in the study area

The study established that out of the 8.3% (Table 7) of the organizations addressing climate change extremities in the three agro-ecological zones, 11.3% of them were from Kibwezi East, while the remainder were from Makueni and Mbooni agro-ecological zones. There was no significant correlation between the presence of institutions in assisting to mitigate effects of climate change and the agro-ecological zones (Pearson chi-square 2.197, p-value > 0.05).

Table 7: Presence of institutions addressing climate change across the agro-ecological zones

Presence of institutions to address climate change extremities					Chi-Square Tests	Value	df	Asymp. Sig.
	Kibwezi East	Makueni	Mbooni	Totals	Chi-Square	2.197a	2	0.333
No	94	73	98	265	Likelihood Ratio			
	88.70%	92.40%	94.20%	91.70%				
Yes	12	6	6	24		2.176	2	0.337
	11.30%	7.60%	5.80%	8.30%				

3.4.2 Distribution of non-governmental organizations

The distribution of the organizations in the study area was not significantly correlated to the agro-ecological zones (p-values >0.05) (Table 8). Makueni agro-ecological zone had more church organizations (46.7%) that supported mitigation efforts against climate change compared to Mbooni (33.3%) and Kibwezi East (20.0%). There were more mitigation efforts supported by the County government and NGOs in Kibwezi East, at 50.0% and 43.5% respectively while more CBOs (39.1%) were present in Makueni agro-ecological zone.

Table 8: Distribution of organizations mitigating climate change in the agro-ecological zones

	Sub County						
	Kibwezi East	**Makueni**	**Mbooni**	**Total**	**Pearson X2**	**df**	**Asymp. Sig. (2-sided)**
Church Organization	3	7	5	15	3.130a	2	0.209
	20.0%	46.7%	33.3%	100.0%			
County dept/ ministry	12	6	6	24	3.378a	2	0.185
	50.0%	25.0%	25.0%	100.0%			
NGOs	10	8	5	23	4.295a	2	0.117
	43.5%	34.8%	21.7%	100.0%			
CBOs	8	9	6	23	1.043a	2	0.593
	34.8%	39.1%	26.1%	100.0%			

3.5 Trainings to handle extreme weather conditions

The study established that farmers had received various forms of trainings regarding extreme weather conditions that were offered by different institutions in the study area. At least 14.5% of the farmers had been trained on early warning alerts, followed by 12.8% who had been trained on periodic weather updates, and only 5.5% had received training on observation and mitigation strategies of extreme weather conditions (Table 9).

Table 9: Training services

Training service	Frequency	Percentage
Weather forecast services	27	9.3
Periodic weather updates	37	12.8
Extreme events	16	5.5
Disaster preparedness	20	6.9
Early warning	42	14.5
Financial aid	34	11.8

3.6 Institutions' interventions on climate change adaptation

From the Pearson correlation analysis, it was established that institutions played a significant role in injecting interventions to promote climate change adaptation across the three agro-ecological zones (X^2 =0.405, df=2, $p<0.05$). There were statistically significant differences in terms of how the institutions promoted climate change adaptation for smallholder farmers in the three agro-ecological zones (Table 10). It was revealed that eight of the 12 institutions in Kibwezi East (66.7%), six (100.0%) in Makueni and six (100.0%) in Mbooni offered training to farmers on agricultural smart technologies. Seven of the 12 institutions in Kibwezi east (58.3%) offered Food for work programme, a service that was not reported in the other two agro-ecological zones. The institutions that provided drought resistant crops and livestock breeds were five in in Kibwezi East (41.7%), three in Mbooni (50.0%) and three in Makueni (50.0%). Cash donation services were offered by 16.7% of the institutions in Makueni while 66.7% of the institutions in each of the agro-ecological zones gave seeds for planting. Market linkage services were offered by 16.7% of the institutions in Kibwezi east, 33.3% in Makueni, and 50.0% in Mbooni. Only 8.3% and 33.3% of the institutions in Kibwezi East and Makueni respectively offered assistance to farmers inform of farm machineries.

Table 10: Institutional interventions across the agro-ecological zones (n=24)

Pearson chi-square values	**Pearson X^2**		0.405
	df		2
	Asymp. Sig. (2-sided)		0.050
Institutional interventions	Sub County		
	Kibwezi East (n=12)	Makueni (n=6)	Mbooni (n=6)
Training on smart technologies	8	6	6
	66.7%	100.0%	100.0%
Giving relief food	6	0	0
	50.0%	0.0%	0.0%
Giving food for work	7	0	0
	58.3%	0.0%	0.0%
Providing farmers with drought resistant crop/livestock breeds	5	3	3
	41.7%	50.0%	50.0%
Cash donations	0	1	0
	0.0%	16.7%	0.0%
Seeds for planting	8	4	4
	66.7%	66.7%	66.7%
Creating market linkages for produce	2	2	3
	16.7%	33.3%	50.0%
Assisting farmers with farm machineries	1	2	0
	8.3%	33.3%	0.0%

3.7 Participation in climate change related decision-making forums

The study revealed that, a significant number of farmers participated in decision-making across the ecological zones (X^2 =15.11, df=2, p<0.001). Majority of the farmers, at 86.5% did not participate in decision making processes. There were 25.3% farmers in Makueni, 13.3% in Mbooni and 4.8% in Kibwezi east who reported to have participated in climate change decision making forums (Table 11).

Table 11: Smallholder farmers' participation in climate change decision making (n=289)

Pearson Chi-Square	15.119a		
Df	2		
Asymptotic significance	0.001		
	Participation in decision making		Total
	No	Yes	
Kibwezi East	100	5	105
	95.2%	4.8%	100.0%
Makueni	59	20	79
	74.7%	25.3%	100.0%
Mbooni	91	14	105
	86.7%	13.3%	100.0%
Totals	250	39	289
	86.5%	13.5%	100.0%

The study also indicated that majority of those who had participated in climate change decision-making (n=39) were involved in water resource management issues at 82.1% (n=32 out of 39), followed by 79.5% (n=31 out of 39) who were involved in soil and water conservation matters, while 59.0% (n=23 over 39) were involved in identification of community needs. There were further 20.5% of the farmers who participated in decision-making on other roles, as shown in Table 12.

Table 12: Farmers participation in climate change related issues (n=39)

Option	**Kibwezi East (n=5)**	**Makueni (n=20)**	**Mbooni (n=14)**	**Totals (in all zones)**	
	N (%)	**N (%)**	**N (%)**	**Frequency**	**Percent**
Identification of community needs	3 (60.0%)	12 (60.0%)	8 (57.1%)	23	59.0
Water resource management	4 (80.0%)	16 (80.0%)	12 (85.7%)	32	82.1
Soil and water conservation	5 (100.0%)	18 (90.0%)	8 (57.1)	31	79.5
Other roles	1 (20.0%)	4 (20.0%)	3 (21.4%)	8	20.5

3.8 Challenges of climate change and variability mitigation programs in the three agro -ecological zones

The study revealed that climate change and variability mitigation programs faced some challenges in the study area, which were not significantly different in the three agro-ecological zones (X^2 =2.811, df=2, p<0.245). The greatest challenges facing effective implementation of climate change and variability mitigation programs in the study area were corruption (88.2%) inadequate infrastructure (85.8%), top-down implementation strategies (83.4%), duplication of roles and institutional inefficiency in government agencies (73.7%), lack of meaningful community involvement and participation (73%), lack of proper communication (69.9%) and ineffective law enforcement (45.7%) in that order (Table 13).

Table 13: Challenges facing climate change and variability mitigation programs in the study area

Pearson chi-square	2.811a	
Df	2	
Asymptotic significance (2-sided)	0.245	
List of Challenges	**Frequency**	**Percent**
Lack of meaningful community involvement and participation	211	73.0
Inadequate infrastructure	248	85.8
Duplication of roles and institutional inefficiency	213	73.7
Top-down implementation strategies	241	83.4
Ineffective law enforcement	132	45.7
Lack of proper communication	202	69.9
Corruption	255	88.2

3.9 Suggestions and recommendations for effective climate change programme management

Amongst the recommendations made by the respondents, the need for creating awareness and sensitization on climate-change and variability, and also support on water harvesting to enhance effective climate change intervention programmes led, each reported by 20.8% of the respondents, followed by educating farmers on new farming technologies (19.7%), availability of more agricultural extension officers (18%) and adaptation to climate smart agriculture (17%) among others (Table 14).

Table 14: Recommendations for effective mitigation on climate change

Recommendation	Frequency	Percentage
Adaptation of climate smart agriculture	49	17.0
Involvement of community groups in development programmes	34	11.8
Availability of Agricultural Extension Officers to educate locals	52	18.0
Awareness on climate-sensitive practices, and aiding in water harvesting	60	20.8
Conserve our environment through community initiatives	28	9.7
Desilting of existing earth dams and digging boreholes	33	11.4
Educate farmers on new farming technologies	57	19.7
Loans for community environment conservation measures	46	15.9
Harvesting of rain water in dams, gabions, and farm ponds.	39	13.5
More Training and support	44	15.2
Planting trees	51	17.6

3.10 Regression analysis of institutional responses on climate change vulnerabilities

I Institutional responses were categorized into: households receiving relief foods, financial aid from government or NGOs, government disaster preparedness, presence of institutions working on climate change initiatives, local programs to enhance farmer adaptation to climate change, and decision-making involvement in climate change mitigation forums (Table 15). Among the reviewed institutional responses, only disaster preparedness by the government was found to have significant correlation with climate change and handling of extreme weather events (X^2 =17.557, df=1, sig. 0.00). The findings revealed that 52.3% of those who had reported to have experienced extreme weather events agreed that there was adequate government disaster preparedness, while majority (81.2%) indicated that there was no adequate government mitigation and preparedness strategies in place. The results confirmed that government preparedness in terms of allocation of resources and sharing information with the public is deemed critical in reducing exposure to extreme weather conditions (Table 15).

Table 15: Institutional responses on climate change

		Climate change extreme weather events				
Indicator for institutional response		**No**	**Yes**	***X^2* value**	**df**	**Sig. (2-sided)**
	No	23.6%	76.4%	.760a	1	0.383
Receiving financial aid from gov	Yes	11.1%	88.9%			
Received any relief food from government/NGO	No	23.5%	76.5%	1.224a	1	0.269
	Yes	0.0%	100.0%			
	No	18.8%	81.2%	17.557a	1	0
Disaster preparedness by government	Yes	47.7%	52.3%			
	No	23.9%	76.1%	.102a	1	0.75
Warnings on extreme weather conditions	Yes	22.3%	77.7%			
	No	24.2%	75.8%	1.677a	1	0.195
Institutions working on climate change	Yes	12.5%	87.5%			
	No	24.4%	75.6%	1.540a	1	0.215
Participation in decision making	yes	15.4%	84.6%			
	No	19.8%	80.2%	.929a	1	0.335
Local Programs	Yes	24.9%	75.1%			

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

IV. DISCUSSION

In this study, the distribution of the respondents was fair, ranging from 36.3% in Mbooni and Kibwezi East to 27.4% in Makueni sub-county. The representation allowed comparison of the distribution of variables across the three agro-ecological zones. The findings that the majority of the respondents were spouses at 48.1%, and household heads were 38.1% implied that the respondents were the key decisions makers on climate change mitigation at household level. A study by Below *et al*. (2016) reiterates, that smallholder farmers with extremely low-income levels are more likely to seek help on handling climate change and its associated effects, while families that had higher income were reluctant to depend on local institutions for climate change interventions. However, local institutions cannot be ignored in their role that they play in assisting smallholder farmers mitigate the effects of climate change (Below *et al*., 2016).

On the perception on climate change, about 76.8% of the respondents experienced extreme weather conditions. The findings relate to previous studies that found out that most farmers in the rural areas of most developing countries bear the largest burden of climate change due to extreme weather conditions (Harvey *et al.*, 2018; Minh *et al.,* 2019). As confirmed in MoALF (2016), (there was significant correlation between the climate change and the agro-ecological zones studied (X^2=13.3, df=2, P<0.01). Over 93.8% of the respondents agreed that there was a general decrease in water availability for the past five years. This finding corroborated well with other findings (Amuzu *et al*., 2018; Mbuli *et al*., 2020; Kieti *et al.,* 2016) which established that due to climate change, there has been observable reduction in water availability in most rural areas.

The study revealed that the government had offered agriculture related services as reported by 31.8% of the respondents. This is confirmed in a related study by Wamsler *et al.,* (2018) who noted that governments, non-governmental organizations and other institutions stand a better chance to help smallholders deal with climate change and its impacts.

It was established that institutions such as NGOs, Church Organizations, the Private sector, CBOs and other entities have a huge role to play in ensuring that farmers can withstand climate change and its impacts. Wamsler *et al.,* (2018) confirmed that most institutions have adequately assisted smallholder farmers to cope up with effects of climate change by providing market link outlets for their farm produce. The findings revealed that there was no significant correlation between the presence of institutions assisting to mitigate impacts of climate change and the benefits by farmers across agro-ecological zones. This could be associated with the few households (n=24) who indicated that there were institutions supporting climate change mitigation efforts. This finding agreed with Chaudhury *et al.* (2020) who observed that not all farmers might benefit across the agro-ecological zones since some farmers have limited capacity to integrate climate information in their livelihoods and development plans.

The findings on the distribution and the role of private institutions on mitigating climate change corroborate with observations by Heltberg *et al.* (2019) who found out that private players had significant role on addressing human vulnerability to climate change. The current study established that training services were a common mitigation measure against impacts of climate change. It was revealed that about eight institutions, representing 66.7% (six out of twelve) trained farmers on smart agriculture technologies from Kibwezi East, while the other six institutions (100.0%) in Makueni and six (100.0%) in Mbooni empowered farmers on smart technologies. Similar studies by Shilaho (2016) and Heltberg *et al.,* (2019), have established that capacity building among farmers on weather updates, weather forecast and projection, disaster preparedness and early warning formed part of the training services that improved farmer resilience against impacts of climate change. In addition, studies by Kieti *et al.* (2016) and Rahman and Hickey (2020) noted that farmers improved their livelihoods through trainings on how to mitigate the effects of climate change.

In terms of participating in climate change related decisions, 11.1% of the farmers indicated that they were involved in water resource management issues while only 10.7% participated in soil and water conservation decision making. The findings corroborate with a study by Mbuli *et al.* (2021) who noted that not all farmers are engaged in decision-making on climate change programs as most lack technical capacity and have poor access to support systems to enable them contribute effectively in decision making.

The fact that 82.1% of the respondents were involved in water resource management decisions, 79.5% in soil and water conservation and 59.0% in community needs assessment related to findings by Shilaho (2016) and

Below *et al.,* (2016) who noted that effective institutional contribution to climate change should involve participation by local farmers and focus on improved agricultural methods, solving water resource conflicts and promoting equitable sharing of natural resources.

Among the reviewed institutional responses, only disaster preparedness by the government was found to have significant correlation with climate change and handling of extreme weather events (X^2 =17.557, df=1, P< 0.00). The findings revealed that 52.3% of those who reported to have experienced extreme weather events agreed that the government had put in place adequate disaster preparedness mechanisms. The findings in this current study were similar with others done elsewhere. Some of the studies have expressed various forms of institutional responses that have significant impact on mitigating effects of climate change. For instance, Nyika (2022) on a study on climate change situation in Kenya and the adaptive management to it noted that there was need for adaptive responses from different players. Such adaptive mechanisms included infrastructural modifications of water body environments, disseminating earl warnings and forecasting weather using models to predict climate change uncertainties. Similarly, the authors called for government interventions in policy making and strong institutions to mitigate the effects of climate change in Kenya. In his study in Laikipia, Kenya, Ndiritu (2021) recommended that there is need for strengthening policy on early warning mechanisms especially in the semi-arid areas in Kenya. The study also recommended the need to improve training of farmers on mitigation practices to enhance their preparedness. Further, another study by Opoku, Filho, Hubert and Adejumo (2021) recommended that there was need for improving government policies at all levels (local, regional and even national) on climate change and the associated mitigations. The authors also noted the need to improve basic knowledge for professionals in climate mitigation to better respond to adverse effects of climate change.

V. CONCLUSION

This study examined how institutions responded to climate change in three agro-ecological zones of Makueni county, Kenya. The various institutions involved in assisting smallholder farmers to mitigate against impacts of climate change in the study area were NGOs, CBOs, private sector, church organization and the county/national government. Majority of the respondents reported that they had experienced extreme weather conditions, signifying climate change. Only about a third of the respondents received agricultural related services from government, where only farm inputs (seeds, implements and tools) were found to be significantly correlated to effective mitigation of impacts of climate change across the three agro-ecological zones.

Of all the reported government induced mitigation strategies, disaster preparedness was found to have significant correlation with climate change and handling of extreme weather events. The study underscores the critical role of both government and non-governmental institutions in promoting effective adaptation and mitigation strategies against climate change to small scale farmers in the country. However, the study highlights the importance of need for more institutional concerted efforts in order to cushion small scale farmers against the impacts of climate change and variability.

ACKNOWLEDGEMENT

The authors would like to acknowledge all the participants who gave their quality time in ensuring the success of the study. We acknowledge the farmers in Makueni County in the three agro-ecological zones who volunteered to share information during the study. We also acknowledge the research assistants who took part in data collection in the course of the study. We are deeply indebted to the different institutions and organizations who provided important information regarding the study.

DECLARATION OF CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

[1] Amuzu, J., Kabo- B., Amos T., Jallow, B. P., Yaffa, S., (2018) : *Households' Livelihood Vulnerability to Climate Change and Climate Variability*: A Case Study of the Coastal Zone, The Gambia, Journal of Environment and Earth Science, ISSN 2225-0948, IISTE, s.l., Vol. 8, Iss. 1, pp.3546,http://dx.doi.org/10.13140/RG.2.2.36057.42081,http://iiste.org/Journal/index.php/JEES/article/view/40664

[2] Asfaw, A., Bantider, A., Simane, B., & Hassen, A. (2021). *Smallholder farmers' livelihood vulnerability to climate change-induced hazards: agroecology-based comparative analysis in Northcentral Ethiopia* (Woleka Sub-basin) https://doi.org/10.1016/j.heliyon.2021.e06761

[3] Chaudhury, M., Summerlin, T. & Ginoya N. (2020). *"Mainstreaming Climate Change Adaptation in Kenya: Lessons from Makueni and Wajir Counties."* Working Paper. Washington, DC: World Resources Institute. Available online at www.wri.org/publication/mainstreaming-adaptationkenya

[4] FAO (2015). *Scoping study on climate-smart agriculture in Kenya:* Smallholder Integrated Crop-Livestock Farming Systems.

[5] GOK (2018). *National Climate Change Action Plan (Kenya): 2018-2022. Volume 3: Mitigation Technical Analysis Report.* Nairobi: Ministry of Environment and Forestry.

[6] Gray, D. (2004). *Doing Research in the Real World, London.* Oxford: Sage Publications.

[7] Harvey, C.A, Rodriguez, M.S., Rodriguez R.M, Viguera, B., Guadarrama, A.C.,Vignola, R. & Alpizar, F. (2018). *Climate Change Impacts and Adaptation among Smallholder Farmers in Central America, Agriculture & Food Security.* https://doi.org/10.1186/s40066-018-0209-x

[8] Intergovernmental Panel on Climate Change (IPCC) (2021): *Climate Change Impacts, Adaptation and Vulnerability.* Cambridge University.

[9] Jaetzold, R., Schmidt H., Hornetz, B. and Shisanya, C. 2006. Farm management handbook of Kenya. Vol.II – Natural conditions and farm management information – 2nd edition. Part C, East Kenya, Sub-part C1, Eastern Province.

[10] KEPSA (2014). *Climate Change and the Agriculture Sector,* Nairobi Kenya

[11] Kieti R.N., Kauti M.K., & Kisangau D.P. (2016). *Biophysical Conditions and Land Use Methods Contributing to Watershed Degradation in Makueni County, Kenya*. J Ecosys Ecograph 6: 216. doi:10.4172/2157-7625.1000216

[12] Mbuli, C.S., Fonjong, L.N &, Fletcher, A.J. (2021). *Climate Change and Small Farmers' Vulnerability to Food Insecurity in Cameroon.* Sustainability,13, 1523. https://doi.org/ 10.3390/su13031523.

[13] MoALF (2016). *Climate Risk Profile for Makueni. Kenya County Climate Risk Profile Series.* The Kenya Ministry of Agriculture, Livestock and Fisheries (MoALF), Nairobi,Kenya.

[14] Muema, E., Mburu, J, Coulibaly, J., & Mutune, J., (2018). *Determinants of access and utilisation of seasonal climate information services among smallholder farmers in Makueni County, Kenya.* Elsevier Heliyon 4 (2018) e00889. doi: 10.1016/j.heliyon.2018. e00889

[15] Ndiritu, S. W. (2021). Drought responses and adaptation strategies to climate change by pastoralists in the semi-arid area, Laikipia County, Kenya. *Mitigation and adaptation strategies for Global Change*, *26*, 1-18.

[16] Nyika, J. M. (2022). Climate change situation in Kenya and measures towards adaptive management in the water sector. In *Research anthology on environmental and societal impacts of climate change* (pp. 1857-1872). IGI Global.

[17] Ochieng, J., Kirimi, L. & Mathenge, M. (2016). *Effects of climate variability and change on agricultural production:The case of small scale farmers in Kenya*. NJAS - Wageningen Journal of Life Sciences http://dx.doi.org/10.1016/j.njas.2016.03.005

[18] Opoku, S. K., Filho, W. L., Hubert, F., & Adejumo, O. (2021). Climate change and health preparedness in Africa: analysing trends in six African countries. *International Journal of Environmental Research and Public Health*, *18*(9), 4672.

[19] Rahman, T. H.M. and Hickey, G.M., (2020). *An Analytical Framework for Assessing Context- Specific Rural Livelihood Vulnerability, Sustainability* 2020, 12, 5654.

[20] Simotwo, H.K., Mikalitsa, S. M. & Wambua, B.N. (2018). *Climate change adaptive capacity and smallholder farming in Trans-Mara East sub-County, Kenya.* Geoenvironmental Disasters 5:5 https://doi.org/10.1186/s40677-018-0096-2.

[21] Ylva N., Mattias J, Emmeline L. A, Johanna, W., & Ingrid, O. (2020). *Smallholders' Awareness of Adaptation and Coping Measures to Deal with Rainfall Variability in Western Kenya, Agroecology and Sustainable Food Systems* VOL. 44, NO. 10, 1280–1308 https://doi.org/10.1080/21683565.2020.1782305.

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Effect of Spacing and Fertilizer Levels on Growth, Yield and Economics of Grain Amaranth (*Amaranthus hypochondriacus* L.)

Shivani Sunil Tandle

PG Scholar, Department of Agronomy, College of Agriculture, VNMKV, Parbhani, 431402 (MS)- India
*Corresponding author: shivanitandle9374@gmail.com

Received: 30 Sep 2024; Received in revised form: 01 Nov 2024; Accepted: 06 Nov 2024; Available online: 12 Nov 2024

***Abstract*— *The present investigation was conducted to estimate the Impact of spacing and fertilizer levels on growth, yield and economics of grain amaranth during rabi season of 2022 at Experimental farm, Agronomy Department, College of Agriculture, Parbhani. The experiment was laid out in split plotdesign with three replication. Main plots were assigned to the different spacingviz S1: 45cm x 15cm, S2 : 45cm x 20cm and S3 : 30cm x 20cm and subplot comprises of fourfertilizer levels viz. F1 : 30:20:10 NPK kg ha^{-1}, F2 :45:30:15 NPK kg ha^{-1}, F3 :60:40:20 NPK kg ha^{-1} and F4 :75:50:25 NPK kg ha^{-1}. The experimental gross plot size was 5.4 x 4.8 m^2 and net plot size varied as per treatment. On 21st November, 2022, sowing was carried out by dibbling the seed @ 2 kg ha^{-1}. The result of experiment revealed that sowingof amaranth at spacing of 45cm ×15cm and application of 75:50:25 NPK Kg ha^{-1} were found more productive and profitable.*

***Keywords*— Amaranth, Spacing, Fertilizer levels, Growth, Yield, Economics**

I. INTRODUCTION

Amaranth is one of the important and popular plant for grain and leafy vegetable purpose. Amaranth is popularly known as ‘Chaulai’ and Grain Amaranth is called as pseudocereal It belongs to the family Amaranthaceae. In addition to protein, carbohydrates, dietary fiber and dietary fiber and lipids, grain amaranth also contains high levels of calcium, iron, magnesium, phosphorous, copper, maganese, cobalt, chromium, iodine, selenium, zinc, molybdenum and sodium like other cereals which are also required by the human body in very small quantities.

Amaranth has C_4 metabolism as well as deep root system, results in increased efficiency to use CO_2 under wide range of both temperature and moisture stress environment. The crop can be grown in any type of soil. Amaranth grows best under hot and humid climate although, it tolerates drought, low fertility and adverse climate condition. Amaranth has a short growing period, grain amaranth can be harvested at 90 days. In India, Amaranth is cultivated both in hills as well as plains covering states of Madhya Pradesh, Uttar Pradesh, Uttarakhand, Maharashtra, Gujarat, Orissa, Karnataka, Bihar. The exact information about area, production and productivity of grain amaranth at national level is lacking.

Plant spacing is a non-monetary input, but it plays a vital role by changing the magnitude of competition. Uniform distribution of crop plants over an area results in efficient use of nutrients, moisture, and suppression of weeds leading to high yield. Higher plant population may compensate the lower individual plant yield. Hence, it is necessary to maintain optimum plant population to get high productivity. The balanced use of fertilizer plays a vital role in enhancing the productivity of crop. Nitrogen, phosphorus and potassium are the essential plant nutrients required for healthy growth of plants. Availability of low concentration of these nutrients in plants rigorously limits the yield and produces more or less distinct deficiency symptoms. In one of the study, it has been observed that the grain amaranth respond good up to fertilizer dose of 60:40:20 NPK kg ha^{-1} (Raiger *et al.*,2009). There is limited and preliminary information available on the plant spacing and fertilizer requirements of amaranth (Olaniyi *et al*., 2008). Keeping this in view, the present investigation entitled 'Effect of spacing and fertilizer levels on growth, yield and economics of grain amaranth (*Amaranthus hypochondriacus* L.)

II. MATERIAL AND METHODS

The experiment was conducted during rabi season of 2022 at Research Farm, Department of Agronomy, College of Agriculture Parbhani, Maharashtra. The experimental site featured a clay-like soil texture with a slightly alkaline reaction (pH 7.67). Prior to sowing, the soil's nutrient profile revealed moderate levels of available nitrogen (276.5 kg ha^{-1}), moderate levels of available phosphorus (11.9 kg ha^{-1}) and very highlevels of available potassium (428.2 kg ha^{-1}). The site is well-drained nature facilitated to optimal growth of amaranth.

The experiment was laid out in split plotdesign with three replication. Main plots were assigned to the different spacing viz S1: 45cm x 15cm, S2: 45cm x 20cm and S3: 30cm x 20cm and subplot comprises of three fertilizer levels viz.F1 : 30:20:10 NPK kg ha^{-1}, F2 :45:30:15 NPK kg ha^{-1}, F3 :60:40:20 NPK kg ha^{-1} and F4:75:50:25 NPK kg ha^{-1}. The experimental gross plot size was 5.4 x 4.8 m^2 and net plot size varied as per treatment. Sowing was done by dibbling seeds @ 2 kg ha^{-1} on 21st November, 2022. The harvest took place on April 05, 2023.

III. RESULTS AND DISCUSSION

Growth attributes:

The data pertaining to various growth parameter of amaranth were significantly influenced by different spacing and fertilizer levels are presented in Table 1. The result revealed that sowing of amaranth seed at spacing of 45 x20 cm recorded maximum number of branches $plant^{-1}$ (41.58), number of functional leaves $plant^{-1}$ (121.1), leaf area $plant^{-1}$ (41.17), drymatter accumulation $plant^{-1}$ (49.16 g) which was significantly superior over rest of the spacings. The maximum growth was recorded in wider spacing as compared to close spacing. The higher growth might be due to sufficientspace, moisture and nutrients in wider spacing, which accelerated the growth and development of the crop. Similar findings were observed by Rahman *et al*. (2007), Patel *et al*. (2011), Chaudhari *et al*. (2022)

In case of fertilizer levels, application of 75:50:25 NPK kg ha^{-1} (F4) recorded significantly higher growth attributes like plant height (157.2 cm), number of branches $plant^{-1}$(42.60), number of leaves $plant^{-1}$ (120.9), leaf area $plant^{-1}$(42.00 dm^2), total dry matter accumulation $plant^{-1}$ (48.25 g). The higher growth of plant might be due to beneficial effect of nutrients which resulted in higher growth of crop. The results were in line with the findings of Kushare *et al*. (2010), Nawlakhe *et al*. (2011), Dehariya *et al*. (2019), Srujan *et al*. (2021)

Table 1: Effect of different treatments on growth- related attributes of amaranth.

Treatments	Plant height (cm)	No. of branches $plant^{-1}$	No. of functional leaves $plant^{-1}$	Leaf area $plant^{-1}$ (dm^2)	Dry matter accumulation $plant^{-1}$ (g)
Spacing (S)					
S1 : 45 cm × 15 cm	148.7	37.41	115.5	37.76	40.76
S2 : 45 cm × 20 cm	140.3	41.58	121.1	41.17	49.16
S3: 30 cm × 20 cm	158.6	36.53	107.4	35.65	37.16
SE (m) ±	3.1	0.89	2.6	0.96	0.86
C.D. at 5 %	12.0	3.50	10.1	3.77	3.36
Fertilizer levels (F)					
F1 : 30:20:10 NPK kg ha^{-1}	138.7	33.58	106.3	33.87	35.27
F2 : 45:30:15 NPK Kg ha^{-1}	146.8	36.34	113.1	35.78	39.39
F3 : 60:40:20 NPK Kg ha^{-1}	154.1	41.49	118.3	41.12	46.54
F4 : 75:50:25 NPK Kg ha^{-1}	157.2	42.60	120.9	42.00	48.25

SE (m) ±	1.3	0.45	1.8	0.57	0.97
C.D. at 5 %	3.9	1.33	5.2	1.69	2.89
SxF					
SE (m) ±	2.2	0.78	3.1	0.98	1.68
C.D. at 5 %	NS	NS	NS	NS	NS
GM	**149.2**	**38.50**	**114.7**	**38.19**	**42.36**

Yield:

The yield parameters including grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and biological yield (kg ha^{-1}) was influenced significantly due to spacing. The result presented in Table 2 inferred that the effect of spacing and fertilizer levels was found significant on yield. The grain yield (1419 kg ha^{-1}), straw yield (4245 kg ha^{-1}), biological yield (5664 kg ha^{-1}), harvest index (25.06 %) were recorded maximum with the spacing 45 cm x 15 cm (S_1) and was significantly superior over 45cm x 20 cm (S_2), however, it was at par with 30 cm x 20 cm (S_3). Thus it can be concluded that spacing 45 cm x 15 cm and 30 cm x20 cm were found comparable for getting higher yield of amaranth. This might be due to higher plant population under closer spacing that resulted in higher photosynthetic activity along with proper grain filling and thus contributed to higher yield. The similar observations also recorded by Vaghela *et al*. (2018), Verma *et al*. (2022).

The result revealed that application of 75:50:25 NPK kg ha^{-1} (F_4) recorded the higher yield like grain yield (1544 kg ha^{-1}), straw yield (4463 kg ha^{-1}), biological yield (6007 kg ha^{-1}), harvest index (25.70 %) as compared to 30:20:10 NPK kg ha^{-1}(F_1) and 45:30:15 NPK kg ha^{-1}(F_2) but it was found at par with 60:40:20 NPK kg ha^{-1}(F_3). This might be due to balanced application of nutrients which enhanced growth and development of the crop and resulted higher yield. The results corroborated the findings of Parmar *et al*. (2009), Solanki *et al*. (2016), Keraliya *et al*. (2017), Jangir *et al*. (2019), Srujan *et al*. (2021), Rana *et al*. (2022).

Table 2: Effect of different treatments on yield of amaranth.

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index
Spacing (S)				
S_1 : 45 cm × 15 cm	1419	4245	5664	25.06
S_2 : 45 cm × 20 cm	1206	3737	4943	24.39
S_3: 30 cm × 20 cm	1318	4019	5337	24.69
SE (m) ±	38	90	109	-
C.D. at 5 %	150	355	429	-
Fertilizer levels (F)				
F_1 : 30:20:10 NPK kg ha^{-1}	1026	3387	4413	23.25
F_2 : 45:30:15 NPK Kg ha^{-1}	1187	3776	4964	23.92
F_3 : 60:40:20 NPK Kg ha^{-1}	1500	4375	5876	25.53
F_4 : 75:50:25 NPK Kg ha^{-1}	1544	4463	6007	25.70
SE (m) ±	29	40	45	-
C.D. at 5 %	85	118	132	-
SxF				
SE (m) ±	50	69	77	-
C.D. at 5 %	NS	NS	NS	-
GM	**1314**	**4000**	**5315**	**24.73**

Table 3: Effect of different treatments on economics of amaranth.

Treatments	Cost of cultivation (₹ ha^{-1})	Gross Monetary Returns (₹ ha^{-1})	Net Monetary Returns (₹ ha^{-1})	B : C ratio
Spacing (S)				
S_1 : 45 cm × 15 cm	35691	99359	63668	2.77
S_2 : 45 cm × 20 cm	35306	84414	49108	2.38
S_3: 30 cm × 20 cm	35993	92225	56232	2.56
SE (m) ±	-	2682	2664	-
C.D. at 5 %	-	10530	10460	-
Fertilizer levels (F)				
F_1 : 30:20:10 NPK kg ha^{-1}	34217	71820	37603	2.10
F_2 : 45:30:15 NPK Kg ha^{-1}	35157	83106	47948	2.36
F_3 : 60:40:20 NPK Kg ha^{-1}	36155	105008	68853	2.90
F_4 : 75:50:25 NPK Kg ha^{-1}	37124	108064	70940	2.91
SE (m) ±	-	2007	1994	-
C.D. at 5 %	-	5963	5924	-
SxF				
SE (m) ±	-	3476	3453	-
C.D. at 5 %	-	NS	NS	-
GM	**35663**	**91999**	**56336**	**2.57**

Economics:

The data furnished in Table 3 revealed that economics like GMR (99359 ₹ ha^{-1}), NMR (63668 ₹ ha^{-1}) were recorded maximum with the spacing 45 cm x 15 cm (S_1) and was found at par with spacing 30 cm x20 cm (S_3). This might be due to higher grain yield was obtained with 45 cm ×15 cm (S_1) and 30 cm × 20 cm (S_3) which reflected in achieving returns. The result of experiment revealed that the spacing of 45cm×15cm (S_1) recorded higher benefit-cost ratio (2.77) followed by 30 cm ×20 cm (S_3) (2.56). This might be due to higher gross monetary return and less cost of cultivation in spacing 45cm×15cm (S_1). These results are inconformity with those reported by Chaudhari *et al.*(2009), Vaghela *et al*. (2018), Palanjiya *et al*. (2019) in grain amaranth.

The economic analysis of the data revealed that application of 75:50:25 NPK kg ha^{-1} (F_4) recorded the higher economics like GMR (108064 ₹ ha^{-1}), NMR (70940 ₹ ha^{-1}) and it was found at par with 60:40:20 NPK kg ha^{-1} (F_3). It might be due to a higher grain yield achieved due to better nutrition which eventually resulted in higher GMR and NMR. The application of 75:50:25 NPK kg ha^{-1} recorded higher B: C ratio (2.91), which was closely followed by application of 60:40:20 NPK kg ha^{-1}(2.90). The higher B:C ratio might be due to higher gross monetary return obtained under fertilizer level 75:50:25 NPK kg ha^{-1} and 60:40:20 NPK kg ha^{-1}. These findings are in line with the earlier findings of Patel *et al*. (2011), Keraliya *et al.* (2017), Srujan *et al.* (2021), Rana *et al.* (2022).

IV. CONCLUSION

The findings of the experimentation indicated that dibbling of amaranth at spacing of 45 x15 cm was found more productive and profitable. application of 75:50:25 NPK kg ha^{-1} recorded significantly higher growth, yield attributes and economics of amaranth. However, it was comparable with 60:40:20 NPK kg ha^{-1}.

REFERENCES

[1] Chaudhari, J.H., Raj,V.C., Rajeev K Srivastava and Ahir, M.P.(2009). Effect of varying sowing date and row spacings on yield attributes and yields of Rabi grain amaranth (Amaranthus hypochondriacus) under south Gujarat

conditions. Agric. Sci. Digest, 29(2):1-2.

[2] Chaudhari, R.H., Mali, P.C., Darulekar, V.R., Salvi, B.R. and Mahadik, S.G. (2022). Effect of consecutive sowings and spacing on growth and yield of Amaranthus. The pharma Innovation Journal., **11**(7): 2274-2278

[3] Jangir, R., Thanki, J.D.,Tajane, D. and kumar, S.(2019) .Growth, yield and economic of grainamaranth (*Amaranthus hypochondriacus* L.)as affected by integrated nitrogen management. *Int.J.Pure App.Biosci.*,**7**(3): 329-334.

[4] Keraliya, S.J., Desai,L.J., Patel,S.J. and Kanara,D.A. (2017). Effect of integrated nitrogen management on yield, quality and economics of grain amaranth (*Amaranthus hypochondriacus* L.). *Int.J.Pure App. Biosci*., **5**(6):531-534.

[5] Kushare, Y.M., Shete, P.G., Adhav, S.L. and Baviskar, V.S.(2010).Effect of FYM and inorganic fertilizer on growth and yield of Rabi grain amaranth (*Amaranthus hypochondriacus* L.) *Internat.J.Agric.sci.*,**6**(2): 491-493.

[6] Nawlakhe, S.M. and Mankar,, D.D. (2010). Response of grain amaranth (*Amaranthus gangeticus* L.) to spacing and fertilizer levels under irrigated condition., *Crop. Res*.**41**(1,2,3):85-87.

[7] Olaniyi, J.O., Adelasoye, K.A. and Jegede, C.O. (2008). Influence of nitrogen fertilizer on the growth, yield and quality of grain amaranth varieties. *World J. Agric. Sci.* **4**, 506-513.

[8] Pallavi Dehariya, D.K. Mishra, Rajkumar Dhakad and Arun kumar (2019). Studies on different levels of nitrogen application on growth and yield of amaranthus (*Amaranthus tricolor* L.).*Int. J. Curr. Microbio. App. Sci.* **8**(04): 1423-1427.

[9] Palanjiya, R.R., Solanki, R.M., Meena, A. and Malam, K.V. (2019). Effect of spacing and nitrogen levels on growth and yield of rabi fodder sorghum (sorghum bicolor L.) International Journal of Chemical Studies, 7(5): 2566-2269.

[10] Parmar, J.K. and Patel, J.J.(2009). Effect of nitrogen management on growth and yield of grain amaranth (*Amaranthus hypochondriacus* L.) grown on loamy sand soil. An Asian Journal of Soil Science, **4**(1):106-109.

[11] Patel. K.I., Patel, B.M., Patel, S.J., Patel, P.T., Patel, S.M. and Patel, P.M. (2011). Effect of levels of nitrogen and iron on yield on grain amaranth (*Amaranthus hypochondriacus* L.) under different planting techniques. Agric. Sci. Digest., **32**(3) : 193-198

[12] Rahman, M.J., Uddain, J. and Halim, M.A. (2007). Effect of different levels of nitrogen andspacing of growth and yield of stem amaranth (*Amaranthus lividis* L.) *J. Sher. Agric.Univ.*, **1**(1):30-38.

[13] Raiger, H.L., Phogat, B.S., Dua, R.P. and S.K. Sharma (2009). Improved varieties and cultivation practices of grain amaranth. *Intensive agriculture,*8-17.

[14] Rana, R., Paliwal, A., Kumar, A., Shikha and Goswami, G. (2022). Productivity and Profitability enhancement in grain amaranth (*Amaranthus hypochondriacus* L.) through muse of sulphur fertilization in hilly region of Uttarakhand. The pharma Innovation Journal., **11**(3): 648-651

[15] Solanki, R.P., Solanki, R.M., Patel, H.A., Odedra, R.K., Prajapati, V.S. and Dodia, V.D. (2016). Effect of scheduling irrigation and organic manure on yield attributes, nutrient content and uptake of rabi amaranthus (*Amaranthus paniculatus* L.) in Saurashtra Region. International Journal of Science, Environment & Technology., **5**(4): 2076- 2083

[16] Srujan, C.S., Patel, H.H., Madagaudre, Y.B., Lokesh, R. and Terin, P. (2021). The effect of irrigation and nitrogen levels on growth, yield and economics of grain amaranth (*Amaranthus hypochondriacus* L.). The pharma Innovation Journal., **10**(9): 1146-1149

[17] Vaghela, G.M., Chauhan, N.P., Dabhi, M.S. and Patel, H.K. (2018). Effect of dates of sowingand crop geometry on growth, yield attributes, yield and quality of Amaranthus (*Amaranthus hypochondriacus* L.). International journal of Agriculture Sciences., **10**(10): 6044-6046

[18] Verma, V., Kumar, S., Yadav, S., Maurya, S. and Yadav, V. (2002). Effect of different varietiesand spacing on growth and yield of amaranths (*Amaranthus tricolor* L.) under Lucknow conditions. *The Pharma Innovation Journal*; **11**(1): 984-986.

IJEAB
a

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available:https://ijeab.com/
Journal DOI:10.22161/ijeab

On Farm Study on the Efficacy of Nutrient Management Treatments on *Bt.* Cotton

Manmohan Puniya[1], L. R. Choudhary[2] and D. K. Bagri[3]

[1]Krishi Vigyan Kendra, Phalodi, Jodhpur-II, Agriculture University, Jodhpur Rajasthan, India
Present affiliation:
[1, 2 and 3] Krishi Vigyan Kendra, Maulasar,Nagaur-II, Agriculture University, Jodhpur, Rajasthan, India
*Corresponding author. Email: mmpuniya2011@gmail.com

Received: 29 Sep 2024; Received in revised form: 02 Nov 2024; Accepted: 09 Nov 2024; Available online: 14 Nov 2024

Abstract— *A farmer's participatory field experiment was conducted during two kharif seasons of 2020 and 2021 at farmers' fields in Mokheri, Bhojka, Kalimali and Phalodivillages of Jodhpur district of Rajasthan on loamy fine to coarse and medium to low in fertility status. To test the OFT on Efficient use of foliar fertilization technology in Bt cotton cropdeeloped by the Junagadh Agriculture University, Gujarat.The study aimed to analyze the performance and adoption of improved new agriculture technology is a crucialaspects under innovation diffusion process and the most important forenhancing agriculture production at a faster rate. These aspect On Farm Trials technology is one of the most powerful tools for assessment and transfer of technology.The present study was find out the production enhancement and economics through On Farm Trials technology of Bt. cottonon farmers' fields. The technology On Farm Trial recorded additional pooled yield over farmers' practices under OFTs the seed cotton and stalkyieldsof Bt. cottonwas increased 14.70 and11.48percent over farmers' practices. Adoption of improvedpackage of practices under OFTs in Bt. cotton cultivation recorded higher B:C ratio 2.19 as compared to farmers' practices 1.96 and net returns under OFTs was Rs. 69,287 and farmers' practicesRs 54,287 recorded. Improved technology (OFTs seed cotton and stalk yields was 19.5 and 23.3 q/ha as compared to farmers' practices 17.0 and 20.9q/ha. Thus, it may be concluded thatuse of fertilizers as per recommendation with foliar spray of WSF 1 % NPK (19:19:19) at flowering, Boll formation and Boll development stages is effective and economical feasible practice in Bt. Cotton of farming community under irrigated conditon of Rajasthan.*

Keywords*— *Economics, WSF, On Farm Trial, Productivity, Bt. C

I. INTRODUCTION

Bt. cotton(*Gossypium spp.)is*King of fibreis one of the most important textile fibres in the world, accounting for around 35 per cent of total world fibre use. It is a major cash crop in the world and is grown commercially in more than 52 countries. It is grown in both irrigated as wella s rainfed conditions and seed cotton yield is manly depends on timing and intensity of rainfall. It is mainly grown for fibre production and seed yield is considered to be secondary importance. Now a days farmers are unable to gain maximum production of *Bt.* Cotton as compared to area under cultivation due to several constraints, uneven distribution of rainfall throught the growing season,imbalanced use chemical fertilizers without knowing soil nutrients status and requirement of the crop. World cotton area is stagnant from last fie decades but production ha sbeen sharply increased due to introduction of *Bt.* cottonhybrids. Intensive agriculture with very high nutrient turnover in the soil- plant system coupled with low and imbalanced fertilizers use resulting in deterioration of soil fertility and productivity and this is serios threat to long term sustainability of crop producccction. The area under *Bt.* Cotton is increasing continuously but productivity are due to derecasingsoil fertility especially micronutrients,imbalanced fertilizers use and occurrences of physiological disorders like Square dropping and drying, leaf reddening and boll drop. Etc. Amomg all these, imbalanced use fertilizers is the major problem. These nutrientare more importance in *Bt.* Cotton synchronized boll developmentaltered the soure-sink relationship due tomrapid translocation of saccharides and nutrients from leavesto development bolls (Hebbar *et* al., 2007). Tooercome the problems, additional nutrition through foliarspary is required over and above the normal fertilizers recommendation. This is on eof most efficient ways to supplying essential nutrients for a growing crop. Bt cotton hybrids now constitute about 90 per cent of the cotton area sown in the country (Kakade et al., 2017). The obvious reasons for low productivity of cotton can be attributed to large area (more than 90 per cent) under rainfed conditions, use of sub-optimum doses of fertilizers, application of nutrients and irrigation water at improper stages of crop growth as well as the imbalanced plant nutrition. To overcome these problems, it is imperative to apply optimum doses of nutrients with judicious use of irrigation water at proper crop growth stages. Water and fertilizers are the most important critical inputs for producing vigorous healthy plants and improving the yield of cotton crop. However, the rising prices for fertilizers and other inputs are of increasing concern for farmers as fertilizer and water management has an important impact on the profitability of cotton production. Hence careful scheduling, quantity and method of application of both water and fertilizer are needed. Drip fertigation is an efficient method of applying fertilizers where irrigation water is utilized as the carrier and distributor of plant nutrients thus ensuring accurate and uniform application of nutrients in the vicinity of active root zone and influences the uptake and yield of the crop with minimum losses of nutrients through volatilization, leaching and fixation in the soil (Yende, 2003 and Pawar et al., 2014). However, fertigation with liquid fertilizer or 100 per cent water soluble fertilizer has been found to increase the efficacy in the application of fertilizer besides reducing the quantity of fertilizers applied. This in turn, reduces the cost of production and also minimizes the ground water pollution thereby preventing ecological disturbances and health risks occurred due to leaching and accumulation of nitrates in the deeper layers. As such use of fertigation could prove as a blessing for Indian farming may pave the way for efficient use of costly and scarce fertilizers. In India, due to continuos use of imbalanced chemical fertilizers resulted in adverse effect on the production of land and high cost of fertilizers enforced to farmers to search alternatiesto fertilizers. Scientific and efficient use offertilizers play back to farmers more profit as per unit cost of cultivation. that The water soluble fertilizers gives a better crop response than either hand or broadcasting methods. soluble fertilizers like NPK (19:19:19) at flowering, Boll formation and Boll development stages is completely dissolved easily in water and are immediately available for crops. The water soluble NPK fertilizers play major role in growth Boll formation and Boll development for cotton. The *Bt.* Cotton production was 6.13 million tonnes from an area of 662498 hectares with a productivity of 1573 kg/ha in Rajasthan. In the Phalodi district, the *Bt.* cotton crop is grown in an area of 106412 ha with an annual production of over 267465 million tons with a productivity of 427 kg/ha (GoR, 2024).

To conducting the On Farm Trials on farmers' field help to identify potential technology compared to farmers' practices and powerful tools to find out the suitable technology for aarea(Singh *et al.,* 2013) it help in improving the socio-economic status. Fertigation is the most effective and convenient mean of maintaining optimum fertility levels and water supply according to specific needs of each crop and types of soil resulting in higher yields and better quality of crops. Fertigation offers advantages of saving in fertilizers as well as increase in fertilizer use efficiency (Nakayama and Bucks, 1986)

II. MATERIALS AND METHODS

The present study On Farm Trials were conducted on*Bt.* cottonin irrigated condition in Jodhpur district of Rajasthan. *Bt.* cottonis an important cash crop of the area in *kharif* season. Farmers of this area usually prefer use of DAP in standing crop of cotton after first and second irrigation. They believe that it increases plant growth and yield. Therefore, the present OFT is undertaken by KVK Phalodi to find out low costefficient fertilizer in Bt cotton. The title of OFT was: "Efficient use of foliar fertilization in *Bt* cotton crop".TheJunagadh Agriculture University, Gujarat recommended a practice use of fertilizers as per recommendation with foliar spray of WSF NPK (19:19:19) at flowering, Boll formation and Boll development stages. So, KVK Phalodi decided to sort out the problems at farmer's field in the district. In total 08 on farm trials were conducted on farmers' field in villages *viz.*,Mokheri, Bhojka, Kalimaliand Phalodiof Jodhpur district of Rajasthan during 2020 and 2021. Each on farm trials was conducted on an area of 0.4 ha, adjacent-to the onfarm trials plot was kept as farmer's practices. Observation on two major performance indicators *viz.* (1) Technical observations: Plant height (cm) of *Bt.* cottonat harvest stage, nos of sympodial branches per plant, yield and yield attributes of *Bt.* cottonduring crop season, (2) Economic indicator: likes Gross cost (Rs./ha) Gross return (Rs./ha), Net return (Rs./ha) and Benefits Cost Ratio and ICBR and (3) Farmers reaction and feedback:On assessed technology were also observed and all the observations collected from eight on farm trials (assessed and control plots) and there feasibility and economic viability were evaluated.The package of improved technologies like line sowing, nutrient management, seed treatment and whole package were used in the onfarm trials. The private sectors *Bt.* cottonvarieties were included in on farm trials methods used for the present study with respect to on farm trials and farmers' practices. In case of local check plots, existing practices being used by farmers were followed. In general, soils of the area under study were loamy fine to coarse and medium to low in fertility status. The spacing was 108 cm between rows and 60 cm between plants in the rows. Seed sowing was done in the last week of May to first week of June, with a seed rate of 1.8 kg/ha. The crop was fertilized with recommended dose of fertilizers *viz*., 150:40:0 NPK/ha. Full dose of P and one third part of N were applied at basal application and remaining N was applied in 2 equal splits at first irrigation and boll development stage. Other management practices were applied as per the PoP for *kharif* crops by Department of Agriculture, Agro-climatic Zone Ia-Arid Western Plains Zone (DOA, 2020-21). Data with respect to seedcottonyieldand stalk yield from on farm trials plots and from farmer's fields cultivated following local practices adopted by the farmers of the area were collected and evaluated.Herbicides were applied with manually operated knapsack sprayer delivering a spray volume of 500 l/ha through flat-fan nozzle at pre-emergence and 30 DAS. The crop was harvested in last week of October during both of the years. Average total annual rainfall received389.9 mm during crop growing season in 2020 and 262 mm in 2021, as most of the annual rain occurred in monsoon season. Economics were calculated using prevailing market price of inputs. Keeping these facts in view aOFT was conducted to study the effect of water soluble fertilizers through foliar spray at different stages on quality, nutrient content and nutrient uptake of *Bt.*Cotton.

Treatments details:

Farmer's practices (T1): Use of DAP in standing crop (Farmer's Practice)

Recommended technology(T2): Use of fertilizers as per recommendation 150:40:0 NPK/ha (Recommended practice)

Assessed technology (T3): Use of fertilizers as per recommendation with foliar spray of WSF 1 % NPK (19:19:19) at flowering, Boll formation and Boll development stages (Assessed technology)

III. RESULTS AND DISCUSSION

(i) **Plant height (cm):** It was observed in table 1 that Plant height was maximum in T_3 (132, 136 and 134 cm) followed by T_2 (129, 132 and 130.5 cm) and farmer practice (124, 126 and 125 cm) in both years of trials as well as in pooled data. It enhanced the plant height by 6.45 and 2.32 per cent in 2020, 7.93 and 3.03 per cent in 2021 and 7.20 and 2.60 per cent in pooled analysis at harvest stage, over T1 and T2 treatments, respectively.

(ii) **Sympodial branches per plant:** The sympodial branches per plant were maximum in T_3 (12.5, 12.47 and 12.48) followed by T_2 (11.40, 11.65 and 10.83) and farmer practice (10.65, 10.83 and 10.74) in both years of trials as well as in pooled data.

(iii) **Numbers of bolls per plant:** It was observed that numbers of bolls per plant were maximum in T_3 (55, 58 and 56.5) followed by T_2 (51, 54 and 52.5) and farmer practice (46, 49 and 47.5) in both years of trials as well as in pooled data. It enhanced the numbers of bolls per plant by 19.56 and 7.84 per cent in 2020, 18.36 and 7.40 per cent in 2021 and 18.94 and 7.60 per cent in pooled analysis over T1 and T2 treatments, respectively.

(iv) **Impact of OFTs on seed cotton yield and stalk & Biological yields:** KVK Phalodi assessed efficient use of foliar fertilization in *Bt* cotton hybrid crop using of DAP instanding crop (Farmer's Practices-T_1), use of fertilizers as per recommendation (Recommended practices-T_2) and fertilizers as per recommendation with foliar spray of WSF 1 % NPK (19:19:19) at flowering, Boll formation and Boll development stages (T_3). It was observed that seed cotton yield under T_3 treatment increased by 14.20 % and 6.62 % during 2020 and 15.11 % and 7.02 % during 2021 whereas, seed cotton yield increased by14.70 % and 6.55 % in pooled analysis over farmer practice (T_1) and Recommended practice (T_2). The seed cotton yield was maximum in T_3 (19.30,19.8 and 19.5 q/ha) followed by T_2 (18.10, 18.50 and 18.3 q/ha) and farmer practice (16.9, 17.2 and 17.0q/ha) in both years of trials as well as in pooled data. Further, the stalk yield under T_3 treatment increased by 12.20 % and 2.22 % during 2020 and 10.28 % and 3.05 % during 2021 whereas, seed cotton yield increased by 11.48 % and 2.65 % in pooled analysis over farmer practice (T_1) and Recommended practice (T_2). The stalk yield was maximum in T_3 (23.0, 23.6 and 23.3 q/ha) followed by T_2 (22.5, 22.90 and 22.7 q/ha) and farmer practice (20.5, 21.2 and 20.9 q/ha) in both years of trials as well as in pooled data, respectively. The technology of On Farm Trial recorded additional yield over farmers' practices under OFTs. The results are close conformity with the research results of Sharma *et al.*, 2016. The data (Table 2) indicated that both years of trials as well as in pooled data observed that treatment T3 produced the maximum biological yield of *Bt.* Cotton was 42.3, 43.4 and 42.8 q/ha followed by T_2 treatment 40.6, 41.4 and 41.0 q/ha and over farmers' practices (37.4, 38.6 and 37.9 q/ha). It registered remarkable increase in biological yield of *Bt.* Cotton was to the extent of 12.92 and 4.39 % over T1 and T2 treatments, respectively in pooled analysis. Further, the harvest index from T_3 group was also the highest (45.56) followed by T_1 (44.85) and T_2 (44.63), respectively.

Table 1. The growth parameters & yield attributes influenced by different treatments of foliar fertilization of Bt. cotton during 2020 and 2021

Treat ments	Plant height at harvest			Nos of sympodial branches/plant			Nos of bolls/plant		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T1	124	126	125	10.65	10.83	10.74	46	49	47.5
T2	129	132	130.5	11.40	11.65	11.52	51	54	52.5
T3	132	136	134	12.5	12.47	12.48	55	58	56.5

Table 2. Effect of foliar fertilization treatments on Seed cotton yield, Stalk and biological yields (q/ha) and harvest index (%) yield of Bt.cotton during 2020 and 2021

Treat ments	Seed cotton yield			Stalk yield			Biological yield			Harvest index (%)		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Poole d	2020	2021	Pooled
T1	16.9	17.2	17.0	20.5	21.4	20.9	37.4	38.6	37.9	45.19	44.56	44.85
T2	18.1	18.5	18.3	22.5	22.9	22.7	40.6	41.4	41	44.58	44.69	44.63
T3	19.3	19.8	19.5	23.0	23.6	23.3	42.3	43.4	42.8	45.63	45.62	45.56

Table 3. Impact of foliar fertilization treatments on economics on Bt. cotton during 2020 and 2021

Treatm ents	Gross cost			Gross returns			Net returns			B: C ratio		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T1	56175	56900	56538	92950	129000	110825	36775	72100	54287	1.65	2.26	1.96
T2	56875	57600	57238	99550	138750	118950	42675	81150	61712	1.75	2.40	2.07
T3	57427	58100	57788	106150	148500	127075	48723	90350	69287	1.84	2.55	2.19

Table 4. Observation on farmers feedback on assessed technology (Use of fertilizers as per recommendation with foliar spray of WSF 1 % NPK (19:19:19) at flowering, Boll formation and Boll development stages on Bt. cotton

SNo	Particulars	Percent
1	Adaptability	75
2	Level of assessed technology acceptance to the farmers	85
3	Compatibility to farming system components	75
4	Compatibility to household internal resources	70
5	Affordability	90

ECONOMICS

The economics parameters of On Farm Trial of *Bt.* Cotton crop are calculated in table 3 and Fig.1). it clearly observed that net returns in *Bt.* cotton were affected to a great extent by foliar spray of WSF practices during both the years of trials as well as in pooled mean. Providing the highest net return under treatment T3 (Fertilizers as per recommendation with foliar sprayof WSF 1 % NPK (19:19:19) at flowering, Boll formation and Boll development stages) of Rs 69287/ha followed by T_2 (Recommended practices) of Rs 61712/ha and T_1 (farmers practices) of Rs. 54287. It provided additional net returns of Rs 15000/ha and 7575 with B:C ratio of 2.19 and over T2 and T1. The higher cost of cultivation Rs 57788/ha observed in T3 group followed by T2 of Rs 57238/ha in On Farm Trial of *Bt.* cotton crop as compared to farmers' practices (56538). The T3 plots have higher mean gross return of Rs 127075/ha followed by T2 of Rs 118950/ha as compared to farmers' practices (110825). Hence, favourable B:C ratio proved the intervention made under in On Farm Trial and convinced the farmers on the utility of technology. The higher net returns and B:C ratioin the demonstrations on improved technologies as compared to farmers' practices and at par with results of present study was also reported by Sreelakshmi *et al.* 2012 and Joshi *et al.* 2014. The farmers' feedback were collected on assessed technology after conducted OFTs for two years trials and its mentioned in Table 4. These observation find out that 75 per cent adaptability, 85 per cent assessed technology acceptance to the farmers, 75 per cent compatibility to farming system components, 70 per cent compatibility to household internal resources and 90 per cent affordability on farmers reactions on assessed technology (Fertilizers as per recommendation with foliar spray of WSF 1 % NPK (19:19:19) at flowering, Boll formation and Boll development stages)

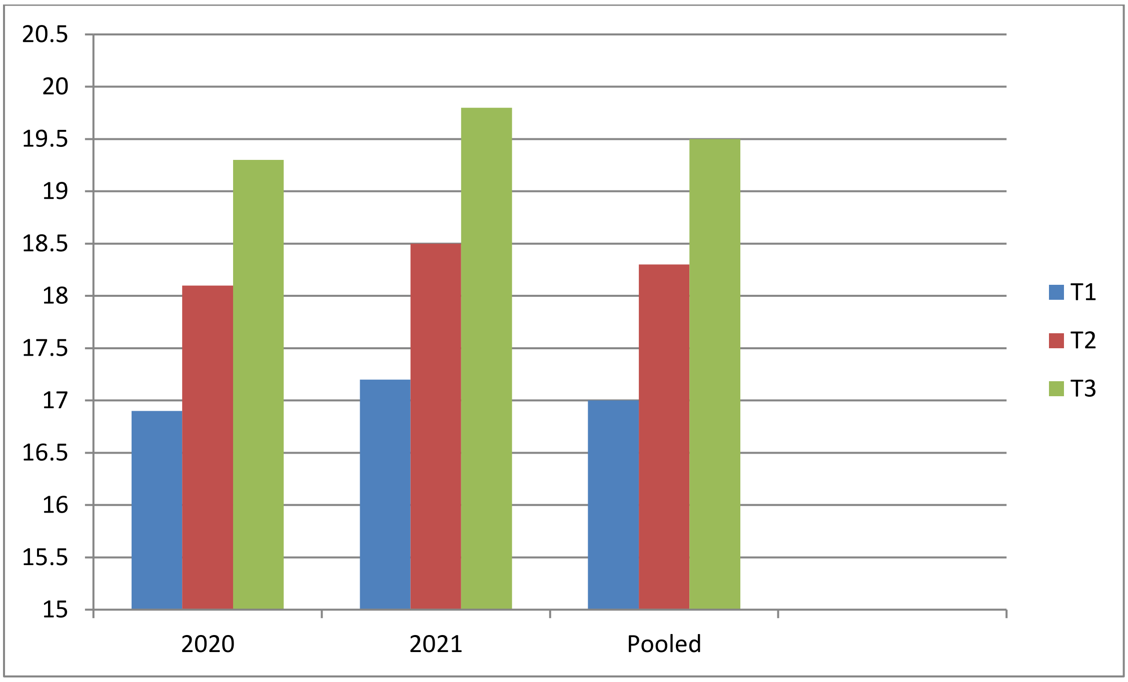


Fig 1. BCR of Bt. cottonunder On Farm Trial in Jodhpur districtof Rajasthan

IV. CONCLUSION

It may be concluded that the seed cotton productivity and net returns in *Bt.*cotton increased statisticallywith improved technologyuse of fertilizers as per recommendation with foliar spray of WSF 1 % NPK (19:19:19) at flowering, Boll formation and Boll development stages.Hence, this practice may be widely popularized for improving socio-economic condition of poor farming community of wester Rajasthan. However, the yield levels under On Farm Trial was better as compared to farmers' practices.The OFTsalso strengthened the interactions and trust between farmers and KVK scientists. It was also concluded that besides other practices of nutrient and weed management, insect-pest management, and water stress are to be given for attention to enhancing*Bt.*cottonproduction in the area. This will subsequently increase the income as well as the livelihood of the farming community of the Jodhpur district.

Fig 2. Performance of fertilizers as per recommendation with foliar spray of WSF 1 % NPK (19:19:19) at flowering, Boll formation and Boll development stageson Bt. cottonunder On Farm Trial in Jodhpur district of Rajasthan (T3)

ACKNOWLEDGEMENT

The authors are highly thankful to the Director, ICAR-ATARI, Zone –II, Jodhpur (Rajasthan) for OFT on *Bt.* cotton under financial support sanctioned towards conducting On Farm Trials at farmers' fields. I am faithfully thankful to all the farmers on whose fields On Farm Trial were conducted and this will be increased the income as well as the livelihood of the farming community of the Jodhpur district.

REFERENCES

[1] DOA.(2020-21). Production and productivity of *kharif* oilseeds in the Agro-climatic zone of Rajasthan.

[2] GOR.(2024). Vital Agricultural Statistics, Govt. of Rajasthan, Pant Krishi Bhawan, Jaipur. pp.05-06.

[3] Hebbar, K.B., Rao, R.K. and Khadi, B.M. 2007. Synchronized boll development of Bt cotton hybrids and their physiological consequences. *Current Science* 93: 693–95.

[4] Joshi, N.S., Bariya, M.K. and Kunjadia, B.B.(2014). Yield gap analysis through frontline demonstrations in wheat crop. *Internation J. Scientific Res. Pub*, 4(9*):1-3.*

[5] Kakade, S., Bhale, V., Deshmukh, J. and Wadatkar, S., 2017. Growth, nutrient uptake and seed cotton yield as influenced by split application of nutrients through fertigation in *Bt* cotton. *Int. J. Curr. Microbiol. App. Sci*., 6 (9): 2982-2990.

[6] Nakayama FS, Bucks DA. Trickle irrigationfor crop production: Design, operation and management, Elsevier, Amsterderdam. The Netherlands 1986, 223.

[7] Pawar, D. D., Dinger, S. K., Bhakre, B. D. and Surve, U. S., 2014. Nutrient and water use by Bt Cotton (Gossypium hirsutum) under drip fertigation. *Indian J. Agron*., 58 (2): 238-242.

[8] Singh, G. C. and Singh, S. K.(2013). Impact of on farm trials and various varieties of okra on the farmers field. *Journal of Agri Res*,13(1):78-80.

[9] *Sharma, V., Kumar, V., Sharma, S. C. and Singh, S.(2016).* Productivity enhancement and popularization of improved production technologies in wheatthrough frontline demonstrations. *Journal of Applied and Natural Science, 8(1):423-428.*

[10] *Sreelakshmi, C. H., Sameer, K., C.V. and Shivani, D.(2012).* Productivity enhancement of pigeonpea through improved production technology. *Madras Agril. J*,99 (4-6):248-250.

[11] Yende, B. S., Ahatonde, N. D. and Vyas, J. S., 2003. Response of pre-monsoon hybrid cotton to NPK fertilization through fertigation. *Annals Plant Physiol*., 17 (2): 211-212.

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Effect of Organic manure and Jeevamrit on growth yield and quality of radish (*Raphanus sativus* L.) under U.P. condiotion

Deepti Srivastava*, S P Singh, LP Yadava, J K Singh, Richa Singh

Department of Horticulture, Chandra Bhanu Gupta Agriculture Post Graduate College, Lucknow, U.P., India
*Corresponding author: dsrivastava48@gmail.com

Received: 02 Oct 2024; Received in revised form: 03 Nov 2024; Accepted: 08 Nov 2024; Available online: 16 Nov 2024

***Abstract*— *Radish is one of the well-known root crop and its popularity could be due to its wider climatic adaptation, easy cultivation method and a wider range of its uses. Excessive chemical fertilizer could lead to chemical toxicity in the root crop and affected the growth and yield of radish. A field experiment was assessed to conducted in randomized block design with five treatment and three replications with the setup of T1 –Without manuring,T2-FYM @5Tha^{-1} +Vermicompost@ 1.75Tha^{-1}+ jeevamrit@5%conc, T3-FYM@5Tha^{-1}+vermicompost@1.75Tha^{-1} +jeevamrit@ 10%conc, T4-FYM @2.5Tha^{-1} +Vermicompost @.087Tha^{-1}+jeevmrit@5% conc and T5-FYM @2.5 Tha^{-1}+Vermicompost@ 0.87Tha^{-1} +jeevamrit @10% conc. respectively to evaluate the effect of organic manure and jeevamrit on growth, yield and quality of radish.The results revealed that treatment T3 -FYM@5Tha^{-1}+vermicompost@1.75Tha^{-1} +jeevamrit@ 10%conc were significantly enhanced the growth characters i.e. number of leaves(28.67)at 120 DAS, leaf length(26.63cm) at 120DAS , Leaf breadth(6.06cm) after 120 DAS whereas, yield characters i.e. root length (26.16cm),root diameter(3.79cm),TSS(5.25^{0}B),Fresh weight of root(20.16g),fresh weight of plant(61.21g), yield(224.64gha^{-1}), were also found highest with T3-FYM@ 5Tha^{-1}+vermicompost@1.75Tha^{-1} +jeevamrit 10% conc. The study suggested that the application of jeevamrit along with organic manures was found more beneficial and significantly improved the growth and yield of radish under U.P. condition.*

Keywords— ***jeevamrit, organic manure, vermicompost, DAS, root weight.***

I. INTRODUCTION

Radish *(Raphanus sativus* L.*)* is an annual quick growing root vegetable crop, grown for their young tender roots and widely cultivated in both tropical and temperate areas of the world. It belongs to the Brassicaceae family and diploid chromosome numbers are 2n=18. Radish is low in calories and a good source of vitamin C, protein, fat, minerals, fibre, and carbohydrates. It supplies variety of minerals like calcium, potassium and phosphorous (Kumar *et al*., 2013). Uses of organic manures and liquid natural fertilizers fertilize the soil and provide nutrients to the plants. By delivering nutrients and increasing the physical, chemical and biological qualities of soil organic manures also adds improvement in soil water holding capacity, aeration and fertility (Mani and Amburani.,2018). Higher cost of synthetic fertilizer contributes to poor health of water and soil (Khalid *et al* 2015). Because of the higher concentration of synthetic fertilizer it becomes imperative to go for alternative and cheeper sources like organic manure and natural liquid fertilizer like jeevamrit (kumar *et al*.,2014). Organic manure increases water holding capacity and improve the nutrient supply of the soil, it reduces the nitrogen loss due to slow release of nutrients and improves the production parameter of radish and dry matter production (Subramani *et al*., 2011). Jeevamrit is a microbial culture that can improve soil fertility and crop productivity. it's a key component of zero budget natural farming. microorganism present in liquid nutrient manure that help in break down the organic matand ter and release nutrients into the soil (Jaisankar.,2018)

II. MATERIALS AND METHODS

The investigation was assessed to conduct during Rabi season 2023-24 at Hazipur Agriculture Research Farm, Chandra Bhanu Gupta Krishi Mahavidyalaya, B.K.T., Lucknow (U.P.). The field was well leveled having good soil condition. For the entire experiment, 5 treatments were obtained with 3 replications so that there were 15 experimental plot units. Where each experimental plot consists of 40 plants and each experimental unit consists of 5 sample plants that are observed. The data from the observations were then analyzed using analysis of variance (F test) with a level of .05% with the aim of testing significance level of the treatments. Thus, The experiment i.e. effect of different organic manure and jeevamrit on growth yield and quality of radish (*Raphanus sativus* L.) was set up with 5 treatments i.e.T_1Control (without manuring), T_2 (FYM @ 5tha^{-1} +V.C@1.75t/ha+jeevamrit @5%conc. at 2,3&4 days interval), T_3 (FYM @5tha^{-1} +V.C@1.75t/ha+jeevamrit @10%conc. at 2,3&4 days interval), T_4 (FYM @2.5tha^{-1} +V.C@0.87t/ha^{-1}+jeevamrit @5%conc. at 2,3&4 days interval) and T_5 FYM @2.5tha-^{1} +V.C@0.87tha^{-1}+jeevamrit @10%conc. at 2,3&4 days interval)respectively and are replicated three times. The different observations were recorded by various methods are number of leaves, leaf length (cm.), leaf breadth (cm.), root diameter (cm.), root length (cm.), Fresh weight of root (g), Fresh weight of plant (g), yield (q/ha).The experimental field was thoroughly ploughed 1-2 times. Deep ploughing was done to bring the soil to a fine tilth and all the clods of the soil were thoroughly broken stubble and weeds were removed.

Preparation of Jeevamrit -Jeevamrit is a mixture of cow dung, cow urine, jaggery, pulse floor and living soil. For preparation of jeevamrit, required quantities of ingredients were thoroughly mixed in water and allowed to ferment for 7 days. Ingredients were stirred once in morning and once in evening in clockwise direction. Jeevamrit (@ 10 % drenching) was given at fortnight interval in the respective treatments.

Seed treatment 200 g of Jaggery was dissolved in 100 ml of warm water. Seeds were soaked in Jaggery solution for 15-20 minutes and seeds were dried under shade. Sowing was done on 14th October 2023. Seeds were sown on the ridges at spacing of 20-20 cm.

III. RESULT &DISCUSSION

4.1Growth parameters

The effect of different levels of organic manure with combination of fym, vermicompost and liquid organic fertilizer presented in Table 1 showed the significant results at 30,60,90, and 120 days after sowing. The maximum no of leaves(19.05,23.61,26.63,and28.96),leaf length(19.73,21.90,25.36 and 28.67cm),leaf breadth(3.80,4.80,5.60and 6.06cm)were found with treatment T3(FYM @5tha^{-1} +V.C@1.75tha^{-1}+jeevamrit @10%conc.) at all growth stages after 30,60,90 and 120 days after sowing significantly which was followed by treatment T2(FYM @ 5tha^{-1} $\pm$V.C@1.75tha^{-1}+jeevamrit @5%conc.)respectively in comparison to the other treatment .The increase in no of leaves ,length and breadth of leaves with treatment T3 (FYM @5tha^{-1} +V.C@1.75tha^{-1}+jeevamrit @10%conc.) might be due to quick release of N,P,K to the soil and their quick uptake by plants which results in early maturity with good growth of crop. The liquid natural fertilizer that was applied containing the nutrients by which plants need to grow (Bhattarai.,2013). This is in accordance with the result of research by kumar and Painuli 2014) stated that the plants fertilized with animal based liquid fertilizer exhibited higher total biomass with more profuse development of leaves and fibrous roots. Furthermore, it was noted that the liquid natural fertilizer resulted in increased uptake of nutrients. However, the minimum growth characters such as no. of leaves (13.50,16.43,18.20 and 20.96), leaf length (14.85,18.53,21.26 and 23.36 cm) and leaf breadth (3.20,3.66,4.43 and 5.03 cm) were found with control(T1) significantly after 30,60,90 and 120 days of sowing at all stages of growth respectively.

4.2 Yield Parameter

Root diameter and root length was taken after harvest. Statistical analysis revealed significant differences in between the treatments. The application of liquid natural fertilizer jeevamrit in combination of organic manures increase the root diameter, length of root, fresh weight plant and root yield of radish significantly. The data on root diameter, root length, fresh weight of root fresh weight of plant and root yield of radish were furnished in Table 2. Treatment T3(FYM @5tha^{-1} $\pm$V.C@1.75tha^{-1}+jeevamrit @10%conc.) showed the highest root diameter (3.79cm) which was followed by 3.58 cm with T2(FYM @ 5tha^{-1} $\pm$V.C@1.75tha^{-1}+jeevamrit @5%conc).Application of treatment T3 increased the root diameter but higher concentration of jeevamrit in treatment T3(3.79cm)was found at par with T2(3.58cm). An increase in diameter of root of radish may be attributed with the presence of growth regulators like auxin and gibberellin in it. The lowest root length(21.30 cm)was found with control (T1 Control without manuring)).Application of treatment T3 increased the root diameter but higher concentration of jeevamrit in treatment T3 (3.79cm) was found at par with T2(3.58 cm).Maximum root length(26.16cm),fresh weight of root(20.16g),fresh weight of plant(61.21g) and root yield (224.64qha^{-1})was found with T3(FYM @5tha^{-1} V.C@1.75tha^{-1}+jeevamrit @10%conc) significantly.

Table 1: Effect of different organic manure and jeevamrit on number of leaves, leaf length, and leaf breadth of radish.

Treatments	Number of Leaves				Leaf length(cm)				Leaf breadth(cm)			
	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
T_1: Control (without manuring)	13.50	16.43	18.20	20.96	14.85	18.53	21.26	23.36	3.20	3.66	4.43	5.03
T_2: FYM @ 5tha^{-1} +V.C@1.75tha^{-1}+jeevamrit @5%conc.	18.30	21.56	24.26	28.20	18.98	23.23	26.46	28.56	3.63	4.20	5.10	5.70
T_3: FYM @5tha^{-1}. +V.C@1.75tha^{-1}+jeevamrit @10%conc	19.73	21.90	25.36	28.67	19.05	23.61	26.63	28.96	3.80	4.80	5.60	6.06
T_4: FYM @2.5tha^{-1} +V.C@0.87tha^{-1}+jeevamrit @5%conc.	17.40	19.33	23.26	26.50	17.48	20.33	23.40	27.23	3.53	4.16	4.80	5.10
T_5: FYM @2.5tha-^{1} +V.C@0.87tha^{-1}+jeevamrit @10%conc.	16.26	17.40	20.23	23.20	16.24	19.20	22.33	25.50	3.50	4.20	5.30	5.40
SE m$\pm$	0.186	0.190	0.071	0.144	0.092	0.298	0.245	0.119	.073	.074	.077	.075
CD at .05% level	0.616	0.630	0.236	0.476	0.304	0.987	0.811	0.394	.242	.246	.254	.247

Table 2 Effect of different organic manure and jeevamrit on Root diameter, Root length, Fresh weight of root, Fresh weight per Plant and Root Yield of radish.

Treatments	**Root diameter (cm.)**	**Root length (cm.)**	**Fresh weight of root (g.)**	**Fresh weight of plant (g.)**	**Root Yield (q/ha.)**
T_1: Control (without manuring)	2.72	21.30	16.59	49.79	184.34
T_2: FYM @ 5tha^{-1} +V.C@1.75tha^{-1}+jeevamrit @5%conc.	3.58	25.56	19.54	58.97	217.12
T_3: FYM @5tha^{-1} +V.C@1.75tha^{-1}+jeevamrit @10%conc.	3.79	26.16	20.16	61.21	224.64
T_4: FYM @2.5tha^{-1} +V.C@0.87tha^{-1}+jeevamrit @5%conc.	3.17	25.33	18.81	56.63	209.71
T_5: FYM @2.5tha-^{1} +V.C@0.87tha^{-1}+jeevamrit @10%conc.	3.44	25.03	19.48	58.41	216.45
SE m$\pm$	0.013	0.153	0.028	0.372	0.468
CD at .05% level	0.042	0.506	0.093	1.231	1.551

Different levels of organic liquid formulations like jeevamrit and organic manures enhanced the carbohydrate synthesis and effective translocation of photosynthesis to developing sinks. Jeevamrit increased synthesis of growth promoting substance which in turn helped in increasing growth and yield attributes and finally yield of root. Same findings were revealed by patel (2019).Talashikar et al (1999) reported the beneficial effect of jeevamrit which was attributed to high microbial populations and enzyme due to availability and uptake of nutrients and growth hormone ultimately resulted in better growth and yield of crop. The lowest root diameter(2.72cm)root length (21.30cm)fresh weight of root (16.5g),fresh weight of plant (49.79g) and root yield per hectare (184.34Q) were recorded with T1(control) significantly at all stages of growth of crop.

IV. CONCLUSION

On the basis of present investigation, it could be inferred that vegetative growth for higher numbers of leavers, leaf length, leaf breadth and yield characters like root diameter, maximum root length, fresh weight of root, fresh weight of plant, root yield were obtained with the application of FYM @5t/ha, vermicompost @1.75t/ha + jeevamrit @10%conc. with treatment T3 significantly. The liquid organic manure are rich source of different plant growth hormone and beneficial microorganism and was applied in combination with RDF gave highest growth and yield in radish.The study clearly revealed that there was significant improvement in growth and yield with the combined application of liquid natural manure i.e. jeevamrit @10% concentration,Fym@5Tha^{-1} and vermicompost1.75Tha^{-1} and recommended dose of fertilizer as compared to control.

REFERENCES

[1] Bhattarai B P and Maharjan A. 2013. Effect of organic nutrient management on the growth and yield of carrot (Daucus carota) and the soil fertility status. Nepalese Journal of Agricultural Sciences **11:**16-25.

[2] Degwale, A. (2016) Effect of vermicompost on growth, yield and quality of garlic (Allium sativum L.) in Enebse Sar Midir District, Northwestern Ethiopia. Journal of Natural Sciences Research6(**3**): 2224- 3186

[3] Jaisankar, P. (2018). Effect of integrated nutrient management on growth and yield of radish (Raphanus sativus L.) cv. Pusa chetki. International Journal of Current Microbiology and Applied Sciences, 7(**11**), 461–466, https://doi.org/10.20546/ijcmas.2018.711.054

[4] Kirad K S, Barch S and Singh D B. 2010. Integrated nutrient management on growth, yield and quality of carrot. Karnataka Journal of Agricultural Sciences **23**:542-543.

[5] Khalid, M., Yadav, B. K. and Yadav, M. P. (2015) Studies on the effect of integrated nutrient management on growth and yield attributes of radish (Raphanus sativus L.). Annals of Horticulture8 (**1**): 81-83.

[6] Kumar P, Kumar D, Kumar S and Sharma S. 2013. Effect of integrated nutrient management practices on seed yield and economics of seed production in radish (Raphanus sativus) cv. Chinese Pink. Plant Archives **13**:234-246.

[7] Kumar, S., Maji, S., Kumar, S. and Singh, H.D. (2014) Efficacy of organic manures on growth and yield of radish (Raphanus sativus L.) cv. Japanese White. International Journal of Plant Sciences 9(**1**): 57-60.

[8] Kumar P, Meghwal P R and Painuli D K. 2014b. Effect of organic and inorganic nutrient sources on soil health and quality of carrot. Indian Journal of Horticulture 71:222-226.

[9] Kushwah L, Sharma R K, Kushwah S S and Singh O P. 2019. Influence of organic manures, inorganic fertilizers and their combinations on growth and quality of radish (Raphanus sativus L.). International Journal of Chemical Studies 7:2972-2974.

[10] Mali D L, Singh V, Sarolia D K, Teli S K, Chittora A and Dhakar R. 2018. Effect of organic manures and bio-fertilizers on growth and yield of radish (Raphanus sativus L.) cv. Japanese White. International Journal of Chemical Studies 6:1095-1098.

[11] Mani A P and Anburani A. 2018. Organic nutrient management technique for enhancing growth and physiological parameters in radish (Raphanus sativus L.). Journal of Phytology 10:40-42.

[12] Patel R. 2019. Effect of nutrient management on growth, yield and quality of radish (Raphanus sativus L.) under Malwa region. M.Sc. Thesis. Department of Horticulture. Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Indore. 82p.

[13] Subramani A, Anuburani A and Gayathiri M. 2011. Response of growth parameters of radish (Raphanus sativus L.) to various organic nutrients and biostimulants. The Asian Journal of Horticulture 6:32-34.

[14] Talashilkar, S.C., Bhangarath, P.P. and Mehta, 1999. Changes in chemical properties during composting of organic residues as influenced by earthworm activity. Journal of the Indian Society Soil Science, 47(**1**): 50-53

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Isolation of novel Steroidal Saponin from the stem extract of Andrographis echioides L.Nees

I Helen Diana[1*], Vanathi Sundarapandiyan[2]

[1*]PG & Research Department of Botany, Holy Cross College (Autonomous), Bharathidasan University, Tiruchirappalli, Tamil Nadu, India
[2]PG & Research Department of Botany, National College (Autonomous), Bharathidasan University, Tiruchirappalli, Tamil Nadu, India
*Corresponding Author: Assistant Professor of Botany, PG & Research Department of Botany, Holy cross college (Autonomous), Bharathidasan University, Tiruchirappalli-02
helendiana1981@gmail.com

Received: 12 Oct 2024; Received in revised form: 13 Nov 2024; Accepted: 18 Nov 2024; Available online: 21 Nov 2024

***Abstract*— *The field of ethnopharmacology recommends the use of traditional approaches for the development of drugs from natural sources. The herbaceous species Andrographis echioides, commonly found in the dry regions of the Indian subcontinent and Sri Lanka, was the subject of the present study, which aimed to test this hypothesis by isolating and characterizing compounds from the plant. Specimens were collected from Trichy and identified using monographic data. The ethanolic extract was subjected to preliminary analysis, and chromatographic techniques were employed to separate secondary metabolites. The bioactive compounds were then characterized to determine their chemical compositions and molecular structures. This study emphasizes the significance of natural medicines, specifically focusing on diosgenin, a secondary metabolite found in Andrographis echioides. HPTLC analysis of the ethanolic extract revealed promising results, with Rf values similar to those obtained by ultraviolet spectrum analysis. IR analysis indicated the presence of chemical groups with distinct peak formation, while NMR results demonstrated the intricate structure of the molecules and their associated chemical groups. In conclusion, harnessing the power of natural sources in the pharmaceutical industry has the potential to revolutionize drug discovery and development, as long as the challenges associated with standardization, quality control, and safety are addressed.*

***Keywords*— Drug discovery, Ethnopharmacology, Herbaceous, Molecular structures, Standardization.**

I. INTRODUCTION

Drug discovery necessitates balancing safety and health care [1,2]. Institutions have been established to advance drug discovery [3,4], Aspirin's discovery transformed modern medicine. Despite this progress, ongoing challenges remain. Research strategies must be adapted owing to high costs, lengthy processes, low success rates, and high productivity. Natural sources from plants and microbes, utilizing combinational and genomic methods and rapid in vitro screening, have emerged from traditional medicine [5]. An interdisciplinary approach is essential, involving species identification, compound isolation, and extraction using ethnopharmacology [6]. The isolation of morphine from *Pappaver somniferum* (Opium) initiated natural product drug isolation [7]. Numerous scientists have isolated phytochemicals, primarily alkaloids, from medicinal plants [6]. Historical records show the use of over 1000 medicinal plants, such as *Glycyrrhiza glabra* and *Papaver somniferum*, dating back 5000 years [8]. Ethnopharmacological studies suggest that traditional methods can be used to derive drugs from plants, microorganisms, and animals. In India, over 45,000 species have been identified, with 7000-7300 used in clinical applications [9]. Since the discovery of aspirin in Salix trees, the importance of ethnopharmacology has increased [10]. Metformin from *Galega officinalis*, initially used for type II diabetes, shows potential against cancer [11]. Various medicinal plants enhance community wellness, with some native species serving as edibles, condiments, and spices [12]. Specific plants provide immediate clinical aid to children, elderly individuals, and pregnant women [13]. Indigenous plants contain phytoconstituents in their stems, leaves, roots, bark, flowers, fruits, and seeds, which aid in the treatment of severe diseases [6]. Advancements in secondary metabolite isolation, genetic modifications, animal experiments, and human studies [14] have led to the discovery of specific metabolites for various ailments, such as Taxol from *Taxus officinalis* for cancer [15], Quinone from *Cinchona officinalis* for malaria [16], Emetine from *Carapichea ipecacuanha* for protozoan infections [17], Colchicine from *Colchicum autumnale* [18], and *Gloriosa superba* [19] for gout and rheumatoid arthritis pain, Atropine from *Atropa belladona* as an anti-motility agent [20], and galantamine from *Galanthus woronowii* for early-stage Alzheimer's disease [21]. *Andrographis echioides*, a herbaceous Acanthaceae species, is prevalent in dry regions of the Indian subcontinent and Sri Lanka [22]. The plant, known by various names [23], features an erect habit, with numerous outgrowths, sessile hairy leaves, and sparsely branched raceme inflorescences. The rhombic hairy stem bears white and brownish tubular corollas with hairy lanceolate calyces. Ovoid yellow seeds are found in elliptical, minimally hairy capsules [24,25]. *Andrographis echioides* treats various ailments and is used in traditional Indian medicine [26,27]. Its pharmacological effects are attributed to various phytocompounds, including echioidinin, flavonones, dihydroechioidinin, skullcapflavone derivatives, pinostrobin, androechin, methyl salicylate glucoside, glucopyranoside, and andrographidine [26-29]. The current century underscores the necessity of healthy diets and medications for survival, highlighting dependency on medicines. This indicates a significant interest in naturally occurring medicines, owing to their minimal side effects and accessibility. The present study tested this hypothesis by isolating and characterizing drugs from the natural plant source of *Andrographis echioides.*

II. MATERIALS AND METHODS

2.1 Plant collection and extraction

In this study, stems of *Andrographis echioides* were collected from Trichy. It was identified using keys and plant descriptions from several articles and monographs [30]. The *Andrographis echioides* stem was collected, cleaned, and shaved. The dried stems of the plant were ground using a mechanical grinder and then passed through a 20-mesh sieve. The ethanolic extract of the powdered sample (500 g) was extracted using the hot percolation method. The extract was kept at room temperature (35 °C) for 24 h with mild shaking and then filtered for further analysis [31].

2.2 Phytochemical analysis:

2.2.1 Qualitative analysis:

To evaluate the presence of bioactive compounds, including flavonoids, saponins, terpenoids, tannins, alkaloids, steroids, glycosides, phytosterols, protein, coumarin, emodin, anthraquinone, anthocyanin, carbohydrates, leucoanthocyanin, cardiac glycosides, xanthoproteins, and phenols in the *Andrographis echioides* stem extract, qualitative analysis is performed using specific tests tailored to each chemical compound, along with appropriate solvents [32,33].

2.2.2 *Quantitative analysis:*

Quantitative analysis was performed to determine the concentration of bioactive compounds in the stems of *Andrographis echioides*, enumerating the phytochemicals present, such as flavonoids, saponins, phenols, terpenoids, alkaloids, and tannins, by conducting specific tests for each compound [32,33].

2.3 Preparations of ethanolic extracts

The ethanol extracts were prepared by immersing 500 g of dried plant material in 1 liter of ethanol for a continuous 10-hour period utilizing a Soxhlet extractor. Subsequently, the samples were strained through Whatman filter paper no. 42 which is 125 mm, concentrated, and dried using a rotary evaporator at a reduced pressure. The resulting dried samples, weighing 50 g, were then securely stored in sterile bottles at -20 °C [22].

2.4 Isolation techniques

2.4.1 Column chromotography

The ethanol extract of the samples was used for column chromatography analysis to separate the compounds using thin-layer chromatography with silica gel (Figure 1). The column was eluted with n-hexane, which resulted in an increased amount of ethyl alcohol, and fractions were obtained along with methanol. The solvents used to generate disogenin (56 mg/ 403 g) and ethyl alcohol: methanol (60:40 v/v) were 13 fractions. The secondary metabolites were identified TLC plates by spraying with the Libermann-Burchard reagent and heating at 100 °C for 10 min [34].

Fig: 1 Column chromatography

2.5 Purification techniques of the Isolated compounds:

2.5.1 High perfomance Thin-layer chromotography (HPTLC)

Individual compounds were subsequently dissolved in an appropriate solvent. Of the isolated compounds, 5 µL of disogenin was submerged in silica plates (measuring 20 × 20 centimeters and 0.25 millimeters in thickness) procured from Merck (Germany). A solvent system comprising n-hexane and ethyl acetate at a ratio of 7:3 (v/v) was used to develop the plates for disogenin. Application of the newly prepared Liebermann reagent resulted in distinct zones. The reagent was heated at 100 °C for 10 min. The chromatograms were inspected under normal daylight conditions within the stipulated timeframe [35].

2.5.2 High-performance liquid chromatography (HPLC)

The HPLC System was found with a diode-array detector, and 200 x 4.6 mm C18 column. Methanol (HPLC grade, 0.2 mm filtered) was used as the mobile phase. Disogenin was isolated using a mobile phase consisting of acetonitrile and water (80:20 v/v) at a flow rate of 1.0 ml/min and temperature of 30o C. The injection volume was 40 µL and detection was performed at 346 nm [36].

2.6 Characterization techniques of the separated compound:

Numerous assessments have been performed to identify the isolated substances. Spectroscopic methods employed included ultraviolet analysis, Fourier transform infrared analysis, Hydrogen-1 Nuclear Magnetic Resonance, and Carbon - 13 Nuclear Magnetic Resonance, and gas chromatography-mass spectrometry. The UV–visible spectrum of the isolated compounds in methanol was recorded using a 160A UV–visible spectrophotometer [37]. FTIR spectra were obtained using the Kbr technique, with a nominal resolution of 4 cm^{-1} and a range of 400–4000 cm^{-1} [38]. 1H and 13C NMR spectra were acquired on Bruker WP 200 SY and AM 200 SY instruments (1H, 200.13 MHz; 13C, 50.32 MHz) with TMS serving as the internal standard and CDCL3 as the solvent [39].

III. RESULT AND DISCUSSION

3.1 Phytochemical analysis

3.1.1 Qualitative analysis:

The ethanolic extract of the stem contains various phytoconstituents, including tannins, saponins, flavonoids, terpenoids, alkaloids, steroids, proteins, coumarins, phenols, xanthoproteins, glycosides, emodin, anthocyanins, cardiac glycosides, and leucoanthocyanins shown in TABLE 1. These active phytoconstituents are responsible for the therapeutic properties of the plants. A study conducted in Shahada yielded anticipated outcomes. This investigation utilized *Elytraria acaulis* from the family Acanthaceae. A preliminary investigation was conducted on three types of extraction: chloroform, petroleum ether, and methanol. The two initial extractions resulted in a predominance of steroids and alkaloids, consistent with the aforementioned outcomes [40]. Comparable results were found in another study on *Astercantha longifolia*, which demonstrated the abundance of sterols in petroleum ether extraction, whereas ethanolic extraction revealed alkaloids, tannins, and sterols [41]. Another study on *Andrographis lineata* also reported the presence of steroids and flavonoids in all five types of extracts [42]. Additionally, *Dyschoriste pedicellata* showed increased levels of steroids, terpenoids, and glycosides [43].

Table 1: Qualitative analysis of Andrographis echoides stem

S.No	Phytochemical constituents	Andrographis echoides
1	Terpenoids	+++
2	Flavanoids	+++
3	Saponin	+++
4	Tannin	+++
5	Alkaloids	+++
6	Steroids	+++
7	Glycosides	+++
8	Phlobotannins	-

9	Protein	+++
10	Coumarin	+++
11	Emodin	++
12	Anthroquinone	+++
13	Anthocyanin	+++
14	Carbohydrate	++
15	Leucoanthocyanin	-
16	Cardiac glycosides	+++
17	Xanthoproteins	+++
18	Phenol	++

[+ = slightly present, ++ = moderately present, +++ = strongly present, - =absence]

3.1.2 Quantitative analysis

A quantitative investigation of some significant phytochemicals in the ethanolic extract of *Andrographis echoides* revealed the presence of various quantities of these phytochemicals. As shown in the TABLE 2, phytochemical steroids were found to be the most abundant, followed by flavonoids, tannins, saponins, alkaloids, and terpenoids. Several investigations have been conducted on *Strobilanthes kunthias*, including phytochemical analyses. Quantitative analysis revealed that steroids exhibited the highest values, which was consistent with the aforementioned findings [44]. In another study, *Andrographis echoides* leaves demonstrated the highest yield of flavonoids, tannins, and steroids [45]. The steroids and glycosides present in *Adathoda vasica* and *Adathoda beddomei* were found at significantly higher levels [46]. In addition, *Tubiflora acaulis* from Acanthaceae yielded the highest number of steroid compounds [40].

Table 2: Quantitative analysis of Andrographis echoides stem

S.No	Phytocompounds	Empty Value (mg/g)	Yield Value (mg/g)	Final Value (mg/g)
1.	Phenol	18.830	18.846	0.016
2.	Flavonoid	20.656	20.669	0.013
3.	Tannin	20.286	20.326	0.04
4.	Saponin	21.046	21.088	0.42
5.	Alkaloids	19.325	19.595	0.27
6.	Terpenoids	18.771	18.785	0.014

3.2 Isolation techniques

3.2.1 Column chromatography:

In the present study, 29 fractions were isolated. Notably, the final 29th fraction contained the desired secondary metabolite, disogenin, which had a strong brown color. The initial fraction was transparent, while the 2nd and 3rd fractions were dark green. The color gradually faded throughout the subsequent fractionations, with transparency returning to the 13th fraction before reappearing as a dark brown color in the 24th fraction. The next two fractions were transparent once more, before a brown color began to emerge in the 27th fraction. Finally, the 29th fraction yielded crude disogenin with a thick, strongly brown color shown in Figure 2. A study was conducted to isolate bioactive compounds from *Tagetes erecta* of the Asteraceae family using column chromatography. These findings are consistent with previously mentioned outcomes. The final fractions were brownish and exhibited promising yields [47]. Similarly, a study on *Careya arborea* from the Lecythidaceae family confirmed the aforementioned results by providing expected yield values with a light yellow appearance [48]. Column chromatography isolation of *Curcuma longa* also produced a brownish color, suggesting promising results [49]. *Odontonema strictum* exhibited white-colored formations in the final fractionation, partially supporting previously mentioned findings [50]. Biological investigation of Andrographis panniculata revealed a dark green appearance in the final fractionation, which was consistent with the results described above [51].

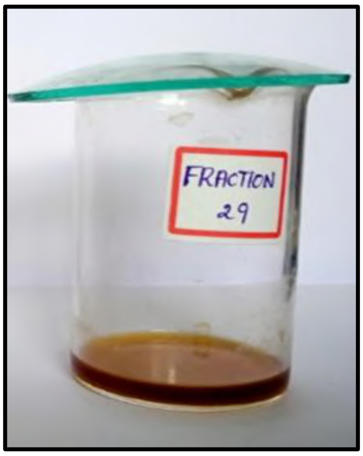


Fig: 2 Isolated end product from Column chromatography

3.3 Purification techniques of the Isolated compounds:

3.3.1 High perfomance Thin liquid chromatography (HPTLC)

The ethanolic extract of diosgenin was subjected to High-Performance Thin-Layer Chromatography (HPTLC) analysis using a 1-D method with silica gel and various solvent systems. Specifically, n-hexane, ethyl acetate, and methanol were used as solvents. The ratios of these solvents were optimized to 3:7 (ethyl acetate/methanol) and 2:8 (ethyl acetate/methanol). Movement of the active compound was expressed using a retention factor (Rf) value of 0.69. A study on *Periploca aphylla* was initiated to investigate the presence of bioactive compounds. The investigation yielded promising Rf values, with each compound displaying different values that were partially aligned with previously mentioned results [52]. It is plausible that an evaluation of steroidal compounds in *Ipomoea sagittifolia* would yield similar results. The Rf values varied across compounds, displaying several similarities with previously reported outcomes [53]. Another investigation of the same plant provided in-depth results, including the standard Rf values [54]. Researchers used *Holoptelea integrifolia* to investigate the presence of phytosterols, which were subjected to HPTLC analysis at 227 nm to yield the expected results [55]. A study on *Achyranthes aspera* focused on steroidal compounds, and the results indicated that the sixth peak exhibited an Rf value similar to that of the present study [56].

3.3.2 High Perfomance Liquid Chromatography (HPLC):

HPLC analysis yielded a noteworthy peak, as indicated by the retention time of 2.463 min. This measurement was performed at a wavelength of 270 nm. The peak height was 75,000 V, indicating a significant concentration of the analyte. The sharp and well-defined peak coupled with a robust baseline demonstrates strong chromatographic and detector performance (Figure 3). The compound was identified using a combination of retention time and other structural interpretation methods, which were employed to confirm its identity. A study employing HPLC on *Trigonella foenum* seeds yielded expected results. A total of 23 distinct peaks were identified, representing various bioactive compounds with different retention times aligned with the aforementioned outcomes [57]. Similarly, *Tribulus terrestris* and steroidal compounds were examined using HPLC, resulting in 7-8 peaks with different retention times [58]. Investigations into bioactive compounds in several fruit species have demonstrated promising retention times, which supports the findings of the current study [59]. *Mangifera indica* was used to quantify bioactive compounds, revealing two peaks with different retention times [60]. Additionally, *Andrographis paniculata* was subjected to HPLC with various solvents, each of which yielded 20-23 peaks with different retention times [61].

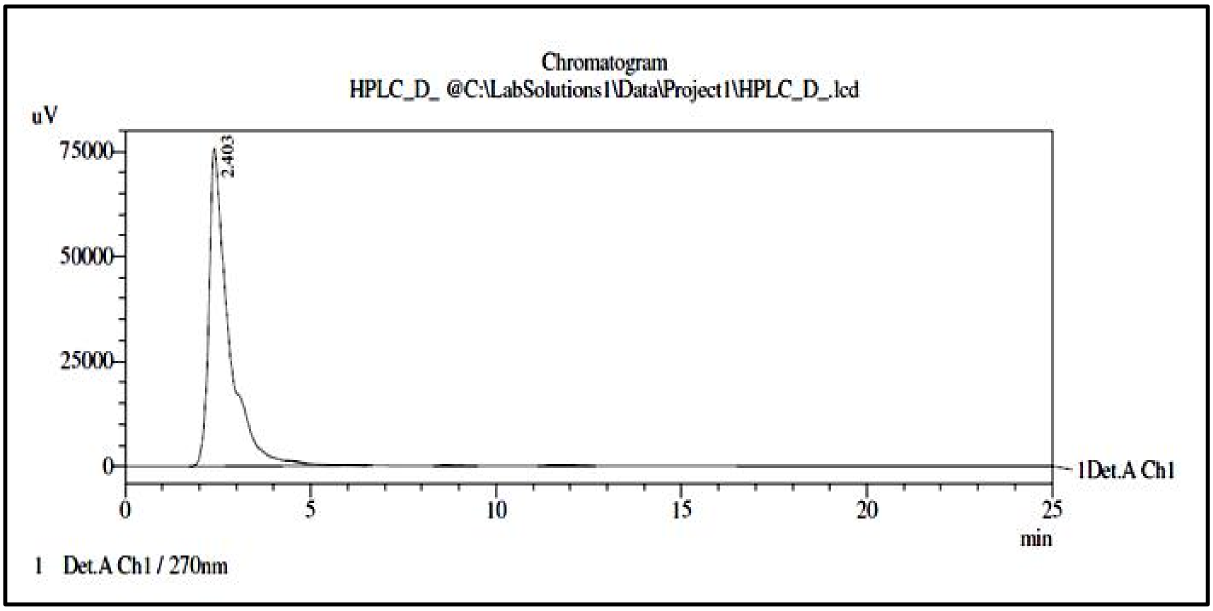


Fig: 3 Chromotogram of High perfomance Liquid chromatography (HPLC)

Table: 3 HPLC Chromotogram interpretation

Peak #	**Ret. Time**	**Area**	**Height**	**Area%**	**Height%**
1	2.403	2863901	76505	100.000	100.000
Total		2863901	76505	100.000	100.000

(Detector A Ch 1 270 nm)

3.4 Characterization techniques of the separated compound

3.4.1 Ultra-violet spectral analysis:

The identified compound was a light-crystalline powder that was dissolved in an appropriate solvent. Disogenin is associated with the 203oC melting point and the molecular formula is C27H42O3. The λmax value of diosgenin was 212 nm (Figure 4). The reported outcomes have been examined in other studies on various plant species. *Elaeocarpus tectorius* is a plant that can be used to treat tract infections. Ultraviolet spectral analysis was conducted between 250 nm and 800 nm. The two extraction methods resulted in different peak absorptions. Each peak corresponded to distinct compounds present in the plant samples [62]. *Bauhinia purpurea* was subjected to isoflavonoid isolation, which led to structural elucidation. The results of the ultraviolet spectral analysis showed four distinct peaks, which were attributed to two different ranges: 300–380 nm and 240–340 nm [63]. The leaves of *Peronema canescens* were used to isolate the bioactive compounds. Ultraviolet characterization revealed two significant bands at 329 and 270 nm. These two bands represented each group of bioactive compounds [64]. *Cordia dichotoma* from Boraginaceae was subjected to isolation studies. Ultraviolet peaks that resulted in the identification of two active compounds were observed. Upon the addition of sodium hydroxide, band shifting was observed [65]. The isolation of secondary metabolites from *Mamordica balsamina* from Cucurbitaceae was subjected to ultraviolet analysis, which resulted in the identification of ten distinct peak ranges between 200 and 750 nm [66].

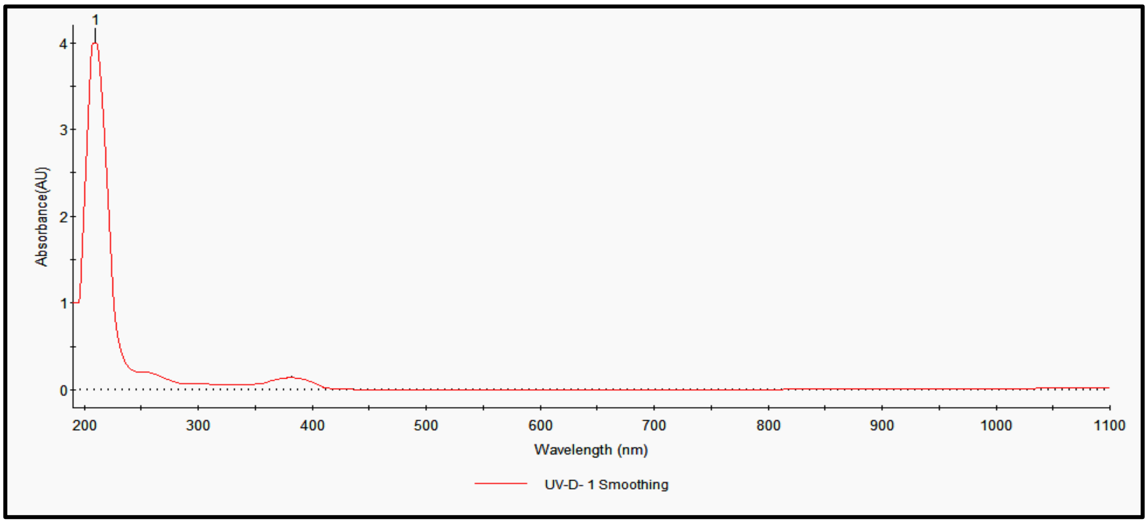


Fig: 4 Ultra violet spectroscpy analysis on the plant extract

3.4.2 Fourier transform infrared analysis

The FT-IR spectrum (KBr, vmax, cm^{-1}): diosgenin 3449.78 cm^{-1} shows the strong alcohol group, 2075.38 cm^{-1} express the C=C=C stretching with medium band spectrum, 1639.62 cm^{-1} denotes the C=C stretching with medium to weak band peak, 1457.48 cm^{-1} shows the methylene vibration with medium band peak, 1116.87 cm^{-1} denotes the C-O stretching with strong band, 1055.02 cm^{-1} strong peak express the C-O stretching, 1014.25 cm^{-1} strong denotes sulfoxide groups and the last strong 625.18 cm^{-1} denotes the presence of halo compound groups (Figure 5) TABLE 4. The IR analysis shows promising results with four strong bands, three medium bands, and one medium to weak band. Phytochemicals from the Lamiaceae family, including *Colebrookea oppositifolia*, were isolated by Fourier Transform Infrared Spectroscopy (FTIR). Analysis of the stem resulted in two strong bands, five medium-strong bands, and four weak bands within the range–750-3500 cm^{-1} [67]. Additionally, FTIR analysis in the range of 400-4000 cm^{-1} identified 10 different peaks in medicinally rich formulations, with three being strong, five medium, and the remaining two weak [68]. *Albizia coriaria*, a medicinal plant, was subjected to FTIR characterization in the range of 500-4000 cm^{-1}, resulting in two strong bands, four medium bands, and one weak band [69]. *Fritillaria roylei*, a plant belonging to the Liliaceae family, was used for the isolation of stigmasterol and subjected to FTIR analysis, which resulted in one strong band, three medium-to-strong bands, and six medium bands [70]. Finally, *D. diversifolia* was used for the isolation of secondary metabolites, and Fourier Transform Infrared Spectroscopy was used to investigate the chemical compounds in the range of 450-4000 cm^{-1}, resulting in two strong and medium-to-strong intensity bands and four medium bands [71].

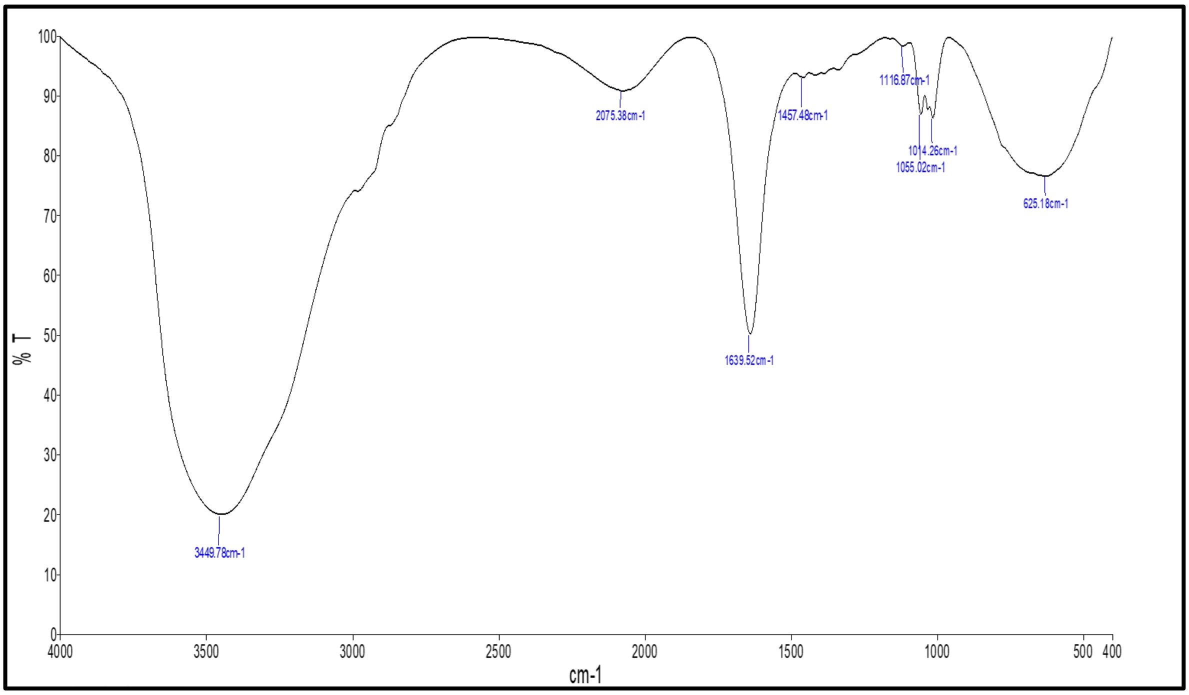


Fig: 5 FTIR analysis on the plant extract

Table: 4 FTIR analysis on the plant extract

Peak no	Wavelength	Group	Compound Class	Band type
1.	3449.78 cm^{-1}	OH	Alcohol	Strong
2.	2075.38 cm^{-1}	C=C=C	Alkene	Medium
3.	1639.62 cm^{-1}	C=C	Alkene	Medium to weak
4.	1457.48 cm^{-1}	CH2	Methylene class	Medium
5.	1116.87 cm^{-1}	C-O	Alcohol	Strong
6.	1055.02 cm^{-1}	C-O	Alcohol	Strong
7.	1014.25 cm^{-1}	Spiroketal ring	Steroidal sapogenin	Strong
8.	625.18 cm^{-1}	Halo group	Halogenated compound class	Strong

3.4.3 NMR analysis:

(a) 1H NMR Analysis

The molecule structures from 1HNMR (δ, CDCl3 as solvent, 300 MHz analysis shows 0.692 (s, C-18 methyl), 0.698 (d, J = 6.2 Hz; C-27 methyl), 0.881 (J = 7.1 Hz;C-21 methyl), 1.361 (s, C-19 methyl), 1.894 (t,J = 10.6 Hz; C-26a-H), 5.245 (d, dd, J = 10.5 Hz and J approx. 4Hz; C-26,B-H), 5.253 (broad, C-3a-H), 3.277 (q, J=7.lHz; C-16H), 5.245 (broad d,J = 5.3Hz; C-6H). The Proton H1-NMR analysis clearly shows the expected output in Figure 6 & TABLE 5. Two plant species from the Euphorbiaceae and Asteraceae families were investigated for their ability to isolate bioactive compounds. This paper proposes a characterization technique involving 1H (500 MHz) and 13C (125 MHz) proton NMR analyses. The results indicate the presence of methyl, methine, and methylene proton groups, whereas 13C proton analysis revealed the presence of acetyl and tiglyol groups [72]. Analysis of saffron plants from the Iridaceae family was conducted to separate the secondary metabolite crocetin. Heteronuclear single-quantum coherence (HSQC) revealed the presence of methylene, methyl, and anomeric protons [73].

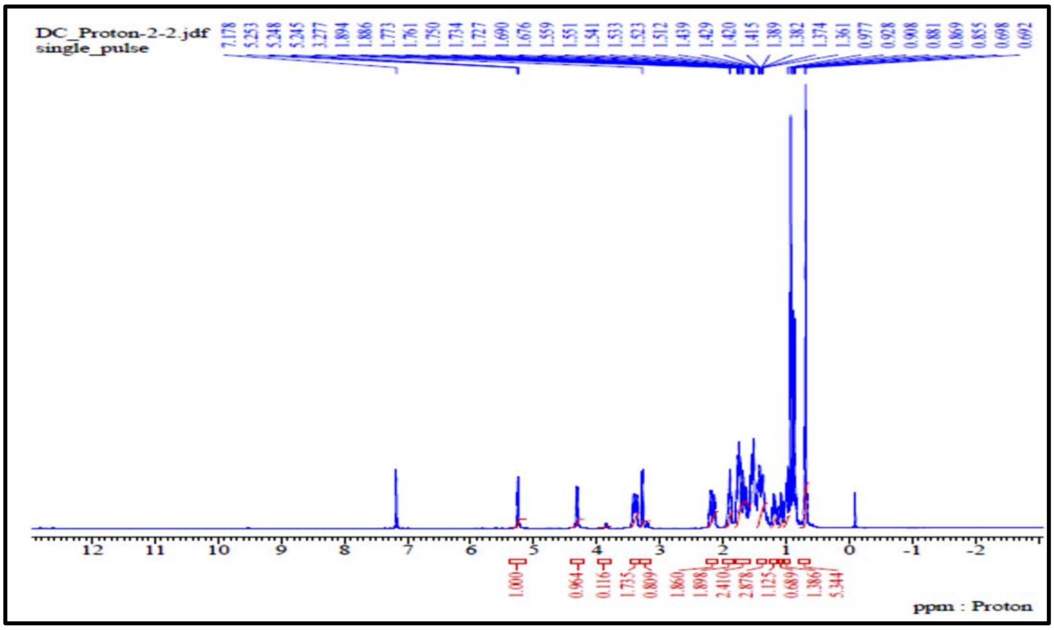


Fig.6 1H NMR analysis on the plant extract

Table: 5 1H NMR analysis result interpretation

Sample No	Chemical shift	Multiplet	J-Coupling Hz
1	0.692	s	-
	0.698	d	6.2
	0.881	-	7.1
	1.361	s	-
	1.894	t	10.6
	5.245	ddd	10.5 -4
	5.253	broad	-
	3.277	q	7
	5.245	broad,d	5.3

(s-singlet, d-doublet,t-triplet,q-quartet, ddd-doublet of doublets of doublets, broad d-broad doublet)

(b) 13C NMR Analysis

Then the another proton 13C NMR (CDCl3, 500 MHz); 37.183 (C1), 31.798 (C2), 71.648 (C3), 42.220 (C4), 140.773 (C5), 121.360 (C6), 31.338 (C7), 31.391 (C8), 50.009 (C9), 36.599 (C10), 20.830 (C11), 39.745 (C12), 41.559 (C13), 56.476 (C14), 31.558 (C15), 80.782 (C16), 62.039 (C17), 16.248 (C18), 19.379 (C19), 40.214 (C20), 14.486 (C21), 109.253 (C22), 31.558 (C23), 28.753 (C24), 30.251 (C25), 66.798 (C26), 16.248 (C27) provide the promising results Figure 7. *Capparis ovates* were subjected to steroid and triterpenoid isolation and 1H and 13C proton NMR analyses were performed at 600 MHz and 150 MHz, respectively. The outcome was an oleanane triterpene connected to long-chain methyl singlets, with ends showing methyl triplets with long chains [74]. *Euphorbia cotinilia* from Euphorbiaceae was used to separate and characterize bioactive compounds, and hydrogen and carbon proton NMR analyses were performed at 300 MHz. The results indicated the presence of aliphatic chains, methyl and methoxy groups, amine and alcohol groups, aliphatic and olefinic carbons, and aromatic protons [75]. *Cola lateritia* from Sterculiaceae were involved in the separation of bioactive compounds, and heteronuclear single-quantum coherence (HQSC) was performed at 500 MHz (1H) and 600 MHz (13C). Eight different compounds were characterized, and each showed promising results, partially supporting the findings of the current study [76].

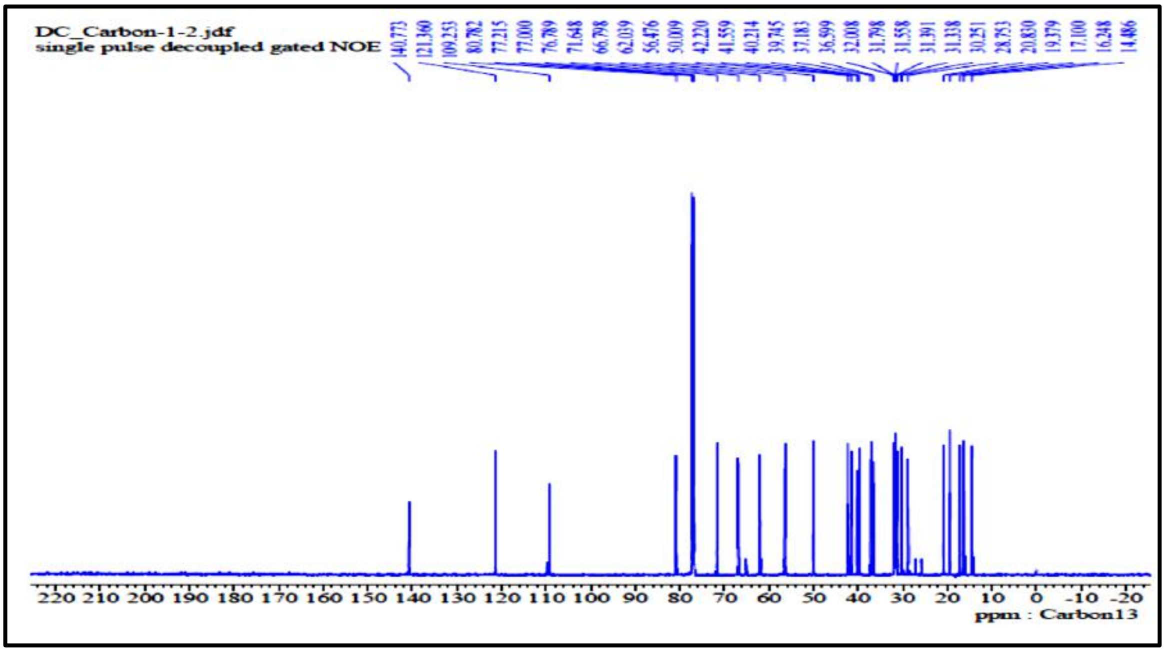


Fig: 7 13C NMR analysis on the plant extract

IV. CONCLUSION

This study focused on diosgenin, a secondary metabolite isolated and characterized from Andrographis echioides, to emphasize the value of naturally occurring medicines. The ethanolic extract of the plant was analyzed using HPTLC, revealing an Rf value of 0.69, whereas HPLC analysis showed a significant peak at 2.463 min, 270 nm, and 75,000 V peak height. The melting point of diosgenin ($C_{27}H_{42}O_3$) was 203°C and λmax was measured at 212 nm. IR analysis revealed strong, medium, and weak bands, whereas the NMR results indicated the presence of methyl, methine, methylene groups, aliphatic regions, oxygenated carbons, and aromatic and olefinic carbons, which were further subjected to pharmacological activities to analyze their viability. Currently, there is a need to develop herbal and naturally synthesized drugs. An effective method to advance the pharmaceutical industry is to utilize the secondary metabolites found in plants and microorganisms, which can provide clinical assistance in treating unwanted infections and other harmful diseases. However, despite the potential benefits of using natural resources, challenges still need to be addressed in order to fully exploit these sources. By overcoming these obstacles, a new pharmaceutical world can be created that leverages the advantages of natural sources without drawbacks.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the Principal of Holy Cross College (Autonomous), Tiruchirappalli-02 for their unwavering encouragement throughout this research endeavor. We are deeply indebted to the faculty members of the PG & Research Department of Botany, Holy Cross College (Autonomous) for their valuable guidance, insightful suggestions and constant motivation.

REFERENCES

[1] Nicolaou, K. C. (2014). Advancing the drug discovery and development process. *Angewandte Chemistry*, 126(35), 9280-9292. DOI: 10.1002/anie.201404761

[2] Drews, J. (2003). In quest of tomorrow's medicines. *Springer Science & Business Media*.New York.

[3] Drews, J. (2000). Drug discovery: a historical perspective. *science*, 287(5460), 1960-1964.DOI: 10.1126/science.287.5460.1960.

[4] Thomford, N. E., Senthebane, D. A., Rowe, A., Munro, D., Seele, P., Maroyi, A., & Dzobo, K. (2018). Natural products for drug discovery in the 21st century: innovations for novel drug discovery. *International journal of molecular sciences*, 19(6), 1578.DOI: 10.3390/ijms19061578

[5] Fabricant, D. S., & Farnsworth, N. R. (2001). The value of plants used in traditional medicine for drug discovery. *Environmental health perspectives*, 109(suppl 1), 69-75. DOI: 10.1289/ehp.01109s169.

[6] Süntar, I. (2020). Importance of ethnopharmacological studies in drug discovery: role of medicinal plants. *Phytochemistry Reviews*, 19(5), 1199-1209.DOI:10.1007/s11101-019-09629-9

[7] Siddiqui, A. A., Iram, F., Siddiqui, S., & Sahu, K. (2014). Role of natural products in drug discovery process. *International Journal of Drug Develoment and Research*, 6(2), 172-204.

[8] Butler, M. S. (2004). The role of natural product chemistry in drug discovery. *Journal of natural products*, 67(12), 2141-2153.DOI: 10.1021/np040106y.

[9] Kataky, A., & Handique, P. J. (2010). A brief overview on *Andrographis paniculata* (Burm. f) Nees., a high valued medicinal plant: Boon over synthetic drugs. *Asian Journal of Science and Technology*, 6, 113-118.

[10] Mahdi, J. G. (2010). Medicinal potential of willow: A chemical perspective of aspirin discovery. *Journal of Saudi Chemical Society*, *14*(3), 317-322.DOI.org/10.1016/j.jscs.2010.04.010

[11] Daugan, M., Wojcicki, A. D., d'Hayer, B., & Boudy, V. (2016). Metformin: An anti-diabetic drug to fight cancer. *Pharmacological research*, *113*, 675-685. DOI:10.1016/j.phrs.2016.10.006.

[12] Njoku, O. V., & Obi, C. (2009). Phytochemical constituents of some selected medicinal plants. *African journal of pure and applied chemistry*, *3*(11), 228-233.

[13] Okwu, D. E. (2001). Evaluation of chemical composition of indeginous species and flavouring agents. *Global journal of pure and Applied Sciences*, *7*(3), 455-460. DOI:10.4314/gjpas.v7i3.16293

[14] Patwardhan, B. (2005). Ethnopharmacology and drug discovery. *Journal of ethnopharmacology*, 100(1-2), 50-52. DOI: 10.1016/j.jep.2005.06.006.

[15] Surapaneni, M. S., Das, S. K., & Das, N. G. (2012). Designing paclitaxel drug delivery systems aimed at improved patient outcomes: current status and challenges. *International Scholarly Research Notices*, *2012*(1), 623139.doi: 10.5402/2012/623139.

[16] Pirintsos, S., Panagiotopoulos, A., Bariotakis, M., Daskalakis, V., Lionis, C., Sourvinos, G., ... & Castanas, E. (2022). From traditional ethnopharmacology to modern natural drug discovery: A methodology discussion and specific examples. *Molecules*, 27(13), 4060.DOI: 10.3390/molecules27134060.

[17] Rosales-López, C., Muñoz-Arrieta, R., & Abdelnour-Esquivel, A. (2020). Emetine and cephaeline content in plants of Psychotria ipecacuanha in Costa Rica. *Revista Colombiana de Química*, 49(2), 18-22. DOI:10.15446/rev.colomb.quim.v49n2.78347

[18] Yoshida, K., Hayashi, T., & Sano, K. (1988). Colchicoside in Colchicum autumnale bulbs. *Agricultural and biological chemistry*, 52(2), 593-594.DOI: 10.1271/bbb1961.52.593

[19] Balkrishna, A., Das, S. K., Pokhrel, S., Joshi, A., Laxmi, Verma, S., ... & Joshi, C. S. (2019). Colchicine: Isolation, LC–MS QTof screening, and anticancer activity study of Gloriosa superba seeds. *Molecules*, 24(15), 2772. DOI: 10.3390/molecules24152772.

[20] Śramska, P., Maciejka, A., Topolewska, A., Stepnowski, P., & Haliński, Ł. P. (2017). Isolation of atropine and scopolamine from plant material using liquid-liquid extraction and EXtrelut® columns. *Journal of chromatography B*, 1043, 202-208. DOI: 10.1016/j.jchromb.2016.09.003.

[21] Newman, D. J., Cragg, G. M., & Snader, K. M. (2003). Natural products as sources of new drugs over the period 1981− 2002. *Journal of natural products*, 66(7), 1022-1037. DOI: 10.1021/np030096l. PMID: 12880330.

[22] Murugan, A., Elangovan, K., & Singh, A. (2017). Evaluation of Andrographis Echioides for Its Phytochemical and In Vitro Antioxidant Properties. *Indo American Journal of Pharmaceutical Research*, 7(7), 8778-8785.

[23] Kumar, P. P., Ayyanar, M., & Ignacimuthu, S. (2007). Medicinal plants used by Malasar tribes of Coimbatore district, Tamil Nadu.

[24] Anandanayaki, S., & Uma, C. (2014). Pharmacognostical and phytochemical studies on Andrographis Echioides (L.) Nees. *International Journal of advances in Pharmacy, Biology and Chemistry*, 3(3), 640-645.

[25] Mathivanan, D., & Suseem, S. R. (2015). Phytochemical and pharmacological review of Andrographis echiodies. *Journal of Chemical and Pharmaceutical Research*, 7(7), 1167-1171.

[26] Nadkarni, K. M. (1954). Indian materia medica, popular Book Depot. *Bombay*, *7*, 946-8.

[27] Nirubama, K., Kanchana, G., & Rubalakshmi, G. (2015). Evaluation of free radicals scavenging and glucose uptake by isolated rat hemidiaphragm study of Andrographis echioides an indigenous medicinal plant.

[28] PS, P., & AJ, A. K. (2021). Elemental analysis of Andrographis echioides (L.) Nees. leaves, a potential pharmaceutical plant using atomic absorption spectroscopy (AAS). *Asian Journal of Pharmaceutical Research and Development*, 9(3), 43-47.

[29] Jayaprakasam, B., Damu, A. G., Gunasekar, D., Blond, A., & Bodo, B. (1999). Dihydroechioidinin, a flavanone from Andrographis echioides. *Phytochemistry*, 52(5), 935-937. DOI: 10.1016/S0031-9422(99)00295-2

[30] Sharma, M., & Sharma, R. (2013). Identification, purification and quantification of andrographolide from Andrographis paniculata (burm. F.) Nees by HPTLC at different stages of life cycle of crop. *Jouurnal of current chemical and pharmacceutical sciences*, *3*(1), 23-32.

[31] Polash, S. A., Saha, T., Hossain, M. S., & Sarker, S. R. (2017). Investigation of the phytochemicals, antioxidant, and antimicrobial activity of the Andrographis paniculata leaf and stem extracts. *Advances in Bioscience and Biotechnology*, 8(05), 149-162. DOI**:** 10.4236/abb.2017.85012

[32] Gurupriya, S., & Cathrine, D. L. (2022). Qualitative and Quantitative Phytochemical analysis of *Andrographis echioides* Leaves..(2021). *International Journal of Life Science and Pharmaceuticcal Researcch*, 11(1), 148-155. DOI:10.22376/ijpbs/lpr.2021.11.1.P148-155

[33] Helen Diana I, Auxilia A. (2022). Evaluation of Antibacterial, Antioxidant and Phytochemical Analysis of *Amomum subulatum* Roxb. Seed extract. Research Journal of Agricultural Sciences,13(05),1366–1369.

[34] Devanesan, S., Ranjitsingh, A. J., AlSalhi, M. S., Murugan, A., Abd Elkader, O. H., Nicoletti, M., & Brindhadevi, K. (2022). Cytotoxic effects of bioactive extracts from *Andrographis echioides* (L.) Nees: An In vitro

approach. *Process Biochemistry*, 120, 169-177. DOI: 10.1016/j.procbio.2022.06.008

[35] Ghule, B., Kakad, P., Shirke, A., Kotagale, N., & Rathi, L. (2021). A validated high-performance thin-layer chromatography method for quantification of echioidin from *Andrographis echioides* plant. *JPC–Journal of Planar Chromatography–Modern TLC*, 34(2), 131-138. DOI: 10.1007/s00764-021-00095-8

[36] Gurupriya, S., Cathrine, L., & Ramesh, J. (2018). In vitro antidiabetic and antioxidant activities of lupeol isolated from the methanolic extract of *Andrographis echioides* leaves. *Journal of Pharmacognosy and Phytochemistry*, 7(4), 768-775.

[37] Fuloria, N. K., Fuloria, S., Sharma, V. K., Ali, M., Singh, A., & Sharma, P. K. (2020). Isolation of new diterpene from methanolic extract of *Capsicum annuum* Linn. fruits. *Pharmacognosy Magazine*, 16(72). DOI: 10.4103/pm.pm_250_20

[38] Pratheema, P., Cathrine, L., & Gurupriya, S. (2020). Isolation and Characterization of some Phytochemical compounds from the Methanolic extract of *Solanum torvum* swartz fruits. *International Journal of Pharmaceutical Sciences and Research*.11(12), 6213-6221. DOI:10.13040/IJPSR.0975-8232.11(12).6213-21

[39] Gomathi, S., & Maneemegalai, S. (2024). Isolation, characterization of β-Sitosterol from the herbal extracts and evaluation of in vitro anti-oxidant and anti-diabetic activities. *Journal of microbiology, biotechnology and food sciences*, 13(4), e10236-e10236. DOI: 10.55251/jmbfs.10236

[40] Gomase PV, Pawar S. (2019). Current Evaluation of the *Tubiflora acaulis* Kuntze (Acanthaceae): Pharmacognostical, Preliminary Phytochemical Investigation and Antioxidant Activity. *Methodology*, 21. DOI: 10.9734/JPRI/2021/v33i44A32594

[41] Samrit, S. R., Kamble, N. S., Dambhare, A., Hemke, A. T., & Umekar, M. J. (2020). Preliminary Phytochemical Screening of ethanolic extract of *Astercantha longifolia* (*Hygrophylla schulli*) roots along with various activities. *World Journal of Pharmaceutical Research*, 9(15),1269-1279. DOI : 10.20959/wjpr202015-19333

[42] Kumari BR, Raveesha HR. (2024). Phytochemical analysis and antibacterial activity of *Andrographis lineata* Nees (Acanthaceae). *Current botany*,15,1-6. DOI: 10.25081/cb.2024.v15.8577

[43] Kantiok, G. Y., Sallau, M. S., & Iyun, O. R. A. (2020). Qualitative Phytochemical Screening and In-vitro Antimicrobial studies of extracts of *Dyschoriste pedicellata* (Acanthaceae). *Nigerian Journal of Pharmaceutical and Applied Science Research*, 9(3), 35-39.

[44] Balasubramaniam, G., Sekar, M., & Badami, S. (2020). Pharmacognostical, physicochemical and phytochemical evaluation of *Strobilanthes kunthianus* (Acanthaceae),12(4),731-741 DOI : 10.5530/pj.2020.12.106

[45] Jeevanantham K, Hussain AZ. (2020) Phytochemical studies and elemental analysis of *Andrographis echioides* (Acanthaceae) leaves by using LC-MS Techniques. *Infokara research*, 9(9).

[46] Nandhini, S., & Ilango, K. (2020). Comparative study on pharmacognostical, phytochemical investigations and quantification of vasicine content in the extracts of *Adhatoda vasica* Nees and *Adhatoda beddomei* CB Clarke. *Pharmacognosy Journal*, *12*(4).DOI**:**10.5530/pj.2020.12.126

[47] Devika, R., & Koilpillai, J. (2015). Column chromatographic separation of bioactive compounds from *Tagetes erecta* Linn. *International Journal of Pharmaceutical Sciences and Research*, 6(2), 762. DOI:10.13040/IJPSR.0975-8232.6(2).762-66

[48] Navya, A. S., & Anitha, S. (2018). Isolation of compound (CA-01) from the bark of *Careya arborea* by using column chromatography. *Journal of Pharmacognosy and Phytochemistry*, 7(2), 3695-3702.

[49] Revathy, S., Elumalai, S., & Antony, M. B. (2011). Isolation, purification and identification of curcuminoids from turmeric (*Curcuma longa L.*) by column chromatography. *Journal of Experimental sciences*, 2(7).

[50] Pierre, L. L., & Moses, M. N. (2015). Isolation and characterisation of stigmasterol and β-sitosterol from *Odontonema strictum* (acanthaceae). *Journal of Innovations in Pharmaceuticals and Biological Sciences*, 2(1), 88-95.

[51] Obi, L. K., & Okwute, S. K. (2023). Chemical and Biological Investigations of the Leaf Extracts of *Andrographis paniculata* (Acanthaceae). *Journal ISSN - Journal of Biomedical Research & Environmental Sciences ,* 2766-2276. DOI: 10.37871

[52] Orfali, R., Perveen, S., Aati, H. Y., Alam, P., Noman, O. M., Palacios, et al. (2021). High-performance thin-layer chromatography for rutin, chlorogenic acid, caffeic acid, ursolic acid, and stigmasterol analysis in periploca aphylla extracts. *Separations*, 8(4), 44. DOI: 10.3390/separations8040044

[53] Peeriga, R., Shaik, A., Arabath, S. M. S., Latha, M., & Chennuru, S. N. M. (2023). Assessment of Steroids in ethanolic stem extract of Morning glory by High Performance Thin Layer Chromatography.*International Journal of Chemical and Biochemical Sciences* 23(3): 361-366

[54] Peeriga, R., Balagani, P. K., Raju, G. E., Narayanan, R., Mohammed, J., & Yarlagadda, L. C. Findings of Steroids, Coumarins and Saponins in Ipomea sagittifolia (Burn. f.)., Leaf Extract by HPTLC Fingerprints. *International Journal of Chemical and Biochemical Sciences*. 24 (4):132-140.

[55] Sutar, R. C., Gowtham, M., & Kashid, G. A. (2023). High Performance Thin Layer Chromatography Fingerprinting of Phytosterols from Hydroalcoholic Extract of *Holoptelea Integrifolia* (Roxb.) Leaves. *Journal of Survey in Fisheries Sciences*, 10(4S), 990-999. DOI: 10.17762/sfs.v10i4S.1120

[56] Aparna, S., & Aruna, S. (2014). HPTLC fingerprint profile of steroidal constituents of *Achyranthes aspera* Linn. *Journal of Biomedical and Pharmaceutical Research*, 3(5), 60-66.

[57] Król-Kogus, B., Głód, D., & Krauze-Baranowska, M. (2020). Qualitative and quantitative HPLC-ELSD-ESI-MS analysis of steroidal saponins in fenugreek seed. *Acta Pharmaceutica*, *70*(1), 89-99. DOI:10.2478/acph-2020-0013

[58] Yang, M., Oppong, M. B., Di, J., Yuan, Q., Chang, Y., Jiang, M., ... & Zhang, P. (2022). Steroidal saponins with anti-inflammatory activity from *Tribulus terrestris* L. *Acupuncture and Herbal Medicine*, *2*(1), 41-48. DOI: 10.1097/HM9.0000000000000026

[59] Stoenescu, A. M., Trandafir, I., & Cosmulescu, S. (2022). Determination of phenolic compounds using HPLC-UV method in wild fruit species. *Horticulturae*, *8*(2), 84. DOI: 10.3390/horticulturae8020084

[60] Marcillo-Parra, V., Anaguano, M., Molina, M., Tupuna-Yerovi, D. S., & Ruales, J. (2021). Characterization and quantification of bioactive compounds and antioxidant activity in three different varieties of mango (*Mangifera indica* L.) peel from the Ecuadorian region using HPLC-UV/VIS and UPLC-PDA. *NFS Journal*, *23*, 1-7.DOI: 10.1016/j.nfs.2021.02.001

[61] Rafi, M., Devi, A. F., Syafitri, U. D., Heryanto, R., Suparto, I. H., Amran, M. B., ... & Lim, L. W. (2020). Classification of *Andrographis paniculata* extracts by solvent extraction using HPLC fingerprint and chemometric analysis. *BMC Research Notes*, *13*, 1-6.DOI:10.1186/s13104-020-4920-x

[62] Lydia, M. A., Thamburaj, S., Jagadeesan, G., Nataraj, G., Muniyandi, K., Sathyanarayanan, S., & Thangaraj, P. (2020). UV/V is Spectrophotometric Characterization of the Leaf Polyphenolics Content in *Elaeocarpus tectorius* and its Therapeutic Potential against Selected Urinary Tract Infection Pathogens. In *Phytomedicine*,1st Edition, (pp. 169-178). CRC Press.

[63] Shamala, T., Surendra, B. S., Chethana, M. V., & Shanmukhappa, S. (2022). Extraction and isolation of Isoflavonoids from stem bark of *Bauhinia purpurea* (L): Its biological antipsychotic and analgesic activities. *Smart Materials in Medicine*, 3, 179-187. DOI:10.1016/j.smaim.2022.01.004

[64] Tarigan, I. L., Aini, I. P. S., & Latief, M. (2022). Isolation of a Flavone Apigenin and a Steroids Squalene from *Peronema canescens* Jack Leaves with Anti-Inflammatory Activities. *Pharmacognosy Journal*, *14*(6). DOI: 10.5530/pj.2022.14.162

[65] Oo KT, Aye SS, Win KC.(2021). Extraction, isolation and identification of phytoconstituents from the leaves of *Cordia dichotoma* G. Forst. *Journal of Myanmar Academy of Arts and Science.* Vol. XIX. No.4A

[66] Mabasa, X. E., Mathomu, L. M., Madala, N. E., Musie, E. M., & Sigidi, M. T. (2021). Molecular Spectroscopic (FTIR and UV-Vis) and Hyphenated Chromatographic (UHPLC-qTOF-MS) Analysis and In Vitro Bioactivities of the *Momordica balsamina* Leaf Extract. *Biochemistry Research International*, 2021(1), 2854217. DOI: 10.1155/2021/2854217.

[67] Ishtiaq, S., Hanif, U., Shaheen, S., Bahadur, S., Liaqat, I., Awan, U. F., ... & Meo, M. (2020). Antioxidant potential and chemical characterization of bioactive compounds from a medicinal plant *Colebrokea oppositifolia* Sm. *Anais da Academia Brasileira de Ciências*, *92*(2), e20190387.DOI: 10.1590/0001-3765202020190387.

[68] Singh, P. K., Singh, J., Medhi, T., & Kumar, A. (2022). Phytochemical screening, quantification, FT-IR analysis, and in silico characterization of potential bio-active compounds identified in HR-LC/MS analysis of the polyherbal formulation from Northeast India. *ACS omega*, *7*(37), 33067-33078. DOI: 10.1021/acsomega.2c03117.

[69] Omara, T., Kiprop, A. K., & Kosgei, V. J. (2022). Isolation and characterization of compounds in ethanolic extract of *Albizia coriaria* (Welw ex. Oliver) leaves: a further evidence of its ethnomedicinal diversity. *Bulletin of the National Research Centre*, *46*(1), 30. DOI: 10.1186/s42269-022-00716-0

[70] Kaur, G., Gupta, V., Singhal, R. G., & Bansal, P. (2020). Isolation and Characterization of Stigmasterol from *Fritillaria roylei*. *Biology, Medicine, & Natural Product Chemistry*, 9(2), 77-80. DOI: 10.14421/biomedich.2020.92.77-80

[71] Dhiman, N., Sinha, J., Rani, D., & Kumar, V. (2022). Extraction, Isolation and Characterization of Bioactive Compound from *G. diversifolia* Methanolic Extract.

[72] Saidu, M. B. (2023). *Isolation and structure elucidation of biological active compounds from Euphorbia deightonii and Centrapalus pauciflorus* (Doctoral dissertation, Szeged University (Hungary); 204:113344.

[73] Mir, M. A., Ganai, S. A., Mansoor, S., Jan, S., Mani, P., Masoodi, K. Z., ... & Ahmad, P. (2020). Isolation, purification and characterization of naturally derived Crocetin beta-d-glucosyl ester from *Crocus sativus* L. against breast cancer and its binding chemistry with ER-alpha/HDAC2. *Saudi Journal of Biological Sciences*, 27(3), 975-984. DOI: 10.1016/j.sjbs.2020.01.018. Epub 2020 Jan 27.

[74] Gazioglu, I., Semen, S., Acar, O. O., Kolak, U., Sen, A., & Topcu, G. (2020). Triterpenoids and steroids isolated from Anatolian *Capparis ovata* and their activity on the expression of inflammatory cytokines. *Pharmaceutical Biology*, *58*(1), 925-931. DOI: 10.1080/13880209.2020.1814356.

[75] Jayalakshmi, B., Raveesha, K. A., & Amruthesh, K. N. (2021). Isolation and characterization of bioactive compounds from *Euphorbia cotinifolia*. *Future Journal of Pharmaceutical Sciences*, *7*, 1-9. DOI: 10.1186/s43094-020-00160-9

[76] Kamdem, M. H., Ojo, O., Kemkuignou, B. M., Talla, R. M., Fonkui, T. Y., Silihe, K. K., ... & Ndinteh, D. T. (2022). Pentacyclic triterpenoids, phytosteroids and fatty acid isolated from the stem-bark of *Cola lateritia* K. Schum.(Sterculiaceae) of Cameroon origin; evaluation of their antibacterial activity. *Arabian Journal of Chemistry*, *15*(1), 103506. DOI: 10.1016/j.arabjc.2021.103506.

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available:https://ijeab.com/
Journal DOI:10.22161/ijeab

Estimation of Ataturk Dam Evaporation Amount Using Fuzzy Logic Method

Ahmet Gül*, Fatih Üneş, Bestami Taşar

Department of Civil Engineering, Iskenderun Technical University, Türkiye
*Email: ahmetgul6300@gmail.com

Received: 14 Oct 2024; Received in revised form: 12 Nov 2024; Accepted: 18 Nov 2024; Available online: 24 Nov 2024

Abstract**—** *Accurate prediction of evaporation is important for various purposes such as dam structure design, operation, and the development and management of water resources. Determining water evaporation from the reservoir volume is an important parameter for reservoir operation studies, based on hydrological and meteorological data. In this study, daily average relative humidity, air temperature, wind speed, and sunshine duration parameters were used for evaporation estimation. In the study, daily evaporation estimation was performed using the methods of Multiple Linear Regression (MLR), Adaptive Neuro-Fuzzy Inference System (ANFIS) and Fuzzy Logic - Simple Membership Functions and Fuzzy Rule Generation Technique (Fuzzy -SMRGT). As the study area, the Atatürk Dam, located between the provinces of Adıyaman and Şanlıurfa, has been chosen. In the study, the model results were evaluated according to statistical criteria such as Mean Absolute Error (MAE), Root Mean Square Error (RMSE) and Coefficient of Determination. When evaluating the model results, it was determined that the MLR, ANFIS and Fuzzy-SMRGT models yielded similar results in daily evaporation estimation and that the Fuzzy Logic (ANFIS and Fuzzy SMRGT) models were applicable.*

Keywords**— *Evaporation, Prediction, Regression, Fuzzy Logic, Modeling, ANFIS***

I. INTRODUCTION

Evaporation (E) estimation is important in water management and hydraulic designs. Evaporation is the process of converting the amount of water in liquid form into gas (vapor) form in nature. Evaporation is also one of the basic components of the hydrological cycle. Evaporation depends on factors such as solar energy, air temperature, wind, humidity and environmental conditions. Natural events are affected by many different variables and it is quite difficult to explain the nonlinear relationships between natural events and these variables.

Like all events in nature, since evaporation depends on many nonlinear variables and parameters and it is difficult to determine all of these parameters, it is difficult to estimate the amount of evaporation. Using classical methods, it is difficult to create a realistic hydrological model that accurately reflects its real dimensions due to the large number of affecting parameters and nonlinear structures. For this reason, efforts have been made to develop applicable practical methods to solve nonlinear problems and when the researches are examined, it is seen that the studies are still ongoing to determine the amount of evaporation that is realistic. These studies generally consist of experimental, numerical, statistical and recently artificial intelligence-based studies.

In recent years, many researchers have used artificial intelligence methods as an alternative to classical methods in hydrology and water resources studies[1-15] Tzimopoulos et al. [16] also tried to estimate evapotranspiration using the temperature parameter. Doğan et al. [17] studied evaporation estimation using data from 1990 to 2004 related to Lake Sapanca. Balve and Patel [18] tried to estimate evapotranspiration by entering the meteorological data of average temperature, relative humidity, wind speed and net radiation as parameters. For the predictions, models created by the Fuzzy Inference System of Fuzzy Logic method were used. Taşar et al. [19]

studied evaporation prediction by using wind speed, duration of sunshine and relative humidity data from the Massachusetts region of the United States from 2014 to 2017, employing classical methods and artificial neural network techniques. Kaya et al. [20] studied to estimate the amount of evaporation. They used M5-Tree and Turc methods to predict. Özel and Büyükyıldız [21] used ANN, epsilon-support vector regression (ε-SVR), and ANFIS techniques to predict the monthly evaporation amount of the Karaman meteorological station, which is located in Konya, Turkey. Petković et al. [22] investigated the effect of meteorological parameters on reference evapotranspiration using the ANFIS method. Yaseen et al. [23] used classification and regression trees, the cascade correlation neural network, gene expression programming, and the support vector machine (SVM) models for the prediction of evaporation. According to their model result, SVM has the best performance. Wu et al. [24] studied the Poyang Lake Basin of Southern China for monthly pan evaporation estimation. They used hybrid models (extreme learning machine) and improved M5 model tree and artificial neural network models.

Since the parameters affecting the event are difficult and expensive to measure in the field, soft computing techniques such as Fuzzy-SMRGT, ANFIS are used today to reduce the need for large data sets. One of the models that can be developed to reduce the need for large data sets is the experience-based easily adjustable fuzzy rule generation approach (Fuzzy-SMRGT). One of the first applications of this approach was made by Toprak [25] using Fuzzy-SMRGT in modeling the relationship between open channel flow (natural or artificial) and its hydraulic and geometric properties.

In this study, the applicability and validity of artificial intelligence methods such as Simple Membership Functions and Fuzzy Rule Generation Technique (Fuzzy-SMRGT) and Adaptive Neuro-Fuzzy Inference System (ANFIS) as well as classical methods such as Multiple Linear Regression (MLR) in evaporation estimation were investigated.

II. MATERIAL and METHODS

2.1. Study Area

The Atatürk Dam is a dam located between the provinces of Adıyaman and Şanlıurfa, intended for energy and irrigation purposes. Within the GAP Project, the Karakaya Dam is located 51 km away from Adıyaman province and 24 km away from the Bozova district of Şanlıurfa province, situated on the Euphrates River, at an elevation of 180 km².With the dam's completion, the Atatürk Dam Lake, the third largest lake in Turkey, has been formed. The height from the base is 169 meters. The minimum water level in terms of height above sea level is 513 meters, and the maximum water level reaches 542 meters. In Dam, the depth must be at least 133 meters for electricity generation. The length of the dam crest is 1644 meters, and its width is 15 meters. There are 6 spillway outlets, each controlled by radial gates measuring 16x17 meters. The maximum discharge is 16800m^3/s. The spatial and general appearance of the studied area and the dam is presented in Figure 1.

Fig. 1: The location of the work area and the dam view [26,27]

The data used in this study was obtained from the Şanlıurfa Regional Directorate of Meteorology. Parameters such as daily average relative humidity (%), daily average temperature (°C), daily average wind speed (m/s) and daily average sunshine duration (hours) were used in model studies to estimate evaporation. The statistical variations of all the parameters used are presented in Table 1. The daily variation of evaporation amounts related to the Atatürk Dam for the water years between 2004 and 2011 is shown in Figure 2.

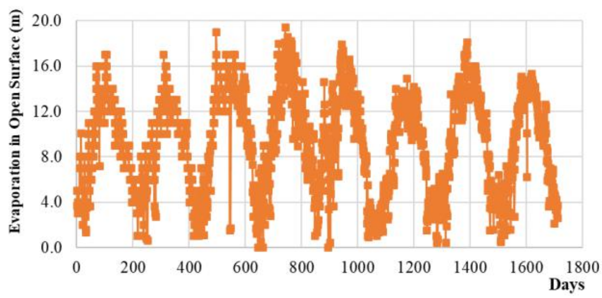


Fig. 2: Daily evaporation data change used in the study

Table 1. Statistical Changes for used data

Statistical Changes	Daily Average Relative Humidity (%)	Daily Average Temperature (°C)	Daily Average Wind Speed (m/s)	Daily Sunshine Duration (hours)	Daily Total Open Surface Evaporation (mm)
Average	42.97	23.95	1.16	10.41	9.27
Standard Error	0.34	0.16	0.03	0.08	0.10
Median	41	25	0.8	11.4	10
Mode	37.3	28	0.1	12.7	13
Standard Deviation	14.10	6.52	1.11	3.24	4.29
Sample Variance	198.84	42.55	1.24	10.47	18.42
Kurtosis	0.31	-0.75	1.35	1.70	-1.02
Skewness	0.67	-0.39	1.23	-1.48	-0.15
Range	80.40	31.80	6.90	14.10	19.40
Maximum	11.90	4.70	0.00	0.00	0.00
Minimum	92.30	36.50	6.90	14.10	19.40
Total	73560.10	40994.20	1982.00	17828.50	15874.80
Count	1712	1712	1712	1712	1712
Confidence Level (95.0%)	0.67	0.31	0.05	0.15	0.20

2.2 Methods

2.2.1. Multi Linear Regression (MLR)

A linear method for simulating the relationship between a scalar response and one or more explanatory variables is known as linear regression in statistics. Simple linear regression is used when there is only one explanatory variable; multiple linear regression is used when there are several variables. One method for simulating the relationship between a numerical dependent variable (y) and one or more independent variables (x) is called linear regression. The regression model is referred to as simple linear regression if there are only one independent variable. Multiple linear regression(MLR) is the term used when the model contains more than one explanatory independent variable. The dependent variable in linear regression needs to be numerical. The MLR equation is presented below in Equation 1.

$$y = A_0 + A_1 * X_1 + A_2 * X_2 \dots . +A_i * X_i + B \qquad (1)$$

In Equation 1, X_i (i = 1, …, n) represents the independent variables (inputs), y denotes the dependent variable (output), A indicates the regression coefficients, and B signifies the error.

2.2.2. Adaptive Neuro-Fuzzy Inference System (ANFIS)

Adaptive Neuro-Fuzzy Inference System (ANFIS) is used as an artificial neural network method based on fuzzy inference systems. The ANFIS model was developed by Jang starting in the early 1990s and is used for modeling nonlinear functions and predicting chaotic time series. ANFIS consists of nodes that are directly connected to each other, and each node represents a processing unit. ANFIS uses a hybrid learning algorithm because it employs both artificial neural networks and fuzzy logic inference methods. There are two approaches to fuzzy inference systems. These approaches are those of Mamdani and Sugeno. To apply the ANFIS, data sets with input and output are generally required. The ANFIS method finds the optimal values of membership functions of fuzzy sets by training the model based on the principle of error reduction. It also establishes fuzzy rules for FIS. The structure of the ANFIS is shown in Figure 3. Here; "X, Y" are independent inputs, "A1, A2, B1, B2" are input parameters, "∏ (pi)" represents the membership functions, "N" denotes the rules, and "wi" indicates the weights of the parameters, while ∑ represents the bias (summation function).

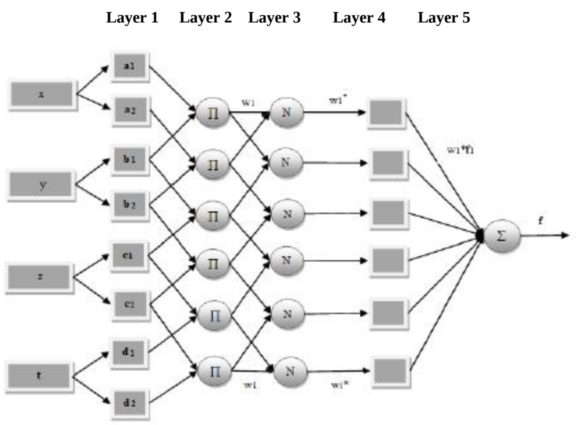


Fig.3: ANFIS model with four inputs and one output

The layers in Figure 3 represent the following:

Layer 1-) The degrees of membership of the variables and the selection of the membership function. In this study, the ANFIS model has at least two membership functions for each independent variable.

Layer 2-) All nodes in the second layer, represented by the symbol "∏", are fixed nodes. Fuzzy rules are a result of the product of the outputs of the first layer.

Layer 3-) In this layer, fixed nodes are represented by the symbol "N". ANFIS standardizes the values within the network structure. And as a result, these values are obtained.

Layer 4-) In this layer, all nodes are normalized nodes, and the weight values (w) coming from the third layer are multiplied by a first-degree polynomial equation. It is the layer output of "w1*f1".

Layer 5-) This layer contains a single fixed node. It shows the total result of all operations expressed as "Σ" [28].

2.2.3. Fuzzy Logic and Simple Membership Functions and Fuzzy Rules Generation Technique (Fuzzy SMRGT)

The components of a fuzzy logic system are the input, database, fuzzification unit, fuzzy inference mechanism, rule base, defuzzification unit, and output[29]. Below, the flowchart of the fuzzy logic system is shown in Figure 4.

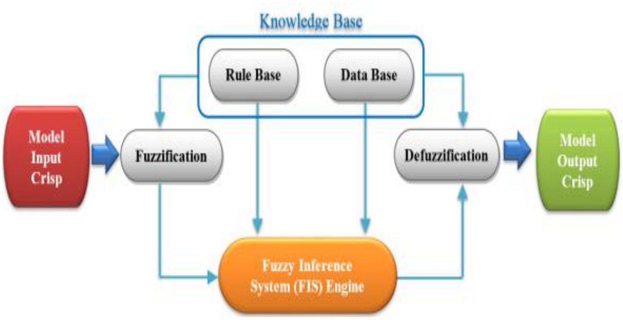


Fig.4: General Fuzzy Logic System[30]

Figure 4 shows the Input/Database of the General Fuzzy Logic System. This database contains the input variables that affect the event being studied and all related information. This information can be verbal or numerical. The unit where the necessary transformation process is carried out for the data coming from the input section to be used in the fuzzy inference mechanism is known as the fuzzification unit. This unit carries out personnel functions. However, the fuzzy rule base unit includes all the logical IF-THEN type rules that connect the input and output variables of the database. The fuzzy inference mechanism ensures that the system behaves as a single output by bringing together all the relationships established in parts between the input and output fuzzy sets within the fuzzy rule base. This method determines how the entire system will produce an output for given inputs by combining the inference of each rule. The fuzzy output values converted to a specific scale for the initial problem (values within the range of [0-1]) are known as the defuzzification unit. However, the output unit is used to solve the problem of the fuzzy logic system. This is obtained through the fuzzy output from the fuzzy inference mechanism and the defuzzification unit[31]

In fuzzy modeling, the two most important aspects are the correct determination of fuzzy sets and the fuzzy rule base[32]. Although there are many methods developed for this purpose, the Fuzzy-SMRGT method, which allows for the simultaneous determination of both, is a relatively new method that was first presented by Toprak[25]. The method can only be used in conjunction with the "centroid" defuzzification method for determining both membership functions (triangular/trapezoidal) and fuzzy rules. According to the selected input and output data, fuzzy clusters and the most suitable cluster intervals have been obtained using the Fuzzy-SMRGT method. In the Fuzzy-SMRGT method, the maximum and minimum values for the dependent and independent variables are first determined. After that, the number and shape of the membership functions are determined. The parameters used to shape and structure the membership functions are calculated using the following equations. (Eq.3-11). The structure of the membership functions of the fuzzy SMRGT-based prediction model is represented in Figure 5. Fuzzy sets have been chosen as triangular. A total of 1712 data points from the years 2004-2011 were used at the station studied. In the study, 75% of all the data was used for training, and the remaining 25% was used for testing. The results/boundary values obtained from the equations for the Fuzzy-SMRGT prediction model for these data are shown in Table 2.

The unit width (UW), core value (Ci), and key values (Ki) of the fuzzy sets corresponding to each membership function created for the prediction model have been determined. To determine these values, it is first necessary to know the range of variation of fuzzy sets (XR). To determine the range of change, the lowest and highest values of the fuzzy sets specified in the second phase were used. The range of variation (XR) for each input and output parameter is seen in the formula. In the fuzzy model, since neighboring clusters overlap, an extended base width (EUW) is required. UW represents the unit width shown in Figure 5. nu shows the number of right triangles. The right triangle number is 8(2x3+2) and has been accepted as the determined core value (Ci).

$$X_R = X_{max} - X_{min} \quad (3)$$

$$UW = \frac{X_R}{n_U} \quad (4)$$

$$O = \frac{UW}{2} \quad (5)$$

$$EUW = \frac{X_R}{n_U} + O \quad (6)$$

$$K_1 = X_{min} + \frac{EUW}{3} \quad (7)$$

$$K_5 = X_{max} - \frac{EUW}{3} \quad (8)$$

$$Ci = \frac{X_R}{2} + X_{min} \quad (9)$$

$$C_{i-1} = \frac{Ci - X_{min}}{2} + X_{min} \quad (10)$$

$$C_{i+1} = X_{max} - \left(\frac{X_{max} - Ci}{2}\right) \quad (11)$$

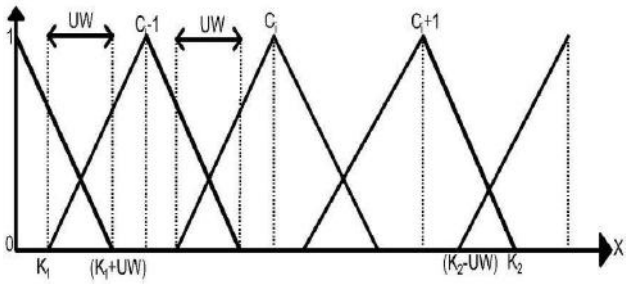


Fig. 5: Boundary parameters of the Fuzzy-SMRGT method with 5 membership functions[33]

Table 2. The Fuzzy-SMRGT boundary values of the 5 parameters obtained from this study

	Daily Average Relative Humidity (%)	Daily Average Temperature (°C)	Daily Average Wind Speed (m/s)	Daily Sunshine Duration (hours)	Daily Total Open Surface Evaporation (mm)
Max	91.00	36.10	6.90	14.10	18.10
Min	11.90	7.20	0.70	0.00	0.40
Xr	79.10	28.90	6.20	14.10	17.70
Ci	51.45	21.65	3.80	7.05	9.25
Ci-1	31.68	14.43	2.25	3.53	4.83
Ci+1	71.23	28.88	5.35	10.58	13.68
UW	9.89	3.61	0.78	1.76	2.21
O	4.94	1.81	0.39	0.88	1.11
EUW	14.83	5.42	1.16	2.64	3.32
K1	16.84	9.01	1.09	0.88	1.51
K5	86.06	34.29	6.51	13.22	16.99

III. ANALYSIS RESULTS AND DISCUSSION

In this study, 75% of the entire dataset (1284) was used for training, while the remaining 25% (428) was used as test data. The results of the MLR, ANFIS, and SMRGT models for test data have been evaluated using statistical parameters (RMSE, MAE, and R^2). For each model evaluation, the mean absolute error (MAE) (Equation 12), the square root of the mean of the squared errors (RMSE) (Equation 13), and the coefficient of determination (R2) have been used.

The statistical criteria used in the equations below are given. The comparisons of model performance based on the analysis results are shown in Table 3.

$$\mathbf{MAE} = \frac{1}{N}\sum_{i=1}^{N}\left|\mathbf{Ei}_{\mathbf{measured}} - \mathbf{Ei}_{\mathbf{predicted}}\right| \quad (12)$$

$$\mathbf{RMSE} = \sqrt{\frac{1}{N}\left(\sum_{i=1}^{N}\mathbf{Ei}_{\mathbf{measured}} - \mathbf{Ei}_{\mathbf{predicted}}\right)^{2}} \quad (13)$$

Here, E represents the evaporation, and N represents the number of data used.

Table 3. Error amount and correlation changes of the models

Model	Model Inputs	MAE (mm)	RMSE (mm)	R^2
MLR	RH, AT, WS, SD	1.61	3.95	0.86
ANFIS	RH, AT, WS, SD	1.49	3.39	0.87
Fuzzy-SMRGT	RH, AT, WS, SD	1.51	3.47	0.87

In Table 3, relative humidity (RH), air temperature (AT), wind speed (WS), and sunshine duration (SD) were used in the models to estimate evaporation (E).

3.1. MLR Results

In the method of MLR, daily average relative humidity (%), daily average temperature (°C), daily average wind speed (m/s), and daily average sunshine duration (hours) data have been used for the estimation of evaporation (mm). The distribution graph of the results for the test data in the MLR method is shown in Figure 6, while the scatter plot is presented in Figure 7.

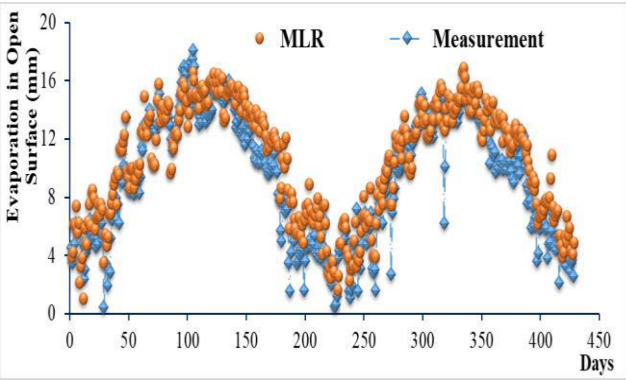


Fig.6: Distribution graph of MLR and Measurement values for the test phase

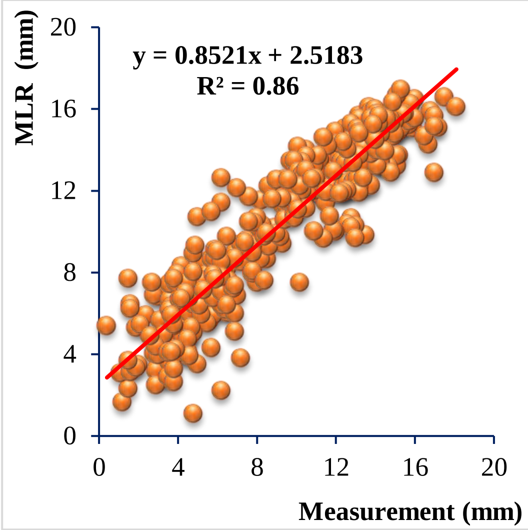


Fig.7: Scatter plot of MLR and Measurement values for the test phase

According to the scatter plot (Figure 7) and Table 1, the coefficient of determination $R^2 = 0.86$. The MLR model has the lowest determination value when examined in the testing phase. The MLR model has shown that some high evaporation amounts provided lower predictions than the actual evaporation values.

3.2. ANFIS Results

In the ANFIS model (similar to the MLR method), the inputs used to predict Evaporation (mm) include daily average relative humidity (%), daily average temperature (°C), daily average wind speed (m/s), and daily average sunshine duration (hours). The results of the ANFIS method on the test data are shown below in the distribution (Figure 8) and scatter plot (Figure 9).

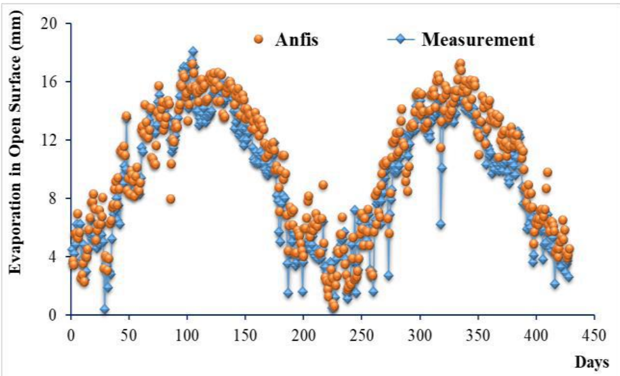


Fig. 8: Distribution graph of ANFIS and Measurement values for the test phase

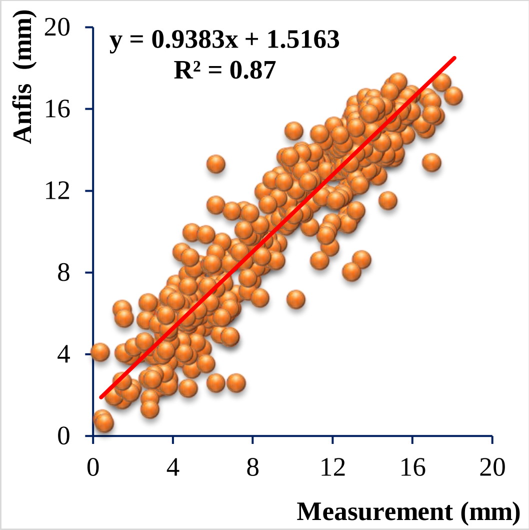


Fig. 9: Scatter plot of Anfis and Measurement values for the test phase

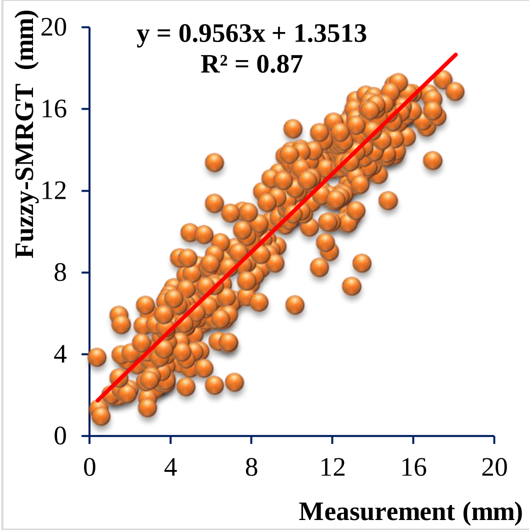


Fig.11: Scatter plot of Fuzzy-SMRGT and Measurement values for the test phase

As shown in Figures 8 and 9, there is a correlation between the actual measurement values of evaporation (mm) and the prediction results of the ANFIS model. The ANFIS method, which has a determination coefficient, R^2 = 0.87, has provided slightly more accurate results in evaporation prediction compared to the classical method of MLR.

3.3. Fuzzy-SMRGT Results

In the Fuzzy-SMRGT method, similar to the MLR and ANFIS methods, the amount of Evaporation (mm) has been estimated using data on daily average relative humidity (%), daily average temperature (°C), daily average wind speed (m/s), and daily average sunshine duration (hours). The results obtained using the test data of the Fuzzy-SMRGT model are shown below as a distribution (Figure 10) and scatter plot (Figure 11).

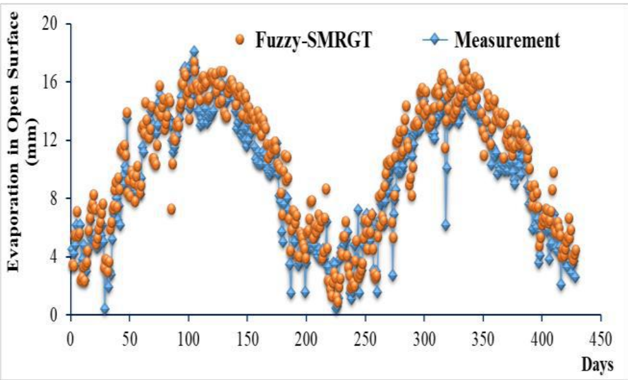


Fig. 10: Distribution graph of Fuzzy-SMRGT and Measurement values for the test phase

As shown in Figures 10 and 11, there is a correlation between the actual measurement values of evaporation (mm) and the prediction results of the Fuzzy-SMRGT method. The coefficient of determination R^2 = 0.87 observed in the Fuzzy-SMRGT method has yielded results that are more accurate than the classical method of MLR, which is almost the same as the ANFIS method, in predicting evaporation.

As the MAE, RMSE and R^2 results in Table 2 show, the estimation results obtained using ANFIS and Fuzzy Logic methods are seen to be slightly more successful than the results obtained from the classical method MLR in estimating evaporation amounts.

IV. CONCLUSION

In this study, daily evaporation amount was estimated using 'daily relative humidity, air temperature, wind speed and sunshine duration' for the Atatürk Dam located between Adıyaman and Şanlıurfa provinces between 2004-2011. For daily evaporation estimation, Fuzzy-SMRGT, ANFIS and MLR models were used and the models were compared with each other according to statistical criteria. From a total of 1712 daily data, 1284 were used for training and 428 for testing in the estimation models. The measured evaporation values were compared with the estimation output of the model.

To evaluate the performance of Fuzzy-SMRGT, ANFIS and MLR models, coefficients of determination (R2), RMSE and MAE were calculated. It was determined that the Fuzzy-SMRGT model performed better than the MLR model and had results close to the traditional ANFIS model.

It is thought that the Fuzzy-SMRGT method can be an alternative to classical methods for hydrology science and can be used for regions with different climatic conditions.

ACKNOWLEDGEMENTS

The data used in this study was obtained from the Şanlıurfa Regional Directorate of Meteorology. The authors express their gratitude to the mentioned institution.

REFERENCES

[1] Hipni, A., El-shafie, A., Najah, A., Karim, O. A., Hussain, A., & Mukhlisin, M. (2013). Daily forecasting of dam water levels: comparing a support vector machine (SVM) model with adaptive neuro fuzzy inference system (ANFIS). Water resources management, 27, 3803-3823.

[2] Ünes, F., Yildirim, S., Cigizoglu, H.K., & Coskun, H. (2013). Estimation of dam reservoir volume fluctuations using artificial neural network and support vector regression. Journal of Engineering Research, 1(3), 53-74.

[3] He, Z., Wen, X., Liu, H., & Du, J. (2014). A comparative study of artificial neural network, adaptive neuro fuzzy inference system and support vector machine for forecasting river flow in the semiarid mountain region. Journal of Hydrology, 509, 379-386.

[4] Demirci, M., Üneş, F., & Aköz, M.S. (2015). Prediction of cross-shore sandbar volumes using neural network approach. Journal of Marine Science and Technology 20(1), 171-179.

[5] Mirzavand, M., Khoshnevisan, B., Shamshirband, S., Kisi, O., Ahmad, R., & Akib, S. (2015). Evaluating groundwater level fluctuation by support vector regression and neuro-fuzzy methods: a comparative study. Natural Hazards, 1(1), 1-15.

[6] Üneş, F., Demirci, M., & Kişi, Ö. (2015). Prediction of millers ferry dam reservoir level in usa using artificial neural network. Periodica Polytechnica Civil Engineering, 59(3), 309–318.

[7] Demirci, M., Unes, F., & Akoz, M. S. (2016). Determination of nearshore sandbar crest depth using neural network approach. International Journal of Advanced Engineering Research and Science, 3(12).

[8] Tezel, G., & Buyukyildiz, M. (2016). Monthly .evaporation forecasting using artificial neural networks and support vector machines. Theoretical and applied climatology, 124, 69-80.

[9] Taşar, B., Üneş, F., Demirci, M., & Kaya, Y. Z. (2018). Yapay Sinir Ağları Yöntemi Kullanılarak Buharlaşma MİktarI Tahmini. DÜMF Mühendislik Dergisi, 543-551(in Turkish).

[10] Yin, Z., Feng, Q., Yang, L., Deo, R. C., Wen, X., Si, J., & Xiao, S. (2017). Future projection with an extreme-learning machine and support vector regression of reference evapotranspiration in a mountainous inland watershed in north-west China. Water, 9(11), 880.

[11] Üneş, F., Doğan, S., Taşar, B., Kaya, Y. Z., & Demirci, M. (2018). The Evaluation and Comparison of Daily Reference Evapotranspiration with ANN and Empirical Methods. Naural and Engineering Sciences 3(3), 54-64.

[12] Meshram, S. G., Singh, V. P., Kisi, O., Karimi, V., & Meshram, C. (2020). Application of artificial neural networks, support vector machine and multiple model-ANN to sediment yield prediction. Water Resources Management, 34(15), 4561-4575.

[13] Niu, W. J., & Feng, Z. K. (2021). Evaluating the performances of several artificial intelligence methods in forecasting daily streamflow time series for sustainable water resources management. Sustainable Cities and Society, 64, 102562.

[14] Yilmaz, M., Tosunoğlu, F., Kaplan, N. H., Üneş, F., & Hanay, Y. S. (2022). Predicting monthly streamflow using artificial neural networks and wavelet neural networks models. Modeling Earth Systems and Environment, 8(4), 5547-5563.

[15] Samantaray, S., & Sahoo, A. (2024). Prediction of flow discharge in Mahanadi River Basin, India, based on novel hybrid SVM approaches. Environment, Development and Sustainability, 26(7), 18699-18723.

[16] Tzimopoulos, C., Mpallas, L., & Papaevangelou, G. (2007). Estimation of Evapotranspiration Using Fuzzy Rules and Comparison with the Blaney-Criddle Method. International Symposium of European Water Resources Association

[17] Dogan, E., Isik, S., & Sandalci, M. (2007). Estimation of daily evaporation using artificial neural networks. Tek Dergi 18 (2), 4119–4131.

[18] Balve, P. N., & Patel, J. N. (2016). Prediction of evapotranspiration using Fuzzy logic. Journal of Agrometeorology, 18(2), 311–314.

[19] Taşar, B., Kaya, Y. Z., Varçin, H., Üneş, F., & Demirci, M. (2017). Forecasting of suspended sediment in rivers using artificial neural networks approach. International Journal of Advanced Engineering Research and Science, 4(12), 237333.

[20] Kaya, Y. Z., Mamak, M., & Unes, F. (2016). Evapotranspiration prediction using M5T data mining method. International Journal of Advanced Engineering Research and Science, 3(12), 236973.

[21] Özel, A., & Büyükyıldız, M. (2019). Aylık Buharlaşma Tahmininde Yapay Zeka Yöntemlerinin Kullanılabilirliği. Niğde Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi, 8(1), 244-254(in Turkish).

[22] Petković, B., Petković, D., Kuzman, B., Milovančević, M., Wakil, K., Ho, L. S., & Jermsittiparsert, K. (2020). Neuro-fuzzy estimation of reference crop evapotranspiration by neuro fuzzy logic based on weather conditions. Computers and Electronics in Agriculture, 173. https://doi.org/10.1016/j.compag.2020.105358

[23] Yaseen, Z. M., Al-Juboori, A. M., Beyaztas, U., Al-Ansari, N., Chau, K. W., Qi, C., ... & Shahid, S. (2020). Prediction of evaporation in arid and semi-arid regions: A comparative study using different machine learning models. Engineering applications of computational fluid mechanics, 14(1), 70-89.

[24] Wu, L., Huang, G., Fan, J., Ma, X., Zhou, H., & Zeng, W. (2020). Hybrid extreme learning machine with meta-heuristic algorithms for monthly pan evaporation prediction. Computers and electronics in agriculture, 168, 105115.

[25] Toprak, Z. F. (2009). Flow discharge modeling in open canals using a new fuzzy modeling technique (SMRGT). CLEAN–Soil, Air, Water, 37(9), 742-752.
[26] Google Earth, www.earth.google.com
[27] Anonymous, https://www.balikligol.com/gundem/ataturk-barajinda-doluluk-orani-yuzde-94u-asti-h67618.html
[28] Kocabaş, H., Üneş, F., Taşar, B., & Cansız, Ö. F. (2023). Türkiye Karayollarındaki Karbondioksit Emisyonunun Yapay Zekâ Yöntemleri ile Tahmini. Türkiye Teknoloji ve Uygulamalı Bilimler Dergisi, 4(2), 82-101(in Turkish).
[29] Jang, J. S. R., Sun, C. T., & Mizutani, E. (1997). Neuro-fuzzy and soft computing-a computational approach to learning and machine intelligence [Book Review]. IEEE Transactions on automatic control, 42(10), 1482-1484.
[30] Üneş, F., Demirci, M., Zelenakova, M., Çalışıcı, M., Taşar, B., Vranay, F., & Kaya, Y. Z. (2020). River flow estimation using artificial intelligence and fuzzy techniques. Water, 12(9), 2427.
[31] Uygunoğlu T., Ünal O. Seyitömer uçucu külünün betonun basınç dayanımına etkisi üzerine bulanık mantık yaklaşımı. Yapı Teknolojileri Elektronik Dergisi 2005; 1(1): 13-20 (in Turkish).
[32] Dayan, F., Demirci, M., Üneş, F., Taşar, B. (2021). Nehirlerdeki Katı Madde Miktarının Bulanık Smgrt Yöntemi İle Tahmini. Kahramanmaraş Sütçü İmam Üniversitesi Mühendislik Bilimleri Dergisi, 24(4), 294-307(in Turkish). https://doi.org/10.17780/ksujes.912425
[33] Er, E. E., Üneş F., & Taşar, B. Estimating Dam Reservoir Level Change of Istanbul Alibey Dam with The Fuzzy-SMRGT Method. Osmaniye Korkut Ata Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 5(Özel Sayı), 80-95.

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Effect of N, P K, Ca and Mg Fertilizer Application on Peanuts in Tra Vinh Province, Vietnam

Tran Khanh Thi Nguyen, Hieu Chi Bui, Lang Thi Nguyen*

High Agricultural Technology Research Institute for Mekong delta (HATRI)
Web: hatri.org
*Corresponding author's email: ntlang.prof@gmail.com

Received: 11 Oct 2024; Received in revised form: 13 Nov 2024; Accepted: 17 Nov 2024; Available online: 24 Nov 2024

***Abstract*— *This study was to evaluate the effects, determine the appropriate, fertilizers on peanut production. The experiment was installed in Tra Cu with two variety MD7, L14. Seven fertilizer treatments were designed. The treatments consisted of the application of T1:(Trichoderma sp + Bordeaux 1% + Probiotics 3M); T2: (organic fertilizer =10 ton/ha) ;T3:(Trichoderma sp + Bordeaux 1% + Probiotics 3M) + chemical fertilizers (35N-60P-60K + 150kg Ca + 40kg Mg) + organic fertilizer 100%); T4: (Trichoderma sp + Bordeaux 1% + Probiotics 3M) + chemical fertilizers(35N-60P-60K + 150kg Ca + 40kg Mg) + organic fertilizer 75% ;T5(Trichoderma sp + Bordeaux 1% + Probiotics 3M) + chemical fertilizers + organic fertilizer 50%) ;T6: chemical fertilizers (35N-60P-60K + 150kg Ca + 40kg Mg) +(Trichoderma sp + Bordeaux 1% + Probiotics 3M) and T7 control and treatment of farmers: (120 N-60 P-60 K + 200 Ca kg/ha). The experimental design adopted consisted of randomized complete blocks with three replications. Results showed that the analysis of absorption N, P, K in the seeds, both varieties have statistical significance on the experiments. The treatment T5, with the highest N content (2.175) for MD7, and L14 variety (2.588). For P both varieties the highest N content at treatment T7. Only K with MD7 varieties the highest N content at treatment T7 and L14 in the treatment T4. The Ca and Mg content in the seed had the highest in treatment T5 with both two varities. For the leaf: +N content in the leaves in the treatment T2 was the highest N content (4.852) for MD7. For the L14 variety in the treatment T6 (4.989) (Trichoderma sp + Bordeaux 1% + CPVS 3M) for the highest N content, followed by the fertilization level in the treatment T3 (4,625) using probiotics (Trichoderma sp + Bordeaux 1% + CPVS 3M) + MKC chemical fertilizer + 100% organic fertilizer). P content, on MD7 varieties, at the treatment (T2) using only organic fertilizers and (T3) using biological products (Trichoderma sp + Bordeaux 1% + CPVS 3M) + MKC chemical fertilizers + 100% organic fertilizers for the highest P content (1.521; 1.365) respectively. K content, on the MD7 variety, at the treatment T2 and treatment T4, had the highest content (0.142; 0.102) respectively. For the L14 variety, the treatment T7 gave the highest K content (0.612). The leaves in the treatment T3 gave the highest Ca content. Mg content in the leaves depends on the age and genotypic location of the plant. On MD7 varieties, the highest Mg content in treatment T5 (1.140). For the L14 variety, at the level of treatment T3, use biological products (Trichoderma sp + Bordeaux 1% + CPVS 3M) + MKC chemical fertilizer + 100% organic fertilizer for the highest Mg content (0.712) and the lowest in T1 (0.012). It is essential to apply the correct dose and correct time for peanut at Tra Vinh.*

***Keywords*— *absorption, Peanut. N. P. K Ca, Mg. leaf, seed.*

I. INTRODUCTION

Nitrogen (N) stands out as a crucial nutrient and a limiting factor in agricultural systems worldwide (Fageria et al., 2005). N fertilizer application is a common practice to sustain crop productivity, supporting the rapid global population growth (Maaz et al., 2021), however, excessive use can reduce N utilization efficiency, leading to environmental issues like soil degradation and water contamination (Michalczyk et al., 2020). Previous studies have shown that NPK combined with calcium and magnesium sulfate fertilizers significantly increased the yield of rape (Tian et al., 2019). In Jinzhou, Fujian and other places, experiments applying calcium, magnesium and sulfur containing fertilizers to peanut have shown that peanut yield has increased significantly (Huang et al., 2012). Effective management and appropriate use of nitrogen fertilizers in the pod zone present a promising strategy to boost peanut productivity and optimize nitrogen utilization efficiency. Peanut cultivars are commonly categorized into large-seeded and small-seeded based on seed size/weight. Large-seeded cultivars generally have a more extended pod filling period, leading to increased nitrogen uptake and accumulation compared to small-seeded ones (Sun et al., 2010). In Brazil, for peanut cultivation normally nitrogen is supplied by biological fixation, phosphorus is supplied up to 100 kg ha^{-1} P_2O_5 and potassium up to 60 kg ha^{-1} of K_2O, both at sowing, while calcium and magnesium are provided by liming and sulfur about 20 kg ha^{-1} of S (Ambrosano et al., 1997) Similarly, Ca should be applied during early bloom of groundnuts. This is because the developing pods and pegs absorb Ca directly from the root zone (Rodrigues et al., 1986). According to (FAO. 2006), the application of high K can potentially cause Ca deficiencies in groundnut production. In K deficient soils, the K requirement of the crop can be met by applying potassium sulphate (K2SO4) to supply (FAO. 2006) 16.60-41.55 kg K ha–1.Additionally, the crop requires more Ca especially at seed filling and pod development which must be readily available in the pegging zone (Fao. 2006), Our study aims to explore the NPK, Ca, Mg accumulation in two peanut cultivars with seed and leaf when apply fertilizer application at Tra Cu (Tra Vinh).

II. MATERIAL AND METHODS

2.1. Varieties: MD7 and L14.

2.2. Experimental design and treatments

- Experiment was conducted at Tra Cu Tra Vinh province, with sandy soil structures. Experimental soils have been growing peanuts for ten years and in recent years are managed in the conservation system for the peanut region. Prior to the experiment the soil layer was collected in each area in layers 0 to 30 cm deep to make up the composite sample. which was used to analyze chemical indicators according to the method of Raij et al. (2001) and particle size according to Camargo et al. (2009).

- The experiment was arranged on the farmer's field in a completely random mass (02 varieties, 7 treatments, 3 repetitions. at Tra Cu locations. the area of plots is 25 m^2).

Table 1: Treatments

no	Treatments	Contents	note
1	T1	(Trichoderma sp + Bordeaux 1% + Probiotics 3M)	
2	T2	organic fertilizer =10 ton/ha	
3	T3	Trichoderma sp + Bordeaux 1% + Probiotics 3M) + chemical fertilizers (35-60-60 + 150kg Ca + 40kg Mg)+ organic fertilizer 100%	
4	T4	Probiotics (Trichoderma sp + Bordeaux 1% + Probiotics 3M) + chemical fertilizers (35-60-60 + 150kg Ca + 40kg Mg)+ organic fertilizer 75%	
5	T5	Probiotics (Trichoderma sp + Bordeaux 1% + Probiotics 3M) + chemical fertilizers(35-60-60 + 150kg Ca + 40kg Mg) + organic fertilizer 50%	
6	T6	Chemical fertilizers (35-60-60 + 150kg Ca + 40kg Mg)+ (Trichoderma sp + Bordeaux 1% + Probiotics 3M)	
7	T7	Fellowing farmers (120-60-60+ 200 Ca kg). (control)	

The process of planting and caring techniques (land preparation, planting density, care, harvesting) is carried out in accordance with Guidance No. 52/HD-SNN.

2.3. Data collection

Plant samples were collected at growth stages (90 DAE) for leaves and for nuts, to determine plant concentration of N, P, K, Ca, Mg following standard procedures for each. The concentration of phosphorus, potassium, calcium, magnesium, in the plants were determined by inductively coupled plasma (ICP) after digestion in a mixture of concentrated HNO_3 and H_2O_2 in a microwave oven. Nitrogen was determined by Kjeldahl after digestion in a mixture of concentrated H_2SO_4 and H_2O_2.

The effects of different combinations of the applied NPK and polyhalite fertilizers on the leaf and seed accumulation and partitioning were statistically analyzed using ANOVA.

III. RESULTS AND DISCUSSION

3.1. Experimental soil propertie

In the condition that the land of peanuts has been arranged to grow peanuts for 1 crop with innocuous fertilizer levels. Soil analysis results at Tra Cu locations showed that the soil Nitrogen parameters were 1.04% at Tra Cu. Organic C levels were not high (0.92% and 0.86%) (Tran et al., 2021) to 1.04 (Tra Cu) at this experiment after planting a peanut experiment. (Table 2). Total Nitrogen also increased from 0.87% for Tra Cu. Mild sour soil - neutral (pHKCl 6.1-6.5). Peanuts grow best in slightly acidic soil with 6.0 to 6.5.

Table 2: Some properties of the tested soil (0–30 cm depth) after harvested one season (Lang et al.,2021)

Property	Tra Cu
% Nitrogen	0.87
% Potassium	150.2
% Sodium	71.6
% Magnesium	97.2
% Calcium	241
% Manganese	95.7
% Zinc	2.56
% Cooper	3.68
% Iron	79.5
% Organic	1.04
pH	6.1
% Sand	58.36
% Silt	31.5
% Clay	1.20

3.2. Nutrient absorption peanut in seed

3.2.1. Nutrients N, P, K. Through the analysis of absorption in the seeds, both varieties have statistical significance on the experiments. (Table 3). N content in the seed in the treatment T5, with the highest N content (2.175) for MD7, and L14 variety in the treatment T5 (2.588). For P both varieties the highest P content at treatment T7. Only K have the highest K content at treatment T7 at MD7 and L14 in the treatment T4.

Table 3. Nutrient analysis of peanuts in the winter-spring crop 2022

Fertilizer Factor (F) (N-P-K)	MD7			L14		
	N	P	K	N	P	K
Sites: Tra Cu						
T1	1.750d	0.850e	0.097e	1.880e	0.981b	0.190c
T2	1.850c	0.690f	0.095e	1.570f	0.850c	0.189c
T3	2.145a	1.350b	0.170d	2.023c	0.980b	0.139c
T4	2.135a	1.180c	0.191d	2.180b	0.698d	0.371a
T5	2.175a	1.071d	0.391c	2.588a	0.941b	0.137c
T6	2.127a	1.071d	0.541b	1.930d	0.625d	0.257b
T7	2.013b	1.425a	0.981a	2.037c	1.001a	0.269b

Cv%	2.33	2.11	1.33	1.78	0.17	0.98
LSD 0.05	0.04	0.34	0.15	0.06	0.12	0.22

3.2.2. Ca, Mg nutrients

Through the analysis of the absorption of Ca and Mg in the seeds, both varieties were analyzed with statistical significance on the experiments. (Table 4). The Ca and Mg content in the seed had the highest in treatment T5 with both two varities.

Table 4. Analysis of Ca and Mg nutrients of peanut seed in the winter-spring crop 2022

Fertilizer Factor (F) (N-P-K)	MD7		L14	
	Ca	Mg	Ca	Mg
Site: Tra Cu				
T1	1.026c	0.055e	1.021d	0.178e
T2	1.541a	0.058e	1.102c	0.215d
T3	1.24b	0.181d	1.474a	0.787b
T4	0.953d	0.654b	1.235b	0.045f
T5	1.574a	1.182a	1.451a	1.541a
T6	1.512a	0.132d	1.457a	0.567c
T7	0.541e	0.214c	1.412a	0.781b
CV%	1.17	3,25	5.81	3.58
LSD 0.05	0.83	0.12	0.24	0.15

3.3 Nutrient absorption peanut in leaves

3.3.1. Nutrients N, P, K

Through the analysis of the absorption of nitrogen, phosphorus, and potassium fertilizers on peanut leaves of the above treatment of statistical significance on the MD7 variety, while on the L14 variety, the absorption of potassium fertilizers was not statistically significant. The N content in the leaves in the treatment T2 was only using the organic fertilizer with the highest N content (4,852) calculated for MD7, which was significantly different from the other treatment (Table 4) and then in the treament T3 (4,742) using probiotics (Trichoderma sp + Bordeaux 1% + CPVS 3M) + MKC chemical fertilizer + 100% organic fertilizer; T4 (4,487) uses probiotics (Trichoderma sp + Bordeaux 1% + CPVS 3M) + MKC chemical fertilizer + 75% organic fertilizer and the lowest in T5 (3,151). For the L14 variety in the treatment T6 (4,989) using MKC chemical fertilizer + Bio-products (Trichoderma sp + Bordeaux 1% + CPVS 3M) for the highest N content, followed by the fertilization level in the T3 experiment (4,625) using probiotics (Trichoderma sp + Bordeaux 1% + CPVS 3M) + MKC chemical fertilizer + 100% organic fertilizer and the lowest in T7 (3,365). N content in leaves decreases with age and varies with plant variety, according to Cox et al. (1970) reported that the N content in leaves at the vegetative stage is more than 5%. The sufficient level of N in the leaves, has been reported to be between 3.0-4.0% (Dwivedi, 1988; Jones et al., 1991) and nitrogen deficiency symptoms appear when the concentration of N in the leaves drops below 2.2% (Dwivedi, 1988).

P content, on MD7 varieties, at the treatment (T2) using only organic fertilizers and (T3) using biological products (Trichoderma sp + Bordeaux 1% + CPVS 3M) + MKC chemical fertilizers + 100% organic fertilizers for the highest P content (1,521; 1,365) respectively and the lowest P content in the treatment T1 (0.154) using only biological fertilizers without using organic fertilizers and chemical fertilizers. For the L14 variety, in contrast to the MD7 variety, the treatment T1 gave the highest P content (1.725), followed by the treatment T4 (1.552) and the lowest in the treatment T5, treatment T6 and treatment T7 (0.125; 0.154; 0.174) respectively.

The K content in the leaves of MD7 varieties was the highest (0.654; 0.302) in treatment T6 and T5 respectively and the lowest in T2 and T4 respectively (0.025; 0.052). The L14 variety, the content of K in the leaves in the treatment was not statistically significant. (Table 5)

Table 5. Nutrient analysis of leaf peanut in the winter-spring crop 2022

Fertilizer Factor (F) (N-P-K)	MD7			L14		
	N	P	K	N	P	K
Site: Tra Cu						
T1	4.151d	0.154e	0.120d	4.541c	1.725a	0.012b
T2	4.852a	1.521a	0.025e	4.321d	0.895c	0.024b
T3	4.742b	1.365b	0.210c	4.625b	0.399d	0.023b
T4	4.487c	1.125c	0.052e	4.184e	1.552b	0.056b
T5	3.151f	1.021d	0.302b	4.562c	0.125e	0.142a
T6	4.132d	1.011d	0.654a	4.989a	0.154e	0.014b
T7	3.999e	1.124c	0.065d	3.365f	0.174e	0.012b
Cv%	7.25	2.13	4.25	1.42	0.58	0.47
LSD 0.05	0.12	0.74	0.02	0.17	0.52	0.23

3.3.2. Ca, Mg nutrients: Analyzed the absorption of Ca and Mg in peanut leaves of statistical significance on both MD7 and L14 varieties.

The Ca content in the leaves in the T1 test of probiotics (Trichoderma sp + Bordeaux 1% + CPVS 3M without chemical fertilizer and organic fertilizer with the lowest Ca content (0.857), followed by the T2 test (0.951) using only organic fertilizers calculated for MD7 was significantly different from the other tests (Table 6) and in the test using bioproducts (Trichoderma sp + Bordeaux 1% + CPVS 3M) + MKC chemical fertilizer + 50% organic fertilizer (T5) for the highest Ca content, followed by T4, T7 and T3 experiments with values of 1,314; 1,251; 1,214 and 1,104 respectively. For the L14 variety in the T3 experiment, use biological products (Trichoderma sp + Bordeaux 1% + CPVS 3M) + MKC chemical fertilizer + 100% organic fertilizer for the highest Ca content (1,514). Suggest that the Ca content in the leaves gives a maximum yield of 1.8% and is stable at 1.2 – 2.0% (Nicholaides and Cox, 1970).

The Mg content in the leaves depends on the age and genotypic location of the plant. On MD7 varieties, T1 and T2 fertilization yielded the lowest Mg content (0.154; 0.239) respectively and the highest Mg content in T5 experiment (1.140). For the L14 variety, at the level of T3 fertilization, use biological products (Trichoderma sp + Bordeaux 1% + CPVS 3M) + MKC chemical fertilizer + 100% organic fertilizer for the highest Mg content (0.712) and the lowest in T1 (0.012).

Table 6. Analysis of Ca and Mg nutrients of peanut leaves in the winter-spring crop 2022

Fertilizer Factor (F) (N-P-K)	MD7		L14	
	Ca	Mg	Ca	Mg
Site: Tra Cu				
T1	0.857e	0.154f	1.147c	0.012d
T2	0.951d	0.239e	1.365b	0.021d
T3	1.104c	0.625c	1.514a	0.712a
T4	1.251b	0.951b	1.112c	0.132c
T5	1.314a	1.140a	1.120c	0.054d
T6	1.187c	0.954b	1.002d	0.084d
T7	1.214b	0.321d	1.121c	0.561b
CV%	5.12	4,25	5.22	2.57
LSD 0.05	0.41	0.15	0.47	0.24

3.4. Discussion

The soil growing peanut at Tra Cu with sand: 58.36%, a favourable condition for plant and hight yield for peanut (Lang et al., 2021) .The role of soil during pegging and pod development, and reported loam soil more suitable for peg swelling and pod development, as well as yield formation over clay and sandy type of soil (Zhao C. et al., 2015). The loam soil provides moderate aeration and water along with fertility retention, a favourable condition for plant and peg growth, and pod development (Zhao C. et al., 2015). The optimal growth of subterranean peg and pod require slightly acid soil pH of 6.0 to 6.5, but a range of 5.5 to 7.0 is acceptable. Plant nutritional balance combined with proper nutrient supply can maximize productivity and quality of peanuts, ensuring an adequate supply of this oilseed with analysis of absorption in the seeds, both varieties have statistical significance on the experiments. (Table 3). N content in the seed in the treatment T5, with the highest N content (2.175) for MD7, and L14 variety in the treatment T5 (2.588). The Ca and Mg content in the seed had the highest in treatment T5 with both two varities. (Table 4) mean note treament with: Probiotics (Trichoderma sp + Bordeaux 1% + Probiotics 3M) + chemical fertilizers (35-60-60 + 150kg Ca + 40kg Mg) + organic fertilizer 50%. However, N content in the leaves in the treatment T2 was only using the organic fertilizer with the highest N content (4.852) calculated for MD7. For the L14 variety in the treatment T6 for the highest N content, followed by the fertilization level in the treatment T3 (4.625). This the same (Godoy et al., 2017), high oleic type cultivars have expanded their production area. The development of more productive genotypes with higher levels of protein and oil increased the demand for more fertile soils so that the maximum potential of the crop is reached (da Silveira et al., 2013). The cultivars used MD7 absorbed in seed an average of 1.574 and 0.981 more Ca and K than the L14 cultivars, respectively (table 4 and 5). The greater need for K and Ca by newer modern peanut cultivars suggests that they are more responsive to soil acidity correction by liming, thus providing Ca and improving the availability of Mg for the crop. The same with research Potassium is the second most absorbed nutrient by peanut plants (Neto et al., 2012), while Ca is the third most absorbed (Rodrigues et al., 1986). For Peanut at Tra Cu , Tra Vinh the famers do not pay attention to the decline of the soil and the quality of peanut , but focus on productivity. Sometimes the selling price is high, so it affects the quality of the peanut. For the proper management of fertilization, it is essential to apply the correct dose and correct time, among others (Roberts et al., 2007). However, any fertilization recommendation must be based on knowing the rate of nutrient accumulation by plants (Xie et al., 2020).

IV. CONCLUSION

-For the seed, the analysis of absorption N, P, K in the seeds, both varieties have statistical significance on the experiments. N content in the seed in the treatment T5, with the highest N content (2.175) for MD7. and L14 variety in the treatment T5 (2.588). For P both varieties the highest N content at treatment T7. Only K MD7 varieties the highest N content at treatment T7 and L14 in the treatment T4. The Ca and Mg content in the seed had the highest in treatment T5 with both two varities.

- For the leaf

+ N content in the leaves in the treatment T2 was only using the organic fertilizer with the highest N content (4.852) calculated for MD7. For the L14 variety inthe treatment T6 for the highest N content, followed by the fertilization level in the treatment T3 (4.625) using probiotics

+ P content, on MD7 varieties, at the fertilization level (T2) using only organic fertilizers and (T3) using biological products (Trichoderma sp + Bordeaux 1% + CPVS 3M) + MKC chemical fertilizers + 100% organic fertilizers for the highest P content (1.521; 1.365) respectively,

+K content, on the MD7 variety, at the treatment T2 and treatment T4 fertilization levels, had the highest content. For the L14 variety, on the contrary, the treatment T7 gave the highest K content.

+ Ca content in the leaves in the T1 test of probiotics (Trichoderma sp + Bordeaux 1% + CPVS 3M without chemical fertilizer and organic fertilizer with the lowest Ca content (0.857), followed by the T2 test (0.951).

+ Mg content in the leaves depends on the age and genotypic location of the plant. On MD7 varieties, Treatment T1 and treatment T2 fertilization yielded the lowest Mg content and the highest Mg content in T5 experiment (1.140). For the L14 variety, at the level of T3 fertilization, use biological products.

ACKNOWLEDGEMENT

The authors are extremely grateful to Tra Vinh Department of Science and Technology for providing funding to implement this topic. Thanks are due to HATRI and our colleagues in the Genetics and Plant Breeding Division for their support and valuable suggestions.

REFERENCES

[1] Ambrosano E.J., Tanaka R.T., Mascarenhas H.A.A., van Raij B., Quaggio J.A., Cantarella H. Leguminosas e oleaginosas. In: van Raij B., Cantarella H., Quaggio J.A., Furlani A.M.C., editors. Recomendações de Adubação e Calagem para o Estado de São Paulo. Instituto Agronômico; Campinas, Brazil: 1997. pp. 187–203.

[2] Baughman, T. and P. Dotray, 2015. Texas peanut production guide. Texas Cooperative Extension, The Texas A&M University System, pp: 1-57.

[3] Camargo. O.A.. Moniz. A.C.. Jorge. J.A.. Valadares. J.M. 2009. Métodos de análise química. mineralógica e física de solos do Instituto Agronômico de Campinas. Rev. andupdated ed. Instituto Agronômico de Campinas. Campinas. Boletim técnico. 106. 77p.Fageria NK, Baligar VC. Enhancing nitrogen use efficiency in crop plants. Adv Agron. 2005;88:97–185.

[4] da Silveira P.S., Peixoto C.P., da Ledo C.A.S., Passos A.R., Borges V.P., Bloisi L.F.M. Phenology and yield of peanut in different sowing seasons in southern bahia recôncavo. Biosci. J. 2013;29:553–561.

[5] Godoy I.J., Santos J.F., Michelotto M.D., Moraes A.R.A., Bolonhezi D., de Freitas R.S., de Carvalho C.R.L., Finoto E.L., Martins A.L.M. IAC OL 5—New high oleic runner peanut cultivar. Crop Breed. Appl. Biotechnol. 2017;17:289–292. doi: 10.1590/1984-70332017v17n3c45.

[6] FAO, 2006. Plant nutrition for food security: A guide for integrated nutrient management. FAO Fertilizer and Plant Nutrition Bulletin 16, Food and Agriculture Organisation of the United Nations, Rome, Italy, pp: 1-366.

[7] Huang Mei-ling, Chen Wei, and Wu Wen-zhen. 2012. Effect of Calcium and Magnesium Sulphide Fertilizer on Peanut. Tillage and Cultivation 18(2):34-34.

[8] Neto J.F., Costa C.H.M., Castro G.S.A. Ecophysiology of peanut. Sci. Agrar. Paranaensis. 2012;11:1–13. doi: 10.18188/1983-1471/sap.v11n4p1-13.

[9] Maaz TM, Sapkota TB, Eagle AJ, Kantar MB, Bruulsema TW, Majumdar K. Meta-analysis of yield and nitrous oxide outcomes for nitrogen management in agriculture. Glob ChangeBiol. 2021;27:2343–60.

[10] Michalczyk A, Kersebaum KC, Dauck HP, Roelcke M, Yue SC, Chen XP, Zhang FS. Quantifying nitrogen loss and wateruse via regionalization and multiple-year scenario simulations in the North China Plain. J. Plant Nutr. Soil Sci. 2020;183:718–33.

[11] Raij. Van B.. Andrade. J.C.. Cantarella. H.. Quaggio. J.A. 2001. Análise química para avaliação da fertilidade de solos tropicais. Instituto Agronômico. Fundação IAC. Campinas. 285 p.

[12] Roberts T.L. Right Product, Right Rate, Right Time, and Right Place…the Foundation of BMPs for Fertilizer. Fertil. Best Manag. Pract. 2007:29–32.

[13] Rodrigues Filho F.S.O., Godoy I.J., Fetosa C.T. Accumulation of dry matter and nutrients by peanut plants CV Tatui-76. Rev. Bras. Ciência do Solo. 1986;10:61–66.

[14] Sun H, Li SX, Wang YF, Wang ML. Effects of nitrogen application on source of nitrogen accumulation and yields of different peanut cultivars. J Plant Nutri Fertil. 2010;16:153–7.

[15] Xie M., Wang Z., Xu X., Zheng X., Liu H., Shi P. Quantitative estimation of the nutrient uptake requirements of peanut. Agronomy. 2020;10:119. doi: 10.3390/agronomy10010119.

[16] Tian Gui-sheng, Gao Jie, Meng Fan-jin, Ren Tao, and Lu Jian-wei. 2019. Effect of Different Polysulphate Fertilizer on Yield and Economic Benefit of Rape. Hubei Agricultural Sciences 58(6):26-29.

[17] Zhao, C., Zhao, S., Hou, L., Xia, H., Wang, J., Li, C., et al. (2015). Proteomics analysis reveals differentially activated pathways that operate in peanut gynophores at different developmental stages. *BMC Plant Biol.* 15 (1), 188. doi: 10.1186/s12870-015-0582-6

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Impact of Urbanisation on Cropping Pattern in Tamil Nadu – An Economic Analysis

E. Gayathri*, K. Sita Devi

Department of Agricultural Economics, Faculty of Agriculture, Annamalai University, Tamil Nadu, India
*Corresponding Author: gayathrielangovan00@gmail.com

Received: 23 Oct 2024; Received in revised form: 18 Nov 2024; Accepted: 22 Nov 2024; Available online: 29 Nov 2024

Abstract— *Urbanisation per se becomes significant, since it affects land use, cropping pattern, occupational pattern, migration, literacy, access to markets and infrastructure, etc. Dynamics of cropping pattern is usually expressed at macro level and it has a significant bearing on the urbanization, mainly due to the availability and proximity of markets in the urban areas. The specific objectives set forth for the study are, to study the temporal changes and the shift in the cropping pattern and to measure the extent of diversification in the study area. The tools used for the study were descriptive statistics, growth rate analysis, markov chain analysis and diversification indices. The changes in the cropping pattern was estimated for the period from 2000-01 to 2019-2020 and further discussed under two decadal periods. The results revealed that there has been a gradual shift in the cropping pattern in Tamil Nadu state. The shift in cropping pattern, might be due to the awareness of the farmers on the profitability of the crops and developments in the market infrastructure and urbanisation.*

Keywords— ***Cropping pattern, dynamic changes, urbanization, diversification***

I. INTRODUCTION

Urbanisation and economic development are broadly synonymous and therefore the issue of agriculture needs to be dealt in the context of recent developments of sustained growth in incomes and urbanisation as well. Urbanisation *per se* becomes significant, since it affects land use, cropping pattern, occupational pattern, migration, literacy, access to markets and infrastructure, etc. Dynamics of cropping pattern is usually expressed at macro level and it has a significant bearing on the urbanization, mainly due to the availability and proximity of markets in the urban areas. The changes in the cropping pattern of India for the period from 1950-51 to 1997-98 revealed that the proportion of area under cereals to total cropped area had decreased from 61.10 per cent to 53.80 per cent, which was attributed to conversion of land for non-agricultural uses led by pressures of urbanization, industrialization, and demand for land for housing (Goswami and Challa, 2004).

The economic implications of urbanisation from a general perspective and the effect of labour migration on the demand for agricultural products and changes in cropping pattern which witnessess the noticeable changes with the urban profile. Besides urban demand, a well-developed infrastructure (roads, electricity, cold storage, processing, input markets, information sources, etc.) in urban areas encourage farmers to diversify towards high-value perishable food commodities. And the impact of urbanisation on crop diversification with temporal variations. With the above background, the present study was done to study the temporal changes, shift in the cropping pattern in the study area and to measure the extent of diversification in the study area.

II. MATERIALS AND METHODS

2.1 Methodology:

The time series data pertaining to area under different crops, net area sown, area sown more than once and gross cropped area was collected from the published sources, viz., the Season and Crop Report of Tamil Nadu. The changes in the cropping pattern was estimated for the period from 2000-01 to 2019-2020 and further discussed under two decadal periods, namely, Decade I (2000-01 to 2009-10) and Decade II (2010-11 to 2019-2020). The major crop categories considered for the analysis were cereals, pulses, oilseeds, fiber crops, cash crops and fruits and vegetables.

2.2 Tools of Analysis

2.2.1 Descriptive Analysis - Descriptive statistical analysis was undertaken using percentage, mean etc.

2.2.2 Growth Rate Analysis

Compound growth rates of area under major crops were estimated to capture the trend in these variables. Exponential function of the following form was used to estimate the growth rates

$$Y_t = Y_o (1+r)^t \quad \text{------- (1)}$$

Where,

Y_t = Area under the crop category at time t (ha)

r = Compound rate of growth of Y

Y_o = Initial year area under the crop category (ha)

By taking natural logarithm,

$$\ln Y_t = \ln Y_o + t \ln (1+r) \quad \text{------- (2)}$$

Now letting,

$\beta_1 = \ln Y_o$

$\beta_2 = \ln (1+r)$

Equation (2) can be written as

$$\ln Y_t = \beta_1 + \beta_2 t \quad \text{------- (3)}$$

Adding the disturbance term to (3), it can be written as

$$\ln Y_t = \beta_1 + \beta_2 t + U_i \quad \text{------- (4)}$$

$$\sum_{i=1}^{n} P_{ij} = 1 \text{ and } 0 \leq P_{ij} \leq 1$$

Y_t = Area under crop category at time‘t’ (ha)

t = time in years

β_1 = constant term

β_2 = regression co-efficient

This log linear function was fitted by using Ordinary Least Square (OLS) method. The compound growth rate (r) was obtained using the formula.

$$r = (\text{Antilog of } \beta_2 - 1) \times 100 \quad \text{------- (5)}$$

The major crop categories considered for the growth rate analysis were cereals, pulses, oil seeds, fiber crops, cash crops and fruits and vegetables.

2.2.3 Markov Chain Analysis

The dynamism in the direction of area under crop categories were analyzed using the first order Markov chain approach using LINGO software. Central to Markov chain analysis is the estimation of the transitional probability matrix ‘P’ whose elements, P_{ij} indicate the probability (share) of crop categories switching from i^{th} crop category to j^{th} crop category over time. The diagonal element P_{ij}, where i=j, represents the retention share of respective crop category in terms of area under crop categories.

This can be denoted algebraically as

$$E_{jt} = \sum_{i=1}^{n} (E_{it-1}) \quad + e_{jt}$$

Where,

E_{jt} = Area under crop category to the j^{th} crop in the year t

E_{it-1} = Area under i^{th} crop category during the year t-1

P_{ij} = The probability of shift in area under i^{th} crop category to j^{th} crop category

e_{jt} = The error term which is statistically independent of E_{it-1}

n = Number of crop categories

The transitional probabilities P_{ij}, which can be arranged in a (m x n) matrix, have the following properties:

Thus, the expected share of each crop category during the period ‘t’ is obtained by multiplying the share of these crop categories in the previous period (t-1) with the transitional probability matrix.

The transitional probability matrix is estimated using linear programming (LP) framework by a method referred to as minimization of Mean Absolute Deviation (MAD), the formulation is stated as

Min, OP* + I e

Subject to,

X P* + V = Y

GP* = 1

P* ≥ 0

Where,

P* is a vector of the transitional probabilities P_{ij} to be estimated

O is the vector of zeros

I is an appropriately dimensional vector of areas e is the vector of absolute errors

Y is the proportion of area to each crop category

X is a block diagonal matrix of lagged values of Y

V is the vector of errors

G is a grouping matrix to add the row elements of P arranged in P* to unity.

2.2.4 Diversification Indices

There are quite a few methods, which explain either concentration (i.e. specialization) or diversification of crops in a given time and space. Each method has some limitations and/or superiority over the others. The following indices were used in the study to measure the extent of diversification.

2.2.4.1 Herfindahl Index (HI)

Herfindahl Index is the sum of square of the acreage proportion of each crop in the total cropped area. The index is computed as

$$= \sum_{i=1}^{N} P_i^2$$

where, P_i represents acreage proportion of the i^{th} crop in total cropped area.

2.2.4.2 Simpson Index (SI)

The Simpson Index (SI) is the most suitable index of measuring diversification in a particular geographical region. Mathematically, SI is defined as

$$SI = 1 - \sum_{i=1}^{N} P_i^2$$

Where, $P_i = A_i / \Sigma A_i$ is the proportion of the i^{th} crop in acreage.

If Simpson Index is nearer to zero, it indicates that the zone or region is near to the specialization in growing of a particular crop and if it is close to one, then the zone is fully diversified in terms of crops.

2.2.4.3 Entropy Index (EI)

The Entropy Index is a direct measure of diversification having a logarithmic character. The index is computed as:

$$EI = \sum_{i=1}^{N} P_i * \log (1/P_i)$$

where, P_i represents acreage proportion of the i^{th} crop in total cropped area.

2.2.4.4 Modified Entropy Index

Modified Entropy Index is used to overcome the limitation of Entropy Index by using variable base of logarithm instead of fixed based logarithm. It can be computed as:

$$MEI = \sum_{i=1}^{N} P_i * \log_N P_i$$

where, P_i represents acreage proportion of the i^{th} crop in total cropped area.

2.2.4.5 Composite Entropy Index

This index possesses all desirable properties of Modified Entropy Index and is used to compare diversification across situations having different and large number of crops, since it gives due weightage to the number of crops. The formula of CEI is given by:

$$CEI = -[\sum_{i=1}^{N} P_i * \log_N P_i] * \{1-(1/N)\}$$

where, P_i represents acreage proportion of the i^{th} crop in total cropped area.

2.2.4.6 Ogive Index

Ogive Index (OI) is used to measure diversity. It measures deviations from benchmark given by equal proportion of each crop. For example, if there are N crops, the norm used for measuring deviations is 1/N. The formula of computing Ogive Index is as follows.

$$OI = \sum_{i=1}^{N} P_i \{Pi - (1/N)\}^2 / (1/N)$$

where, P_i represents acreage proportion of the i^{th} crop in total cropped area.

III. RESULT AND DISCUSSION

3.1 Changes in the Area under Major Crop Categories

The average area under selected major crop categories, the relative share of each crop category in the total area and the decadal growths have been calculated to study the changes in the cropping pattern in the study area. These changes in the cropping pattern were estimated for the period from 2000-01 to 2019-2020 and further discussed under two decadal periods, namely, Decade I (2000-01 to

2009-10) and Decade II (2010-11 to 2019-2020), and are presented here under.

It could be seen from Table 1 that the share of average area under cereals in the total cropped area of Tamil Nadu state was accounted for 57.58 per cent in Decade I, and it has increased marginally to 58.66 per cent in Decade II. The decadal growth of the average area under cereal crops was only 0.79 per cent, which revealed that the average area under cereal crops was consistent over the years and still occupied the major share in the total cropped area.

The proportion of pulses area, the second major crop, accounted for 11.25 per cent in Decade I and it has sharply increased to 15.42 per cent in Decade II and the decadal growth was 35.48 per cent, which recorded the highest decadal change. Also, the average proportion of area under fiber crops has increased marginally from 2.63 per cent to 3.46 per cent and the decadal growth was 30.17 per cent. The proportion of average area under fruits and vegetables has also increased from 6.54 per cent to 7.36 per cent, thus resulting in a decadal growth of 11.45 per cent.

A further look at Table 1 would reveal that the share of average area under oilseeds declined from 15.05 to 9.23 per cent and has recorded a negative change of -39.37 per cent. Also, the share of cash crops area has declined from 6.95 per cent to 5.87 per cent between the decades, with a negative decadal change of -16.33 per cent and there was a marginal decline in the total cropped area by 1.07 per cent in the state.

The above results revealed that the area under four major crop categories, *viz.*, cereals, pulses, fiber crops and fruits and vegetables have recorded a positive change between the two decadal periods and the other crop categories, such as, oilseeds and cash crops had negative decadal growths, still had a considerable share in the total cropped area.

Table 1. Average Area under Major Crop Categories in the Study Area, 2000-01 to 2019-2020

(in '000 hectares)

S. No	Major Crop Categories	Tamil Nadu State		
		Decade I (2000-01 to 2009-10)	Decade II (2010-11 to 2019-2020)	Decadal Growth
1.	Cereals	25.37 (57.58)	25.57 (58.66)	0.79
2.	Pulses	4.96 (11.25)	6.72 (15.42)	35.48
3.	Oilseeds	6.63 (15.05)	4.02 (9.23)	-39.37
4.	Fiber crops	1.16 (2.63)	1.51 (3.46)	30.17
5.	Cash crops	3.06 (6.95)	2.56 (5.87)	-16.33
6.	Fruits and Vegetables	2.88 (6.54)	3.21 (7.36)	11.45
	Total	**44.06 (100.00)**	**43.59 (100.00)**	**-1.07**

Note: Figures in the parentheses indicate percentage to the respective totals

3.1.2 Growth Rates of Area under Major Crop Categories in the Study Area

The changes in the cropping pattern of Tamil Nadu state could also be ascertained through studying the growth in area under major crops. The growth rates of different crop categories have been analyzed using an exponential growth function. The results of the growth rates in area under major crop categories are presented in Table 2 and Figure 1.

It could be observed from Table 2 that the growth rate of area under cereals had shown a negative trend in Decade I (-0.05 per cent) and it had been positive in Decade II (1.28 per cent) and thus recorded a significant overall growth of 0.20 per cent. So also, the pulses area has shown a negative growth rate of -0.87 per cent in Decade I and then recorded a positive trend in Decade II (3.67 per cent), with an overall significant growth of 2.60 per cent.

The growth in area under fiber crops and fruits and vegetables have registered a positively significant overall growth rates of 2.01 per cent and 1.15 per cent over the two decadal periods. However, the area under oilseeds and cash crops have recorded significant negative growth rates of -4.33 per cent and -2.63 per cent, respectively. It is understood that oilseeds and cash crops showed a negative trend in the area under these crops in Tamil Nadu. On the contrary, cereals, pulses, fiber crops and fruits and vegetables had a positive growth trend over the periods. This result is in accordance with Velavan and Balaji (2012).

Table 2. Growth Rates of Area under Major Crop Categories in the Study Area, 2000-01 to 2019-2020

S. No	Major Crop Categories	Tamil Nadu State		
		Decade I (2000-01 to 2009-10)	**Decade II (2010-11 to 2019-2020)**	**Overall Period (2000-01 to 2019-2020)**
1.	Cereals	-0.05	1.28	0.20***
2.	Pulses	-0.87	3.67	2.60***
3.	Oilseeds	-4.07***	-1.59	-4.33
4.	Fiber crops	-3.37	2.62	2.01***
5.	Cash crops	1.81	-10.16	-2.63
6.	Fruits and Vegetables	2.29***	0.34	1.15

(** and *** indicate significance at 5 per cent and 1 per cent levels, respectively)

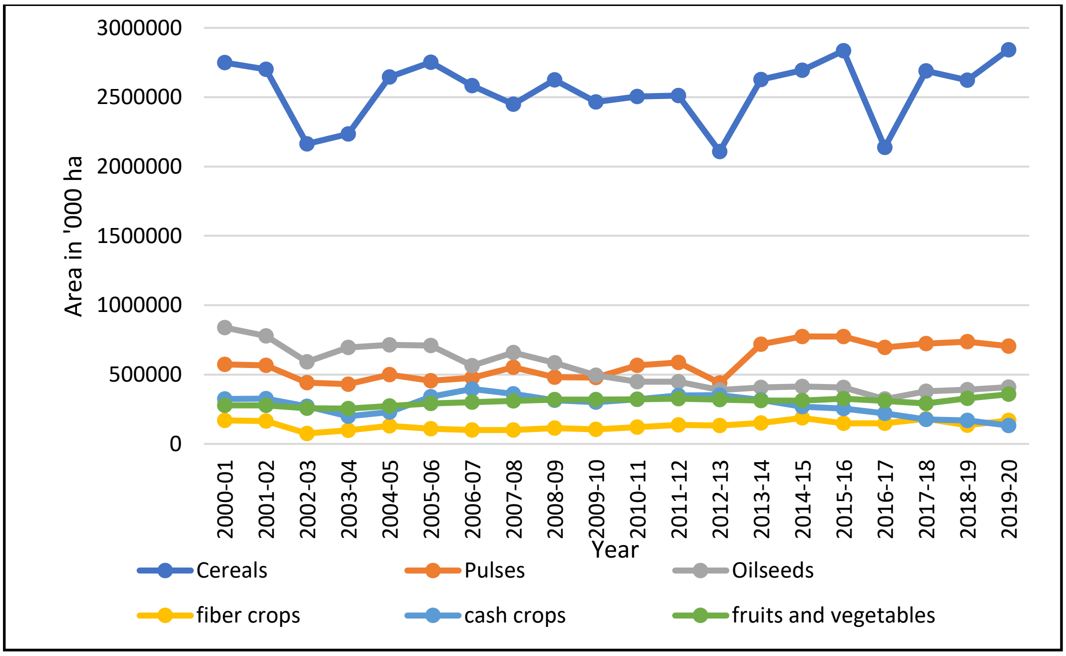


Fig. 1. Trends in the Area under Major Crop Categories in Tamil Nadu State

3.1.3 Crop Diversification Indices for Area under Major Crop Categories

Crop diversification based on the proportion of area under major crop categories has been measured and quantified using Herfindahl Index (HI), Simpson Index (SI), Entropy Index (EI), Modified Entropy Index, Composite Entropy Index and Ogive Index for a period of 20 years and for the two decadal periods separately, i.e., Decade I (2000-01 to 2009-10) and Decade II (2010-11 to 2019-2020). The average values of these indices for different crop categories in the study area are presented in Table 3.

The Herfindahl index would decrease with increase in diversification. It could be seen from Table 3 that the calculated average values of Herfindahl Index for the selected crop categories have been decreased in Tamil Nadu over the two decadal periods, i.e., from 0.38 in Decade I to 0.35 in Decade II, implying more crop diversification over the period of study.

The Simpson index and Entropy index would increase with the increase in diversification and vice versa**.** The results revealed that the calculated average values of Simpson Index moved up from 0.62 in Decade I to 0.65 in Decade II in Tamil Nadu, implying a gradual shift in the cropping pattern.

The Modified Entropy index increases with increase in diversification and vice-versa. The modified entropy index of crop diversification on the proportion of area under the selected crop categories in Tamil Nadu during Decade I to Decade II, clearly revealed that this index of crop diversification varied from 1.32 to 1.44, indicating increased diversification in Tamil Nadu over the decadal periods.

The Composite Entropy index increases with decreases in concentration. This index of crop diversification on the proportion of major crop categories in Tamil Nadu varied from Decade I to Decade II, i.e., 1.30 to 1.28, implying increased diversification in the state

The ogive index measures the idealness or equity with the crop categories and this index clearly revealed that the crops grown were not ideal and shows slight variation in the cropping pattern from Decade I to Decade II in both the state.

From the above results, it is evident that there has been a gradual shift in the cropping pattern in Tamil Nadu state.

Table 3. Crop Diversification Indices for Area under Major Crop Categories in the Study Area

S. No	Diversification Indices	Tamil Nadu State		
		Decade I (2000-01 to 2009-10)	Decade II (2010-11 to 2019-2020)	Overall Period (2000-01 to 2019-2020)
1.	Herfindahl Index	0.38	0.35	**0.38**
2.	Simpson Index	0.62	0.65	**0.62**
3.	Entropy Index	0.57	0.56	**0.56**
4.	Modified Entropy Index	1.32	1.44	**1.29**
5.	Composite Entropy Index	1.30	1.28	**1.28**
6.	Ogive Index	2.61	2.46	**4.84**

3.1.4 Dynamic Changes in the Area under Major Crop Categories

The direction of changes in the area under major crop categories in Tamil Nadu state have been analysed by employing Markov chain analysis using the secondary data on the area under major crop categories for a period of 20 years. The results are presented in Table 4.

It could be revealed from Table 4 that the diagonal elements represent the probability of retention of existing area under different crops. The probability of retention of existing area under cereals was estimated to be the highest at 81.69 per cent, followed by 48.45 per cent for pulses, 39.11 per cent for oilseeds, 10.14 per cent for cash crops and 8.88 per cent for fruits and vegetables. The probability of shift in area from cereals was 9.91 per cent to fruits and vegetables and 8.40 per cent to oilseeds. However, it gained around 99 per cent of area from fiber crops, 51.55 per cent from pulses and 17.73 per cent from oilseeds.

The fiber crops were found to be less stable in the state and could retain only at 0.03 per cent. The shift in the area from fiber crops was only to cereals (99.97per cent). However, it gained 43.54 per cent of area from cash crops.

The estimated steady state probability reveals that if the cropping pattern continues, in the future, around 62.39 per cent of area will be under cereals, 15.71 per cent will be under pulses, 8.60 per cent will be under oilseeds, 7.37 per cent will be under fruits and vegetables, 4.13 per cent under cash crops and only 1.80 per cent will be under fiber crops. These results are in conformity with Paramasivam *et al.*, (2017).

The future forecasted share of area under different crop categories obtained vide steady state probabilities revealed that the area under cash crops and fibre crops would likely to increase its share in the future, while all the other crop categories would likely to retain its share, indicating the shift in the cropping pattern in the state.

The analysis revealed that cereals was found to be highly stable in the state and could retain as high as 81 per cent, followed by pulses, oilseeds, cash crops and fruits and vegetables. The fiber crops was found to be highly unstable and could retain as low as 0.03 per cent.

Table 4. Transitional Probability Matrix for Area under Major Crop Categories in Tamil Nadu, 2000-01 to 2019-2020

Major Crops Categories	Cereals	Pulses	Oilseeds	Fiber crops	Cash crops	Fruits and Vegetables
Cereals	**0.8169**	0.0000	0.0840	0.0000	0.0000	0.0991
Pulses	0.5155	**0.4845**	0.0000	0.0000	0.0000	0.0000
Oilseeds	0.1773	0.0000	**0.3911**	0.0000	0.4316	0.0000
Fiber crops	0.9997	0.0000	0.0000	**0.0003**	0.0000	0.0000
Cash crops	0.0000	0.3352	0.0000	0.4354	**0.1014**	0.1280
Fruits and Vegetables	0.0000	0.9112	0.0000	0.0000	0.0000	**0.0888**
Steady State Probability	**0.6239**	**0.1571**	**0.0860**	**0.0180**	**0.0413**	**0.0737**
Current Year Share (in Percentage)	**61.59**	**15.25**	**8.86**	**3.67**	**2.88**	**7.75**

IV. CONCLUSIONS

The results on the changes in the cropping pattern in the study area, it is understood that oilseeds and cash crops area showed a negative trend in Tamil Nadu. On the contrary, cereals, pulses, fiber crops and fruits and vegetables had a positive growth trend over the periods.

The area under cereals was found to be highly stable in the state. The fiber crops were found to be highly unstable in the state. From the above results, it is evident that there has been a gradual shift in the cropping pattern in Tamil Nadu state. The shift in cropping pattern, might be due to the awareness of the farmers on the profitability of the crops and developments in the market infrastructure and urbanisation. Thus, the government should need to take up productivity enhancing measures in these crops, like varietal improvement, improved cultural practices, disease control measures, etc.

ACKNOWLEDGEMENT

I would like to thank ICSSR for providing me a fund for this research work on urbanization in the study area.

REFERENCES

[1] Amirthalingam, N., Sita Devi, K., Prabakar, C., and Ponnarasi, T., (2020), "An Economic Analysis of the Temporal Changes in Land Use Pattern in Tamil Nadu", *Adalya Journal*, 9(11): 329-344.

[2] Goswami, S. N., and Challa, O., (2004), "Indian Land Use Scenario: An Overview" *Agricultural Situation in India*, 60(11): 783 – 797.

[3] Kanwar, JS., (1971), "Cropping Pattern Scope and Concept", Proceeding of the National Symposium on Cropping Patterns, *Indian Council of Agricultural Research*.

[4] Murimi, E.K., Njeru, L.K., Gichimu, B.M., and Ndirangu, S.N., (2019), "Effects of Urban Expansion on Agricultural Resources: A Case Study of Embu Town in Kenya", *Journal of Agricultural Extension, Economics & Sociology*, 33(4):1-11.

[5] Rahman, S., and Kazal, M. M. H., (2015), "Determinants of Crop Diversity in the Regions of Bangladesh (1990–2008)", *Singapore Journal of Tropical Geography*, 36(1): 83-97.

[6] Tripathi R.S, and Vishwakarma J.P., (1988), "Land Use, Cropping Pattern and Development Levels in Banda District (U.P.)", *The Deccan Geographer*, 24(2-3): 417-27.

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

The Effect of Number of Branches and Level of Nitrogen Fertilizer on Growth and Yield of Melon (*Cucumis melo* L.)

Sekar Kinanti[1*], Husni Thamrin Sebayang[2], Eko Widaryanto[2]

[1]Master Student at Department of Agronomy, Faculty of Agriculture, Brawijaya University, Malang, Indonesia
[2]Department of Agronomy, Faculty of Agriculture, Brawijaya University, Malang, Indonesia
*Email: sekarkynanti06@gmail.com

Received: 15 Oct 2024; Received in revised form: 17 Nov 2024; Accepted: 23 Nov 2024; Available online: 30 Nov 2024

Abstract— *This study was conducted with the aim of examining the effect of the number of branches and the level of nitrogen fertilization on the growth and yield of melon (Cucumis melo L.). The study was conducted using a factorial completely randomized design (CRD) with two factors, namely, the number of branches (J1: 1 branch and J2: 2 branches) and the level of nitrogen fertilization (N150, N175, N200, N225 and N250). Observation parameters included plant length, number of leaves, leaf area, flowering time, number of flowers, chlorophyll content, and fruit yield (quality). The results showed that the number of branches and the level of nitrogen fertilizer gave significant results on growth parameters. The application of a higher nitrogen fertilizer level of 250 kg N ha^{-1} generally increased plant growth in the 1 branch treatment (J1) and increased fruit weight in the 2 branch treatment (J2). This study indicates that the right number of branches and nitrogen fertilization levels can increase melon production.*

Keywords— ***Number of branches, N fertilizer, Melon***

I. INTRODUCTION

Melon or muskmelon is a horticultural plant that has a production level of 27.3 t ha^{-1} in the world. According to Rosa *et al*. (2017), planting or cultivating melons requires a minimum soil temperature of 15˚ C for germination and 20-30˚ C for growth, because melons are plants that require a warm environment.

In Indonesia, melon fruit consumption reaches ± 332,698 t year^{-1} (Widaryanto *et al*., 2017).The high demand for melon commodities has resulted in an increase in farmers income (Makful *et al*., 2017). However, melon production in East Java Province has decreased from 68,520 t ha^{-1} in 2021 to 62,286 t ha^{-1} in 2022. This is thought to be due to climate factors and less than optimal cultivation practices.

The nutrient N plays an important role in higher yields. Strengthened by the opinion of Leghari *et al*. (2016) that the N rate can increase the photosynthesis process, leaf area, and net assimilation rate, where the maximum leaf area and total leaf biomass of the plant are determinants of higher harvest yields.

In melon plants, optimizing branch management can increase light interception and increase photosynthesis efficiency, which is important for melon development and quality (Leite *et al*., 2023)

Branch pruning and fertilizer application are important factors that can affect melon growth and yield, so this study was conducted to determine the effect of the number of branches on melon yield, evaluate the effect of nitrogen fertilization levels on growth and production, and identify interactions between the number of branches and nitrogen fertilizer levels on melon plant growth and yield.

This research is expected to provide useful information for melon farmers in increasing melon production through optimal branch number management and nitrogen fertilization.

II. MATERIALS AND METHODS

2.1 Time and place

This research will be conducted from April to July 2024 in the greenhouse of UPT. Puspa Lebo on Jl. Raya Lebo No.48, Kec. Sidoarjo, Kab. Sidoarjo, East Java 61223, with an altitude of 6 meters above sea level.

2.2 Tools and materials

The tools used are scissors, thread/rope, scales, mulch, SPAD, Refractometer and Leaf Area Meter (LAM). While the materials used are melon seeds var. Red Pearl Melon, Urea fertilizer and ZA fertilizer.

2.3 Research methods

This study used a factorial completely randomized design (CRD) with two factors. Factor 1 is (Number of branches), namely J1 : Number of 1 branch (Cultivate 1 branch) and J2 : Number of 2 branches (Cultivate 2 branches). Factor 2 is (N fertilizer level), namely N150 (150 Kg N ha^{-1}), N175 (175 Kg N ha^{-1}), N200 (200 Kg N ha^{-1}), N225 (225 Kg N ha^{-1}) and N250 (250 Kg N ha^{-1})

In the combination of treatments, 10 treatment combinations were obtained which were repeated 3 times with 6 plant samples. The plant requirements for this study were 180 plants.

Branch pruning is done when the plant is 15 DAP. In the number of 1 branch, pruning is done on all lateral branches and leaving the main branch. While in the number of 2 branches, lateral branches that have the same size are selected.

Fertilization is done 3 times, namely at the age of 15, 22 and 29 DAP. Nitrogen fertilizer is applied in granular form and placed in the fertilizer hole with a distance of 5 cm from the planting hole.

Growth observations including plant length and number of leaves were conducted once a week after fertilization. Leaf area was observed twice at the age of 22 and 36 DAP using LAM with ALA method (*Average Leaf Area*). Chlorophyll was observed twice at 30 and 44 DAP using SPAD. Fruit weight, brix° and vitamin C were observed after harvest.

ALA formula: (Widaryanto *et al*., 2020)

$$A_y = n_y \times \bar{A}_s$$

Description :

A_y : Total leaf area (cm^2)

n_y : Number of leaves

$\bar{A}_s$: Average leaf area (cm^2)

2.4 Data analysis

From the observation results that have been obtained, then analyzed using ANOVA in the form of a 5% level F test. If there are real results, then continued with the Smallest Real Difference (LSD) test.

III. RESULTS

3.1 The Effect of Number of Branches and Level of N Fertilizer on Melon Plant Growth

This study shows research results based on observations of various growth parameters such as plant length, leaf area, flowering time of male flowers and chlorophyll.

At increasing levels of N fertilizer showed increasing growth in various treatments of the number of branches. (Table 1) shows that the number of branches and the level of N fertilizer have an effect on the growth of melon plant length. The level of N250 fertilizer gave significantly higher results in various treatments of the number of branches.

Table 1. Effect of Interaction between Number of Branches and N Fertilizer Level on Melon Plant Length

Treatment	Plant length (cm) at 29 DAP				
	N150	N175	N200	N225	N250
J1	126,6 a B	154,3 b B	160,6 Bc B	168,7 cd A	176,4 d A
J2	101,6 a A	125,3 b A	133,2 b A	160,3 c A	171,0 d A
LSD 5%	11,57				
CV (%)	4,59				

Description: Numbers followed by the same lower case letter in the same row or the same upper case letter in the same column indicate no difference based on the 5% LSD test. DAP = days after planting, CV = coefficient of variation, J = number of branches, N = level of nitrogen fertilizer

The leaf area of melon plants presented in (Table 2) shows the interaction between the number of branches and the level of N fertilizer. At the N250 fertilizer level, the leaf area was wider in various treatments of the number of branches.

(Table 3) shows the chlorophyll content in various treatments of the number of branches and the level of N fertilizer. In the treatment of 1 branch (J1) at the N225 and N250 fertilizer levels, the chlorophyll content was higher. While in the treatment of 2 branches (J2), at the N250 fertilizer level, the chlorophyll content was higher, but not different from N200 and N225.

Table 2. Effect of Interaction between Number of Branches and N Fertilizer Level on Melon Leaf Area

Treatment	Leaf area (cm^2 $plant^{-1}$) at 36 DAP				
	N150	N175	N200	N225	N250
J1	561,9 a A	625,6 ab A	723,6 b A	749,7 b B	757,9 b A
J2	499,8 a A	600,2 ab A	617,4 ab A	610,8 ab A	677,8 b A
LSD 5%	133,66				
CV (%)	12,19				

Description: Numbers followed by the same lower case letter in the same row or the same upper case letter in the same column indicate no difference based on the 5% LSD test. DAP = days after planting, CV = coefficient of variation, J = number of branches, N = level of nitrogen fertilizer

Table 3. Effect of Interaction between Number of Branches and N Fertilizer Level on Chlorophyll

Treatment	Chlorophyll (mg g^{-1}) at 44 DAP				
	N150	N175	N200	N225	N250
J1	65,06 a A	65,53 a A	77,98 b A	93,56 c B	91,00 c B
J2	69,81 a A	66,51 a A	81,68 b A	81,89 b A	82,26 b A
LSD 5%	7,85				
CV (%)	5,90				

Description: Numbers followed by the same lower case letter in the same row or the same upper case letter in the same column indicate no difference based on the 5% LSD test. DAP = days after planting, CV = coefficient of variation, J = number of branches, N = level of nitrogen fertilizer

3.2 The Effect of Number of Branches and Level of N Fertilizer on Melon Plant Yield

The results of the study showed that there was an interaction between the number of branches and the level of fertilizer. As shown in (Table 4), the number of branches and the level of N fertilizer treatment had an effect on the time of male flowers appearing. At the number of 1 branch (J1) at the N150 fertilizer level, the male flower flowering time was the fastest compared to other fertilizer levels, the higher the N fertilizer level, the faster the flowering time. While at the number of 2 branches (J2) at the N250 fertilizer level, the flowering time was longer, the higher the N fertilizer level, the longer the flowering time.

In (Table 5), the weight of fruit per plant and (Table 6), the weight per fruit are shown. The weight of fruit in the treatment of 1 branch number (J1) with a fertilizer level of N200 produces a heavier weight. While in the treatment of 2 branches (J2) with a fertilizer level of N250, the weight of fruit is heavier.

In (Table 7), the fruit diameter with the treatment of 1 branch (J1) and fertilizer levels N225 and N250 showed a significantly larger fruit diameter. While the number of 2 branches (J2) at the fertilizer level N250 gave a significantly larger fruit diameter, but no different from N200 and N225.

Table 4. Effect of Interaction between Number of Branches and N Fertilizer Level on Male Flowering Time

Treatment	Flowering time of male flowers (flowers plant^{-1})				
	N150	N175	N200	N225	N250
J1	19,39 c A	18,72 b A	18,17 A A	18,61 ab A	18,11 a A
J2	19,11 a A	19,34 ab B	19,44 abc B	19,81 bc B	19,89 c B
LSD 5%	0,54				
CV (%)	1,67				

Description: Numbers followed by the same lower case letter in the same row or the same upper case letter in the same column indicate no difference based on the 5% LSD test. DAP = days after planting, CV = coefficient of variation, J = number of branches, N = level of nitrogen fertilizer

Table 5. Effect of Interaction between Number of Branches and N Fertilizer Level on Fruit Weight Per Plant

Treatment	Fruit weight (g plant^{-1})				
	N150	N175	N200	N225	N250
J1	1392 a A	1490 ab A	1843 b A	1637 ab A	1576 ab A
J2	1897 a B	2228 ab B	2600 b B	2658 bc B	3085 c B
LSD 5%	432,7				
CV (%)	12,43				

Description: Numbers followed by the same lower case letter in the same row or the same upper case letter in the same column indicate no difference based on the 5% LSD test. DAP = days after planting, CV = coefficient of variation, J = number of branches, N = level of nitrogen fertilizer

Table 6. Effect of Interaction between Number of Branches and N Fertilizer Level on Fruit Weight Per Fruit

Treatment	Fruit weight (g fruit^{-1})				
	N150	N175	N200	N225	N250
J1	1392 a A	1490 a A	1843 b B	1637 ab A	1576 ab A
J2	1259 a A	1265 a A	1491 a A	1749 b A	2944 b B
LSD 5%	299,0				
CV (%)	11,17				

Description: Numbers followed by the same lower case letter in the same row or the same upper case letter in the same column indicate no difference based on the 5% LSD test. DAP = days after planting, CV = coefficient of variation, J = number of branches, N = level of nitrogen fertilizer

Table 7. Effect of Interaction between Number of Branches and N Fertilizer Level on Fruit Diameter

Treatment	Fruit diameter (cm fruit^{-1})				
	N150	N175	N200	N225	N250
J1	19,11 a A	21,67 ab B	22,61 ab A	20,39 b A	20,39 b A
J2	18,33 a A	18,94 a A	23,78 b A	24,44 b B	26,00 b B
LSD 5%			2,54		
CV (%)			6,89		

Description: Numbers followed by the same lower case letter in the same row or the same upper case letter in the same column indicate no difference based on the 5% LSD test. DAP = days after planting, CV = coefficient of variation, J = number of branches, N = level of nitrogen fertilizer

Table 8. Effect of Interaction between Number of Branches and N Fertilizer Level on Brix˚ Content

Treatment	Brix˚ fruit^{-1}				
	N150	N175	N200	N225	N250
J1	9,50 a B	8,51 a A	8,43 a A	8,31 a A	7,92 b A
J2	7,37 a A	7,83 a A	9,28 b B	9,36 b B	9,97 b B
LSD 5%			0,83		
CV (%)			5,66		

Description: Numbers followed by the same lower case letter in the same row or the same upper case letter in the same column indicate no difference based on the 5% LSD test. DAP = days after planting, CV = coefficient of variation, J = number of branches, N = level of nitrogen fertilizer

Furthermore, in (Table 8) on the brix˚ content parameters of the number of branches and N fertilizer levels, there is an interaction. In the treatment of 1 branch (J1) and N250 fertilizer levels, the highest real brix˚ content results were obtained. While in the treatment of 2 branches (J2) and N250 fertilizer levels, the results were significantly higher, but not different from N200 and N225.

IV. DISCUSSION

4.1 The effect of number of branches and N fertilizer levels on melon growth

To obtain good plant growth, good management is also needed, such as plant care, appropriate fertilizer doses and also environmental conditions that are suitable for the cultivated plants. In this study, the treatment of the number of branches and the level of N fertilizer was used, where the number of branches is included in the biotic factor and the level of N fertilizer is included in the edaphic factor.

In the treatment of the number of branches and the level of N fertilizer showed an increase in the growth of melon plants. In the parameters of plant length, leaf area, flowering time of male flowers and chlorophyll content of plants, it was shown that the increasing level of nitrogen fertilizer applied to the treatment of the number of branches could increase plant growth. In the treatment of the number of 1 branch (J1) at the application of N225 and N250 fertilizer levels gave optimal plant growth results compared to the treatment of the number of 2 branches (J2). This is thought to occur due to intraception competition, because the planting distance in the treatment of the number of 2 branches (J2) was too close and resulted in less than optimal growth. According to Mardhiana *et al.* (2017) the more branches and too close, the less light the plant will get so that growth tends to decrease.

In addition, small leaf area also affects plant growth. Leaves are the part of the plant that plays a role in producing nutrients for plants. Leaves absorb light, CO_2 and also water so that glucose and O_2 can be produced through the process of photosynthesis. Glucose is related to the activity of photosystem II and photochemical reactions that increase total chlorophyll, photosynthesis rate, stomatal conductance and rubisco activity in photosystem I (Limbongan *et al*, 2023)

With the addition of optimal N fertilizer, it can produce better plant growth. Increasing the dose of N fertilizer significantly increases plant vegetative growth (Mardhiana *et al*., 2017).Nitrogen application affects chlorophyll content and plant yield (Li *et al*., 2011; Zhang *et al*., 2020)

4.2 Effect of number of branches and N fertilizer level on melon yield

Generative growth in this study includes the flowering time of male flowers, fruit weight, fruit diameter and also the brix˚ content of the plant. Significantly, the treatment of 1 branch (J1) and the N150 fertilizer level gave the fastest male flower emergence time. In the treatment of 1 branch (J1) the plant nutrients were sufficient and not divided, as in the study of Erniati *et al*. (2023), stating that melon plants with fewer branches will have faster initial growth, but do not always produce better fruit. Increasing the dose or level of N can affect the distribution pathway that regulates the transition from the vegetative to the generative phase (Vidal *et al*., 2014). In line with the opinion of (Andre *et al*., 2017), that increasing nitrogen levels tend to increase the number of male and female flowers in melons.

In the treatment of 2 branches (J2) and fertilizer levels of N225 and N250 showed better results in fruit weight, fruit diameter and also brix˚ content than the treatment of 1 branch (J1). It is suspected that this occurs because the distribution of photosynthate in the treatment of 2 branches (J2) is greater, thus supporting the growth of melon fruit *(Mendonça et al*., 2021). In addition, the treatment of 2 branches (J2) has more growing points so that it can increase the potential for harvest yields. The hormones ethylene and abscisic acid also play a role in fruit growth. According to (Zhou *et al*., 2023), ethylene is the main regulator in fruit ripening which interacts with abscisic acid for fruit growth and development. With the addition of optimal nitrogen, it can contribute to increasing fruit diameter and weight (Parmar *et al*., 2023). In the treatment of 1 branch (J1) with an N fertilizer level of more than 50% tends to reduce fruit weight and fruit diameter. This shows that there is an optimal limit for nitrogen use to obtain maximum fruit growth (Olesińska *et al*., 2021).

Meanwhile, according to (Park and Seo, 2012), the application of N fertilizer affects the quality of melons, such as fruit size, texture and also the level of fruit sweetness (Brix˚). Nitrogen plays a role in the formation of chlorophyll which can increase sugar accumulation in the fruit (Assunção *et al*., 2020)

In (Fig 1) it is shown that the number of 1 branch (J1) of fruit weight/plant , the polynomial equation obtained is $y = -0.1003x^2 + 42.183x - 2711.6$ with $R^2 = 0.3669$ shows that the optimal N dose used is 210.28 kg N ha^{-1} with a fruit weight of 1,72 tons ha^{-1}. While in the treatment of the number of 2 branches (J2) fruit weight $fruit^{-1}$, the polynomial equation $y = 0.0417x^2 - 9.0924x + 1648.5$ was obtained with an $R^2 = 0.76677$. The optimal N dose obtained is 109,02 with fruit weight 1,15 tons ha^{-1}.

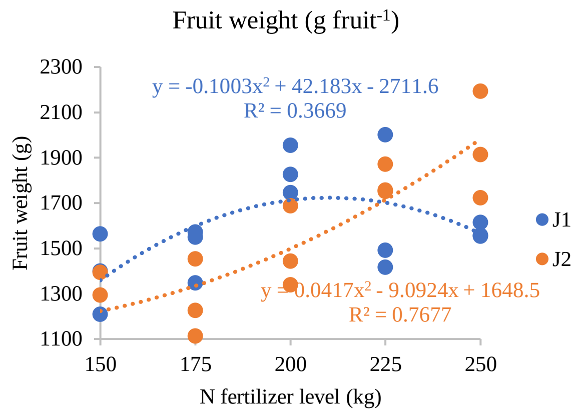


Fig 1. Interaction between number of branches and N fertilizer on melon fruit weight.

The interaction of the number of branches and N fertilizer on fruit diameter is shown in (Fig 2). At the number of 1 branch (J1) fruit diameter, the polynomial equation is obtained $y = -0.0009x^2 + 0.3835x - 16.847$ with an $R^2 = 0.3311$ which shows the optimal N dose is 213,16 kg N ha^{-1} and a fruit diameter of 24,01 cm^2. While at the number of 2 branches (J2) fruit diameter, the polynomial equation is $y = -0.0003x^2 + 0.1877x - 4.4806$ with an $R^2 = 0.8086$ which shows the optimal N dose is 312,84 kg N ha^{-1} and a fruit diameter of 24,88 cm^2.

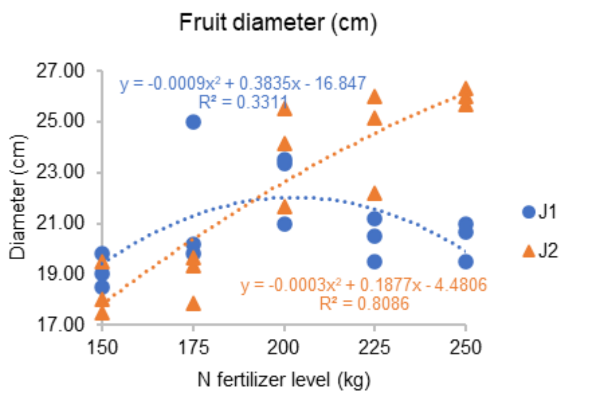


Fig 2. Interaction between the number of branches and N fertilizer on melon fruit diameter.

Furthermore, in the brix˚ content of melon fruit shown in (Fig 3).

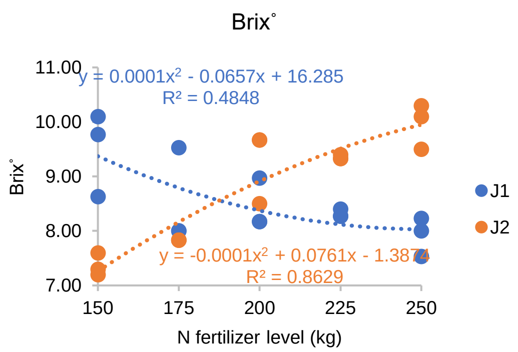


Fig 3. Interaction between the number of branches and N fertilizer on the brix˚ content of melon fruit

The brix˚ content in the number of 1 branch (J1) shows the results of the polynomial equation $y = 0.0001x^2 - 0.0657x + 16.285$ with $R^2 = 0.4848$ which produces a brix˚ content of 5.49. Meanwhile, the brix˚ content is obtained from a polynomial equation, namely $y = -0.0001x^2 + 0.0761x - 1.3874$ with $R^2 = 0.8629$ and the optimal N dose is 380.5 kg N ha^{-1} which produces a brix˚ content of 13.09.

V. CONCLUSION AND SUGGESTIONS

5.1 Conclusion

1. Increasing the dose of nitrogen fertilizer, especially 250 kg ha^{-1}, affects the weight of melon fruit. Higher fertilizer levels increase fruit production.

2. The number of 2 branches (J2) produces heavier fruit weight, while the number of 1 branch (J1) tends to increase the vegetative growth of the plant.

3. The interaction of the treatment of 2 branches (J2) and a nitrogen fertilizer level of 250 kg ha^{-1} provides more optimal fruit yields.

5.2 SUGGESTIONS

Further research can be conducted with more varied fertilizer doses to determine the optimal fertilizer dose for each number of melon branches.

REFERENCES

[1] Andre, F. B. A. A., Cláudia, L. S., Tiago, L. H., Roberto, R., & Andre, R. D. C. (2017). Nitrogen and potassium fertirrigation on yield characteristics of Italian Zucchini in protected cultivation. *African Journal of Agricultural Research*, *12*(3), 200–207. https://doi.org/10.5897/ajar2016.11643

[2] Assunção, N. S., Silva, N. O., Fernandes, F. L., de Aquino, L. A., & Fernandes, M. E. de S. (2020). Physico-chemical characteristics and productivity of tomato plants in function of nitrogen sources and doses. *Bioscience Journal*, *36*(4), 1274–1282. https://doi.org/10.14393/BJ-v36n4a2020-41955

[3] Erniati, E., Suhardiyanto, H., Hasbullah, R., & Supriyanto, S. (2023). Artificial Neural Networks to Predict Melon (*Cucumis melo* L.) Production in Tropical Greenhouse, Indonesia. *Jurnal Keteknikan Pertanian*, *11*(2), 193–204. https://doi.org/10.19028/jtep.011.2.193-204

[4] Leghari, S. J., Wahocho, N. A., & Laghari, G. M. (2016). Role of Nitrogen for Plant Growth and Development: A review. In *Article in Advances in Environmental Biology*. https://www.researchgate.net/publication/309704090

[5] Leite, E. W. S., Garrido, M. da S., Simoes, W. L., Salviano, A. M., & Mesquita, A. C. (2023). Yield, physiology and quality of yellow melon grown with biofertilizer. *Pesquisa Agropecuaria Tropical*, *53*. https://doi.org/10.1590/1983-40632023v5375846

[6] Li, Z., Zhang, L., Yu, Y., Quan, R., Zhang, Z., Zhang, H., & Huang, R. (2011). The ethylene response factor AtERF11 that is transcriptionally modulated by the bZIP transcription factor HY5 is a crucial repressor for ethylene biosynthesis in Arabidopsis. *Plant Journal*, *68*(1), 88–99. https://doi.org/10.1111/j.1365-313X.2011.04670.x

[7] Limbongan, Y. L. (2023). Interrelationship between number of flowers, fruits, and cucumber production (*Cucumis sativus*) grown on a mixture of soil and chicken manure. *Biodiversitas*, *24*(6), 3448–3453. https://doi.org/10.13057/biodiv/d240641

[8] Makful, H. dan S. (n.d.). Evaluasi Dua Calon Varietas Unggul Melon di Sumatera Barat, Jawa Barat dan Jawa Timur (Evaluation of Two Superior Variety Candidates of Melon in West Sumatera, West Java And East Java.).

[9] Mardhiana, M., Pradana, A. P., Adiwena, Muh., Kartina, K., Santoso, D., Wijaya, R., & Maliki, A. (2017). Effects of pruning on growth and yield of cucumber (Cucumis sativus) Mercy variety in The acid soil of North Kalimantan, Indonesia. *Cell Biology and Development*, *1*(1), 13–17. https://doi.org/10.13057/cellbioldev/v010103

[10] Mendonça, V., Silva, F. S. O., Alves, A. A., Martins, E. G. P., Dos Santos, E. C., Farias, W. C., & Pereira, E. C. (2021). Agronomic performance of fig plants grown with different numbers of branches. *International Journal of Agriculture and Natural Resources*, *48*(1), 14–20. https://doi.org/10.7764/ijanr.v48i1.2212

[11] Olesińska, K., Sugier, D., & Kaczmarski, Z. (2021). Yield and chemical composition of raw material from meadow arnica (*Arnica chamissonis* less.) depending on soil conditions and nitrogen fertilization. *Agriculture (Switzerland)*, *11*(9). https://doi.org/10.3390/agriculture11090810

[12] Park, Y. H., & Seo, B. S. (2012). Changes in Growth and Quality of Melon (*Cucumis melo* L.) and in Soil Nitrogen Forms due to Organic Fertilizer Application. *Korean Journal of Soil Science and Fertilizer*, *45*(6), 1009–1016. https://doi.org/10.7745/kjssf.2012.45.6.1009

[13] Parmar, P. M., Joshi, P., Kumari, K., & Darji, D. A. (2023). Effect of different varietal performance and various levels of nitrogen on growth and flowering characters on China aster (*Callistephus chinensis* l. Ness) under north Gujarat condition. *International Journal of Horticulture and Food Science*, *5*(1), 05–07. https://doi.org/10.33545/26631067.2023.v5.i1a.129

[14] Rosa, R., Kosterna-Kelle, E., Franczuk, J., Zaniewicz-Bajkowska, A., & Panasz, M. (2017). The effect of date of planting seedlings and polypropylene fibre covering on the yield and economic efficiency of melon. *Journal of Ecological Engineering*, *18*(1), 168–175. https://doi.org/10.12911/22998993/66403

[15] Vidal, E. A., Moyano, T. C., Canales, J., & Gutiérrez, R. A. (2014). Nitrogen control of developmental phase transitions in Arabidopsis thaliana. In *Journal of Experimental Botany* (Vol. 65, Issue 19, pp. 5611–5618). Oxford University Press. https://doi.org/10.1093/jxb/eru326

[16] Widaryanto, E., Putri, M. R., Yamika, W. S. D., Saitama, A., & Zaini, A. H. (2020). The effect of leaf bud trimming and fruit position arrangement on the quality of golden melon (*Cucumis melo* L.). *Acta Agrobotanica*, *73*(2), 1–7. https://doi.org/10.5586/AA.7324

[17] Widaryanto, E., Wicaksono, K. P., & Najiyah, H. (2017). Drought effect simulation on the growth and yield quality of melon (*Cucumis melo* l.). *Journal of Agronomy*, *16*(4), 147–153. https://doi.org/10.3923/ja.2017.147.153

[18] Zhang, K., Yuan, Z., Yang, T., Lu, Z., Cao, Q., Tian, Y., Zhu, Y., Cao, W., & Liu, X. (2020). Chlorophyll meter–based nitrogen fertilizer optimization algorithm and nitrogen nutrition index for in-season fertilization of paddy rice. *Agronomy Journal*, *112*(1), 288–300. https://doi.org/10.1002/agj2.20036

[19] Zhou, Y., Li, K., Wen, S., Yang, D., Gao, J., Wang, Z., Zhu, P., Bie, Z., & Cheng, J. (2023). Phloem unloading in cultivated melon fruits follows an apoplasmic pathway during enlargement and ripening. *Horticulture Research*, *10*(8). https://doi.org/10.1093/hr/uhad123

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
*Journal Home Page Available:*https://ijeab.com/
*Journal DOI:*10.22161/ijeab

Development of camel milk soft cheese with different levels of salt, fat and solid not fat

Aasma Batool[1], Faizan Ul Haq[2,3], Khubaib Ali[2,3], Muhammad Umair Khalid[2,3,4], Usama Zafar[1], Waleed AL-Ansi[2,3,4,*]

[1]National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan.
[2]State Key Laboratory of Food Science and Resources, Jiangnan University, Wuxi, Jiangsu, 214122, China.
[3]School of Food Science and Technology, Jiangnan University, Wuxi, 214122, China
[4]Synergetic Innovation Centre of Food Safety and Quality Control of Jiangsu Province, Wuxi 214122, China
* Corresponding author: ansiwaleed@yahoo.com and faizanuh81@gmail.com

Received: 20 Oct 2024; Received in revised form: 21 Nov 2024; Accepted: 28 Nov 2024; Available online: 02 Dec 2024

Abstract— *Camel milk is unique from other ruminant's milk in terms of its composition as well as in its health effects. Cheese production from camel milk is considered to be a difficult task due to unique physicochemical properties and its compositional structure. The basic purpose of this research was to optimize the processing conditions of camel milk cheese by using different levels of solid not fat (SNF), fat and $CaCl_2$. Buffalo milk (0.0%, 05%, 10%, and 15%) was mixed with camel milk and the cheese produced, shown better results (protein 17.86%, fat 16%, moisture 64.66%) as compared to other concentrations. The cheese with skimmed camel milk incorporated with 5% buffalo milk gave highly significant ($p<0.01$) results with maximum yield 21.15%, fat 15%, acidity 3.10%, moisture 68% and protein 16.71% with good texture as compared to cheese from whole camel milk and skimmed camel milk. While, for the $CaCl_2$ addition (0.0%, 0.3%, 0.6% and 0.9%) the cheese with 0.9% $CaCl_2$ resulted in increased yield (5 %) with an improved texture and coagulation time ($p<0.01$).*

Keywords— ***Soft cheese, Camel milk cheese, Bovine milk cheese, Fresh cheese, Sensory***

I. INTRODUCTION

Camels can survive in harsh environment, drought-stricken regions and mountainous areas where the other livestock does not survive better for long period of time with remarkably low inputs in terms of feed and water as most often, they browse the shrubs and leaves of trees. Hence, camels contribute an important role in securing food for farmers in these areas [1]. Total world's camel population is about 25.89 million [2]. Approximately in Pakistan, there is about 1.0 million camel population with 818 million litres annual milk production. In Pakistan mostly camels are found in arid and semi-arid areas of Punjab, Baluchistan, Sindh, and few hilly places of KPK [3].

Camel milk, so called white gold of the desert, is more similar to human milk than any other milk and differs from other ruminant milk because it contains low cholesterol, low sugar, high minerals (sodium, potassium, iron, copper, zinc and magnesium), high vitamin C, protective proteins like lactoferrin, lactoperoxidase, immunoglobulins, lysozyme and has potential treatment for a series of diseases such as dropsy, jaundice, anti-hypertensive, asthma, and leishmaniasis or kala-azar [4]. Cheese making from camel milk is not an easy task as compared to milk from bovine milk due to its low level of total solids, unique composition of casein with lower amount of kappa casein and presence of high concentration of lysozymes and lactoferrins [5]. The main problems faced by the processers are the longer coagulation time, texture and yield. The rennet concentration, pasteurization temperature, $CaCl_2$ concentration and selection of the starter culture have strong impact on the cheese attributes [6]. Although camel milk production is very high, so there is a need to develop new dairy products from this milk due to its high nutritious and therapeutically importance to cure main health problems.

The primary objectives of this study are to optimize the processing conditions for the production of soft cheese from camel milk, focusing on achieving the best manufacturing practices. Additionally, the study aims to investigate the effects of varying levels of fat, solids-not-fat (SNF), calcium, and sodium chloride (NaCl) on the quality and characteristics of the resulting cheese. Furthermore, the research seeks to assess the consumer acceptability of camel milk cheese produced under different processing conditions, ensuring that the variations in composition are aligned with sensory preferences and market demands.

II. MATERIALS AND METHODS

2.1 Materials

This research was conducted in Laboratory of Dairy Technology NIFSAT, University of Agriculture Faisalabad. The main objective of current study was to improve the production of camel milk cheese by using different levels of fat, SNF and salt $CaCl_2$ for production.

2.2 Procurement of chemicals and Raw-material

For the preparation of camel milk cheese, the camel milk was obtained from nearly situated village of Faisalabad. The culture (*Streptococcus thermophiles* & *Lactobacillus bulgaricus*) was produced from (SAAF INTERNATIONAL), (Chr. Hansen Denmark Ltd) provided rennet and chemicals were purchased from the local scientific store of Faisalabad.

2.3 Research treatment plan

Flow diagram of camel milk cheese production is shown in **Figure 1.** The research treatment plan for this study was conducted in three distinct steps. In the first step, the solids-not-fat (SNF) content of camel milk was standardized by blending it with buffalo milk in varying proportions. Four treatments were applied, with the ratios of camel milk to buffalo milk as follows: CB0 (100% camel milk and 0% buffalo milk), CB1 (95% camel milk and 5% buffalo milk), CB2 (90% camel milk and 10% buffalo milk), and CB3 (85% camel milk and 15% buffalo milk). The aim of this step was to optimize the texture and flavour of the cheese. In the second step, cheese was prepared using both full-fat and skimmed camel milk, combined with buffalo milk in different ratios. The treatments included C1 (100% skimmed camel milk), C2 (95% skimmed camel milk and 5% buffalo milk), and C3 (95% full-fat camel milk and 5% buffalo milk). Finally, in the third step, the dosage of calcium chloride ($CaCl_2$) was optimized to improve the texture and overall acceptability of the cheese. Four different $CaCl_2$ levels were tested: Ca1 (0%), Ca2 (0.3%), Ca3 (0.6%), and Ca4 (0.9%). This step focused on fine-tuning the cheese's structural and sensory properties to enhance its marketability.

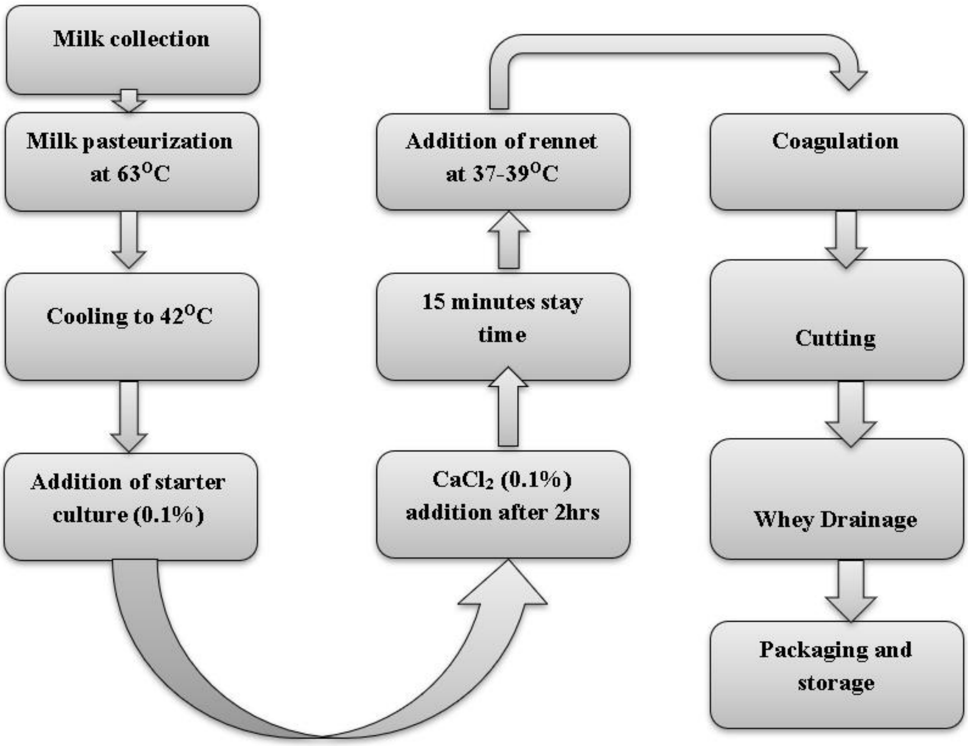


Fig.1: Flow diagram of camel milk cheese production

2.4 Physicochemical analysis

The preparation of camel milk cheese, physicochemical analysis of camel milk; fat, protein, acidity, total solids, moisture content, pH, specific gravity and lactose content, was carried out by AOAC [7]. Similarly, physicochemical analysis of camel milk cheese was carried out by standard methods of AOAC.

2.5 Cheese yield

Cheese yield was calculated after the drainage of whey following the equation as given below:

$$\text{Yield (\%)} = \frac{Cheese\ weight\ (kg)}{Milk\ weight\ (kg)} \times 100$$

2.6 Statistical analysis

The statistical analyses were performed using SPSS software (version 15). The data obtained from every parameter was statistically analysed to find the level of significance and a confidence level 0.05 was used to evaluate significant differences. The means were compared through CRD. Each test was performed in triplicates.

III. RESULTS AND DISCUSSION

Camel milk soft cheese was prepared with traditional cheese making procedure by adding thermophilic starter culture, rennet enzyme and calcium chloride. Before cheese preparation camel milk was analysed for its physicochemical composition. During cheese preparation different concentration such as calcium chloride, fat% and SNF were optimized for better cheese quality. Afterward, compositional analyses along with sensory attributes were performed. The results of physicochemical analysis of fresh camel milk as well as soft cheese are described below.

3.1 Compositional analysis of whole camel milk

The compositional analysis of whole camel milk was shown in **Table 1**. Average pH value of fresh camel milk was 6.67. The similar observations (6.66 pH) was reported by Bhagiel, Mustafa [8]. The average acidity of fresh camel milk was 0.13% to 0.18%. Fahmid et al [9] also reported the 0.12% to 0.15% acidity of fresh raw camel milk. While Galeboe, Seifu [10] observed 0.84% acidity during the summer season. The protein contents of raw camel milk were 4.56%. The result was compatible with the observation of Abd El-Aty, Abdou [11], who found 4.35% protein contents in the raw camel milk. The results of present study were different Babiker and El-Zubeir [12] who stated 3.81% protein in fresh camel milk. Zhao et al [13] reported variation in protein contents of raw camel milk may be due to breed of camel and weather conditions. Average percentage of lactose in raw camel milk was 3.38%. Present study results were supported by Benmeziane–Derradji [14], who found 3.27% lactose in raw camel milk.

Table 1: Physicochemical composition of whole camel milk and skimmed camel milk

Parameters	Whole camel milk (%)	Skimmed camel milk (%)
pH	6.67±0.23	6.00±0.08
Acidity	0.14±0.02	0.22±0.10
Protein	4.56±0.20	3.64±0.26
Fat	2.9±0.52	0.83±0.28
Lactose	3.38±0.10	3.19±0.08
Moisture	85.44±0.50	84.7±0.70
Total solids	14.33±0.57	15.21±0.50
Specific gravity	1.018±0.002	1.020±0.01

In fresh raw camel milk moisture contents were in range of 85.0% to 86.0% while Ahmed, Sayed [15] found 88.0% moisture in raw camel milk. Results for total solids (14.33%) in present study were also supported by Ahmed, Sayed [15]. Specific gravity of raw camel milk was 1.018, while Yoganandi, Mehta [16] reported the normal range of specific gravity up to 1.029, and acclaimed that variation in specific gravity of raw camel milk might be caused due to its adulteration with water.

3.2 Compositional analysis of skimmed camel milk

Results for physicochemical analysis were shown in **Table 1**. pH of skimmed camel milk was 6.05. But results were found dissimilar by Inayat, Arain [17] who reported 6.89 pH of skimmed camel milk. The average acidity of skimmed camel milk was 0.22%. Abeiderrahmane [18] also reported the 0.30% acidity of skimmed camel milk. The difference in pH and acidity of skimmed camel milk may be due to presence of chloride in higher concentration. The protein contents in the range of (3.34% to 3.8%) were studied in skimmed camel milk. The results were compatible with the investigation of Inayat, Arain [17], who found the maximum value of protein 4.01% and minimum value of protein 3.57% in skimmed camel milk. Average fat contents of skimmed camel milk were observed 0.83% in present study. Kaskous [19] also reported 0.88% fat in skimmed camel milk.

The average lactose concentration in skimmed camel milk was 3.19% observed. The results which were comparable to Inayat, Arain [17] who examined 3.14% lactose contents in skimmed milk of camel. Total solids of skimmed milk were 8.26% observed. The total solids in skimmed camel milk investigated by Babiker and El-Zubeir [12], who found maximum level of total solids 8.56% in skimmed camel milk. Specific gravity of skimmed camel milk was in between 1.019 to 1.021 studied. Comparable results were reported by Inayat, Arain [17] who found 1.024 specific gravity of skimmed camel milk. By skimming the camel milk, the fat%, ash% and chlorides decreased but total protein contents of skimmed camel milk increased Inayat, Arain [17].

3.3 Effect of fortification of buffalo milk with camel milk on processing conditions of soft cheese

Soft cheese was prepared by adding different concentration of buffalo milk (CMC, CM+5% Buff, CM+10% Buff, CM+15% Buff) and analysed for the compositional consequences **(Table 2)**. Acidity of camel milk cheese were 1.32%, 1.34%, 1.37% and 1.41% observed prepared with CB_0, CB_5, CB_{10}, CB_{15} respectively. The results of present study showed significant (P<0.01) differences for cheese acidity prepared with CB_{15} as compared to CB_0, CB_5, CB_{10} respectively. Variation in cheese acidity may be due to culture used during processing of cheese, lactic acid production in buffalo milk is more than camel milk and camel milk has weak buffering capacity. Thermophilic starter culture has capacity to produce more acidity as compared to mesophilic [20-22]. Results of cheese acidity were dissimilar to Qadeer, Huma [23], who reported 0.92%, 0.96%, 0.96% and 1.03% acidity for cheese prepared with CM, CM+10% Buff, CM+20% Buff and CM+30% Buff milk. The results were comparable 1.65% to 2.0% for soft cheese [24, 25].

Table 2: Effect of treatments on various parameters of cheese produced by fortifying camel milk with buffalo milk

Treatments	Acidity (%)	Fat content (%)	Moisture content (%)	Protein content (%)	TSS (%)	Cheese yield (%)
CB_0	1.32 ± 0.03^{B}	13.33 ± 0.57^{C}	67.16 ± 0.5^{A}	12.82 ± 0.18^{AB}	33.05 ± 0.85^{C}	12.383 ± 1.71^{C}
CB_5	1.34 ± 0.011^{B}	14.83 ± 0.28^{B}	66.16 ± 0.5^{AB}	16.81 ± 3.89^{AB}	33.83 ± 0.50^{BC}	16.490 ± 0.21^{AB}
CB_{10}	1.37 ± 0.01^{AB}	16.33 ± 0.76^{A}	64.96 ± 0.06^{B}	17.31 ± 0.68^{AB}	35.03 ± 0.06^{AB}	13.810 ± 1.45^{BC}
CB_{15}	1.41 ± 0.03^{A}	16.50 ± 0.5^{A}	64.33 ± 0.33^{B}	18.21 ± 0.35^{A}	35.66 ± 0.33^{A}	18.973 ± 0.18^{A}

Cheese prepared with CB_0, CB_5, CB_{10} and CB_{15} had 13.33%, 14.83%, 15.33% and 16.50% fat contents. Significant differences (P<0.01) were found for cheese fat prepared with CB_{15} as paralleled to CB_0, CB_5 and CB_{10} respectively. Similar results were observed by Qadeer, Huma [23], who reported fat contents 15.33%, 16.02%, 16.67% and 17.33% for cheese prepared with CM, CM+10% Buff, CM+20% Buff and CM+30% Buff milk. But results were found by Derar and El Zubeir [26], who reported 16.56%, 18.10%, 21.23%, 22.21% and 23.08% fat contents of soft cheese prepared with mixing of camel milk with sheep milk respectively. Variation in fat contents is because of buffalo and sheep milk had more fat contents as compared to camel milk and camel milk had weak coagulum feature as compared to cheese prepared with buffalo and sheep milk that is why fat particles drained out through whey [13, 27].

Moisture contents of cheese prepare with CB_0 was 67.16%, CB_5 had 66.16%, CB_{10} contained 64.96% and CB_{15} had 64.33% respectively. Significant (P<0.01) differences were observed in cheese moisture prepared with CB_0 than that of CB_5, CB10, CB_{15}. Results of protein contents were 12.82%, 16.81%, 17.31% and 18.21% for cheese prepared with CB_0, CB_5, CB_{10} and CB_{15} respectively. Increase significant (P≥0.01) differences were examined in cheese protein prepared with CB_{15} as compared to CB_0, CB_5, and CB10 respectively. But results of cheese protein were observed match able with present study by Derar *et al*., *(*2016) who investigated 13.10%, 14.43% and 15.315 in cheese prepared with CM, CM+10% Buff and CM+20% Buff milk. Different results were examined by (Hayaloglu *et al*., 2005) who found protein 16.41%, 17.99%, 21.85% and 21.41% prepared with blending of camel milk with buffalo milk. Variation of protein contents in camel milk cheese observed because camel milk had lower total solids than buffalo and camel milk. Total solids improve the rheological properties of cheese curd and also increase the protein, casein contents, lactose and yield of cheese [20-22].

Total solids of cheese were 33.05%, 33.83%, 35.07% and 35.66% for cheese prepared with CB_0, CB_5, CB10, and CB_{15} respectively. Highly significant differences (P<0.01) were observed for total solids of cheese prepared with CB_{15} than CB_0, CB_5, and CB_{10}. Cheese yield were 12.38% for cheese prepared with CB_0, CB_5 had 16.49%, CB_{10} had 13.81% and CB_{15} had 18.97% respectively. Significant differences (P<0.01) were found for cheese yield prepared with CB_{15} as compared to cheese prepared with CB_0, CB_5, and CB_{10} respectively. Results of cheese yield were different to Qadeer, Huma [23], who reported 20.21%, 22.0%, 25.00% and 27.33% for cheese prepared with CM, CM+10% Buff, CM+20% Buff and CM+30% Buff milk respectively. But results were investigated by Shahein, Hassanein [28], who stated that cheese yield 10.63%, 13.76%, 21.33% 26.20% and 23.53% respectively. Variation in cheese yield is due to presence of maximum total solids present in buffalo milk as compared to camel milk [29]. Mixing of camel milk with buffalo milk enhance the cheese yield along with other quality parameters such as flavour, fat%, protein and total solids Shahein, Hassanein [28], and improves the coagulation process as well.

3.4 Effect of skimmed camel milk on compositional characteristics of soft cheese

Camel milk cheese was prepared by skimming the milk and comparison were marked with cheese prepared by whole milk with 5% buffalo milk. Cheese was prepared with skimmed camel milk (C_1), mixture of skimmed camel milk+ 5% buffalo milk (C_2) and mixture of whole camel milk + 5% buffalo milk (C_3) and compositional differences observed respectively and the results are mentioned in **Table 3**, and discussed below;

Table 3: Effect of skimmed camel milk on compositional characteristics of soft cheese

Treatments	Acidity (%)	Fat content (%)	Moisture content (%)	pH	Protein content (%)	TSS (%)	Cheese yield (%)
C_1	3.15 ± 0.70 ^{A}	8.33± 2.08 ^{B}	67.66 ± 0.57^{A}	4.13 ± 0.06 ^{A}	17.86 ± 5.80 ^{A}	32.33 ± 0.57 ^{A}	8.33 ± 0.85 ^{B}
C_2	3.10 ± 0.45 ^{A}	6.43 ± 1.40 ^{B}	70.66 ± 3.21 ^{A}	4.12 ± 0.04 ^{A}	26.05 ± 3.22 ^{A}	29.77 ± 3.34 ^{A}	14.73 ± 5.53 ^{AB}
C_3	2.91 ± 0.80 ^{A}	15.66 ± 1.15 ^{A}	66.66 ± 1.15 ^{A}	4.17 ± 0.06 ^{A}	17.09 ± 0.66 ^{A}	33.11± 1.01 ^{A}	18.39 ± 3.56 ^{A}

Table 4: Effect of $CaCl_2$ on compositional characteristics of soft cheese

Treatments	Acidity (%)	Fat content (%)	Moisture content (%)	pH	Protein content (%)	TSS (%)	Cheese yield (%)
Ca_1	2.97 ± 0.54 ^{A}	13.33 ± 4.93 ^{A}	64.16 ±1.83 ^{A}	4.31 ± 0.01^{A}	21.00 ± 1.02 ^{A}	35.50 ± 2.35 ^{A}	8.32 ± 0.39 ^{A}
Ca_2	2.88 ± 0.23 ^{A}	13.33 ± 4.16 ^{A}	66.33 ± 1.67 ^{AB}	4.22 ± 0.01 ^{B}	18.75 ± 0.25 ^{AB}	33.67 ± 1.67 ^{AB}	8.62 ± 1.02 ^{AB}
Ca_3	2.91 ± 0.18 ^{A}	13.00 ± 4.35 ^{A}	67.50 ± 1.5 ^{AB}	4.17 ± 0.01 ^{C}	17.71 ± 0.15 ^{BC}	32.50 ± 1.5 ^{AB}	12.34 ± 2.76 ^{BC}
Ca_4	3.03 ±0.28 ^{A}	12.00 ± 4.35 ^{A}	69.16± 0.83 ^{B}	4.17 ± 0.01 ^{C}	19.86 ± 0.295 ^{C}	30.83 ± 0.83 ^{B}	13.50 ± 0.73 ^{C}

pH of cheese was 4.17, 4.12 and 4.13 prepared with C_3, C_2 and C_1 respectively. Results of the present study showed the non-significant differences (*P*>0.05) among the pH of soft cheese. Throughout cheese preparation pH is the key point in cheese coagulation and ripening process. Texture of cheese depends on pH of milk at which cheese prepared reported by Fukuda [30]. Inayat, Arain [17] found that the average pH of soft cheese prepared with skimmed camel milk was 5.23. On the other hand same results were found in cheese pH that was 4.30 investigated by Allam, Darwish [31]. Certain factors such as lactase enzyme present in milk and type of culture used during cheese production caused variation in cheese pH reported [32-34]. Results of cheese acidity for cheese prepared with C_1, C_2 and C_3 were 3.15%, 3.10% and 2.9% respectively. Results of all treatment showed the non-significant (*P*>0.05) differences. Acidity is the main factor after pH in cheese processing for ripening, rennet actions, enhance the syneresis process which ultimately affects the cheese flavor, texture and taste as well [30].

Acidity of soft cheese prepared with skimmed camel milk was 1.80% for Inayat, Arain [17], but results observed in the current study were 2.9% to 3.15%. Reason behind the variation in acidity of cheese was form of bacterial culture used. Cheese prepared with thermophilic starter culture have highest acidity [20-22].

Fat contents of cheese were 8.33%, 6.43% and 15.66% for cheese prepared with C_1, C_2 and C_3 respectively. Increase in significant differences (*P*<0.01) were observed for cheese prepared with C_3 as compared to C_1 and C_2. Fat contents of cheese improves the taste, texture, chewiness flavor as well as appearance reported by Küçüköner and Haque [35]. However fat contents of milk directly affect the useable and processing conditions of cheese. Results were related to Shahein, Hassanein [28], who found 10.0% fat in soft unripen cheese prepared with mixture of camel milk with buffalo milk. Inayat, Arain [17] investigated 3.54% fat in soft cheese prepared with skimmed camel milk; results were different to current study. Adding buffalo milk into camel milk increased the fat contents of soft cheese. Camel milk has week coagulation so fat globules drained out through whey drainage that reduced the fat percentage in camel milk cheese (Shahein, Hassanein [28], Sameen, Anjum [36]).

Moisture contents of soft cheese prepared with C_1, C_2 and C_3 were 67.66%, 70.66% and 66.66% respectively. Non-significant (*P*>0.05) differences were examined among the cheese moisture. Results of total solids were 32.33%, 29.77% and 33.11% for cheese prepared with C_1, C_2 and C_3 respectively. Non-significant differences (*P*>0.05) were observed for total solids of cheese. Protein contents of cheese were 17.86%, 26.05% and 17.09% for cheese prepared with C_1, C_2 and C_3 respectively. Increase in Significant differences ($P \leq 0.05$) were found for protein of cheese prepared with C_2 as compared to $C_1$and C_3 respectively. Similar results for cheese protein were observed by Inayat, Arain [17], who examined the maximum 19.64% and minimum 17.57% protein in skimmed milk cheese. But results were found for cheese protein by Sameen, Anjum [36], who reported 11.0% protein. Difference in protein of cheese depends on factors like mixing of buffalo milk in camel milk because buffalo milk has higher protein contents along with casein as compared to camel milk while, storage stability also decreased the protein contents of cheese by hydrolysing the protein into amino acids and ammonia [37]. Cheese prepared with C_1, C_2 and C_3 had cheese yield 8.33%, 14.73% and 18.39% respectively. The results of present study showed the increase significant (*P*<0.01) differences for cheese yield prepared with WCM+5% Buff as compared to C_1 and C_2. Results for total solids were match able to present study observed by Inayat, Arain [17] who reported 30.69% total solids in soft cheese prepared with skimmed camel milk.

3.5 Effect of $CaCl_2$ on compositional characteristics of soft cheese

$CaCl_2$ has main part in improving the chemical properties of the camel milk soft cheese. The results of physic-chemical analysis of cheese with different calcium chloride doses (0%, 0.3%, 0.6% and 0.9%) were described in **Table 4**. Acidity of camel milk cheese were 3.6%, 3.15%, 2.9% and 2.7% prepared with Ca_1, Ca_2, Ca_3 and Ca_4 $CaCl_2$ concentration respectively. The present study results showed the non-significant value (p>0.05) due to maximum increase in acidity value. The cheese prepared with Ca_1, Ca_2, Ca_3 and Ca_4 $CaCl_2$ had 19%, 18%, 18% and 17% fat contents. Thus, due to decrease in amount of fat on increase of $CaCl_2$ results were non-significant (p>0.05). In camel milk cheese pH is most important because coagulation of milk depends on it. pH value was (4.3%, 4.2%, 4.1% and 4.1%) in cheese on Ca_1, Ca_2, Ca_3 and Ca_4 $CaCl_2$ which showed the result was highly significant (p<0.01) because on increasing of salt concentration the pH of cheese was dropped respectively.

Table 4: Effect of $CaCl_2$ on compositional characteristics of soft cheese

Treatments	Acidity (%)	Fat content (%)	Moisture content (%)	pH	Protein content (%)	TSS (%)	Cheese yield (%)
Ca_1	2.97 ± 0.54 ^{A}	13.33 ± 4.93 ^{A}	64.16 ±1.83 ^{A}	4.31 ± 0.01^{A}	21.00 ± 1.02 ^{A}	35.50 ± 2.35 ^{A}	8.32 ± 0.39 ^{A}
Ca_2	2.88 ± 0.23 ^{A}	13.33 ± 4.16 ^{A}	66.33 ± 1.67 ^{AB}	4.22 ± 0.01 ^{B}	18.75 ± 0.25 ^{AB}	33.67 ± 1.67 ^{AB}	8.62 ± 1.02 ^{AB}
Ca_3	2.91 ± 0.18 ^{A}	13.00 ± 4.35 ^{A}	67.50 ± 1.5 ^{AB}	4.17 ± 0.01 ^{C}	17.71 ± 0.15 ^{BC}	32.50 ± 1.5 ^{AB}	12.34 ± 2.76 ^{BC}
Ca_4	3.03 ±0.28 ^{A}	12.00 ± 4.35 ^{A}	69.16± 0.83 ^{B}	4.17 ± 0.01 ^{C}	19.86 ± 0.295 ^{C}	30.83 ± 0.83 ^{B}	13.50 ± 0.73 ^{C}

The results of protein contents were 21%, 18%, 17% and 19% for cheese prepared by Ca_1, Ca_2, Ca_3 and Ca_4 $CaCl_2$ respectively. Thus, present study results showed highly significant (p<0.01) results of protein. Moreover, Ahmed [38] reported that factors such as milk composition, addition of salt, pasteurization of milk, milk concentration and addition of starter culture affect the yield. The low pH increased acidity, and also there was decrease in fat content and total solids content. The data indicated that there was a ratio of milk total solids retained in the whey which was white in color; this result was in agreement with that of Mehaia [39]. Otherwise, the total protein and fat content were not altered. Yield of cheese was (7%, 8%, 12% and 14%) which indicated that the results of stat highly significant (p<0.01) on Ca_1, Ca_2, Ca_3 and Ca_4 $CaCl_2$ concentration. In comparison of our study the cheese yield obtained using camel milk in this study was reported as 7-14% which was similar to the finding of Mehaia [39] who obtained 10.5-11.5%. On the other hand, Qadeer, Huma [23] acclaimed that the yield of camel milk cheese with starter culture was 13.22% compared with cheese prepared by acidification and rennet action which yielded 12%, Moreover Derar and El Zubeir [26] obtained less yield (11.3%) using Camifloc enzymes and calcium chloride, however, the camel cheese made without addition of calcium chloride was 10.2% while our research cheese was 7% without salt. The latter workers concluded that addition of calcium chloride improved the manufacturing of cheese from camel milk. The high yield of the present study may have been caused by good and favourable temperature that was (63°C) which could not affect dry mater intake and this increase the total solids in milk which it was the main factor in cheese processing.

Total solids in cheese were (33%, 35%, 32% and 31%) thus results showed significant (p<0.05) results. The research which was conducted by Ahmed [38], overall average contents of total solids obtained from camel milk cheese was 35.72 %. Thus, findings indicated significant changes (P<0.05) among the camel milk cheeses made with three different doses of salt. Moisture is main component in cheese for its classification. Cheese shelf life improves on the base of moisture level which is present in it. Moisture percentage in cheese was (64%, 66%, 67% and 69%) that indicated the significant (p<0.05) results according to statistics.

3.6 Sensory evaluation of cheese prepared with different processing conditions

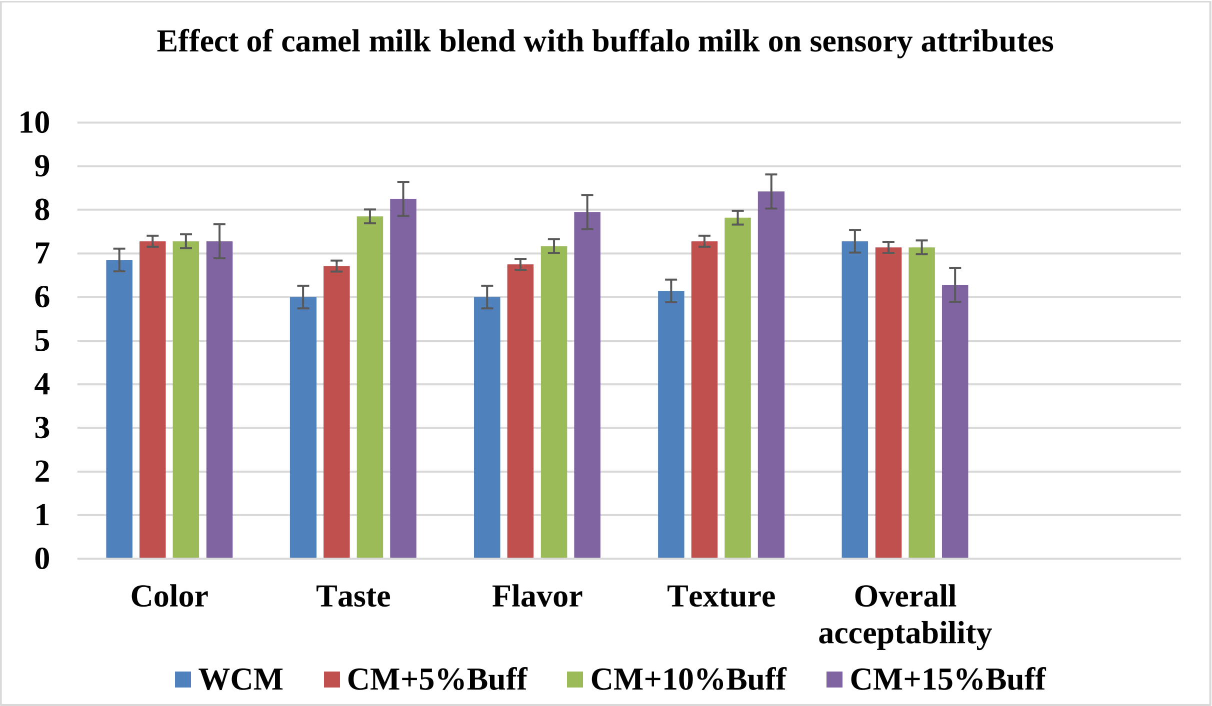
Sensory attributes of freshly prepared cheese were executed by the faculty students, who were well aware to the soft cheese. Sensory attributes such as color, flavour, texture, taste and overall acceptability were evaluated by the panellists. A 9-point Hedonic scale (1= like extremely, 5 = Neither like nor dislike and 9 = Dislike extremely) were developed for evaluation. Cheese was displayed with randomly three digits codes.

3.6.1 Effect of fortifying buffalo milk with camel milk on sensory attributes of soft cheese

Effect of blending camel milk with buffalo milk on final product and sensory attributes of soft cheese is shown in **Figure 2 (a & b).** The mean scores for color of the cheese prepared with CM, CM+5% Buff, CM+10% Buff, CM+15% Buff milk respectively. Results of statistical data showed the increase significant differences (P>0.05) for color of cheese prepared with CB_{15} than that of CB_0, CB_5, CB_{10} respectively. Taste of the cheese prepared with CB_0 had 6.0, CB_5 had 6.71, CB_{10} had 7.85 and CB_{15} had 8.25 mean scores respectively. Increase significant (P<0.01) differences were observed for the taste of cheese prepared with CB_{15} as compared to the cheese prepared with CB_0, CB_5 and CB_{10} respectively. Flavour of the cheese was more liked by the panellists prepared with CB_{15} had 7.95 mean score than the cheese prepared with CB_0, CB_5 and CB_{10} with mean scores of 6.0, 6.75 and 7.17 respectively. Highly significant differences (P<0.01) were found for the cheese prepared with CB_{15} as compared to CB_0, CB_5 and CB_{10} respectively. Mean scores was 7.28 for the cheese prepared with CB_0 and CB_{15} had for the texture but cheese prepared with CB_5 and CB_{10} had scores of 6.0 and 7.14 respectively. Non-significant differences (P>0.05) were observed among the texture of the cheese. Overall-acceptability of cheese were preferred by the more panellist prepared with CB_{15} (8.42) than CB_0, CB_5 and CB_{10} (6.14, 7.28 and 7.82) respectively. Highly significant differences (P<0.01) were observed among Overall-acceptability of the cheese supported by the results of Ong, Soodam [40].

Guasch-Jané, Andrés-Lacueva [41] reported the extreme flavour liked for the cheese prepared with camel and buffalo milk (75:25). Because buffalo milk cheese has strong aroma, flavour and good in taste as compared to camel milk cheese. Qadeer, Huma [23] concluded that the texture of the cheese prepared with camel milk mixed with 10% Buff milk was more firm than pure camel milk cheese. Sensory characteristics of camel milk cheese improved by using more modified starter extracted from pure camel milk microflora [42].

(a)



(b)

Fig.2: (a) Soft cheese curd of camel milk (85%) and buffalo milk (15%) blend, (b) Effect of camel milk blend with different levels of buffalo milk on sensory attributes

3.6.2 Effect of skimmed camel milk on sensory characteristics of soft cheese

Effect of skimmed camel milk on sensory characteristics of soft cheese is shown in **Figure 3.** Color of the cheese was more preferred prepared with WCM + 5% Buff milk with highest mean score of 8.42 as compared to cheese prepared with SM and SM+5% Buff milk (7.28 and 6.85) respectively. Present results showed the highly significant differences (P<0.01) among the color of the cheese. Mean score for the taste was 5.85 prepared with C_1, C_2 cheese had 7.42 and C_3 cheese had 8.75 respectively. Cheese taste was more liked prepared with C_3 as compared to C_1 and C_2 cheese. Results showed highly significant (P<0.01) data among the cheese taste. Flavour of the cheese prepared with C_2 and C_3 had same score (6.57) than cheese prepared with C_1 (6.0). Results indicated that flavour of cheese prepared with C_2 and C_3 more liked than C_1 cheese. Present study results showed the non-significant (P>0.05) results for the flavour of cheese. Texture of the cheese was more preferred for the cheese prepared with C_3 with mean score of 8.85 than the cheese prepared with C_1 and C_2 had 6.42 and 7.42 mean score respectively. Increase significant (P<0.01) results were observed for the cheese prepared with C_3 as compared to C_1 and C_2 cheese. Overall acceptability of cheese showed non-significant (P>0.05) differences prepared with C_1 and C_2 and C_3 with 6.42, 6.57 and 7.28 mean scores respectively.

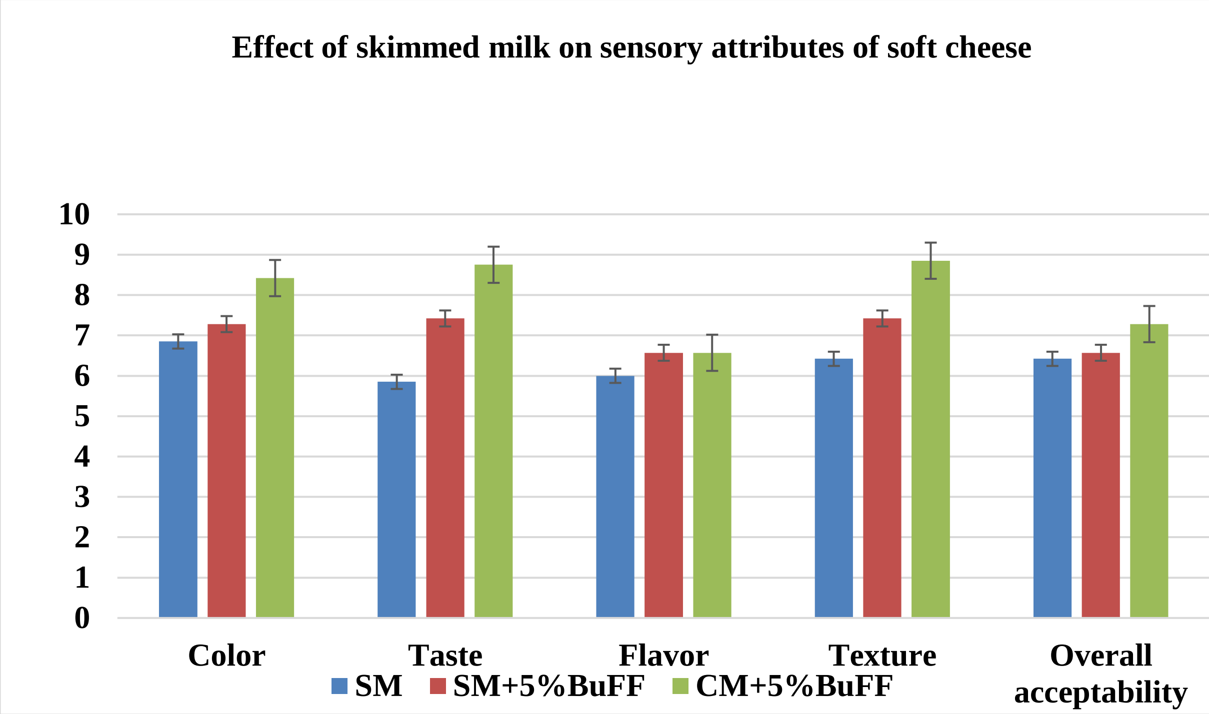


Fig.3: Effect of skimmed milk on sensory attributes of soft cheese

3.6.3 Effect of different $CaCl_2$ dose on sensory evaluation of the cheese

Effect of $CaCl_2$ concentration on sensory evaluation of cheese is shown in **Figure 4.** Color of cheese prepared at 0%, 0.30%, 0.60% and 0.90% $CaCl_2$ dose had mean score of 7.42, 8.0, 8.0 and 7.57 respectively. Results indicated the non-significant (P>0.05) differences among the color of the cheese. Most favoured taste of cheese was that prepared at Ca_2 and Ca_3, $CaCl_2$ had mean score 7.42 than Ca_1 and Ca_4 dose (5.71 and 6.14) respectively. Present study showed the non-significant (P>0.05) results for the cheese taste. Flavour of the cheese was preferred prepared at Ca_2 and Ca_3, $CaCl_2$ dose had average points of 7.0 as compared to the cheese prepared at Ca_1 and Ca_4 dose (6.0 and 6.442) respectively. Non- significant (P>0.05) results were observed among the flavour of cheese. Texture of cheese prepared at Ca_2 and Ca_3, $CaCl_2$ dose had same mean score 8.14 than that of Ca_1 and Ca_4 dose of $CaCl_2$ (7.0 and 7.71). Increase in non-significant (P>0.05) differences were noticed for the cheese prepared at Ca_2 and Ca_3, $CaCl_2$ dose than Ca_1 and Ca_4 respectively. Overall acceptability of cheese was preferred most for the cheese prepared at 0.30% and Ca_3, $CaCl_2$ dose had average value 7.85 than cheese prepared at Ca_1 and Ca_4, $CaCl_2$ dose having 6.71 and 7.42 respectively. Increase in significant (P>0.01) differences were observed the overall acceptability of cheese prepared at Ca_2 and Ca_3, $CaCl_2$ dose as compared to Ca_1 and Ca_4 dose respectively. Results for sensory attributes of cheese prepared at (0.0%, 0.55 and 1.0%) $CaCl_2$ dose like flavour, taste and overall acceptability were preferred more than colour and texture of the cheese [43]. For the production of soft cheese, the concentration of salt affected the flavour, texture, color, taste and overall acceptability. Panellists preferred the cheese with high salt concentration than controlled [44].

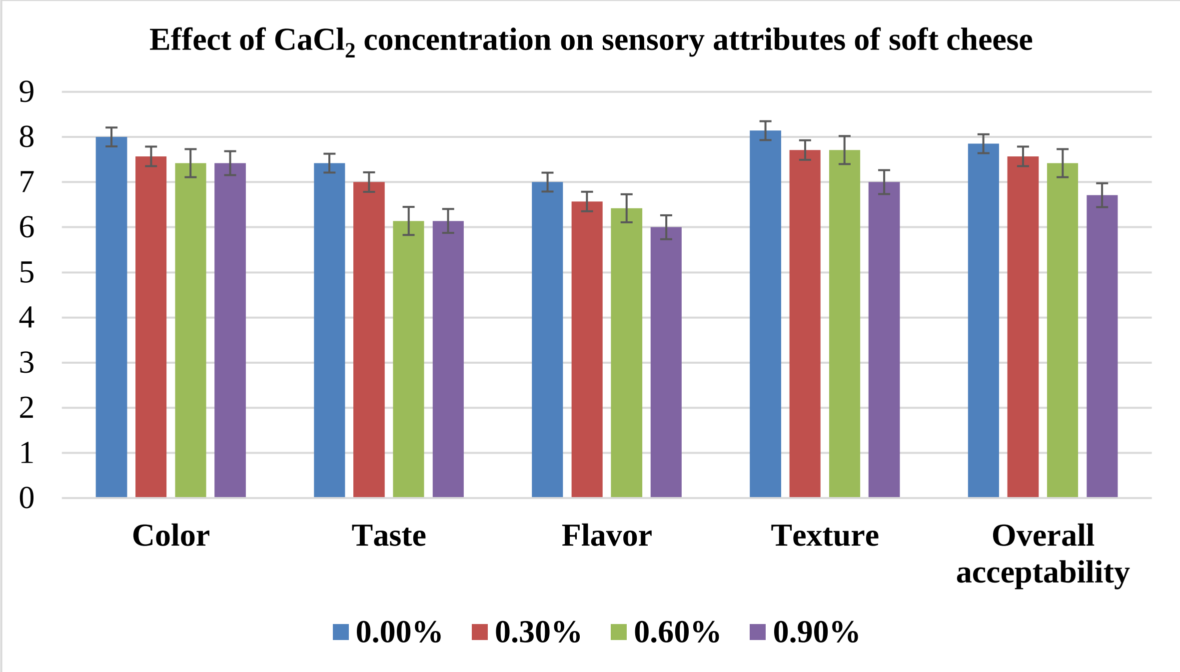


Fig.4: Effect of different salt concentration ($CaCl_2$) on sensory attributes of soft cheese

IV. CONCLUSION

On the basis of present study's results, it is concluded that camel milk cheese can be developed efficiently by 15:85 ratio of buffalo in to camel milk. For further improvements in camel milk cheese flavour and texture, the level of 0.9% $CaCl_2$ added which showed significant results. On the other hand, the cheese quality can further be improved by adjusting the fat percentage of camel milk with addition of 5% whole buffalo milk.

REFERENCES

[1] Sahoo, A., *Camel: a fast-declining animal species but can strive with its unique climate resilience and 'desert to medicine'application".* EC Veterinary science, 2020. **5**: p. 43-57.

[2] Edea, C., et al., *Characterization of camel production and marketing system in southern zone of Tigray region.* Int. J. Sustain. Manage. Inf. Technol., 2024. **10**: p. 12-18.

[3] Faraz, A., et al., *Camel production profile and role in food security.* One Health Triad, Unique Scientific Publishers, Faisalabad, Pakistan, 2023. **2**: p. 216-220.

[4] Jilo, K. and D. Tegegne, *Chemical composition and medicinal values of camel milk.* International Journal of Research Studies in Biosciences, 2016. **4**(4): p. 13-25.

[5] Konuspayeva, G. and B. Faye, *Recent advances in camel milk processing.* Animals, 2021. **11**(4): p. 1045.

[6] Pandey, T., *QUALITY ANALYSIS OF FRESH CHEESE PREPARED USING PARTIALLY PURIFIED MILK CLOTTING PROTEASE FROM GINGER RHIZOME*. 2022, Department of Food Technology Central Campus of Technology Institute of ….

[7] AOAC, *Official Method of Analysis: Association of Analytical Chemists.* 2012, Washington DC. p. 121-130.

[8] Bhagiel, I., et al., *Comparison between the physiochemical attributes of yogurt processed from camel milk and that processed from cow milk and the effect of storage period on pH and acidity.* World journal of pharmacy and pharmaceutical sciences, 2015. **4**(8): p. 1530-1540.

[9] Fahmid, S., et al., *Determination of chemical composition of milk marketed in Quetta, Pakistan.* Int. J. Adv. Res. Biol. Sci, 2016. **3**(5): p. 98-103.

[10] Galeboe, O., E. Seifu, and B. Sekwati-Monang, *Production of camel milk yoghurt: physicochemical and microbiological quality and consumer acceptability.* International Journal of Food Studies, 2018. **7**(2).

[11] Abd El-Aty, A., et al., *Composition and Properties of Camel Milk In Comparison With Cow's and Buffaloes' Milks.*

[12] Babiker, W.I. and I.E. El-Zubeir, *Impact of husbandry, stages of lactation and parity number on milk yield and chemical composition of dromedary camel milk.* Emirates Journal of Food and Agriculture, 2014. **26**(4): p. 333.

[13] Zhao, D.-b., Y.-h. Bai, and Y.-w. Niu, *Composition and characteristics of Chinese Bactrian camel milk.* Small Ruminant Research, 2015. **127**: p. 58-67.

[14] Benmeziane–Derradji, F., *Evaluation of camel milk: gross composition—a scientific overview.* Tropical Animal Health and Production, 2021. **53**(2): p. 308.

[15] Ahmed, A.A.-H., R.G. Sayed, and M. Sayed, *Nutritional value and sanitary evaluation of raw Camel's milk.* Emirates Journal of Food and Agriculture, 2014. **26**(4): p. 317.

[16] Yoganandi, J., et al., *Comparison of physico-chemical properties of camel milk with cow milk and buffalo milk.* Journal of Camel Practice and Research, 2014. **21**(2): p. 253-258.

[17] Inayat, S., et al., *Study of the effect of processing on the chemical quality of soft unripened cheese made from camel milk.* Pak. J. Nutr, 2003. **2**: p. 102-105.

[18] Abeiderrahmane, N., *Report joint FAO Expert comm.* On the code of fresh from your local drome'dairy'. htm. Food and Agriculture Organization of the United Nations, 2001.

[19] Kaskous, S., *Importance of camel milk for human health.* Emirates Journal of Food and Agriculture, 2016. **28**(3): p. 158-163.

[20] Ghasemi, M., et al., *Effect of different media on production of lactic acid from whey by Lactobacillus bulgaricus.* African Journal of Biotechnology, 2009. **8**(1).

[21] Zalán, Z., et al., *Production of organic acids by Lactobacillus strains in three different media.* European Food Research and Technology, 2010. **230**: p. 395-404.

[22] Konuspayeva, G., B. Faye, and A. Musaad, *Some lipid components of the camel milk and blood in intensive farm in Saudi Arabia.* 2014.

[23] Qadeer, Z., et al., *Camel milk cheese: Optimization of processing conditions.* Journal of Camelid Science, 2015. **8**: p. 18-25.

[24] Rossi, F. and M.L. Pallotta, *Bacteriocin producing cultures: A sustainable way for food safety improvement and probiotics with additional health promoting effects.* International Journal of Medical and Biological Frontiers, 2016. **22**(1): p. 59.

[25] Beshkova, D. and G. Frengova, *Bacteriocins from lactic acid bacteria: microorganisms of potential biotechnological importance for the dairy industry.* Engineering in Life Sciences, 2012. **12**(4): p. 419-432.

[26] Derar, A. and I.E. El Zubeir, *Effect of fortifying camel milk with sheep milk on the processing properties, chemical composition and acceptability of cheeses.* Journal of Food Science and Engineering, 2016. **6**: p. 215-226.

[27] Bai, Y.-h. and D.-b. Zhao, *The acid–base buffering properties of Alxa bactrian camel milk.* Small Ruminant Research, 2015. **123**(2-3): p. 287-292.

[28] Shahein, M., A. Hassanein, and A.F. Zayan, *Evaluation of soft cheese manufactured from camel and buffalo milk.* 2014.

[29] Zhang, L., et al., *Proteomic study on the stability of proteins in bovine, camel, and caprine milk sera after processing.* Food Research International, 2016. **82**: p. 104-111.

[30] Fukuda, K., *Camel milk.* Milk and dairy products in human nutrition: Production, composition and health, 2013: p. 578-593.

[31] Allam, M.G., et al., *Lactococcus species for conventional Karish cheese conservation.* LWT-Food science and Technology, 2017. **79**: p. 625-631.

[32] Fox, P.F., et al., *Fresh cheese products: Principals of manufacture and overview of different varieties.* Fundamentals of cheese science, 2017: p. 543-588.

[33] Rynne, N.M., et al., *Effect of milk pasteurisation temperature on age-related changes in lactose metabolism, pH and the growth of non-starter lactic acid bacteria in half-fat Cheddar cheese.* Food chemistry, 2007. **100**(1): p. 375-382.

[34] Hickey, D., et al., *Effects of variation in cheese composition and maturation on water activity in Cheddar cheese during ripening.* International Dairy Journal, 2013. **30**(1): p. 53-58.

[35] Küçüköner, E. and Z. Haque, *Physicochemical properties of low-fat and full-fat Cheddar cheeses.* International Journal of Dairy Technology, 2006. **59**(3): p. 166-170.

[36] Sameen, A., et al., *Chemical composition and sensory evaluation of mozzarella cheese: influence by milk sources, fat levels, starter cultures and ripening period.* Pak. J. Agri. Sci, 2010. **47**(1): p. 26-31.

[37] Sahan, N., et al., *Influence of fat replacers on chemical composition, proteolysis, texture profiles, meltability and sensory properties of low-fat Kashar cheese.* Journal of Dairy Research, 2008. **75**(1): p. 1-7.

[38] Ahmed, N.A.A.E., *Veterinary and Animal Production*, in *Sudan University, college of Veterinary and Animal Production*. 2001, Department of Dairy Production Faculty of Animal Production University of Khartoum.

[39] Mehaia, M.A., *Manufacture of fresh soft white cheese (Domiati-type) from dromedary camels' milk using ultrafiltration process.* 2006.

[40] Ong, L., et al., *The addition of calcium chloride in combination with a lower draining pH to change the microstructure and improve fat retention in Cheddar cheese.* International Dairy Journal, 2015. **46**: p. 53-62.

[41] Guasch-Jané, M.R., et al., *First evidence of white wine in ancient Egypt from Tutankhamun's tomb.* Journal of archaeological science, 2006. **33**(8): p. 1075-1080.

[42] Biratu, K. and E. Seifu, *Chemical composition and microbiological quality of Dhanaan: traditional fermented camel milk produced in eastern Ethiopia.* International Food Research Journal, 2016. **23**(5): p. 2223.

[43] Mohamed, A.E., I.A. Babiker, and T.E. Mohamed, *Preparation of fresh soft cheese from dromedary camel milk using acid and heat method.* 2013.

[44] FAO, *FAOSTAT.* . Food and Agriculture Organization of the United Nations, 2014.

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Turning Trash into Treasure: The Current Landscape and Future of Waste-to-Energy Initiatives in India

Ms. Kirtika Sati [1] and Dr. Aditi Vats[2]

[1]Ph.D. Scholar, Dept. of Resource Management and Consumer Science (College of Community Science), GB Pant University of Agriculture and Technology, Pantnagar-263145, Uttarakhand, India
[2]Professor, Dept. of Resource Management and Consumer Science (College of Community Science), GB Pant University of Agriculture and Technology, Pantnagar-263145, Uttarakhand, India

Received: 27 Oct 2024; Received in revised form: 25 Nov 2024; Accepted: 03 Dec 2024; Available online: 10 Dec 2024

Abstract**—** *Waste management in India has long been a pressing challenge, exacerbated by rapid urbanization and population growth. Among the various strategies to tackle this issue, waste-to-energy (WtE) initiatives have emerged as a promising solution, converting municipal solid waste into usable energy. This paper explores the current landscape of WtE initiatives in India, assessing their effectiveness, challenges, and future prospects. Despite the potential of WtE technologies to mitigate waste disposal problems and contribute to renewable energy production, their implementation in India faces significant hurdles, including technological, financial, and regulatory barriers. The existing WtE projects across different states, highlighting successful case studies such as the Okhla WtE plant in Delhi and the Narela-Bawana plant, which have demonstrated considerable capacity in waste processing and energy generation. Furthermore, we have analysed the policy framework supporting WtE projects, including government incentives and regulations under the Swachh Bharat Mission and the National Policy on Biofuels. The review also addresses the socio-environmental impact of WtE plants, considering public perception, environmental concerns, and the role of informal waste sectors. Challenges such as high capital costs, operational inefficiencies, and the need for improved waste segregation at the source are discussed, alongside potential solutions and technological advancements that could enhance WtE viability. Finally, we have outlined a roadmap for the future of WtE in India, advocating for integrated waste management systems, stronger regulatory frameworks, and increased public-private partnerships to foster sustainable development. This paper aims to provide a comprehensive overview of India's WtE landscape, offering insights and recommendations for stakeholders and policymakers to optimize waste management and energy production.*

Keywords**— *Waste-to-Energy, Municipal Solid Waste, Renewable Energy, Waste Management***

I. INTRODUCTION

Over the past few decades, India's fast urbanization, population growth, and industrialization have made waste management a major concern. The nation produces 62 million tons of municipal solid waste (MSW) a year, and in the upcoming years, this amount is anticipated to increase dramatically. This growing garbage stream is making conventional trash disposal techniques like open dumping and landfilling increasingly ineffective. These practices cause serious environmental and health risks, including as air pollution, groundwater contamination, and the spread of disease vectors, in addition to consuming enormous areas of land.

Waste-to-energy (WtE) technology has drawn attention as a viable waste management solution in the face of these difficulties. waste-to-energy (WtE) operations meet the needs of trash disposal and energy creation by converting waste materials into forms of energy that can be used, such as fuel, heat, or electricity. WtE programs offer a dual-benefit strategy that is in line with sustainable development objectives by lowering the amount of garbage that is sent to landfills and generating renewable energy.

This study aims to present a thorough analysis of the current state of WtE efforts in India, evaluating their viability, obstacles, and potential. The objective of this assessment is to provide a thorough examination of current WtE projects, the legislative framework that underpins them, and the socio-environmental effects that are connected to them. In doing so, the report hopes to pinpoint the critical elements affecting the viability and scalability of waste-to-energy (WtE) systems in India and offer practical suggestions for enhancing energy output and trash management.

It is impossible to overestimate the importance of WtE technology in the Indian setting. The amount of waste produced by India's expanding urban population and economic activity is rising, putting tremendous strain on the country's waste management infrastructure. Additionally, there is a huge energy shortage in the nation, with a sizable percentage of the populace still lacking access to consistent electricity. By turning waste into a resource for the production of energy, WtE programs provide a possible answer to these interconnected problems.

WtE technologies help conserve the environment by lowering the amount of garbage that is dumped in landfills and the greenhouse gas emissions that go along with it. They also aid in reducing reliance on fossil fuels, which helps India meet its targets for renewable energy and mitigates climate change. By generating employment in the waste management and energy industries, the effective execution of WtE projects can help promote economic development.

To achieve its objective, the paper is structured as follows:

Current Landscape of WtE Initiatives: The current state of WtE initiatives is outlined in this part, which also includes successful case studies like the Okhla WtE plant in Delhi and the Narela-Bawana facility and many more. It looks at their capability, effectiveness as an operation, and contributions to energy generation and waste management.

Policy Framework and Support: This section looks at the laws, rules, and subsidies that the Indian government uses to fund WtE projects. It analyses programs under the National Policy on Biofuels, the Swachh Bharat Mission, and other pertinent frameworks that support WtE technology.

Challenges and Barriers: The main obstacles to WtE projects in India are listed in this section, including financial, technological, and regulatory ones. It talks about problems like excessive capital expenses, inefficient operations, and the requirement for better waste segregation at the source.

Socio-Environmental Impact: The social and environmental effects of WtE plants are examined in this section. It takes into account how the general public feels, environmental issues, and the function of unorganized waste sectors in the ecosystem of waste management.

Future Prospects and Recommendations: The future potential of WtE technologies in India is covered in this section. It makes suggestions for how stakeholders and legislators may improve the sustainability and scalability of WtE initiatives. It promotes more public-private collaborations, robust regulatory frameworks, and integrated waste management systems.

This study intends to add to the ongoing discussion on sustainable waste management techniques and the development of renewable energy sources in India by offering a thorough examination of these factors. The purpose of this document is to provide policymakers, industry stakeholders, and researchers with information that will help them manage waste and generate energy in the nation in a more efficient and coordinated manner.

II. METHODOLOGY

In order to analyze secondary data from academic literature, government reports, industry publications, and case studies on waste-to-energy (WtE) efforts in India, this review study employs a qualitative methodology. Important sources include reports from organizations like the Ministry of Environment and Ministry of New and Renewable Energy, as well as databases like Google Scholar. To find trends and important topics, the data was coded and subjected to thematic analysis. To provide a thorough overview of existing practices, obstacles, and future opportunities, expert perspectives were linked with a comparative analysis of several WtE initiatives. Reliance on secondary sources and possible variations in data quality are among the limitations.

III. CURRENT LANDSCAPE OF WASTE-TO-ENERGY INITIATIVES IN INDIA

Overview of Existing Projects

Within the framework of its wider waste management policy, India has achieved significant progress in the development of waste-to-energy (WtE) plants. The goal of these initiatives is to turn municipal solid waste (MSW) into fuel, heat, or electricity in order to provide renewable energy while also disposing of waste. WtE facilities have been installed in a number of cities, each with differing capacities and success rates.

1. **Okhla Waste-to-Energy Plant, Delhi:** Since it opened for business in 2012, this facility has processed 1,950 tons of municipal solid garbage every day, producing 16 megawatts of power. According to Gupta et al. (2015), it has an impact on local waste management and energy supply.
2. **Narela-Bawana Waste-to-Energy Plant, Delhi**: This plant produces 24 megawatts of electricity each day by processing about 2,000 tons of garbage. Sharma and Kumar (2018) in their study talked about the plant's operational efficiencies and contributions to Delhi's waste management system.
3. **Pune Waste-to-Energy Plant, Maharashtra:** Patel et al mentioned in their case study that this facility, run by Hanjer Biotech Energies Pvt. Ltd., produces compost and refuse-derived fuel (RDF) from around 1,000 tons of garbage processed per day.
4. **Jabalpur Waste-to-Energy Plant, Madhya Pradesh:** Since it opened for business in 2016, this facility has processed about 600 tons of municipal solid garbage daily, producing 11.5 megawatts of power. Case study done by Singh et al (2020) stated that the facility has greatly improved trash management practices in the area.
5. **Hyderabad Waste-to-Energy Plant, Telangana**: Upon its commissioning in 2019, the Hyderabad WtE facility produces 19.8 megawatts of power by processing about 1,200 tons of garbage per day. The plant's contribution to the local electricity grid and reduction of landfill usage is highlighted by Reddy et al (2021).
6. **Lucknow Waste-to-Energy Plant, Uttar Pradesh**: Since it opened for business in 2017, the Lucknow WtE plant has processed about 500 tons of garbage daily, producing 9 megawatts of power. The plant's struggles and successes in enhancing the city's waste management are covered by Mishra and Tiwari (2022).
7. **Nagpur Waste-to-Energy Plant, Maharashtra:** Upon its commissioning in 2018, this facility produces 10 megawatts of power per day by processing 800 tons of municipal solid garbage. Deshmukh et al (2019) stated that the plant has greatly assisted Nagpur in improving its waste management system.
8. **Bangalore Waste-to-Energy Plant, Karnataka:** This plant, which has been in operation since 2020, produces 20 megawatts of electricity daily by processing about 1,400 tons of garbage. The influence of Bangalore's waste-to-energy plant on urban trash management and energy generation is examined in detail by Prasad and Suresh (2021).

Technological Approaches

According to Kumar and Agarwal (2020), in India, waste energy (WtE) technologies encompass a range of techniques, including anaerobic digestion, RDF synthesis, and incineration. Because it is so effective at lowering trash volume and producing energy, incineration is still the most widely used approach.

- **Incineration**: The most common method, where waste is burned at high temperatures to produce steam that drives turbines for electricity generation. While effective in reducing waste volume, incineration faces criticism for potential emissions and environmental impact.
- **Refuse-Derived Fuel (RDF)**: This involves processing MSW to produce a high-calorific-value fuel that can be used in industrial boilers or cement kilns. RDF production is a growing trend in India, providing an alternative to conventional fossil fuels.
- **Anaerobic Digestion**: This technology converts organic waste into biogas through microbial processes in the absence of oxygen. The biogas can be used for electricity generation or as a direct fuel source. This method is particularly suitable for managing biodegradable waste from markets and households.

Regional Distribution and Capacity

According to Singh et al (2019) While WtE projects are spread out throughout many regions, they are mostly concentrated in large cities. In relation to waste generation, the total installed capacity is still relatively small, suggesting significant room for growth.

IV. POLICY FRAMEWORK AND SUPPORT

National Policies and Initiatives

India's policy framework for waste-to-energy (WtE) initiatives is built on a foundation of national policies and programs aimed at promoting sustainable waste management and renewable energy production. Key policies and initiatives include:

1. **Swachh Bharat Mission (SBM):** The Swachh Bharat Mission (SBM) is a national initiative that was introduced in 2014 with the goal of cleaning up India's cities, rural areas, and infrastructure. SBM encourages recycling, waste treatment facility development, including WtE plants, and waste segregation at the source. Municipal corporations have benefited greatly from this

mission's encouragement to implement WtE technologies (Ministry of Housing and Urban Affairs, 2017).

2. **Solid Waste Management Rules, 2016:** For the management of municipal solid waste (MSW) in India, a thorough regulatory framework is provided under the Solid Waste Management Rules, 2016. These regulations require municipal governments to set up WtE plants whenever it is practical and promote the recovery of energy from dry trash that is not recyclable. The guidelines also stress how crucial it is to reduce the amount of waste dumped in landfills and to separate waste at the source (Ministry of Environment, Forest and Climate Change, 2016).
3. **National Policy on Biofuels, 2018:** The goal of the 2018 National Policy on Biofuels is to encourage the use of biofuels made from a variety of sources, such as municipal solid waste. According to the Ministry of New and Renewable Energy (2018), this policy offers financial incentives for the establishment of biofuel facilities and encourages the development of technologies for converting trash to biofuels.
4. **National Clean Energy Fund (NCEF):** The National Clean Energy Fund (NCEF) was established to provide funding for creative clean energy initiatives. It offers financial support to WtE initiatives that improve energy security and lessen the negative environmental effects of waste disposal (Press Information Bureau, 2011).

Financial Incentives and Subsidies

To encourage the adoption of WtE technologies, the Indian government offers various financial incentives and subsidies:

1. **Viability Gap Funding (VGF):** The purpose of viability gap funding (VGF) is to close the gap between the project's financial viability and the capital cost of establishing a WtE plant. Municipalities and private companies must have this money in order to invest in WtE infrastructure (Ministry of Finance, 2018).
2. **Subsidies from the Ministry of New and Renewable Energy (MNRE):** For WtE projects, the Ministry of New and Renewable Energy (MNRE) provides capital subsidies. The purpose of these subsidies is to lessen the financial strain on project developers by covering a portion of the project's cost (MNRE, 2021).
3. **Tax Benefits**: WtE projects can take advantage of a number of tax breaks, such as tax holidays, accelerated depreciation, and exemptions from customs duties when importing machinery and equipment. These advantages improve the WtE plants' financial viability and drastically lower their operating costs (Ministry of Finance, 2020).

Regulatory Support

The regulatory environment in India is evolving to support the growth of WtE initiatives:

1. **Streamlined Approval Processes:** To expedite the approval procedures for WtE projects, the government has implemented measures. According to the Ministry of Environment, Forests, and Climate Change (2019), this involves streamlining the processes for getting environmental clearances and other required permissions.
2. **Standardization of Tariffs:** Tariffs for electricity produced by WtE facilities have been established by the Central Electricity Regulatory Commission (CERC). This guarantees project developers a steady flow of income and increases the appeal of WtE projects to investors (CERC, 2020).
3. **Inclusion in Renewable Purchase Obligations (RPO):** WtE plant electricity is covered by the Renewable Purchase Obligations (RPO) framework. This creates a guaranteed market for WtE-generated power by requiring power distribution companies to acquire a specific portion of their total electricity from renewable sources, including WtE (Ministry of Power, 2021).

State-Level Initiatives

Several state governments in India have also taken proactive steps to promote WtE projects:

1. **Delhi**: With several plants running in the city, the Delhi government has been at the forefront in promoting WtE projects. The state has expedited the land acquisition procedure for the establishment of new facilities and offers more incentives (Delhi Pollution Control Committee, 2019).
2. **Maharashtra:** Maharashtra has put regulations in place to help WtE projects, including as expedited clearance procedures and incentives. In an effort to promote waste segregation at the source, the state has also started public awareness programs (Maharashtra State Electricity Distribution Co. Ltd., 2019).
3. **Karnataka:** Karnataka has put in place a strong set of policies to support WtE initiatives. To build additional WtE facilities, the state has partnered with private companies and is offering financial

incentives (Karnataka Renewable Energy Development Ltd., 2020).

Public-Private Partnerships (PPP)

Public-private partnerships (PPP) have emerged as a successful model for developing WtE projects in India. These partnerships leverage the strengths of both the public and private sectors:

Private Sector Expertise: The establishment and management of WtE facilities require the technical know-how, operational effectiveness, and financial resources provided by the private sector (Federation of Indian Chambers of Commerce and Industry, 2018).

Government Support: For WtE projects, the government helps with land acquisition, offers financial incentives, and supports regulations. This partnership guarantees WtE initiatives' effective execution and long-term viability (NITI Aayog, 2019).

The development of this industry is significantly aided by India's waste-to-energy efforts and policy framework. The combination of state-level initiatives, financial incentives, regulatory support, and national regulations fosters an atmosphere that is favorable to the growth and development of WtE projects. Public-private collaborations improve these efforts' viability and scalability even more. The fast urbanization of India makes it imperative to incorporate WtE solutions into the waste management framework in order to reduce environmental effect, promote energy security, and meet sustainable development targets. WtE initiatives have the power to drastically increase India's capacity for renewable energy sources and change the country's waste management environment with sustained policy backing and technology innovation.

IMPACT ON WASTE MANAGEMENT

The integration of WtE plants into India's waste management framework has several positive impacts:

Waste Volume Reduction: WtE facilities greatly reduce the quantity of garbage that must be landfilled, relieving strain on current landfill sites, by turning waste into electricity.

Generation of Renewable Energy: WtE plants deliver renewable energy to the national grid, which helps to diversify India's energy mix and lessen dependency on fossil fuels.

Economic Benefits: The construction and running of WtE facilities boost regional economies and provide job opportunities. Revenue can also be made from the selling of energy and byproducts like compost and RDF.

CHALLENGES FACED

Despite the benefits, WtE initiatives in India face several challenges:

Technological Barriers: The high cost and sophisticated infrastructure needed for many WtE technologies may prevent their broad adoption.

Financial Restrictions: Investment may be discouraged by the high capital expenses of establishing and operating WtE facilities, particularly in towns with limited resources.

Regulatory Obstacles: For WtE projects, navigating the complicated regulatory landscape and securing the required permissions can be difficult and time-consuming.

V. FUTURE PROSPECTS AND RESPONSIBILITIES

Future prospects

The future of waste-to-energy (WtE) initiatives in India is poised for significant growth, driven by both governmental support and increasing technological advancements. Key future prospects include:

1. **Expansion of WtE Capacity:** India's increasing industrialization and urbanization would unavoidably result in a rise in the production of municipal solid waste (MSW). trash treatment plants (WtE) will become increasingly important in trash management as conventional landfills fill up. It is anticipated that more cities will implement WtE technology in order to produce renewable energy and manage their garbage in an environmentally friendly manner (Gupta et al., 2015; Patel et al., 2019).
2. **Technological Advancements:** WtE technologies will continue to be researched and developed, which will result in more effective and affordable solutions. The efficiency and scalability of WtE plants can be increased by innovations including sophisticated thermal treatment procedures, enhanced anaerobic digestion methods, and the incorporation of smart grid technologies. These developments will increase the appeal of WtE projects to municipalities and investors (Kumar & Agarwal, 2020; Choudhury et al., 2021).
3. **Integration with Circular Economy:** WtE programs are in line with the circular economy concept, which stresses material reuse and recycling. India can optimize resource recovery, reduce waste, and establish a sustainable waste management ecosystem by incorporating WtE technologies within a circular economy framework. Additionally, this integration will help by-products like compost, biogas, and refuse-derived fuel (RDF) find secondary markets (Singh et al., 2020; Reddy et al., 2021).

4. **Decentralized WtE Systems:** Decentralized WtE systems may become more prevalent in the future, especially in semi-urban and rural settings. Localized, smaller waste-to-energy (WtE) plants can efficiently handle waste at the source, save down on transportation expenses, and supply electricity to nearby populations. Additionally, decentralized solutions may enhance trash segregation procedures and boost community involvement in waste management initiatives (Sharma & Kumar, 2018; Mishra & Tiwari, 2022).
5. **Enhanced Policy Support:** The development of WtE policies will be sustained by ongoing federal and state policy initiatives. Potential policies in the future could involve enhanced financial incentives, simplified regulatory structures, and augmented financing for research and development. A more conducive environment for the construction and operation of WtE plants nationwide will be produced by increased governmental support (Ministry of New and Renewable Energy, 2021; Ministry of Power, 2021).

Recommendations

To fully realize the potential of WtE initiatives in India, the following recommendations should be considered:

1. **Strengthening Policy Frameworks:** To give WtE projects more substantial incentives and a clearer set of guidelines, the government should improve the policy framework even more. To secure revenue streams for WtE plants, this entails securing long-term power purchase agreements (PPAs) and standardizing pricing (CERC, 2020).
2. **Promoting Public Awareness and Participation:** Increased public awareness initiatives are necessary to inform the public about the advantages of waste-to-energy technology and the significance of trash segregation at the source. Through rewards and instructional initiatives, the community should be encouraged to participate in waste management techniques (Swachh Bharat Mission, 2017).
3. **Encouraging Private Sector Investment**: To maximize private sector investment and experience in WtE projects, public-private partnerships, or PPPs, ought to be encouraged. According to the Federation of Indian Chambers of Commerce and Industry (2018), this can be accomplished by lowering administrative barriers, giving technical assistance for project development, and providing alluring financial incentives.
4. **Investing in Research and Development:** For WtE technologies to evolve and become more efficient and economical, more investment is required for research and development. To promote innovation in this area, cooperation between academic institutions, governmental organizations, and the commercial sector should be promoted (Ministry of Science and Technology, 2020).
5. **Implementing Robust Monitoring and Evaluation Systems:** To monitor WtE project performance and guarantee adherence to operational and environmental requirements, it is imperative to establish strong monitoring and evaluation mechanisms. To find areas for improvement and make sure WtE activities are sustainable, regular audits and impact evaluations should be carried out (Ministry of Environment, Forest and Climate Change, 2016).
6. **Facilitating Access to Finance:** For WtE projects, financial accessibility issues continue to be a major obstacle. In order to create financial instruments specifically for WtE projects, such as low-interest loans, green bonds, and credit guarantees, the government should collaborate with financial institutions (Ministry of Finance, 2020).

VI. CONCLUSION

There have been notable advancements in sustainable waste management and renewable energy production in India's waste-to-energy (WtE) landscape. This analysis demonstrates how these technologies have the potential to revolutionize urban waste management by highlighting the successful execution of many WtE initiatives in different Indian cities. The Okhla, Narela-Bawana, Pune, Jabalpur, Hyderabad, Lucknow, Nagpur, and Bangalore facilities, as well as the incineration, anaerobic digestion, and refuse-derived fuel production instances, demonstrate the variety of technological approaches used.

Together, these initiatives have produced a significant amount of renewable energy, lessened the load on landfills, and reduced the volume of waste produced. Additionally, they have benefited the economy by generating income from energy and by products like compost and RDF as well as jobs. The beneficial effects on urban waste management procedures, especially in lowering the waste disposal process's environmental impact, highlight how crucial WtE technologies are to attaining sustainable urban growth.

Nonetheless, there are a number of obstacles to the growth and improvement of WtE programs in India. Significant impediments still include high capital costs, regulatory constraints, and technological barriers. It will need a coordinated effort from all parties involved—government organizations, businesses, and civil society—to resolve these problems. Prioritizing financial investment and technological innovation is necessary to improve the scalability and efficiency of WtE facilities. Supportive legislation and simplified regulatory structures are also necessary to enable the expansion of this industry.

Future prospects for WtE efforts in India seem bright. In addition to helping the nation achieve its goals for renewable energy, WtE facilities may play a critical role in improving waste management in the nation with the correct combination of legislative support, technological innovation, and community engagement. Leading India's next wave of sustainable growth would require adopting a circular economy strategy that sees trash as an asset rather than a burden. A cleaner and more sustainable future will be made possible by the incorporation of WtE solutions into the larger waste management framework, which will also promote economic growth and improve energy security in addition to helping to minimize environmental challenges.

REFERENCES

[1] **Gupta, M., et al. (2015).** Waste-to-energy: A review of technologies and opportunities in India. *Renewable and Sustainable Energy Reviews*, 50, 475-488.

[2] **Sharma, S., & Kumar, P. (2018).** Case Study: Okhla Waste-to-Energy Plant. *Waste Management*, 79, 649-657.

[3] **Patel, R., et al. (2019).** Comparative Analysis of Waste-to-Energy Technologies in India. *Journal of Cleaner Production*, 223, 131-142.

[4] **Singh, R., et al. (2020).** Impact of Waste-to-Energy Plants on Urban Waste Management: A Case Study of Jabalpur. *Journal of Environmental Management*, 255, 109857.

[5] **Reddy, S., et al. (2021).** Performance Analysis of Hyderabad's Waste-to-Energy Plant. *Renewable Energy*, 163, 1315-1327.

[6] **Mishra, P., & Tiwari, A. (2022).** Evaluating the Success of Lucknow's Waste-to-Energy Initiative. *Sustainable Cities and Society*, 75, 103303.

[7] **Deshmukh, A., et al. (2019).** Nagpur's Waste-to-Energy Project: A Model for Urban Waste Management. *Waste Management & Research*, 37(8), 789-797.

[8] **Prasad, K., & Suresh, B. (2021).** Impact of Bangalore's Waste-to-Energy Plant on Urban Waste Management and Energy Production. *Renewable Energy Journal*, 179, 452-462.

[9] **Kumar, A., & Agarwal, A. (2020).** Technological Approaches in Waste-to-Energy: Current Trends and Future Directions. *Energy Reports*, 6, 300-315.

[10] **Choudhury, B., et al. (2021).** Anaerobic Digestion for Biogas Production in India: Potential and Challenges. *Bioresource Technology*, 332, 125082.

[11] **Singh, A., et al. (2019).** Regional Distribution and Capacity of Waste-to-Energy Plants in India. *Environmental Science & Policy*, 101, 62-70.

[12] Central Electricity Regulatory Commission (CERC). (2020). Tariff regulations for waste-to-energy plants. Retrieved from 159_reg.pdf (cercind.gov.in)

[13] **Choudhury, B., et al. (2021).** Anaerobic Digestion for Biogas Production in India: Potential and Challenges. *Bioresource Technology*, 332, 125082

[14] Delhi Pollution Control Committee. (2019). Annual report on waste management and WtE plants. Retrieved from Delhi Pollution Control Committee (delhigovt.nic.in)

[15] Karnataka Renewable Energy Development Ltd. (2020). Policy framework for WtE projects in Karnataka. Retrieved from Draft Karnataka Renewable Energy Policy 2021-2026_13 Oct 2021.pdf

[16] Maharashtra State Electricity Distribution Co. Ltd. (2019). Waste-to-energy policy and incentives in Maharashtra. Retrieved from Comm-Circular-323-MYT-Tariff-for-FY-2020-21.pdf (mahadiscom.in)

[17] Federation of Indian Chambers of Commerce and Industry (FICCI). (2018). Public-private partnerships in waste-to-energy: Opportunities and challenges. Retrieved from FICCI : Industry's Voice for Policy Change

[18] Ministry of Environment, Forest and Climate Change. (2016). Solid Waste Management Rules. Retrieved from 'Solid Waste Management Rules Revised After 16 Years; Rules Now Extend to Urban and Industrial Areas': Javadekar (pib.gov.in)

[19] Ministry of Finance. (2018). Viability Gap Funding for infrastructure projects. Retrieved from Home-Public Private Partneships in India (pppinindia.gov.in)

[20] Ministry of Finance. (2020). Tax benefits for renewable energy projects. Retrieved from Tax Incentives for Renewable Energy in India (sustvest.com)

[21] Ministry of Housing and Urban Affairs. (2017). Swachh Bharat Mission guidelines. Retrieved from SBM_Guideline.pdf (swachhbharaturban.gov.in)

[22] Ministry of New and Renewable Energy (MNRE). (2018). National Policy on Biofuels. Retrieved from Policies And Regulations | Ministry of New and Renewable Energy | India (mnre.gov.in)

[23] Ministry of New and Renewable Energy (MNRE). (2021). Subsidies for waste-to-energy projects. Retrieved from Waste to Energy Programme | Ministry of New and Renewable Energy | India (mnre.gov.in)

[24] Ministry of Power. (2021). Renewable Purchase Obligations regulations. Retrieved from Seeking_comments_on_Draft_Electricity_Promoting_renewable_energy_through_Green_Energy_Open_Access_Rules_2021.pdf (powermin.gov.in)

[25] Ministry of Science and Technology. (2020). Enhancing Research and Development in Waste-to-Energy Technologies. Retrieved from Research and Development Statistics, 2019-20 | Department Of Science & Technology (dst.gov.in)

[26] NITI Aayog. (2019). Role of public-private partnerships in waste management. Retrieved from Public Private Partnerships | NITI Aayog

[27] Swachh Bharat Mission. (2017). Guidelines and implementation strategies. Retrieved from SBM_Guideline.pdf (swachhbharaturban.gov.in)

[28] Press Information Bureau. (2011). National Clean Energy Fund. Retrieved from Creation of National Clean Energy Fund (pib.gov.in)

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Green Synthesis and DFT study of Nickel Zinc Ferrite Nanoparticles: A Highly Sensitive Room Temperature VOC Sensing Material

Chandra Mukherjee[1*], Subhankar Choudhury[2], Nabajyoti Baildya[3], Narendra Nath Ghosh[4], Debabrata Misra[5], J. Das[6]

[1]The Neotia University, D.H.Road, Kolkata- 743368, India.
[2]Department of Chemistry, Malda College, Malda, 732101, India.
[3]Department of Chemistry, University of Kalyani, Kalyani 741235, India.
[4]Department of Chemistry, University of Gour Banga, Mokdumpur, Malda 732103, India.
[5]Department of Botany, University of Gour Banga, Mokdumpur, Malda 732103, India.
[6]The Department of Physics, Jadavpur University, Kolkata-700032, India.
*Corresponding author: chandra.mukherjee@tnu.in

Received: 30 Oct 2024; Received in revised form: 01 Dec 2024; Accepted: 08 Dec 2024; Available online: 14 Dec 2024

Abstract*— In present communication, nanocrystalline nickel zinc ferrite (NZF) has been prepared by spin controlled coprecipitation method in varied proportions to study the alcohol (primary alcohols viz. ethanol, propanol and butanol) sensing behaviour at room temperature. Nanocrystalline nickel zinc ferrite (NZF) $Ni_{1-x}Zn_xFe_2O_4$ (where x = 0.3, 0.5 and 0.7) are subjected to the structural and surface morphological characterizations, porosity and surface activity through Powder X-ray Diffraction (PXRD) and Field Emission Scanning Electron Microscopy (FESEM). The variations in electrical resistance of $Ni_{0.7}Zn_{0.3}Fe_2O_4$ (NZF1), $Ni_{0.5}Zn_{0.5}Fe_2O_4$ (NZF2) and $Ni_{0.3}Zn_{0.7}Fe_2O_4$ (NZF3) are measured with the exposure of 500 ppm ethanol, propanol and butanol vapours as a time function at room temperature. 89% sensitivity is detected by NFZ1 for 500 ppm of ethanol vapour. The sensing response followed the order of ethanol > propanol > butanol for all the three samples. The increasing trend of VOC (volatile organic substance) sensing properties by NZFs has been verified through extensive DFT (density functional theory) analysis by adopting PAW (projector augmented wave) technique. DFT calculation supports the pulling effect of Ni atoms in NZF nanoparticles which consequently increases the sensing properties of the NZFs. ELF (Electron localization function) study also supports the accelerated adsorption capacity of nickel doped nanoferrites.

***Keywords*— Coprecipitation, DFT study, Nanostructural analysis, NiZn ferrites, room temperature VOC sensor.**

I. INTRODUCTION

Under volatile organic compounds (VOCs), primary aliphatic alcohols like ethanol, propanol and butanol are the most common and widely used harmful toxicants. Reliable detection of hazardous, harmful and toxic vapours is now become a major issue in the field of environmental protection worldwide. For continuous measurement of these volatile organic substances, inexpensive, sensitive, easy to operate and stable sensor sdevices are required. Nanostructured materials including metal oxides, carbon nanotubes, graphene and conducting polymer, nanocarbon composites are being vigorously explored in sensing of various organic vapours [1-6]. In spite of poor selectivity and high working temperature, particularly the nanostructured metal oxides like SnO_2, ZnO, Fe_2O_3 and WO_3 have been widely used in alcohol vapour sensing [7-11]. Spinel type metal ferrites with formula MFe_2O_4 is proven to be a reliable sensor material for room temperature sensing of both oxidizing and reducing vapours overcoming the high temperature and selectivity constrain [12, 13]. Among different ferrite materials, n-type zinc ferrite semiconductor is a widely adopted for the detection of ethanol, acetone, hydrogen and H_2S [14-18]. Due to thermal stability, low cost and moreover simple preparation of spinel ferrites, it becomes a high priority commercially viable electronic material in recent days. Nanostructured mixed ferrites offer a strong surface reactivity towards gases and organic vapours due to their small grain size, high density of grain boundaries and interfaces. Hence are expected to be more sensitive, selective and long-term stable sensor provisions [19-20].

The present work reveals a comparative study of the response behaviour of prepared nanocrystalline nickelzinc ferrite (NZFs) toward the primary aliphatic alcohols like, ethanol, propanol and butanol at ambient temperature. Ethanol, propanol and butanol have been widely used in various manufacturing units, industries and scientific laboratories. Ethanol as a hypnotic solvent is widely applied in the manufacture of wine, medical processes, food industries and biomarker as well [21]. Propanol is used as a cleansing solvent for oil. Long term exposure to propanol can lead to skin irritation and other health complications [22]. Butanol is widely used as dye diluent in textile and chemical units. It also finds its application in the manufacture of biofuels now-a-days. But its toxicity ranges from eye and skin irritation to the central nervous system damage on prolonged exposure.

Hence there is a great search for the suitable, selective and economically viable sensors to monitor VOCs.

II. MATERIALS AND METHODS

2.1. Preparation

$Ni_{0.7}Zn_{0.3}Fe_2O_4$ (NZF1), $Ni_{0.5}Zn_{0.5}Fe_2O_4$ (NZF2) and $Ni_{0.3}Zn_{0.7}Fe_2O_4$ (NZF3) have been successfully prepared by coprecipitation method in varied proportion. Detailed techniques for nanoferrites synthesis are described in the previous article [23]. Post annealed samples are regrind and desiccated for further characterization and analysis.

2.2. Structural characterization

X-ray powder diffraction has been recorded using a Bruker´D8 Advance´ Diffractometer (funded by UGC-DRS (SAP-II) DST (FIST-II), at Jadavpur University), equipped with a Globel mirror using Cu Kα (λ = 1.54184A°) radiation. The generator setting was maintained at 40kV and 40mA.The diffraction patterns has been recorded at ambient temperature with a counting time of 2 s/step over a range of $2\theta=20^0$- 90^0.

The interplane spacing d has been calculated by using Bragg's Law equation,

$$d = \frac{\lambda}{2 Sin\theta} \quad (1)$$

where Θ is Bragg's diffraction angle calculated by equating $2\,\Theta$ with the peak value from XRD pattern, λ is wavelength of Cu Kα (λ = 1.54184A°) radiation.

The following equation has been utilised to calculate the lattice constant a for the NZF samples from the diffraction planes.

$$a = d\sqrt{(h^2 + k^2 + l^2)} \quad (2)$$

where d is the interplane spacing, $h, k, and\ l$ are the Miller indices of the crystal planes after fitting, the 100 line (311 plane) of the XRD pattern of the prepared NZFs [24].

The theoretical density of the samples is determined from XRD data by:

$$\rho_x = \frac{8M}{Na^3} \quad (3)$$

Where ρ_x the density is calculated from XRD data, M is the molecular weight, N is the Avogadro's number, and a is the lattice constant of the cubic unit cell [25].

The experimental density ρ_m of the annealed samples is determined by considering the cylindrical shape of the pellet by the following equation:

$$\rho_m = \frac{m}{\pi r^2 h} \quad (4)$$

Where m is the mass, r is the radius and h is the thickness of the pellet [26].

Porosity P of the pellet is determined through the relation:

$$P = \frac{\rho_x - \rho_m}{\rho_x} \times 100 \quad (5)$$

Where ρ_m and ρ_x are the experimental and theoretical densities respectively [27].

Investigation of surface morphology of the prepared NZFs have been carried out by the FESEM facility (FEI, INSPECT F 50) equipped with an energy dispersive x-ray spectrometer system, (configuration no. QUO-35357-0614 funded by FIST-II, DST, Government of India), at the Physics Department, Jadavpur University.

2.3. Measurements

The palletization technique and criteria of the NZF samples is described in former article [23]. Highly pure silver paste electrode is used to coat the surface of the pellets. The VOC sensing behaviours of NZF1, NZF2 and NZF3 is measured using a static flow vapour sensing set up, developed in our laboratory Fig 1. Vapour sensing measurements are performed in a closed test chamber at a static atmosphere in the ambient temperature. In order to improve the stability of vapour sensor the sensing element is kept in the sensing chamber for more than 12 hours before testing.

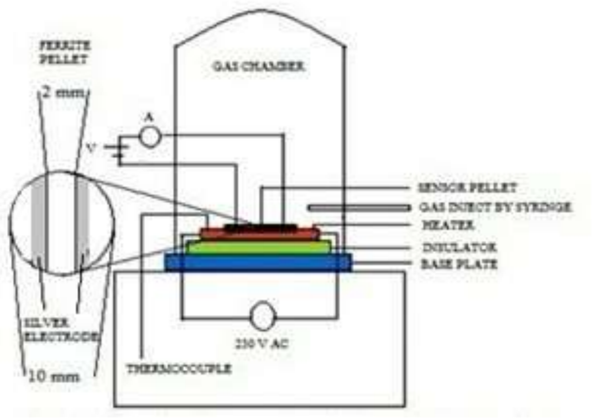


Fig 1: Schematic diagram of static flow vapour sensing

III. RESULTS AND DISCUSSION

3.1. Material characterizations

XRD pattern of all NZF samples, annealed at 1200° C is presented in Fig. 2 below. Prepared NZFs are found to form cubic spinel type structure without any peaks from other phases. The sharp diffraction peaks indicate a high degree of crystallization for the obtained metal ferrite compounds.

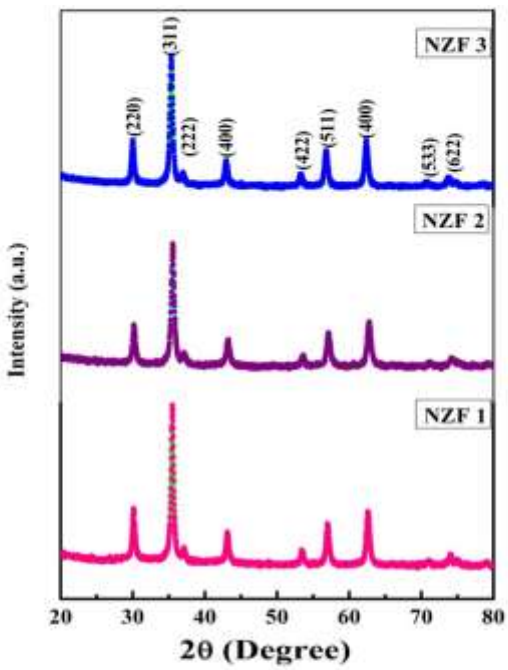


Fig.2. PXRD pattern of NZF1, NZF2 and NZF3.

The sensing response is calculated using the given formula.

$$S\% = \left(\frac{\Delta R}{R_{air}}\right) \times 100$$

$$\text{or } S\% = \left(\frac{\left|R_{air} - R_{gas}\right|}{R_{air}}\right) \times 100 \qquad (6)$$

Where R_{air} and R_{gas} are resistance in the air and the presence of test vapours respectively and ΔR is the resistance variation. The resistance variation of NZF samples is recorded at room temperature with different alcohol vapours. Heater with thermocouple is used here for resetting of the sensor pellet to perform repetitive experiments. This is aimed to further study by optimizing the temperature for different VOCs with varied concentrations. Some crystalline properties of NZFs are compared and shown in Table 1. The calculated lattice constant 'a' is seen to increase with increase in zinc content. The variation in lattice constant can be explained on the basis of the ionic radii of Zn^{2+} (0.82 Å) ions is higher than that of Ni^{2+} (0.78 Å) [28, 29]. Fig.3a. 3b and 3c present the FESEM micrographs for the prepared samples which show microstructures with nanosized grains. The low measured density with open porosity > 60%, thus satisfying the requirements for materials to be used as organic vapour sensors. Presence of both nanostructured grain size and porosity, increases the specific surface area of the prepared samples and make it suitable material for vapour sensing applications [30].

Table 1. Properties of prepared NZF sensors

Composition	a (Å)	ρ_x(g/cc)	ρ_m(g/cc)	P(%)
$Ni_{0.7}Zn_{0.3}Fe_2O_4$	8.338001	5.41645	1.99096	64.16546
$Ni_{0.5}Zn_{0.5}Fe_2O_4$	8.386085	5.35393	1.99137	62.80534
$Ni_{0.3}Zn_{0.7}Fe_2O_4$	8.434177	5.29248	2.01233	61.97756

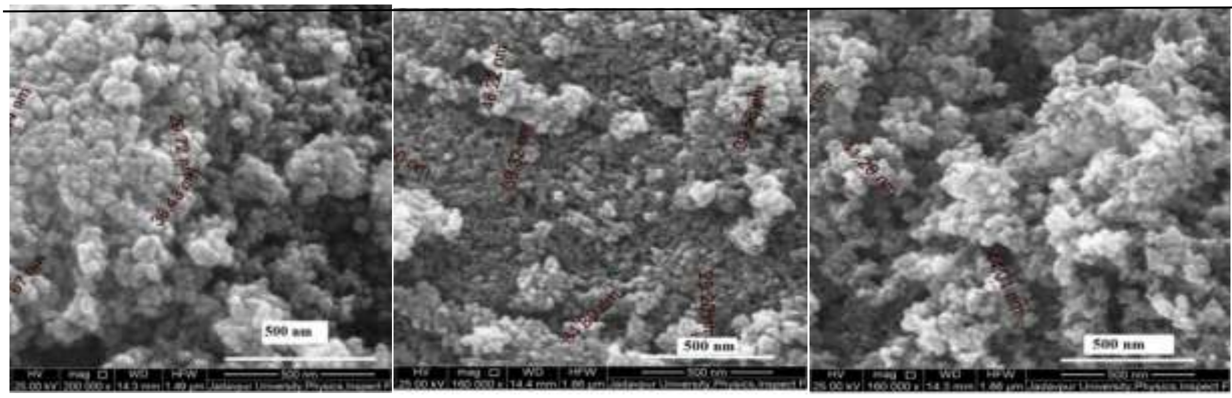


Fig. 3a. *Fig. 3b.* *Fig. 3c.*

Fig. 3a. FESEM micrographs of NZF1, Fig. 3b. FESEM micrographs of NZF2, Fig.3c. FESEM micrographs of NZF3

3.2. Alcohol sensing characteristics

3.2.1 Transient response study

Initially, the behavioral pattern of the vapour sensing by NZF pellets for different alcohol vapours are studied in the ambient temperature. The transient response of NZF1, NZF2 and NZF3 towards the vaopurs of 500 ppm ethanol, propanol and butanol with respect to time are shown in Fig. 4a, 4b and 4c respectively.

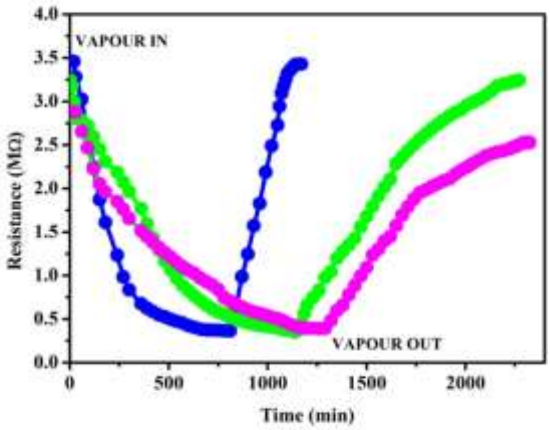


Fig. 4a. Transient response of NZF1 for 500 ppm ethanol (blue), propanol (green) and butanol (pink) at room temperature.

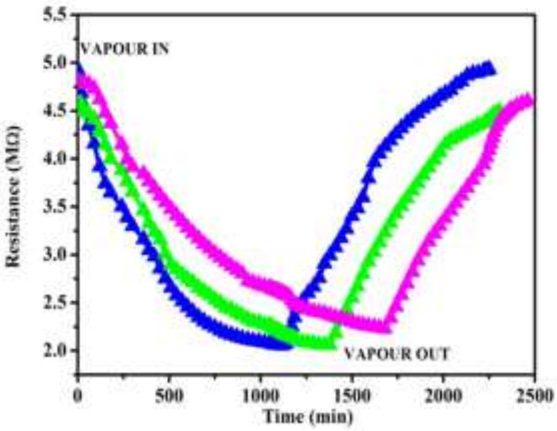


Fig. 4b. Transient response of NZF2 for 500 ppm ethanol (blue), propanol (green) and butanol (pink) at room temperature.

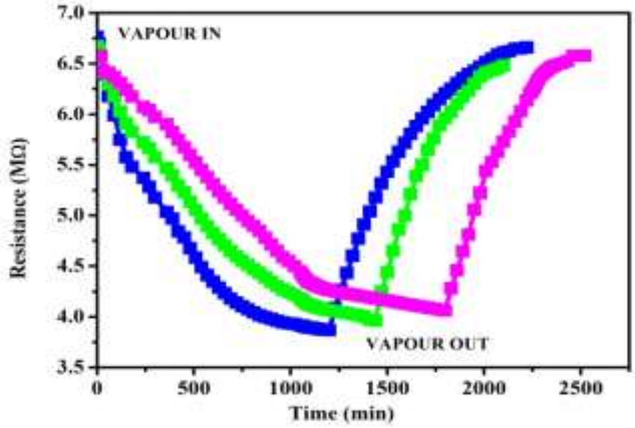


Fig. 4c. Transient response of NZF3 for 500 ppm ethanol (blue), propanol (green) and butanol (pink) at room temperature.

The electrical resistance by the sensor pallet is measured in presence of air before introducing any test vapour in the dome chamber. A quantity of 10 ml of test vapour is inserted in the chamber every time. As soon as the alcohol vapours are inserted, the NZF pellets exhibits lowering of the resistance responses and thus an increasing vapour sensing response is observed in all cases. After a steady response, alcohol vapours are removed from the closed dome by opening the lid and the response pattern is recorded again. The observations show a pretty stable and highly reproducible sensor responses by the samples even at room temperature.

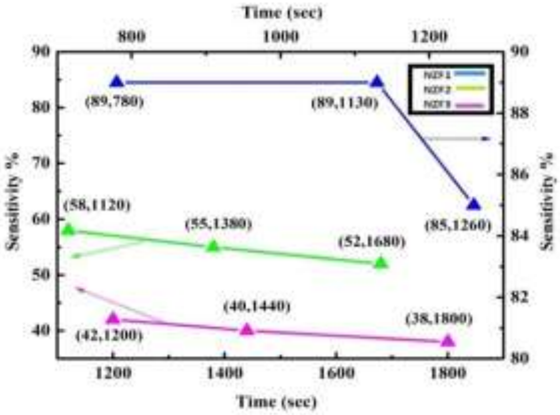


Fig. 5: Sensitivity response of NZF sensors with the response time.
NZF1 (blue): ethanol (89,780), propanol (89, 1130) and butanol (85, 1260)
NZF2 (green): ethanol (58, 1120), propanol (55, 1380) and butanol (52, 1680)
NZF3 (pink): ethanol (42, 1200), propanol (40, 1440) and butanol (38, 1800)

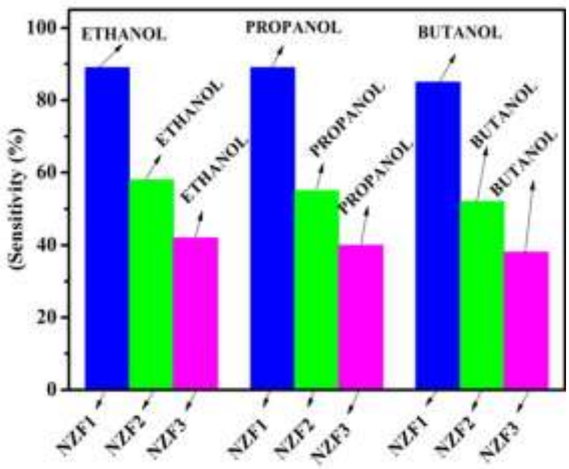


Fig. 6: Selective sensitivity of NZF1 (blue), NZF2 (green) and NZF3 (pink) towards 500 ppm ethanol, propanol and butanol at room temperature.

1.2.2. Sensitivity study

Fig.5 shows the sensitivity response of NZF1, NZF2 and NZF3 towards 500 ppm of ethanol, propanol and butanol vapours in accordance with the response time in the ambient temperature. The response and recovery time of the NZF nano samples towards different alcohol vapours are estimated from the respective resistance variation data. From the comparative study, the sensitivity is found to follow an order of NZF1 > NZF2 > NZF3 with average sensitivity value of 88%, 55% and 40% respectively towards alcohol vapour in the ambient temperature is summarized in Table 2. It took several minutes to recover the original resistance after removal of test vapours from the closed chamber. A long time recovery observed at room temperature is due to the agglomerated nature of the sensing element revealed by FESEM microstructure. When the NZF pellet is exposed to analyte vapours it goes deeper into the pellet and it comes out slowly at room temperature which results in a longer recovery time [31]. The stability data of the three alcohol sensors are obtained under similar conditions at room temperature over a period of 30 days to confirm the reliability of the measurements.

1.2.3. Selectivity study

Selective detection of VOC is a big challenge for any commercial sensor. It is seen that, NZF1 is more selective towards alcohol vapour than NZF2 and NZF3 at ambient temperature. The selectivity study of the annealed NZF pellets has been carried out repeatedly through the exposure of 500 ppm of ethanol, propanol and butanol maintaining the similar ambient condition every time which has been clearly revealed from Fig.6.

Table 2. Comparison of ethanol, propanol and butanol sensitivity characteristics of NZF sensors at room temperature.

Type of Sensing Materials	Test vapours	Concentration (ppm)	Maximum response (%)	Response time(min)	Recovery time(min)
NZF1	Ethanol	500	89	13	05
	Propanol	500	89	18	16
	Butanol	500	85	21	18
NZF2	Ethanol	500	58	18	15
	Propanol	500	55	23	16
	Butanol	500	52	28	18
NZF3	Ethanol	500	42	20	13
	Propanol	500	40	24	14
	Butanol	500	38	30	15

1.2.4. Sensing mechanism

It is observed that the resistance of the sensing element decreases when exposed to reducing vapours like ethanol, propanol and butanol which suggest that NZF sensors behave as n-type semiconductor. The vapour sensing mechanism of the metal ferrite is a surface controlled phenomenon that is based on the surface area of the pellet sensor at which the vapour molecules adsorb and react with pre-adsorbed oxygen molecules. As the prepared metal ferrites are highly porous, the oxygen chemisorptions centers like oxygen vacancies, localized donor and accepter states are formed on the surface during synthesis. These centers are filled by adsorption of oxygen molecules from air. After some time, equilibrium state is achieved between oxygen of metal ferrite and atmospheric oxygen. At room temperature, it took some time to give a stabilized resistance which is known as resistance of air (R_a). The ferrite interacts with oxygen by trapping the electrons from the conduction band to adsorbed oxygen atom, resulting in the formation of ionic species such as O_2^- , O^{2-} and O^-. The transferring of electrons from conduction band of the sample ferrite to adsorbed oxygen atoms may occur through the following reactions [32, 33].

$$O_2(air) \leftrightarrow O_2(ads)$$

$$O_2(ads) + e \leftrightarrow O_2^-(ads)$$

$$O_2^-(ads) + e^- \leftrightarrow 2O^-(ads)$$

$$O_2(ads) + 2e \leftrightarrow O^{2-}(ads)$$

The dropping of the electrical resistance occurs due to the release of more and more electrons back into the conduction band of ferrite as a result of the surface interaction between alcohol vapours attached with ferrites and the surface adsorbed oxygen. The reaction between ROH vapours and adsorbed oxygen ions can take place as;

Alcohol: $ROH_{vap} + O_{ad}^{2-} \rightarrow RO_{ad}^- + OH_{ad}^-$

$$RO_{ad}^- \rightarrow R_2O + O_{ad}^- + e^-$$

$$ROH_{vap} + O_{ad}^{2-} + \text{hole} \rightarrow CO_2 + H_2O + v_0^-$$

(Where v_0^- is a doubly charged oxygen vacancy)

These reactions divert electrons back to the conduction band of the sensing ferrites leading to an increase in electron concentration and a decrease in resistance [34]. After input of test vapours, due to liberation of electrons, the resistance of sensing ferrites decreases drastically at beginning because of rapid adsorption and afterwards it decreases slowly and finally become saturated. Because OH^- group is present on surface of ferrite nanostructure, which can form hydrogen bond with isolated electron pair at oxygen atom. Hence, the physical adsorption to alcohol vapour of ferrite is taking place. In this case, electrons are drawn from the oxide which intensifies the charge in conduction band of the ferrite and hence increases the conductivity. The difference in the sensing response to different vapours might be due to the difference in adsorption pattern and reaction mechanism [35].

2. Density Functional Theory (DFT) Analysis

To investigate alcohol and acetone sensing behavior of NZF, the projector augmented wave (PAW) technique [36] has been adopted as implemented in Quantum Espresso's package to perform periodic density functional theory (DFT) calculations on the zinc ferrite and nickel doped zinc ferrite (001) surfaces. In the present study, zinc ferrite (001) surface is chosen since previous studies reported that this surface is stable and mostly studied **[**37-38**]**. Furthermore, Rodríguez et al within a DFT+U scheme studied the electronic properties and the stability of (001) surface and sowed that between the two terminations, one is fully Zn-terminated surface (Zn2) and the other that "exposes" O and Fe atoms which is suitable to study the sensing behavior [38]. For optimization, the convergence threshold on the total energy of 10^{-6} (a.u.) and the force of 10^{-3} (a.u.) has been set. Wavefunctions were given a kinetic energy cutoff of 100 Ry, while charge density was given a cutoff of 400 Ry. The simulation was accomplished by utilizing the approximate generalized gradient method (GGA) with Perdew-Burke-Ernzerh (PBE) [39] and the Marzari-Vanderbilt smearing technique with a smearing threshold of 0.02 and a 1×1×1 k-point mesh [40]. In this computation, the lattice parameter a=8.46 is utilized as described previously [37]. During the simulation within the GGA+U formalism exchange and correlation effects were accounted as describe in previously literature [37].

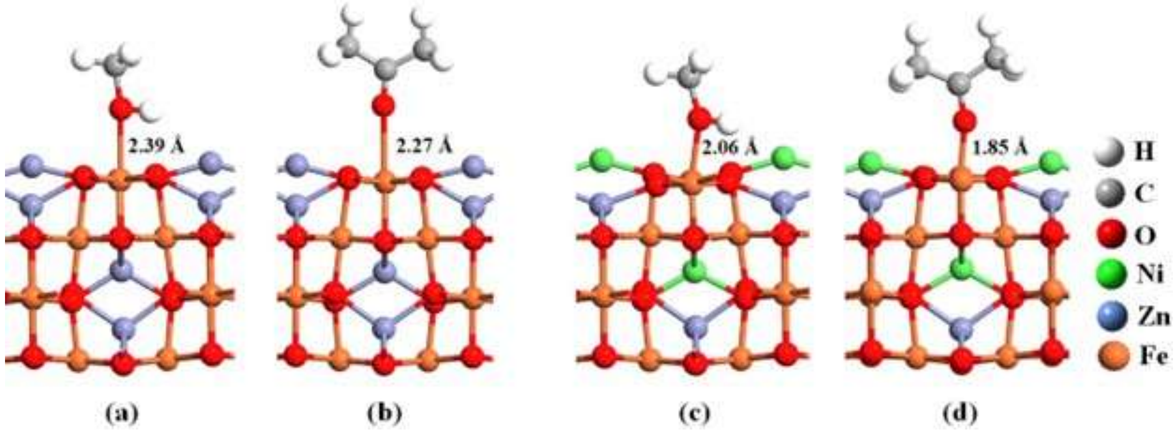


Fig. 7. Adsorption of alcohol and acetone on the Fe-O terminated zinc ferrite (001) surface. (a) Methanol adsorbed zinc ferrite (001) surface (b) Acetone adsorbed zinc ferrite (001) surface (c) Methanol adsorbed Ni- doped zinc ferrite (001) surface (d) Acetone adsorbed Ni-doped zinc ferrite (001) surface. Red, gray, white, green and orange color represents oxygen, carbon, hydrogen, nickel and iron atoms respectively.

To reduce the computational costs simple alcohol *viz.* methanol and acetone have been chosen for adsorption and build a unit cell of 001 surface with 5.96Å thickness. During optimization, the bottom two atomic layers were kept frozen while the remaining layers were completely relaxed during the calculations. A vacuum zone having thickness larger than 30 in the c direction to ensure no contact between the slabs has been optimized and further used for both alcohol and acetone adsorption calculations. To study the nickel doping half of the Zn atoms have been replaced with Ni atoms.

The energy minimized ground state geometries of methanol and acetone adsorbed on (001) surface is illustrated in the Fig.7. The undoped (001) surface the iron atoms showed very weak interaction with methanol and acetone as suggested by the long Fe-O bond distances of 2.39 Å and 2.57 Å respectively. With nickel doped (001) surface iron atom strongly interacts with methanol and acetone yielding very short Fe-O bonds of 2.06 Å and 1.85 Å respectively. The higher adsorption due to the presence of nickel doping can be explained by the electron pulling effect of Ni atoms which thereby increase the sensing behavior against alcohol and acetone.

In order to address how doping affect the overall electronic distribution of the zinc ferrite (001) surface, the electron localization function (ELF) is analysed as shown in the Fig. 8. The ELF study revealed that nickel doping slightly decreases the electron density on the surface and thereby accelerates the absorption of acetone and methanol.

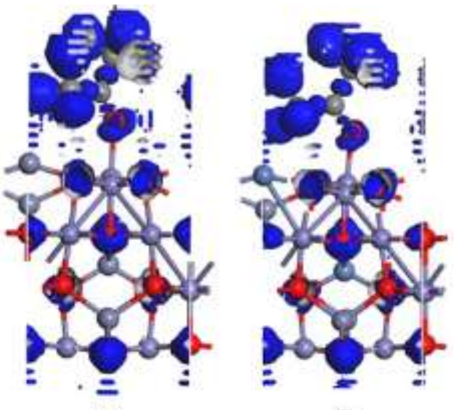


Fig. 8. Electron localization function (ELF) of Acetone adsorbed (a) Undoped and (b) Ni-doped zinc ferrite (001) surface.

IV. CONCLUSION

When NZF sensors are exposed to the saturated alcohol vapours, electrical resistance is shown to vary strongly with a wide variety of response magnitudes with time showing n type conductivity. It is seen that bulk density decreases and the porosity increases progressively with increase in nickel proportion within the ferrite. This confirms that increased proportion of nickel in NZF results in dedensification of the prepared nanomaterial and consequently the sensing response increased many fold. In addition, the DFT calculation also support the pulling effect of Ni atoms in NZF nanoparticles which consequently increases the sensing properties of the prepared NZF nanomaterials. Furthermore, the ELF study backed the accelerated adsorption capacity of nickel doped nanoferrites due to slight decrease of electron density on the surface. Hence, high sensitivity of 89% and quick response towards ethanol vapour at room temperature indicating NZF1 as an excellent material in the manufacture sector of alcohol vapour detector, or electronic nose.

ACKNOWLEDGEMENTS

Authors are thankful to The Neotia University, Department of Physics, Jadavpur University, Department of Chemistry, Malda College, Kalyani University, University of Gour Banga and Department of Botany, University of Gour Banga for providing laboratory and characterization facilities.

FUNDING DECLARATION

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

DATA AVAILABILITY

All data generated or analysed during the study are included in the published article.

REFERENCES

[1] Padmanathan Karthick Kannan., Ramiah Saraswathi., 2014. Impedimetric detection of alcohol vapours using nanostructured zinc ferrite. Talanta 129, 545–551.

[2] M. Ahsan, M.Z. Ahmad, T. Tesfamichael, J. Bell, W. Wlodarski, N. Motta, Low temperature response of nanostructured tungsten oxide thin films toward hydrogen and ethanol., 2012. Sensors and Actuators B 173, 789–796.

[3] F. Rumiche, H.H. Wang, J.E. Indacochea, 2012. Development of a fast response/high-sensitivity double wall carbon nanotube nanostructured hydrogen sensor, Sensors and Actuators B 163, 97–106.

[4] N. Hu, Z. Yang, Y. Wang, L. Zhang, Y. Wang, X. Huang, H. Wei, L. Wei, Y. Zhang, 2014. Ultrafast and sensitive room temperature NH_3 gas sensors based on chemically reduced graphene oxide. Nanotechnology 25. 025502.

[5] C. Wei, L. Dai, A. Roy, T.B. Tolle, 2006. The Chemistry of Nanostructured Materials, Journal of American Chemical Society, 2, 128, 1412–1413.

[6] M. Parmar, C. Balamurugan, D.W. Lee, PANI and Graphene/PANI Nanocomposite Films, Comparative Toluene Gas Sensing Behavior. 2013 Sensors 13, 16611–16624.

[7] H.C. Chiu, C.S. Yeh, 2007. Hydrothermal Synthesis of SnO_2 Nanoparticles and Their Gas-sensing of Alcohol. Journal of Physical Chemistry. *C* 111, 7256–7259.

[8] Y.J. Chen, C.L. Zhu, G. Xiao, 2008. Ethanol sensing characterization of ambient temperature sonochemically synthesized ZnO nanotubes. Sensors and Actuators B 129, 639–642.

[9] L. Wang, T. Fei, Z. Lou, T. Zhang, 2011. Three-Dimensional Hierarchical Flowerlike α-Fe_2O_3 Nanostructures: Synthesis and Ethanol Sensing Properties, ACS Applied Materials and Interfaces 3, 4689–4694.

[10] D. Chen, X. Hou, H. Wen, Y. Wang, H. Wang, X. Li, R. Zhang, H. Lu, H. Xu, S. Guan, J. Sun, L. Gao, 2010. The enhanced alcohol-sensing response of ultrathin WO_3 nanoplates, Nanotechnology 21, 035501.

[11] N. Coppede, M. Villani, R. Mosca, S. Iannotta, A. Zappettini, D. Calestani, 2013 Low Temperature Sensing Properties of a Nano Hybrid Material Based on ZnO Nanotetrapods and Titanyl Phthalocyanine. Sensors 13, 3445–3453.

[12] A.B. Gadkari, T.J. Shinde, P.N. Vasambekar, 2011 Ferrite Gas Sensors, IEEE Sensors Journal 11, 849–861.

[13] H Basti, A Hanini, M Levy, L Ben Tahar, F Herbst, L S Smiri, K Kacem, J Gavard, C Wilhelm, F Gazeau, Size tuned polyol made $Zn_{0.9}M_{0.1}Fe_2O_4$ (M = Mn, Co, Ni) ferrite nanoparticles as potential heating agents for magnetic hyperthermia: from synthesis control to toxicity survey, 2014, Materials Research Express, 1, No. 4.

[14] N. Rezlescu, E. Rezlescu, F. Tudorache, P. D. Popa. 2009. Gas sensing properties of porous Cu-, Cd and Zn- ferrites, Romanian Reports in Physics 61, No. 2, 223–234.

[15] N. S. Chen, X. J. Yang, E. S. Liu, and J. L. Huang, 2000. Reducing gas sensing properties of ferrite compounds

MFe_2O_4 (M = Cu, Zn, Cd and Mg), Sensors and Actuators B, 66, 1–3, 178–180.

[16] A. Sutka, J. Zavickis, G. Mezinskis, D. Jakovlevs, J. Barloti, 2013. Ethanol monitoring by $ZnFe_2O_4$ thin film obtained by spray pyrolysis, Sensors and Actuators B 176, 330–334.

[17] S.L. Darshane, R.G. Deshmukh, S.S. Suryavanshi, I.S. Mulla, 2008. Gas-Sensing Properties of Zinc Ferrite Nanoparticles Synthesized by the Molten-Salt Route, Journal of American Ceramic Society 91, 2724–2726.

[18] Y. Cao, D. Jia, P. Hu, R. Wang, 2013. One step room temperature solid phase synthesis of $ZnFe_2O_4$ nanomaterials and its excellent gas-sensing property, Ceramics International 39, 2989–2994.

[19] R. Godbole, P. Rao and S. Bhagwat, 2017, Magnesium ferrite nanoparticles: a rapid gas sensor for alcohol, Materials Research Express, 4, No. 2.

[20] A. Sutka, K. A. Grossa, 2016. Spinel ferrite oxide semiconductor gas sensors, Sensors and Actuators B 222, 95–105.

[21] N Rezlescu, E Rezlescu, 1993. The influence of Fe substitutions by R ions in a $Ni_{0.7}Zn_{0.3}Fe_2O_4$, Solid State Communications 88, 2, 139-141.

[22] M.A.M. Smeets, C. Maute, P.H. Dalton, 2002. Acute Sensory Irritation from Exposure to Isopropanol (2-Propanol) at TLV in Workers and Controls: Objective versus Subjective Effects. Annals of Occupational Hygiene 46, 359–373.

[23] C.Mukherjee, R.Mondal, S.Dey, S. Kumar and J. Das, 2017. Nanocrystalline CopperNickelZinc Ferrite: Efficient Sensing Materials for Ethanol and Acetone at Room Temperature, IEEE Sensors Journal, 17, 9, 2662-2669.

[24] A. Sutkaa, G. Mezinskisa, A. Lusisb, M. Stingaciuc. 2012. Gas sensing properties of Zn-doped p-type nickel ferrite, Sensors and Actuators B 171– 172, 354– 360

[25] I.H. Gul, F. Amin, A.Z. Abbasi, M. Anis-ur-Rehman, A. Maqsood, 2007. Physical and magnetic characterization of co-precipitated nanosize Co–Ni ferrites, Scripta Mater 56, 497–500.

[26] J.Y. Patil, M.S. Khandekar, I.S. Mulla, S.S. Suryavanshi, 2012. Combustion synthesis of magnesium ferrite as liquid petroleum gas (LPG) sensor: Effect of sintering temperature, Current Applied Physics 12, 319–324.

[27] A.S. Fawzi, A.D. Sheikh, V.L. Mathe, 2010. Structural, dielectric properties and AC conductivity of $Ni_x Zn_{(1-x)}Fe_2O_4$ spinel ferrites, Journal of Alloys and Compounds 502, 231–237.

[28] K. Rama Krishna, K. Vijaya Kumar and Dachepalli Ravinder, 2012. Structural and electrical conductivity studies in Ni-Zn Ferrite, Advances in Materials Physics and Chemistry 2, 185-191.

[29] G. Korotcenkov, 2007. Metal oxides for solid-state gas sensors: What determines our choice? Materials Science and Engineering: B 139, 1–23.

[30] R.B. Kamble, V.L. Mathe. 2008. Nanocrystalline nickel ferrite thick film as an efficient gas sensor at room temperature, Sensors and Actuators B 131, 205–209.

[31] R. Srivastava & B.C. Yadav, 2014. Nanostructured $ZnFe_2O_4$ thick film as room temperature liquefied petroleum gas sensor, Journal of Experimental Nanoscience 10, 1-15.

[32] X.Zhou, Q.Xue, H.Chen and C.Liu, 2010. Current–voltage characteristics and ethanol gas sensing properties of ZnO thin film/Si heterojunction at room temperature, Physica E 42, 2021-2025.

[33] A. B. Gadkari, T. J. Shinde, and P. N. Vasambekar, 2011. Ferrite Gas Sensors, IEEE Sensors journal 11, 849-861.

[34] Z.P. Sun, L. Liu, D.Z. Jia, W.Y. Pan, 2007. Simple synthesis of $CuFe_2O_4$ nanoparticles as gas-sensing materials, Sensors and Actuators B 125, 144-148.

[35] V. Lantto and P. Romppainen, 1987. Electrical studies on the reactions of CO with different oxygen species on SnO_2 surfaces, Surface Science 192, 243–264.

[36] P. Giannozzi, S. Baroni, N. Bonini, M. Calandra, R. Car, C. Cavazzoni, D. Ceresoli, G. L. Chiarotti, M. Cococcioni, I. Dabo, A. Dal Corso, S. de Gironcoli, S. Fabris, G. Fratesi, R. Gebauer, U. Gerstmann, C. Gougoussis, A. Kokalj, M. Lazzeri, L. Martin-Samos, N. Marzari, F. Mauri, R. Mazzarello, S. Paolini, A. Pasquarello, L. Paulatto, C. Sbraccia, S. Scandolo, G. Sclauzero, A. P. Seitsonen, A. Smogunov, P. Umari and R. M. Wentzcovitch, *J. Phys. Condens. Matter*, 2009, **21**, 395502.

[37] Rodríguez, KL Salcedo, JJ Melo Quintero, HH Medina Chanduví, AV Gil Rebaza, Ricardo Faccio, Waheed A. Adeagbo, Wolfram Hergert, CE Rodríguez Torres, and Leonardo Antonio Errico. "Ab-initio approach to the stability and the structural, electronic and magnetic properties of the (001) Znfe2O4 surface terminations." Applied Surface Science 499 (2020): 143859.

[38] Rezende, A.F.D., Oliveira, M.C.D., Ribeiro, R.A.P., Mesquita, W.D., Marques, J.D.J., Magalhães, N.F.D.S., Lemes, J.H.V., Longo, E. and Gurgel, M.F.D.C., 2022. DFT Calculations for Structural, Electronic, and Magnetic Properties of ZnFe 2 O 4 Spinel Oxide: The Role of Exchange-Correlation Functional. *Materials Research*, *25*.

[39] J. P. Perdew, K. Burke and M. Ernzerhof, *Phys. Rev. Lett.*, 1996, **77**, 3865–3868.

[40] N. Marzari, D. Vanderbilt, A. De Vita and M. C. Payne, *Phys. Rev. Lett.*, 1999, 82, 3296–3299.

AUTHOR CONTRIBUTIONS

Chandra Mukherjee: Conceptualization; data curation; formal analysis; investigation; methodology; validation; visualization; roles/writing—original draft.

Subhankar Choudhury: Software; validation; methodology.

Nabajyoti Baildya: Software; investigation.

Narendra Nath Ghosh: Data curation; visualization; roles/writing—original draft.

Debabrata Misra: Resources; validation; writing—review and editing.

J. Das: Conceptualization; formal analysis; funding acquisition; resources; supervision; validation; visualization; writing—review and editing.

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Optimization of Mulching and Plant Spacing on the Improvement of Productivity in Upland Rice *(Oryza sativa L.)* variety INPAGO 13

Waiz Al Qadri[1*], Agus Suryanto[2], Titin Sumarni[2]

[1]Master Student at Department of Agronomy, Faculty of Agriculture, Brawijaya University, Malang, Indonesia
[2]Department of Agronomy, Faculty of Agriculture, Brawijaya University, Malang, Indonesia
*Email: waizalqadri@gmail.com

Received: 30 Oct 2024; Received in revised form: 01 Dec 2024; Accepted: 08 Dec 2024; Available online: 15 Dec 2024

Abstract—*This study was conducted to evaluate the effect of the combination of plant spacing and mulch application on upland rice (Oryza Sativa L.) variety INPAGO 13. The experiment was carried out using a Split Plot Design (RPT), with the main plots (PU) consisting of M0 (no mulch), M1 (straw mulch), and M2 (Black-Silver Mulch), while the subplots (AP) included T1 (plant spacing 20 cm x 20 cm), T2 (plant spacing 30 cm x 30 cm), and T3 (plant spacing 40 cm x 20 cm x 12.5 cm). The observed parameters included plant height, number of tillers per clump, number of leaves per clump, leaf area per clump, leaf area index (LAI), dry weight per clump, dry weight of rice grains per clump, dry weight of rice grains per m², rice yield per hectare, dry weight of 1000 grains, albedo, soil temperature, and solar energy conversion efficiency. The results showed that both mulch application and plant spacing had a significant effect on growth and yield parameters. The application of black-silver mulch with a plant spacing of 40 cm x 20 cm x 12.5 cm generally improved plant growth. This study indicates that the combination of plant spacing and mulch application can enhance the yield of upland rice (Oryza Sativa L.) variety INPAGO 13.*

Keywords— ***Mulch, Plant Spacing, Upland Rice***

I. INTRODUCTION

Rice is one of the most important staple crops in Indonesia. The increasing population in Indonesia also impacts the demand for food, particularly rice. Therefore, improving rice productivity has become a priority in supporting food security. According to BPS (2021), the national average rice productivity in 2020 was 5.1 tons of milled dry paddy (GKG) per hectare, while in 2021, it increased to 5.3 tons (GKG) per hectare. However, it is important to note that the annual increase in rice productivity is only 1.9% per year, while the national population continues to grow. This means that if this trend continues, the government will face a deficit in food production compared to population growth, as population growth far exceeds the productivity of staple crops, particularly rice. Climate change also significantly affects rice productivity. Climate change, through altered rainfall patterns, increased CO_2 concentration in the atmosphere, and rising temperatures, affects rice productivity (Wang, Liu, and Shi, 2023). According to Li (2023), rice production is influenced by several meteorological factors such as temperature, rainfall, wind speed, and solar radiation.

The development of upland rice cultivation on dry land is one strategic alternative to meet national food needs, considering the large potential of unused dry land in Indonesia. According to BPS (2019), the total area of dry land in Indonesia is 63.4 million hectares, accounting for 33.7% of the country's total land area. Of this, 8.8 million hectares are used for dryland farming, while 26.3 million hectares are used for mixed shrubs, and 18 million hectares are used for plantations, leaving 10.3 million hectares that have yet to be fully utilized. Given this, the development of dryland rice farming through the application of technology seems more promising than the productivity of irrigated rice fields, which have long relied on subsidies or other forms of assistance. According to Marwanti (2022), the development of dryland rice based on technology is much more promising compared to the long-standing reliance on aid in various forms since the 1970s. Upland rice (padi gogo) is one variety of rice cultivated on dry land. The underutilization of dryland is due to limited water availability and organic matter in the soil.

Upland rice is an important genetic resource for rice diversity in Indonesia. There are several upland rice varieties available in Indonesia, such as Situbagendit, Inpago 9, Inpago 10, Inpago 11, Inpago 12, and the most recent, Inpago 13. The production potential of Inpago varieties ranges from 6 to 10 tons per hectare, depending on the variety; however, in practice, the average production is only around 3 to 4 tons per hectare (Malik, 2017). It is essential to understand that there are various constraints in upland rice cultivation on dry land that significantly impact productivity, such as the limited water availability and the dominance of weeds, which compete for nutrients and reduce plant growth, ultimately decreasing yield. Additionally, competition for nutrients due to the broadcasting planting system affects soil quality, making proper plant spacing crucial. Improper plant spacing not only increases nutrient competition but also reduces photosynthesis efficiency due to leaf coverage in rice plants.

Mulch is a soil cover material used in crop cultivation. There are two types of mulch: inorganic and organic. Common organic mulches used by farmers include straw, palm oil empty fruit bunches, plant litter, leaves, and plastic mulches, such as black-silver plastic mulch (MPHP). The use of mulch aims to reduce irrigation needs by minimizing water evaporation from the soil, stabilize soil temperature, suppress weed growth (thus reducing weeding costs), prevent water and wind erosion, provide nutrients, protect the soil surface from raindrop impact, reduce surface runoff, and maintain soil moisture (Zhao et al., 2023). In addition, plastic mulches, especially black-silver plastic mulch (MPHP), can reflect light, which is utilized by the plant in the photosynthesis process of the lower leaves. The use of mulch in upland rice farming is unconventional but can have positive effects on photosynthesis due to the light reflection produced by the black-silver plastic mulch. Furthermore, in upland rice cultivation, plant spacing must also be considered as it affects the plant's ability to capture solar energy. Research by Rhauf, Suryanto, and Nurlaili (2022) showed that using three rice seedlings per hole with a 25x25 cm square planting layout resulted in the highest yield of 8.26 tons per hectare compared to other planting distance.

This study is expected to provide useful information for upland rice farmers (Oryza Sativa L.) in improving rice production by managing the combination of plant spacing and mulch application.

II. MATERIALS AND METHODS

2.1 Time and place

This research was conducted from July to December 2023. The experiment was carried out at the Experimental Farm of the Faculty of Agriculture, located in Jatimulyo, Malang, East Java. The elevation of the site is 507 meters above sea level, measured using Google Earth, with an air temperature ranging from 23°C to 25°C, and the soil type is Regosol. The annual rainfall is approximately 1,500 mm.

2.2 Tools and materials

The tools used in this study included an altimeter, a cultivator for land preparation, a LI-3100 Leaf Area Meter, bamboo, netting, writing materials, a digital scale (SF-400), a Memmert Oven (model 21037 FNR), and a smartphone camera. The materials used in the study included Inpago 13 rice seeds, Urea (46% N), KCl, and Fertipos. Solar radiation intensity data were obtained from the nearest climatology station (±10 km), the Meteorology, Climatology, and Geophysics Agency (BMKG) Karangploso, Malang.

2.3 Research methods

The experiment was conducted using a Split Plot Design (RPT), with three replications. The main plots (PU) consisted of M0 (no mulch), M1 (straw mulch), and M2 (Black-Silver Mulch), while the subplots (AP) included T1 (plant spacing 20 cm x 20 cm), T2 (plant spacing 30 cm x 30 cm), and T3 (plant spacing 40 cm x 20 cm x 12.5 cm). The combination of these treatments resulted in nine treatment combinations, each replicated three times.

The observed parameters included plant height, number of tillers per clump, number of leaves per clump, leaf area per clump, leaf area index (LAI), dry weight per clump, dry weight of rice grains per clump, dry weight of rice grains per m², rice yield per hectare, dry weight of 1000 grains, albedo, soil temperature, and solar energy conversion efficiency.

The efficiency of solar energy conversion (EKE) indicates the percentage of solar energy that can be converted into carbohydrate energy through photosynthesis in plant dry matter. The equation for EKE is as follows (Sinclair and Muchow, 1999; Suryanto, 2018):

$$EKE = \frac{\Delta W . K}{I . t . PAR} x100\%$$

Where:

ΔW = Difference in plant dry weight (g) per m² over a given time period

K = Heat combustion coefficient (4,000 cal.g⁻¹)

I = Daily solar radiation intensity (cal.m².day⁻¹)

t = A specific time period (days)

PAR = Photosynthetically Active Radiation (0.45)

Weed observation was carried out using a square raffia cord measuring 25 cm x 25 cm in 4 plots. The weeds were then grouped by species, identified, and the following parameters were calculated: species density, relative species density, species frequency, relative species frequency, relative species dominance, species dominance, and the Important Value Index (IVI) using the formulas according to (Aryani, 2023):

a.Density of a type (K)

K = Σ individual type/Area of example tile

b. Relative density of a type (KR)

KR = K of a type/K All types x 100 %

c. Frequency of a type (F)

F = Σ Sub− tile found of type/Σ All sub−example tiles

d. Relative frequency of a type (FR)

FR = F of a type/ F of all types x 100%

The plant frequency classes are:

Class A : 0 -20%

Class B : 21 - 40%

Class C : 41 - 60%

Class D : 61 - 80%

Class E : 81 – 100 %

e. Dominance of a type (D)

D = Base field area of a type/Example tile area

Base Area = π x (rod diameter/2)2

f. Relative dominance of a type (DR)

DR = D of a type/D of all types x 100%

g. Important Value Index (INP)

INP = KR + FR + DR

Information:

FR = Relative Frequency,

KR = Relative Density,

DR = Relative DominationData analysis

From the observation results that have been obtained, then analyzed using ANOVA in the form of a 5% level F test. If there are real results, then continued with the Smallest Real Difference (LSD) test.

III.RESULTS

3.1 The effect of mulch application and plant layout on the growth of rainfed rice variety Inpago 13.

The effect of mulch application and plant spacing on the growth of upland rice (Oryza Sativa) was observed. In the treatments with no mulch and straw mulch, with plant spacings of 20 cm x 20 cm, 30 cm x 30 cm, and 40 cm x 20 cm x 12.5 cm, no significant increase in plant height was observed. However, in the treatment with black-silver mulch, plant heights at plant spacings of 30 cm x 30 cm and 40 cm x 20 cm x 12.5 cm were significantly taller compared to the 20 cm x 20 cm spacing. In the 20 cm x 20 cm plant spacing treatment, no significant increase in plant height was observed across the no mulch, straw mulch, and black-silver mulch treatments.

Table1. Plant length due to treatment of various types of mulch and plant layout at 70 Days after planting (DAP)

Treatment	Plant Length (Cm)			BNJ 5%
	Without Mulch	Straw Mulch	Black Silver Mulch	
20cm x 20cm	69.67 a	69.42 a	81.92 a	23.79
	A	A	A	
30cm x 30cm	69.17 a	67.33 a	106.83 b	
	A	A	B	
40 cm x 20 cm x 12.5 cm	80.67 a	80.58 a	108.08 b	
	A	A	B	
BNJ 5%		10.45		

Description: Numbers followed by different capital letters in the same column and different non-capital letters in the same row indicate significant differences in the 5% HSD test.

In the treatments with no mulch and straw mulch at plant spacings of 20 cm x 20 cm, 30 cm x 30 cm, and 40 cm x 20 cm x 12.5 cm, there was no significant increase in the number of tillers per clump. However, in the treatment with black-silver mulch at a plant spacing of 40 cm x 20 cm x 12.5 cm, the number of tillers per clump was higher compared to the 20 cm x 20 cm plant spacing. In the 20 cm x 20 cm plant spacing treatment, there was no significant increase in the number of tillers per clump across the no mulch, straw mulch, and black-silver mulch treatments. In contrast, at plant spacings of 30 cm x 30 cm and 40 cm x 20 cm x 12.5 cm, the black-silver mulch treatment resulted in a higher number of tillers per clump compared to the no mulch and straw mulch treatments.

Table 2. Number of shoots per clump due to treatment with various types of mulch and plant layout

Treatment	Number of Tillers Per Clump (tan-1)			BNJ 5%
	Without Mulch	Straw Mulch	Black Silver Mulch	
20cm x 20cm	30.25 a	31.92 a	30.75 a	7.76
	A	A	A	
30cm x 30cm	26.33 a	27.00 a	38.00 b	
	A	A	AB	
40 cm x 20 cm x 12.5 cm	30.50 a	32.17 a	42.17 b	
	A	A	B	
BNJ 5%	7.76			

Description: Numbers followed by different capital letters in the same column and different non-capital letters in the same row indicate significant differences in the 5% HSD test.

The treatments with no mulch and straw mulch at plant spacings of 20 cm x 20 cm, 30 cm x 30 cm, and 40 cm x 20 cm x 12.5 cm did not significantly increase the number of leaves per clump. However, the treatment with black-silver mulch at a plant spacing of 40 cm x 20 cm x 12.5 cm resulted in a higher number of leaves per clump compared to the 20 cm x 20 cm plant spacing. In the 20 cm x 20 cm plant spacing treatment, no significant increase in the number of leaves per clump was observed across the no mulch, straw mulch, and black-silver mulch treatments. In contrast, at plant spacings of 30 cm x 30 cm and 40 cm x 20 cm x 12.5 cm, the black-silver mulch treatment resulted in a higher number of leaves per clump compared to the no mulch and straw mulch treatment.

Table 3. Number of leaves per clump due to various types of mulch treatment and plant layout at 70 Days after planting(DAP)

Treatment	Number of Leaves Per Clump (strands.tan-1)			BNJ 5%
	Without Mulch	Straw Mulch	Black Silver Mulch	
20cm x 20cm	89.75 a	95.75 a	92.25 a	15.45
	A	A	A	
30cm x 30cm	79 a	81 a	114 b	
	A	A	AB	
40 cm x 20 cm x 12.5 cm	91.5 a	96.5 a	126.5 b	
	A	A	B	
BNJ 5%	23.53			

Description: Numbers followed by different capital letters in the same column and different non-capital letters in the same row indicate significant differences in the 5% HSD test.

The treatment with no mulch at plant spacings of 20 cm x 20 cm, 30 cm x 30 cm, and 40 cm x 20 cm x 12.5 cm did not significantly increase the leaf area index (LAI). However, the straw mulch treatment at a plant spacing of 40 cm x 20 cm x 12.5 cm significantly increased the LAI compared to the 30 cm x 30 cm plant spacing. The black-silver mulch treatment significantly increased the LAI, with the 40 cm x 20 cm x 12.5 cm spacing showing the highest LAI compared to the 20 cm x 20 cm and 30 cm x 30 cm spacings.

At the 20 cm x 20 cm and 30 cm x 30 cm plant spacings, the treatments with no mulch, straw mulch, and black-silver mulch did not significantly increase the LAI. However, at the 40 cm x 20 cm x 12.5 cm plant spacing, the treatments with no mulch, straw mulch, and black-silver mulch all significantly increased the LAI, with the black-silver mulch treatment showing the highest LAI compared to the no mulch and straw mulch treatment.

Table 4. Leaf Area Index (LAI) due to various types of mulch and plant layout treatments

Treatment	Leaf Area Index (m2m-2)			BNJ 5%
	Without Mulch	Straw Mulch	Black Silver Mulch	
20cm x 20cm	1.92 a	3.13 a	3.61 a	2.16
	A	AB	B	
30cm x 30cm	0.71 a	1.33 a	1.73 a	
	A	A	A	
40 cm x 20 cm x 12.5 cm	2.3 a	4.31 a	6.92 b	
	A	B	C	
BNJ 5%		1.86		

Description: Numbers followed by different capital letters in the same column and different non-capital letters in the same row indicate significant differences in the 5% HSD test.

The treatment with no mulch showed a significant effect, where plant spacings of 40 cm x 20 cm x 12.5 cm and 30 cm x 30 cm resulted in the highest dry weight per clump compared to the 20 cm x 20 cm plant spacing. The straw mulch and black-silver mulch treatments also showed significant effects on the dry weight per clump, with the 40 cm x 20 cm x 12.5 cm plant spacing resulting in the highest dry weight per clump compared to the 20 cm x 20 cm and 30 cm x 30 cm plant spacings.

For the 20 cm x 20 cm and 30 cm x 30 cm plant spacings, the treatments with no mulch, straw mulch, and black-silver mulch did not show significant differences in the dry weight per clump. However, at the 40 cm x 20 cm x 12.5 cm plant spacing, the black-silver mulch treatment showed a significant difference in dry weight per clump compared to the no mulch and straw mulch treatments.

Table 5.Plant Dry Weight Per Clumpdue to the treatment of various types of mulch and plant layout

Treatment	Dry Weight of Plants Per Clump (g.tan-1)			BNJ 5%
	Without Mulch	Straw Mulch	Black Silver Mulch	
20cm x 20cm	91.08 a	107.83 a	118.33 a	44.37
	A	A	A	
30cm x 30cm	112.58 a	106.83 a	134.75 a	
	B	A	A	
40 cm x 20 cm x 12.5 cm	116.58 a	128.92 ab	169.33 b	
	B	B	B	
BNJ 5%		20.82		

Description: Numbers followed by different capital letters in the same column and different non-capital letters in the same row indicate significant differences in the 5% HSD test.

3.2 The Effect of Mulch Application and Plant Layout on the Yield of Rainfed Rice Variety Inpalgo 13

In the treatment with no mulch, plant spacings of 40 cm x 20 cm x 12.5 cm and 30 cm x 30 cm had significantly higher milling dry grain weight per clump compared to the 20 cm x 20 cm spacing. For the black-silver mulch and straw mulch treatments, the 30 cm x 30 cm plant spacing resulted in significantly higher milling dry grain weight per clump compared to the 20 cm x 20 cm and 40 cm x 20 cm x 12.5 cm spacings.

For the 20 cm x 20 cm plant spacing, treatments with no mulch, straw mulch, and black-silver mulch did not significantly increase the milling dry grain weight per clump. At the 30 cm x 30 cm spacing, the application of straw mulch and black-silver mulch resulted in a significantly higher milling dry grain weight per clump compared to the no mulch treatment. At the 40 cm x 20 cm x 12.5 cm spacing, the application of no mulch, straw mulch, and black-silver mulch increased the milling dry grain weight per clump, with the no mulch and black-silver mulch treatments resulting in the heaviest milling dry grain weight compared to the straw mulch treatment.

In the treatment with no mulch, no significant increase in milling dry grain weight per m² was observed for plant spacings of 20 cm x 20 cm, 30 cm x 30 cm, and 40 cm x 20 cm x 12.5 cm. However, the straw mulch treatment at the 40 cm x 20 cm x 12.5 cm spacing resulted in a higher milling dry grain weight per m² compared to the 20 cm x 20 cm spacing. The black-silver mulch treatment significantly increased milling dry grain weight per m², with the 40 cm x 20 cm x 12.5 cm spacing producing the heaviest milling dry grain weight per m² compared to the 20 cm x 20 cm and 30 cm x 30 cm spacings.

For the 20 cm x 20 cm plant spacing, the application of no mulch, straw mulch, and black-silver mulch did not significantly increase milling dry grain weight per m². At the 30 cm x 30 cm spacing, the black-silver mulch treatment showed a significant result, where black-silver mulch was heavier compared to no mulch and straw mulch treatments for milling dry grain weight per m². At the 40 cm x 20 cm x 12.5 cm spacing, the black-silver mulch treatment significantly increased milling dry grain weight per m², with black-silver mulch resulting in the heaviest milling dry grain weight per m² compared to the no mulch and straw mulch treatments.

In the treatment with no mulch, plant spacings of 20 cm x 20 cm, 30 cm x 30 cm, and 40 cm x 20 cm x 12.5 cm did not significantly increase milling dry grain weight per hectare. For the straw mulch treatment at the 40 cm x 20 cm x 12.5 cm spacing, the milling dry grain weight per hectare was higher compared to the 20 cm x 20 cm spacing. Similarly, the black-silver mulch treatment at the 40 cm x 20 cm x 12.5 cm spacing showed significant results, where this spacing produced the heaviest milling dry grain weight per hectare compared to the 20 cm x 20 cm and 30 cm x 30 cm spacings.

For the 20 cm x 20 cm plant spacing, the application of no mulch, straw mulch, and black-silver mulch did not significantly increase milling dry grain weight per hectare. At the 30 cm x 30 cm spacing, the application of black-silver mulch resulted in a significantly heavier milling dry grain weight per hectare compared to the no mulch and straw mulch treatments. At the 40 cm x 20 cm x 12.5 cm spacing, the black-silver mulch treatment significantly increased milling dry grain weight per hectare, with black-silver mulch resulting in the heaviest milling dry grain weight per hectare compared to no mulch and straw mulch treatments.

In the treatment with no mulch, plant spacings of 20 cm x 20 cm and 40 cm x 20 cm x 12.5 cm had significantly heavier 1000-grain weight compared to the 30 cm x 30 cm spacing. For the straw mulch treatment, plant spacings of 20 cm x 20 cm, 30 cm x 30 cm, and 40 cm x 20 cm x 12.5 cm had no significant effect on 1000-grain weight. However, in the black-silver mulch treatment, the 40 cm x 20 cm x 12.5 cm spacing significantly increased the 1000-grain weight, with this spacing having the heaviest 1000-grain weight compared to the 20 cm x 20 cm spacing.

For the 20 cm x 20 cm and 40 cm x 20 cm x 12.5 cm plant spacings, the application of no mulch, straw mulch, and black-silver mulch did not result in significant differences in 1000-grain weight. However, at the 30 cm x 30 cm spacing, the application of black-silver mulch showed a significant result, where black-silver mulch produced a significantly heavier 1000-grain weight compared to the no mulch and straw mulch treaments.

In the no mulch treatment with plant spacings of 20 cm x 20 cm, 30 cm x 30 cm, and 40 cm x 20 cm x 12.5 cm, there was no significant effect on the albedo value at 110 days after planting (DAP). The straw mulch treatment at the 40 cm x 20 cm x 12.5 cm plant spacing significantly increased the albedo value at 110 DAP compared to the 20 cm x 20 cm plant spacing, while the black-silver mulch treatment at both the 40 cm x 20 cm x 12.5 cm and 30 cm x 30 cm plant spacings significantly increased the albedo value. The 40 cm x 20 cm x 12.5 cm and 30 cm x 30 cm spacings resulted in the highest albedo values at 110 DAP compared to the 20 cm x 20 cm spacing.

For the plant spacings of 20 cm x 20 cm, 40 cm x 20 cm x 12.5 cm, and 30 cm x 30 cm, the application of no mulch, straw mulch, and black-silver mulch had a significant effect. The black-silver mulch treatment at the plant spacings of 20 cm x 20 cm, 30 cm x 30 cm, and 40 cm x 20 cm x 12.5 cm showed the highest albedo values at 110 DAP compared to both the straw mulch and no mulch treatments.

Table 6. Dry Milled Grain Per Clump, Per M2, Per Ha and Weight of 1000 Grains of Graindue to the treatment of various types of mulch and plant layout

Treatment	Milled Dry Grain Per Clump (g.tan-1)			BNJ 5%
	Without Mulch	Straw Mulch	Black Silver Mulch	
20cm x 20cm	23.6 a A	25.67 a A	30.26 a A	15.67
30cm x 30cm	64.95 a B	82.03 b C	90.31 b C	
40 cm x 20 cm x 12.5 cm	68.59 b B	47.58 a B	60.31 b B	
BNJ 5%	11.00			
Treatment	**Dry Milled Paddy Per M2 (g.m2)**			**BNJ 5%**
	Without Mulch	Straw Mulch	Black Silver Mulch	
20cm x 20cm	589.92 a A	641.83 a A	756.42 a A	203.65
30cm x 30cm	584.58 a A	738.25 ab AB	812.75 b A	
40 cm x 20 cm x 12.5 cm	640.00 a A	761.33 a B	965 c B	
BNJ 5%	98.79			
Treatment	**Milled Dry Grain Per ha (ton.ha-1)**			**BNJ 5%**
	Without Mulch	Straw Mulch	Black Silver Mulch	
20cm x 20cm	5.90 a A	6.42 a A	7.56 a A	2.04
30cm x 30cm	5.85 a A	7.38 ab AB	8.13 b A	
40 cm x 20 cm x 12.5 cm	6.40 a A	7.61 a B	9.65 c B	
BNJ 5%	0.99			
Treatment	**Weight of 1000 Grains of Paddy (g)**			**BNJ 5%**
	Without Mulch	Straw Mulch	Black Silver Mulch	
20cm x 20cm	23.82 a B	24.7 a A	24.64 a A	5.01
30cm x 30cm	21.11 a A	23.5 ab A	26.23 b AB	
40 cm x 20 cm x 12.5 cm	23.43 a B	24.12 a A	27.43 a B	
BNJ 5%	2.28			

Description: Numbers followed by different capital letters in the same column and different non-capital letters in the same row indicate significant differences in the 5% HSD test.

Table 7.Albedo 110 Days after planting (DAP) due to the treatment of various types of mulch and plant layout

Treatment	Albedo 110 Hst			BNJ 5%
	Without Mulch	Straw Mulch	Black Silver Mulch	
20cm x 20cm	2.44 a	3.16 b	10.03 c	0.50
	A	A	A	
30cm x 30cm	2.6 a	3.41 b	11.56 c	
	A	AB	B	
40 cm x 20 cm x 12.5 cm	2.66 a	3.55 b	11.4 c	
	A	B	B	
BNJ 5%		0.30		

Description: Numbers followed by different capital letters in the same column and different non-capital letters in the same row indicate significant differences in the 5% HSD test.

In the no mulch treatment with plant spacings of 20 cm x 20 cm, 30 cm x 30 cm, and 40 cm x 20 cm x 12.5 cm, significant effects on temperature changes were observed at 60 days after planting (DAP) at 13:00 WIB, where the no mulch treatment at the 30 cm x 30 cm spacing showed higher temperatures compared to the 20 cm x 20 cm spacing. The straw mulch treatment at the 20 cm x 20 cm, 30 cm x 30 cm, and 40 cm x 20 cm x 12.5 cm plant spacings did not significantly affect the temperature change at 60 DAP at 13:00 WIB. The black-silver mulch treatment at the 30 cm x 30 cm spacing significantly resulted in higher temperatures compared to the 20 cm x 20 cm and 40 cm x 20 cm x 12.5 cm spacings.

For the plant spacings of 20 cm x 20 cm, 30 cm x 30 cm, and 40 cm x 20 cm x 12.5 cm, the application of no mulch, straw mulch, and black-silver mulch showed significant effects, with the black-silver mulch treatment at the 20 cm x 20 cm spacing resulting in the lowest temperature compared to the no mulch treatment. At the 30 cm x 30 cm plant spacing, the application of straw mulch and black-silver mulch significantly resulted in lower temperatures compared to the no mulch treatment. At the 40 cm x 20 cm x 12.5 cm plant spacing, the black-silver mulch treatment significantly resulted in lower soil temperatures compared to the no mulch and straw mulch treatments.

Table 8. Soil Temperature 60 Days after planting (DAP) at 13:00 WIB due to various types of mulch and plant layout

Treatment	Temperature 60 Hst 13:00(o C)			BNJ 5%
	Without Mulch	Straw Mulch	Black Silver Mulch	
20cm x 20cm	28.25b	28.01ab	27.2a	0.87
	A	A	B	
30cm x 30cm	29.57b	28.16a	28.42a	
	B	A	C	
40 cm x 20 cm x 12.5 cm	28.8c	27.79b	26.05a	
	AB	A	A	
BNJ 5%		0.91		

Description: Numbers followed by different capital letters in the same column and different non-capital letters in the same row indicate significant differences in the 5% HSD test.

In the no mulch and straw mulch treatments with plant spacings of 30 cm x 30 cm and 40 cm x 20 cm x 12.5 cm, significant increases in solar energy conversion efficiency (ECE) were observed, with the no mulch and straw mulch treatments at the 30 cm x 30 cm plant spacing showing lower ECE values compared to the 20 cm x 20 cm plant spacing. In contrast, the black-silver mulch treatment at the 20 cm x 20 cm and 40 cm x 20 cm x 12.5 cm plant spacings exhibited higher solar energy conversion efficiency (ECE) compared to the black-silver mulch treatment at the 30 cm x 30 cm spacing.

At the 20 cm x 20 cm and 40 cm x 20 cm x 12.5 cm plant spacings, the application of no mulch, straw mulch, and black-silver mulch showed significant differences in solar energy conversion efficiency (ECE), with the black-silver mulch treatment at both plant spacings resulting in the highest ECE values compared to the no mulch and straw mulch treatments. However, at the 30 cm x 30 cm plant spacing, no significant differences in ECE were observed between the no mulch, straw mulch, and black-silver mulch treatments.

Table 9.Energy Conversion Efficiency (ECE) due to the treatment of various types of mulch and plant layout

Treatment	Energy Conversion Efficiency (ECE)			BNJ 5%
	Without Mulch	Straw Mulch	Black Silver Mulch	
20cm x 20cm	3.56 a	4.22 ab	4.63 b	1.04
	C	C	B	
30cm x 30cm	1.59 a	1.5 a	1.9 a	
	A	A	A	
40 cm x 20 cm x 12.5 cm	2.92 a	3.23 ab	4.24 b	
	B	B	B	
BNJ 5%	0.56			

Description: Numbers followed by different capital letters in the same column and different non-capital letters in the same row indicate significant differences in the 5% HSD test.

Based on Table 10, the Summed Domination Ratio (SDR) percentage of weeds at 14 days after sowing (DAS), the highest Summed Domination Ratio (SDR) percentage was observed in the species (Ipomoea purpurea) under the no mulch and straw mulch treatments with plant spacings of 20 cm x 20 cm, 30 cm x 30 cm, and 40 cm x 20 cm x 12.5 cm. The lowest percentage was observed in the species (Asclepias incarnata L).

Table 10.Summed Dominance Ratio (SDR)on 14 DAP due to the treatment of various types of mulch and plant layout

Summed Dominance Ratio (SDR)				
Species	Relative Density (%)	Relative Frequency (%)	Relative Dominance (%)	SDR (%)
Euphorbia hirta	6.86	16.67	17.53	13.69
Annual Bluegrass	3.92	16.67	13.25	11.28
Cyperus Esculentus	25.49	50.00	6.25	27.25
Hairy Crabgrass	13.73	50.00	5.23	22.99
Ipomoea Purpurea	23.53	83.33	11.18	39.35
Panicum Dichotomiflorum	12.75	33.33	12.6	19.56
Asclepias Incarnata L.	2.94	16.67	8.25	9.29
Diplocyclos Palmatus	10.78	66.67	5.54	27.66

Based on Table 11, the Summed Domination Ratio (SDR) percentage of weeds at 28 days after sowing (DAS), the highest SDR percentage was observed in the species (Ipomoea purpurea) under the no mulch and straw mulch treatments with plant spacings of 20 cm x 20 cm, 30 cm x 30 cm, and 40 cm x 20 cm x 12.5 cm. The lowest percentage was observed in the species (Asclepias incarnata L.).

Based on Table 12, the Summed Domination Ratio (SDR) percentage of weeds at 42 days after sowing (DAS), the highest SDR percentage was observed in the species (Ipomoea purpurea) under the no mulch and straw mulch treatments with plant spacings of 20 cm x 20 cm, 30 cm x 30 cm, and 40 cm x 20 cm x 12.5 cm. The lowest percentage was observed in the species (Asclepias incarnata).

Table 11. Summed Domination Ratio (SDR) on 28 DAP due to the treatment of various types of mulch and plant layout

Species	Relative Density (%)	Relative Frequency (%)	Relative Dominance (%)	SDR (%)
Euphorbia hirta	6.71	16.67	13.69	12.35
Annual Bluegrass	4.03	16.67	11.28	10.66
Cyperus Esculentus	25.50	50.00	27.25	34.25
Hairy Crabgrass	13.42	50.00	22.99	28.80
Ipomoea Purpurea	25.50	83.33	39.35	49.39
Panicum Dichotomiflorum	12.08	33.33	19.56	21.66
Asclepias Incarnata L.	2.68	16.67	9.29	9.55
Diplocyclos Palmatus	10.07	66.67	27.66	34.80

Summed Dominance Ratio(SDR)

Table 12. Summed Domination Ratio (SDR) on 42 DAP due to the treatment of various types of mulch and plant layout

Species	Relative Density (%)	Relative Frequency (%)	Relative Dominance (%)	SDR (%)
Euphorbia hirta	5.67	16.67	13.69	12.01
Annual Bluegrass	4.53	16.67	11.28	10.83
Cyperus Esculentus	24.08	50.00	27.25	33.78
Hairy Crabgrass	14.45	50.00	22.99	29.14
Ipomoea Purpurea	25.21	83.33	39.35	49.30
Panicum Dichotomiflorum	11.33	33.33	19.56	21.41
Asclepias Incarnata L.	2.83	16.67	9.29	9.60
Diplocyclos Palmatus	11.90	66.67	27.66	35.41

Summed Dominance Ratio(SDR)

IV. DISCUSSION

4.1 Application of Mulch and Plant Spacing on the Growth of INPAGO 13 Rainfed Rice

The growth of rice plants, particularly the INPAGO 13 rainfed rice variety, can be observed during the vegetative phase by monitoring the increase in cell number, which results in changes in plant size. During the vegetative phase, rice plants require several factors to grow optimally. Optimizing rice growth can be achieved through mulch application and proper plant spacing arrangements. Rainfed rice plants often face challenges in suppressing weed growth, as weeds tend to thrive in areas with physical and chemical conditions similar to those required by rice plants. Weeds generally grow well in moist soil, warm temperatures, and adequate sunlight, which are also ideal conditions for rice growth. Therefore, effective weed control strategies are essential for improving rainfed rice productivity.

Weed observations shown in Tables 10 to 12 indicate that the application of silver-black mulch did not result in significant weed growth, unlike straw mulch and no mulch treatments. Overall, it can be concluded that the use of mulch helps suppress weed growth. Weeds in straw mulch treatments were caused by the relatively thin straw layer and the influence of strong winds, which created gaps where weeds could grow. The application of straw mulch and silver-black mulch, on the other hand, differs in terms of the light wavelengths reflected. Observations of weeds at 14, 28, and 42 days after sowing (DAS) showed dominance of species *Cyperus esculentus* and *Ipomoea purpurea*. Mulch also plays a role in controlling weeds and improving nutrient availability, both of which contribute to an increase in the number of tillers and leaves (Osman et al., 2020). The increase in the number of tillers and leaves in INPAGO 13 rice plants with silver-black mulch can also be explained through physiological mechanisms. Studies have shown that mulch can enhance photosynthesis and light-use efficiency, which are important for biomass production (Doni et al., 2014). Thus, the use of silver-black mulch not only increases plant height but also improves the plant's ability to produce tillers and leaves, which are key indicators of potential rice yield (Afrin et al., 2017). Overall, this study suggests that applying silver-black mulch in the cultivation of INPAGO 13 rainfed rice can be an effective strategy to enhance plant growth and yield.

Rainfed rice is typically planted with relatively tight spacing to minimize the space available for weeds to grow between plants, thus requiring optimization of plant spacing, which also impacts productivity. However, overly dense planting can negatively affect rice plant growth, as competition for light, water, and nutrients intensifies. Therefore, it is crucial to optimize plant spacing to not only reduce weed growth but also improve rainfed rice productivity. Additionally, the use of superior varieties resistant to biotic and abiotic stresses can also contribute to weed control and increased yield.

In general, weed control in rainfed rice cultivation requires a holistic approach, which includes selecting the appropriate variety, optimizing plant spacing, and applying good land management practices. By doing so, the productivity of rainfed rice can be significantly improved, which in turn will support food security in areas dependent on rice as a primary carbohydrate source.

The results of this study show that the plant height of INPAGO 13 rice (Table 1) with the silver-black mulch treatment was higher than the no mulch and straw mulch treatments. As for the number of tillers (Table 2) and leaves (Table 3), the silver-black mulch treatment significantly increased both the number of tillers and leaves in the INPAGO 13 rice plants. The effect of mulch on the growth of INPAGO 13 rice plants indicates that the use of silver-black mulch can significantly enhance plant height, the number of tillers, and the number of leaves compared to no mulch and straw mulch treatments. This aligns with findings that show mulch can improve microclimate conditions, thereby meeting the light requirements of plants and supporting better vegetative growth (Hidayat et al., 2019; Regmi et al., 2021).

In the context of plant growth, silver-black mulch helps regulate soil moisture and temperature, as shown in Table 8, which is crucial for early plant growth. Research indicates that mulch can reduce irrigation needs and improve microclimate conditions, which contribute to enhanced plant growth (Karki et al., 2020). The use of mulch not only reduces irrigation requirements but also improves the microclimate around the plants, contributing to better plant growth (Lin et al., 2023). By reducing excessive soil temperature, silver-black mulch creates a better environment for root growth and the absorption of water and nutrients, which in turn supports optimal plant growth (Ryan et al., 2021).

At noon, 13:00 WIB, when sunlight intensity is at its peak, the effect of mulch, especially silver-black mulch that reflects light, on soil temperature becomes more evident, as soil exposed to direct sunlight heats up more quickly. At 60 DAS, the plants are larger and more developed with more leaves, which can increase shade and interaction with sunlight. At this stage, the plants can block most of the sunlight, particularly during the peak sunlight hours of 13:00 WIB. This may accentuate the temperature differences more than at younger stages (30 DAS) or older stages (90 DAS), when plants might begin to reduce photosynthetic activity as they approach the reproductive phase.

Overall, the application of silver-black mulch and optimal plant spacing is an important strategy for enhancing the growth of rainfed rice. Further research is needed to explore the interactions between mulch usage and plant spacing in a broader context, as well as to understand the mechanisms underlying the impact of mulch on microclimate conditions and plant growth.

Plant height and the number of tillers are crucial factors in determining rice yield. Optimal plant height and an adequate number of tillers can increase the productivity of rainfed rice (Sinaga et al., 2021). This study shows that rainfed rice varieties grown with proper plant spacing result in better plant height and a higher number of tillers, contributing to better panicle length and higher grain yield. In this context, proper plant spacing not only affects plant height and the number of tillers but also the length of the panicles (Krismiratsih et al., 2022). Therefore, correct plant spacing, alongside other factors such as fertilization and water management, is crucial for enhancing rainfed rice yield.

The application of mulch with plant spacing shown in Table 1 indicates that silver-black mulch with a plant spacing of 30 cm x 30 cm (M2T2) and silver-black mulch with a plant spacing of 40 cm x 20 cm x 12.5 cm (M2T3) significantly increased plant height, resulting in taller plants compared to other treatments. For the number of tillers (Table 2) and the number of leaves (Table 3), the silver-black mulch with a plant spacing of 40 cm x 20 cm x 12.5 cm (M2T3) was higher compared to other treatments. This can be explained by the role of mulch and proper plant spacing, which affect soil temperature and moisture. Silver-black mulch enhances plant growth by regulating soil temperature and moisture, which are critical for vegetative growth (Silmi & Chozin, 2015). Mulch functions to retain soil moisture and reduce temperature fluctuations, ultimately supporting root growth and improving nutrient absorption (Bakri, 2023).

The treatment with silver-black mulch and a plant spacing of 40 cm x 20 cm x 12.5 cm (M2T3) showed higher increases in the number of tillers and leaves compared to other treatments. This can be explained by the fact that denser plant spacing increases competition among plants for light, contributing to enhanced photosynthesis and biomass production (Sumekar et al., 2018). Previous studies have also shown that the use of mulch increases light-use efficiency in plants, which is important for tiller and leaf growth (Juniati, 2023). Additionally, mulch helps suppress weed growth, minimizing competition for nutrients. The positive effects of silver-black mulch can also reduce weed growth, which often competes with plants for resources such as light, water, and nutrients (Slamet, 2023). By reducing weed competition, INPAGO 13 rainfed rice plants can focus more on the growth and development of tillers and leaves, ultimately improving harvest yield (Ismadi et al., 2021). Overall, the application of silver-black mulch with proper plant spacing not only increases plant height but also the number of tillers and leaves, which are essential indicators of productivity in INPAGO 13 rainfed rice.

Leaf Area Index (LAI) is an important parameter for evaluating how effectively plants absorb sunlight for photosynthesis. The LAI results shown in Table 5 demonstrate significant differences based on mulch type. The application of silver-black mulch resulted in a higher leaf area index compared to no mulch and straw mulch treatments. This is influenced by the high albedo value of silver-black mulch, as shown in Tables 8 and 9. The high albedo value maximizes photosynthesis by reflecting sunlight onto parts of the leaves not directly exposed to sunlight. The application of different plant spacings also affects the leaf area index. The plant spacing of 40 cm x 20 cm x 12.5 cm showed a higher leaf area index compared to 20 cm x 20 cm and 30 cm x 30 cm spacings. The use of silver-black mulch enhances this efficiency due to its high albedo value. Albedo refers to the surface's ability to reflect light, and in the case of silver-black mulch, reflected light helps areas of the plant not directly exposed to sunlight to still receive light, enhancing photosynthesis.

Denser plant spacing can cause leaf shading, reducing photosynthesis efficiency. In this context, research by Arogundade indicated that the appropriate use of mulch can mitigate the negative effects of shading by improving light penetration to the leaf surface (Arogundade et al., 2019). Additionally, mulch functions to maintain soil moisture and reduce soil temperature, contributing to better plant growth (Indarwati, 2024).

With denser plant spacing, such as 40 cm x 20 cm x 12.5 cm, plants compete more intensely for light. Overcrowded spacing can cause leaves to be obstructed by neighboring plants, reducing the number of leaves capable of photosynthesizing effectively. Therefore, optimal plant spacing is crucial to ensure all leaves receive maximum light. The close spacing also results in leaf shading, where shaded leaves do not engage in photosynthesis and instead use photosynthates for respiration. Proper plant spacing can enhance plant growth by minimizing shading between leaves, thus improving photosynthesis efficiency (Singh et al., 2020).

4.2 Application of Mulch and Plant Spacing on the Yield of INPAGO 13 Rainfed Rice

The application of silver-black mulch in the cultivation of INPAGO 13 rainfed rice has shown significant results in increasing the dry weight of plants per hill. As shown in Table 6, plants treated with silver-black mulch have higher dry weight compared to those without mulch and those treated with straw mulch. Previous studies have indicated that the use of mulch, especially reflective types like silver-black mulch, can influence plant growth by regulating soil temperature and moisture, as well as reducing competition with weeds (Machanoff et al., 2022; Regmi et al., 2021; Iqbal et al., 2020). Furthermore, plant spacing also plays an important role in plant growth. In this study, the 40 cm x 20 cm x 12.5 cm spacing resulted in higher dry weight compared to 20 cm x 20 cm and 30 cm x 30 cm spacings. This may be due to the increased space for root growth and better access to resources such as water and nutrients (Kusdiana et al., 2018; Nyochembeng & Mankolo, 2021). Research by Nyochembeng and Mankolo also suggests that proper plant spacing can enhance plant performance by maximizing light reception and reducing plant competition (Nyochembeng & Mankolo, 2021).

The combination of silver-black mulch and optimal plant spacing can create a better microclimate, which supports photosynthesis and vegetative growth. Thakur et al. (2019) found that mulch can enhance essential oil composition and crop yields, contributing to higher dry weight. Additionally, silver-black mulch can assist in pest and disease control, further improving harvest outcomes (Agus et al., 2020). Overall, the application of silver-black mulch with a 40 cm x 20 cm x 12.5 cm plant spacing proved to be more effective in increasing the dry weight of plants compared to other treatments. This highlights the importance of selecting the right mulch type and spacing configuration to optimize crop yields.

The application of mulch with a 30 cm x 30 cm plant spacing was found to be more effective in increasing the milling dry grain weight per hill compared to other treatments. This can be explained through several factors that contribute to increased harvest yield. First, the use of mulch, especially silver-black mulch, improves soil moisture retention and reduces evaporation, which is crucial in supporting rice plant growth (Nurhafsah, 2021). Mulch usage can also reduce competition with weeds, allowing rice plants to grow more optimally and produce higher grain weights (Gunaeni et al., 2022). Second, the proper plant spacing, such as the 30 cm x 30 cm layout, provides sufficient space for plant development. A wider spacing allows the plant roots to access more resources, including water and nutrients, contributing to better growth and higher grain yield. Optimal spacing can increase the number of tillers and grain weight per hill, as aligned with findings in this study (Haq, 2024). Additionally, the combination of mulch and proper plant spacing can create a better microclimate, which enhances photosynthesis and vegetative growth. Research by Zuliati et al. (2020) demonstrated that mulch can improve the availability of water and nutrients, which is essential during the rice growth phase. This contributes to the increase in milling dry grain weight per hill, as healthy and strong plants tend to produce more grains.

The parameters for milling dry grain weight per m², milling dry grain weight per hectare, and 1000-grain dry weight, shown in Table 7, indicate that the application of silver-black mulch with a 40 cm x 20 cm x 12.5 cm plant spacing significantly improves milling dry grain weight per m², milling dry grain weight per hectare, and 1000-grain dry weight. The use of silver-black mulch helps regulate soil temperature and moisture, which are vital during the rice growth phase. The use of mulch improves soil moisture retention, allowing rice plants to access water more effectively, contributing to increased grain yields (Paiman, 2022).

The application of optimal plant spacing, such as in the 40 cm x 20 cm x 12.5 cm treatment, provides ample space for plant development. Wider spacing allows the plant roots to access more resources, including water and nutrients, thus enhancing growth and grain yield. Proper plant spacing can increase the number of tillers and grain weight per m² (Yuniansyah et al., 2022). Furthermore, silver-black mulch also reduces competition with weeds, which is a key factor that can hinder rice plant growth. Effective weed control can significantly improve plant growth and yield (Sumekar & Widayat, 2022). By reducing weed competition, rice plants can maximize resource use, leading to higher grain weights.

The application of silver-black mulch with a 40 cm x 20 cm x 12.5 cm plant spacing also shows a positive correlation between yield components, such as panicle length and grain weight per panicle, with the appropriate treatments in rice cultivation (Afa et al., 2021). This indicates that good agronomic management, including the use of mulch and proper plant spacing, can contribute to increased productivity of INPAGO 13 rainfed rice overall. The application of silver-black mulch with a 40 cm x 20 cm x 12.5 cm plant spacing has proven to be more effective in improving milling dry grain weight per m², milling dry grain weight per hectare, and 1000-grain dry weight. This underscores the importance of selecting the right mulch type and plant spacing configuration to achieve optimal yields in rice cultivation.

4.3 Application of Mulch and Plant Spacing on Solar Energy Conversion Efficiency (EKE) in INPAGO 13 Rainfed Rice

The results on Solar Energy Conversion Efficiency (EKE) in INPAGO 13 rainfed rice, presented in Table 14, indicate that the application of silver-black mulch with plant spacing of 20 cm x 20 cm and 40 cm x 20 cm x 12.5 cm exhibited higher EKE values compared to other treatments. The use of silver-black mulch enhances the efficiency of solar energy utilization by reflecting light back onto the plants, thereby increasing the light intensity received by the leaves. Studies have shown that mulch can improve soil physical properties, such as water retention and porosity, which contribute to better plant growth and higher crop yields (Haryati & Erfandi, 2019; Nurdin et al., 2019). Additionally, mulch helps reduce water evaporation from the soil surface, which is crucial in dryland conditions, enabling plants to use water more efficiently (Arifin & Saeri, 2020). Mulch serves as a soil conditioner that improves crop yields, suggesting that the combination of these treatments can produce a synergistic effect (Haryati & Erfandi, 2019). In the context of INPAGO 13 rainfed rice, the optimal planting distances of 20 cm x 20 cm and 40 cm x 20 cm x 12.5 cm also contribute to energy conversion efficiency, as proper spacing allows each plant adequate access to light and nutrients.

The application of silver-black mulch with plant spacing of 20 cm x 20 cm and 40 cm x 20 cm x 12.5 cm effectively converts solar energy into dry plant matter. According to Suryanto (2018), a plant's ability to produce dry matter is influenced by the solar energy absorbed by the leaves. The application of mulch significantly affects plant growth, as evidenced by increases in plant height and leaf number (Nurdin et al., 2019). This suggests that mulch not only acts as a soil protector but also as a factor that supports better vegetative growth, which in turn improves EKE. According to Burke (2017), while high EKE values do not directly increase crop production, they are typically associated with higher rates of photosynthesis. Overall, the application of silver-black mulch in INPAGO 13 rainfed rice not only enhances the efficiency of solar energy conversion but also supports better plant growth through moisture management and optimization of the photosynthesis process.

V. CONCLUSION ALND SUGGESTIONS

5.1 Conclusion

1. The application of mulch on INPAGO 13 rainfed rice can significantly improve albedo values, as confirmed in this study. Mulch, particularly reflective types such as silver-black mulch, can reflect sunlight back onto the plants, thereby increasing the amount of light received by the leaf surface, especially the parts not directly exposed to sunlight. This increase in albedo helps improve photosynthetic efficiency by reflecting more light to the areas of the plant that need it.

2. The application of mulch can also effectively reduce weed populations and maintain soil moisture, which has been proven in this study. Mulch, especially organic or plastic types, serves as a barrier that reduces the intensity of sunlight reaching the soil surface, thereby inhibiting weed germination and growth. Thus, the use of mulch can effectively reduce competition between the main crop and weeds for light, water, and nutrients. Additionally, mulch plays an important role in maintaining soil moisture by reducing evaporation from the soil surface. This helps retain the moisture necessary for plant growth, especially during dry seasons or in soils that tend to dry out.

3. The application of plant spacing can enhance plant populations and maximize rainfed rice productivity, as evidenced by the findings. Optimal plant spacing provides sufficient space for each plant to grow well, allowing the plants to access adequate light, water, and nutrients without excessive competition. Proper spacing also allows for better root spread and minimizes the possibility of shading between plants, which can reduce photosynthetic efficiency. Therefore, proper plant arrangement can increase plant density without sacrificing growth, ultimately supporting increased productivity and maximizing rainfed rice yields.

5.2 Suggestions

Further research For the plastic mulch treatment, it is recommended to plant more rice seeds in each planting hole, about 7 to 10 seeds per hole. After planting the rice seeds, rice husk ash should be applied to stabilize soil temperature and moisture, ensuring optimal plant growth. Although the results of this study demonstrate significant benefits from mulch and plant spacing, further research is needed to explore the long-term effects of these factors, such as the potential increase in microplastics in the soil, which could hinder plant growth.

REFERENCES

[1] Afa, L., Suaib, S., Uge, I., Anas, A., & Maisura, M. (2021). Korelasi antara hasil dan komponen hasil beberapa kultivar padi gogo (Oryza sativa L.) lokal Sulawesi Tenggara pada dua sistem budidaya. Jurnal Agrium, 18(1). https://doi.org/10.29103/agrium.v18i1.3836

[2] Afrin, W., Hossain, M., & Islam, M. (2017). Evaluation of yield and yield contributing traits for submergence tolerance of rice. Progressive Agriculture, 28(1), 7-11. https://doi.org/10.3329/pa.v28i1.32851

[3] Agus, N., Saubil, A., Jumardi, J., Rasyid, B., Siriniang, A., Nasruddin, A., … & Kershaw, D. (2020). Effects of mulch type, plant cultivar, and insecticide use on sweet potato whitefly population in chili pepper. Scientifica, 2020, 1-7. https://doi.org/10.1155/2020/6428426

[4] Arifin, Z., & Saeri, M. (2020). Pengelolaan air dan mulsa pada tanaman bawang merah di lahan kering (water management and mulch on shallot in dry land). Jurnal Hortikultura, 29(2), 159. https://doi.org/10.21082/jhort.v29n2.2019.p159-168

[5] Arogundade, O., Salawu, A., Osijo, A., & Kareem, K. (2019). Influence of mulching on virus disease incidence, growth, and yield of sweet pepper (Capsicum annuum). Poljoprivreda, 25(2), 38-44. https://doi.org/10.18047/poljo.25.2.6

[6] Aryani, I., & Riskawati, S. S. (Year). Analysis of plant vegetation in Sekipan Forest Tawangmangu District, Karanganyar District. Biology Education Department, Faculty of Teacher Training and Education, Universitas Muhammadiyah Surakarta.

[7] Bakri, F. (2023). Pengaruh ketebalan mulsa jerami padi dan jarak tanam terhadap pertumbuhan dan hasil tanaman kacang hijau (Vigna radiata L.). Berkala Ilmiah Agroteknologi - Plumula, 11(2), 164-178. https://doi.org/10.33005/plumula.v11i2.206

[8] Burke, J. J. (2017). Growing the Potato Crop. Vita, Equity House, Upper Ormond Quay, Dublin 7.

[9] Doni, F., Isahak, A., Zain, C., & Yusoff, W. (2014). Physiological and growth response of rice plants (Oryza sativa L.) to Trichoderma spp. inoculants. AMB Express, 4(1). https://doi.org/10.1186/s13568-014-0045-8

[10] Gunaeni, N., Wulandari, A., & Gaswanto, R. (2022). Pengaruh tumpangsari cabai dan tomat terhadap perkembangan hama utama dan hasil cabai (Capsicum annuum L.). Jurnal Agro, 8(1), 37-47. https://doi.org/10.15575/16028

[11] Gunaeni, N., Wulandari, A., & Gaswanto, R. (2022). Pengaruh tumpangsari cabai dan tomat terhadap perkembangan hama utama dan hasil cabai (Capsicum annuum L.). Jurnal Agro, 8(1), 37-47. https://doi.org/10.15575/16028

[12] Haq, A. (2024). Jarak tanam dan dosis pupuk nitrogen memengaruhi pertumbuhan dan hasil padi ketan grendel (Oryza sativa L. var. Glutinosa). Buletin Agrohorti, 12(1), 21-29. https://doi.org/10.29244/agrob.v12i1.51579

[13] Haryati, U., & Erfandi, D. (2019). Improving soil properties and increasing shallot bulb yield by mulching and soil amendment application. Jurnal Hortikultura Indonesia, 10(3), 200-213. https://doi.org/10.29244/jhi.10.3.200-213

[14] Haryati, U., & Erfandi, D. (2019). Improving soil properties and increasing shallot bulb yield by mulching and soil amendment application. Jurnal Hortikultura Indonesia, 10(3), 200-213. https://doi.org/10.29244/jhi.10.3.200-213

[15] Hidayat, R., Susanti, H., & Adriani, D. (2019). The effect of various types of mulch on the growth and yield of Dayak onions (Eleutherine palmifolia (L.) Merr). Tropical Wetland Journal, 5(2), 63-69. https://doi.org/10.20527/twj.v5i2.76

[16] Indarwati, L. (2024). Response of growth and yield of Samhong King curly mustard greens (Brassica juncea L.) to land tillage and differences in mulch application. Jurnal Agronomi Tanaman Tropika (Juatika), 6(1), 164-172. https://doi.org/10.36378/juatika.v6i2.3571

[17] Iqbal, R., Raza, M., Valipour, M., Saleem, M., Zaheer, M., Ahmad, S., … & Nazar, M. (2020). Potential agricultural and environmental benefits of mulches—a review. Bulletin of the National Research Centre, 44(1). https://doi.org/10.1186/s42269-020-00290-3

[18] Ismadi, I., Yani, N., Hafifah, H., Rosnina, R., & Nazaruddin, M. (2021). Pengaruh jenis mulsa dan aplikasi pupuk organik cair terhadap pertumbuhan dan hasil tanaman kentang (Solanum tuberosum L.). Jurnal Agrium, 18(1). https://doi.org/10.29103/agrium.v18i1.3846

[19] Juniati, J. (2023). Pemanfaatan limbah pertanian sebagai mulsa dan kompos dalam peningkatan pertumbuhan dan produksi tanaman kacang tanah (Arachis hypogaea L.). Jurnal Agrotek Tropika, 11(2), 235. https://doi.org/10.239

[20] Karki, A., Sapkota, B., Bist, P., Bista, K., Dutta, J., Marahatta, S., … & Shrestha, B. (2020). Mulching materials affect growth and yield characters of cucumber (Cucumis sativus cv. Malini) under drip irrigation condition in Chitwan, Nepal. Journal of Agriculture and Forestry University, 4(1), 153–159. https://doi.org/10.3126/jafu.v4i1.47061

[21] Krismiratsih, F., Soelaksini, L., & Abidin, Z. (2022). Aplikasi kompos jerami dan teknik pengaturan air terhadap pertumbuhan dan hasil tanaman padi. Buletin Poltanesa, 23(2). https://doi.org/10.51967/tanesa.v23i2.1856

[22] Kusdiana, D., Hadist, I., & Herawati, E. (2018). Pengaruh jarak tanam terhadap tinggi tanaman dan berat segar per rumpun rumput gajah odot (Pennisetum purpureum cv. Mott). Janhus Jurnal Ilmu Peternakan Journal of Animal Husbandry Science, 1(2), 32. https://doi.org/10.52434/janhus.v1i2.245

[23] Lin, C., Hur, J., Zhang, M., Zhang, Y., Zhang, L., Huang, Z., … & Li, W. (2023). Alleviating heat stress and water scarcity in cultivation with biodegradable radiative cooling mulch. https://doi.org/10.21203/rs.3.rs-2922832/v1

[24] Machanoff, C., Vann, M., Woodley, A., & Suchoff, D. (2022). Evaluation of the use of polyethylene mulches in the production of organic flue-cured tobacco. Agronomy Journal, 114(4), 2501–2517. https://doi.org/10.1002/agj2.21100

[25] Malik, A. (2017). Prospek pengembangan padi gogo: Perspektif kebijakan dan implementasi di lapangan. IAARD Press. Jakarta.

[26] Nurdin, M., Khaidir, K., & Munazar, M. (2019). Peranan mulsa dan pupuk organik terhadap pertumbuhan dan hasil kacang tanah (Arachis hypogaea L.). Jurnal Agrium, 16(1), 52. https://doi.org/10.29103/agrium.v16i1.134

[27] Nurhafsah, N. (2021). Produksi cabai merah hibrida dan non-hibrida dengan penggunaan mulsa hitam perak. Jurnal Galung Tropika, 10(2), 165-173. https://doi.org/10.31850/jgt.v10i2.740

[28] Nurhafsah, N. (2021). Produksi cabai merah hibrida dan non-hibrida dengan penggunaan mulsa hitam perak. Jurnal Galung Tropika, 10(2), 165-173. https://doi.org/10.31850/jgt.v10i2.740

[29] Nyochembeng, L. and Mankolo, R. (2021). Colored plastic mulch effects on plant performance and disease suppression in organically grown bell pepper (capsicum annuum). Journal of Agricultural Science, 13(6), 11. https://doi.org/10.5539/jas.v13n6p11

[30] Osman, K., Kang, K., El-Siddg, A., Ahmed, Y., & Abdalla, S. (2020). Assessment of genetic variability for yield and attributed traits among rice doubled haploid (DH) lines in semi-arid zone Sudan. African Journal of Agricultural Research, 16(7), 939-946. https://doi.org/10.5897/ajar2019.14496

[31] Paiman, P. (2022). Memaksimalkan hasil padi salibu menggunakan pupuk urea dan pupuk NPK. Jurnal Ilmiah Agrineca, 22(1), 1-8. https://doi.org/10.36728/afp.v22i1.1633

[32] Regmi, R., Bhusal, N., & Neupane, S. (2021). Efficacy of mulching materials on growth performance and yield characters of summer squash (Cucurbita pepo cv Shlesha 1214) in Mahottari, Nepal. International Journal for Research in Applied Sciences and Biotechnology, 8(1), 57-63. https://doi.org/10.31033/ijrasb.8.1.7

[33] Rhauf, A. A., Suryanto, A., & Nurlaelih, E. E. (2022). The effect of plant spacing and number of seedlings on purple rice (Oryza sativa L.) cv. Black Madras. The 2022 Brawijaya International Conference: Green Economy in Building a Resilient Society. Bali, Indonesia, 7th and 8th October 2022.

[34] Ryan, M., Wayman, S., Pelzer, C., Peterson, C., Menalled, U., & Rose, T. (2021). Winter wheat (Triticum aestivum L.) tolerance to mulch. Plants, 10(10), 2047. https://doi.org/10.3390/plants10102047

[35] Silmi, F., & Chozin, M. (2015). Pemanfaatan biomulsa kacang hias (Arachis pintoi) pada budidaya jagung manis (Zea mays saccharata Sturt.) di lahan kering. Jurnal Hortikultura Indonesia, 5(1), 1-9. https://doi.org/10.29244/jhi.5.1.1-9

[36] Sinaga, A., Konyep, S., Witman, S., & Sunante, I. (2021). Penampilan dan produksi padi ladang lokal varietas 100 malam. Jurnal Agrisistem, 17(2), 115-119. https://doi.org/10.52625/j-agr.v17i2.216

[37] Singh, R., Bajpai, D., & Sharma, A. (2020). Impact of mulch, spacing and fertilizer on growth, yield and economics of broccoli (Brassica oleracea L. var. italica)

under crop cafeteria in Narsinghpur district M.P. International Journal of Chemical Studies, 8(3), 117-122. https://doi.org/10.22271/chemi.2020.v8.i3b.9212

[38] Slamet. (2023). Pengaruh jenis mulsa dan pupuk kandang terhadap pertumbuhan dan hasil kacang tanah (Arachis hypogeae L.). Jurnal Pertanian Presisi (Journal of Precision Agriculture), 7(2), 94-104. https://doi.org/10.35760/jpp.2023.v7i2.8871

[39] Sumekar, Y., & Widayat, D. (2022). Pengaruh dosis herbisida campuran penoksulam dan pretilaklor terhadap gulma, pertumbuhan dan hasil padi sawah. Agrivet Jurnal Ilmu-Ilmu Pertanian Dan Peternakan (Journal of Agricultural Sciences and Veteriner), 10(2). https://doi.org/10.31949/agrivet.v10i2.2886

[40] Sumekar, Y., Mutakin, J., & Rabbani, Y. (2018). Keanekaragaman gulma dominan pada pertanaman tomat (Lycopersicum esculentum Mill) di Kabupaten Garut. Jagros Jurnal Agroteknologi Dan Sains (Journal of Agrotechnology Science), 1(2), 67. https://doi.org/10.52434/jagros.v1i2.308

[41] Suryanto, A. (2018). Upaya peningkatan efisiensi konversi energi matahari pada tanaman padi (Oryza sativa L.), jagung (Zea mays L.) dan kentang (Solanum tuberosum L.). Monograf. UM Pres.

[42] Thakur, M., Bhatt, V., & Kumar, R. (2019). Effect of shade level and mulch type on growth, yield and essential oil composition of damask rose (Rosa damascena Mill.) under mid-hill conditions of western Himalayas. PLOS ONE, 14(4), e0214672. https://doi.org/10.1371/journal.pone.0214672

[43] Wang, Y., Liu, S., & Shi, H. (2023). Comparison of climate change impacts on the growth of C3 and C4 crops in China. Ecological Informatics, 74, 101968. https://doi.org/10.1016/j.ecoinf.2022.101968

[44] Yuniansyah, Y., Darmawan, A., Suparto, S., & Suyanto, A. (2022). Cangkang telur dan air leri sebagai nutrisi hidroponik DFT (deep flow technique) bagi pertumbuhan bayam merah dan bayam hijau. Savana Cendana, 7(4), 65-68. https://doi.org/10.32938/sc.v7i04.1883

[45] Zhao, X. D., Qin, X. R., Li, T. L., Cao, H. B., & Xie, Y. H. (2023). Effects of planting patterns plastic film mulching on soil temperature, moisture, functional bacteria, and yield of winter wheat in the Loess Plateau of China. Journal of Integrative Agriculture, 22(5), 1560–1573. https://doi.org/10.1016/j.jia.2023.02.026

[46] Zuliati, S., Sulistyono, E., & Purnamawati, H. (2020). Pengaruh pemberian mulsa dan irigasi pada pertumbuhan dan hasil bawang merah (Allium cepa L. var. agregatum). Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy), 48(1), 52-58. https://doi.org/10.24831/jai.v48i1.29191

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Isolation and characterization of *Candida tropicalis* from mixed fruit wastes for bio-ethanol production

Dharaneesh T[1]*, Lokeshwaran TR[2], Kalaivanan V[1], Harish Kumar T[1], Sharan K[3] and Nismal Aswin A[4]

[1]Third year 2021 batch, Don Bosco College of Agriculture, Sagayathottam, Ranipet, Tamil Nadu, India
[2]Forth year 2020 batch, Don Bosco College of Agriculture, Sagayathottam, Ranipet, Tamil Nadu, India
[3]Assistant professor, Department of Agricultural Microbiology, Don Bosco college of Agriculture, Sagayathottam, Ranipet, Tamil Nadu, India
[4]Assistant professor, Department of Agricultural Microbiology, College of Agricultural Sciences, Sri Manakula Vinayagar College, Madagadipet, Puducherry, Tamil Nadu, India

Received: 18 Aug 2024; Received in revised form: 13 Sep 2024; Accepted: 18 Dec 2024; Available online: 24 Dec 2024

***Abstract*— *The bioethanol production from the biomass is gaining popularity now-a-days all over the world. The bio-ethanol is produced by the process of fermentation of starch, sugars of fruit wastes. Bioethanol can be utilized as bio-fuel for the transport purpose, sanitizer production. Compared to any other sources for bio ethanol production, mixed fruit wastes were cheaper. The present study focussed on utilization of the fruit wastes which are discarded from the local fruit shops and fresh juice shops for the bioethanol production. Mixed fruit wastes were collected and used as the raw material for the bioethanol production takes place via., Candida tropicalis. Yeast is the common species for bio-ethanol, alcohol, biofuel, wine and cider fermentation and conversion of biomass into ethanol. The mixed fruit waste can be converted into biofuel which can acts as an alternative source of bio-ethanol.*

***Keywords*— Bioethanol, Yeast isolates, mixed fruit wastes, Candida tropicalis**

I. INTRODUCTION

Because it is environmentally beneficial, bioethanol has attracted a lot of attention as a substitute energy source. The current industry and academics' top priority is to develop cost-effective technology for bioethanol production. Cost-effective technology is influenced by the following factors: quick and efficient conversion of carbohydrates to ethanol.

This study was conducted to manufacture bioethanol using economical and environmentally acceptable methods for use as a sanitizer in the current COVID-19 pandemic scenario. Also, bioethanol is a suitable commercial product because it is a petroleum-free substance that may be easily produced from agricultural feedstock or fruit and juice waste. In the study, KMnO4 (5%) was derived from the waste of various fruits and fruit juices (Chitranshi and Kapoor, 2021).

Based on phylogenetic research and nucleotide homology, the sample that was initially identified as yeast was really Candida tropicalis, which demonstrated a high degree of resemblance during the fermentation process. Desirable fermentation characteristics were found in Candida tropicalis strains that were isolated from mixed fruit wastes. Without using the saccharification phase, bioethanol was produced using *C. tropicalis*, both free and immobilized in calcium alginate. There are few reports of *C. tropicalis* strains being employed as ethanol-producing ones, despite the fact that C. tropicalis has the potential to be a valuable agent in the commercial production of bioethanol. This research study has been reported as the pioneer work in bioethanol production by *Candida tropicalis* in mixed fruit wastes (Hermansyah *et al.*, 2015). All the selected over ripened fruit wastes were analysed for variations in parameters like stress, thermal, osmatic, exogenous ethanol tolerance, invertase activity, ADH activity, including levels of inoculum, pH and temperature concentration in complete fermentation of bioethanol production.

II. METHODS AND MATERIALS

Sample collection and isolation of yeast isolates

The mixed fruit wastes were collected from shops from different locations of Chidambaram town. Collected samples were surface sterilized by using 5% Potassium permanganate ($KMnO_4$) and rinsed with sterile water thoroughly. Individual samples were pulverized in a mixer and collected in 1 litre conical flask, sealed with a cotton stopper and covered with aluminium foil for two weeks to ferment naturally. Malt Yeast Agar (MYA) was the media that was made with 3.0g of malt extract, 3.0g of yeast extract, 5.0g of peptone, 10.0g of glucose (dextrose), 20.0g of agar, and a final pH of 6.2±0.2 at 25°C. Following the completion of the fermentation process, the cultures were separated using the pour plate method and incubated for 48 hours at 25–30 degrees Celsius.

Designation of yeast isolates isolated from mixed fruit wastes

The mixed fruit wastes were isolated from various fruit juice shops of Chidambaram town, were designated as Yi-1, Yi-2, Yi-3, Yi-4, Yi-5 sequentially.

Morphological characterization of yeast isolates

The yeast isolates were recognized depending on their Visual traits and Biochemical assays. After 48 hours of growth, the morphological parameters were observed for each yeast colony comprised colony appearance, texture, margin, shape, size, form, height, extremity, visual properties, regularity, colony facet, and tint, multilateral budding, sediment, pseudohypha, pellicle and ascospore formation.

Biochemical characterization of yeast isolates

Urease test

A tiny amount of 24-hour-old culture was transferred, and after 48 hours at 30 degrees Celsius, it was inoculated in urease agar; the appearance of a reddish-pink color indicated a successful outcome. (Tambuwa *et al.*, 2018).

Carbohydrate fermentation and assimilation test

The ability of a culture to ferment sugars with the production of gas and acid was tested using sugar. A peptone water medium containing 1% fermentable sugar and 0.1 % phenol red was used to make sugar indicator broth. Ten milliliters of sugar broth were added to each test tube, and the Durham tube—which would catch any gas that could form—was gently inverted. A loopful of the 48-hour-old yeast cultures was autoclaved and used to inoculate the test tubes. The tubes were then cultured for two to seven days at 36°C, with daily checks for the production of gas and acid. The generation of acid is shown by the yellow coloration, and the displacement of the medium in the Durham tube indicates the production of gas. All the yeast spp. were tested for the utilization and assimilation of carbon sources (A Reddick, 1975).

Efficiency tests of yeast isolates

All ten isolates of yeast obtained from the mixed fruit waste samples were screened for their bioethanol production.

Thermal tolerance

Five milliliters of phosphate buffer were added to a test tube containing one milliliter of each of the chosen yeast isolates. The suspension was kept in a water bath set at different temperatures *viz,* 35º, 40º, 45º, 50º, 55º and 60ºC. The test tubes were removed and rapidly cooled after 20 minutes of exposure. Then, 1 mL of sample from each tube was serially diluted and plated on MYA medium, to determine the viability of yeast cells respectively.

Osmotic tolerance

At various temperatures, one mL of the selected yeast cells isolates was examined. Each thermally equilibrated cell pellet was then immediately combined with glycerol solution at the same temperature. Cell viability was tested in MYA medium, and the cells were slowly reheated to ambient temperature (25ºC) for 15 minutes and rehydrated by adding water (25ºC). The thermocouple was used to measure the temperature of the glycerol solution and cell pellets.

Exogenous ethanol tolerance

After being cultivated on MYA agar medium with varying ethanol concentrations of 5, 10, 15, 20, and 25% (v/v), six distinct chosen yeast species were inoculated with an initial cell concentration of 1×106 cells/ml. The cultures were kept at 35°C for 48 hours of incubation. The use of a hemocytometer and the simple count technique for staining were used for estimating the number of viable cells. The proportion of survival was utilized for estimating the ethanol tolerance, which was classified into three categories: extremely tolerant (>50 per cent survival), moderately tolerant (25–50 per cent survival), and mildly tolerant (<25 per cent survival) (Banerjee *et al.*, 2018).

Alcohol Dehydrogenase Activity (ADH) (Longhurst *et al.*, 1990)

A) Making cell extracts (with the Rude enzyme)

Before the cells broke, the 48-hour-old broth cultures of the chosen yeast isolates were collected by centrifugation at 8000 rpm for 8 minutes. The cell pellets were then twice cleaned with 10 mM potassium phosphate buffer (pH-7.5) containing 2 mM EDTA and kept at -20oC. Samples were prepared by sonicating cell preparation with glass beads (0.7 mm diameter) at 0oC for 2 min (133 V, 0.5 repeating cycles per s), after being maintained at room temperature and cleaned. Debris and intact cells were eliminated by centrifugation at 40°C for 20 minutes at 12000×g. In order to estimate protein, purified cell extracts were utilized as crude enzymes (Vuralhan et al., 2003).

B) Enzyme Assay

Crude enzyme preparations of the productive cells of yeast isolates were evaluated for ADH activity with just minimum changes. The components of the standard assay combination were crude enzyme (0.8 ml), pH 9.6 (1.5 ml), 2.0 M ethanol (0.5 mL), 0.025M NAD (1.0 ml), and 0.1M sodium pyrophosphate buffer. At room temperature (25 oC), the absorbance at 340 nm increased for three to four minutes. The initial linear portion of the curve was used to calculate absorbance (340nm/min).

The quantity of enzyme required to decrease one micromole of NAD+ per minute at 25 °C is known as an enzyme unit.

$$\text{ADH units/mg protein} = \frac{\text{A340/min}}{6.22\text{X mg } \frac{\text{protein}}{\text{mL}} \text{ reactionmixure}}$$

Molecular characterization (Kumar *et al.*, 2018)

18S rRNA sequencing was used to determine the identity of the chosen efficient yeast isolate. A single band of high-molecular-weight DNA was visible on a 1.0% agarose gel. An 18S rRNA gene fragment was amplified using NS1 and NS4 primers. Upon agarose gel resolution, a solitary, unique 1050 bp PCR amplicon band was observed. The PCR amplicon was purified to get rid of contaminants. Using the BDT v3.1 Cycle sequencing kit and NS1 and NS4 primers, forward and reverse DNA sequencing reactions of PCR amplicons were carried out on the ABI 3730xl Genetic Analyzer. From forward and reverse sequence data, an aligner program was used to create a consensus sequence for the 18S rRNA gene.

The 'nr' database of the NCBI GeneBank database was searched using the 18S rRNA gene sequence using BLAST. The distance matrix and phylogenetic tree were produced using MEGA 10 after the first ten sequences were selected based on their largest identity score and aligned using the multiple alignment software program Clustal W (Tamura et al., 2004; Kumar et al., 2018).

III. RESULT AND DISCUSSION

Isolation and molecular characterization of *Candida tropicalis*

The mixed fruit wastes were collected from shops from different locations of Chidambaram town, Cuddalore district, Tamil Nadu. The substrate was prepared and fermented for two weeks, for the isolation of bioethanol producing yeast isolates. The isolated yeast cultures were examined through morphological and biochemical characterizing methods (Table-1). The five different yeast isolates were further subjected to utilization of different carbon sources absorption and fermentation involving lactose, glucose, galactose, and maltose and saccharose. The results revealed that all the yeast spp. tested were able to utilize and assimilate tested carbon sources except lactose.

Furthermore, 18S rRNA sequencing was used to identify Yi-2. The 18S rRNA sequence's NCBI BLAST search showed that Yi-2 and the genus Candida are closely related. A thorough phylogenetic analysis (MEGA 10) was carried out, closely related sequences were aligned, and a neighbour-joining tree was built using MEGA 10 in order to further support this discovery. The Yi-2 has proven to be a substantial sequence homolog of Candida,18S, and has formed a subclade. The rRNA sequence submission with accession number (ON258632) was received by the NCBI gene bank.

Thermal, Osmotic stress tolerance and ADH levels in particular yeast spp.

The Thermal tolerance, osmotic tolerance and ADH levels in particular chosen five yeast spp. was investigated, and the findings are shown in (Fig-3). All the five yeast isolates were shown to have high thermal tolerance The results revealed that, there was a reduction in the survival of yeast spp. as the temperature was increasing. Among the five isolates the yeast spp. *viz.*, *Candida tropicalis* Yi-2 recorded the highest population of 49 CFU/ml and also observed that two different yeast spp. could not survive under a temperature of 60^{o}C.

The isolate Yi-2 has the highest population survival rate (5.28 log10 CFU/ml). Among the five isolates, Yi-2 had the highest ADH activity (10.25 U mg^{-1}) while comparing with other strains. Based on the studies on their stress tolerance, the yeast isolate Yi-2 recorded maximum stress tolerance and enzyme activity, was selected as the efficient yeast species and used for further studies.

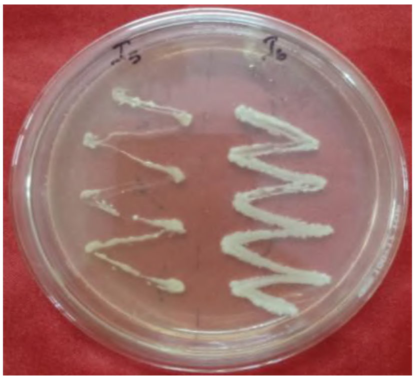
Exogenous Yeast's ability to withstand ethanol

The tolerance to exogenous ethanol of the five selected yeast spp. was examined, and the findings are shown in (Fig-3). It was discovered that all of the selected yeast isolates displayed exogenous ethanol tolerance up to 25% with variance in their efficiency. The isolate Yi-2 had the highest survival rate at all levels of ethanol concentration, namely 5%, 10%, 15%, 20% and 25%, while comparing to all other yeast isolates respectively.

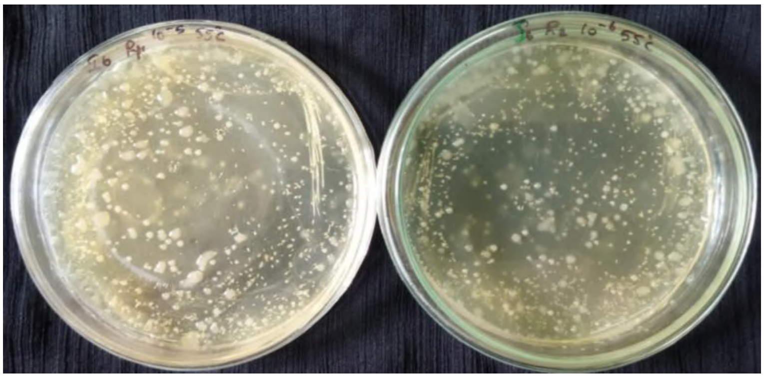
Culture of *Candida tropicalis* maintained in MYA Agar medium

Efficiency tests

Ethanol tolerance test



Thermal tolerance test (after plating)



Recovered Bioethanol from different fruit and fruit juice waste

Table 1. Morphology and Biochemical characterization of different yeast isolate

Isolate designation	Colour	Texture	Margin	Consistency	Shape	Size (µm)	Multilateral Budding	Pellicle	Ascospore Formation	Urease	Sugar fermentation	Flocculation	Pseudohypha	Tentative Identification
Yi-1	Ointment	Flush	Convex	Mucilaginous	Round to oval	4.0×8.0	+	-	+	-	+	+	+	Candida sp.,
Yi -2	Ivory/ actromic	Flush	Convex	Mucilaginous	Oval to elongate	3.25×1.6	+	-	+	-	+	-	+	Candida tropicalis
Yi -3	Ivory	Flush	Lobiform	Mucilaginous	Oval to elongate	2.74×1.28	+	-	+	-	+	-	+	Candida sp.,
Yi -4	Milky-white	Flush	Unbroken	Mucilaginous	Oval	3.77×1.53	+	-	+	-	+	+	+	Candida albicans
Yi -5	Ointment	Flush	Lobate	Mucilaginous	Round to oval	4.0×8.0	+	-	+	-	+	-	+	Candida sp.,

Table 2. Utilization of various carbon sources by different yeast Isolates

Isolate Designation	Fermentation sugar					Assimilation of sugar				
	Glucose	Galactose	Maltose	Lactose	saccharose	Glucose	Galactose	Maltose	Lactose	saccharose
Yi-1	+	+	+	-	+	+	+	+	-	+
Yi-2	+	+	+	-	+	+	+	+	-	+
Yi-3	+	+	+	-	+	+	+	+	-	+
Yi-4	+	+	+	-	+	+	+	+	-	+
Yi-5	+	+	+	-	+	+	+	+	-	+

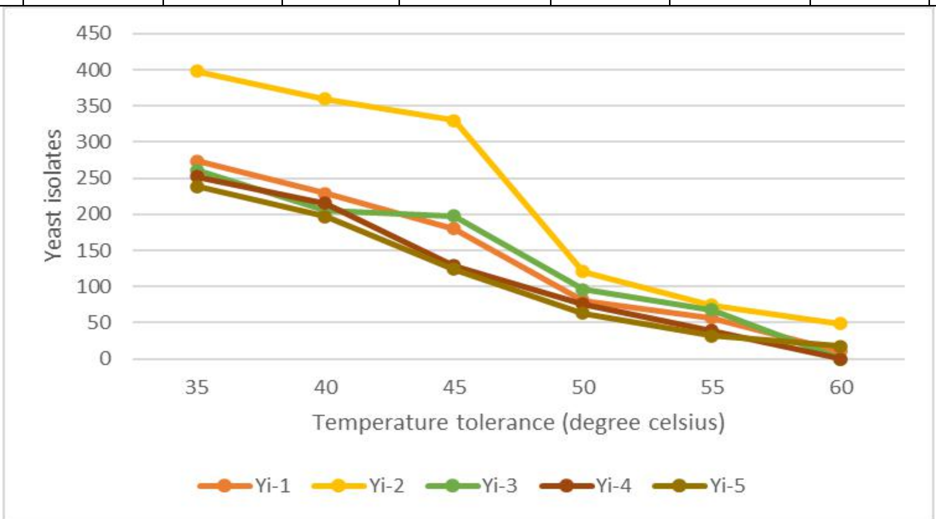


Fig.1 Temperature tolerance of selected yeast spp.

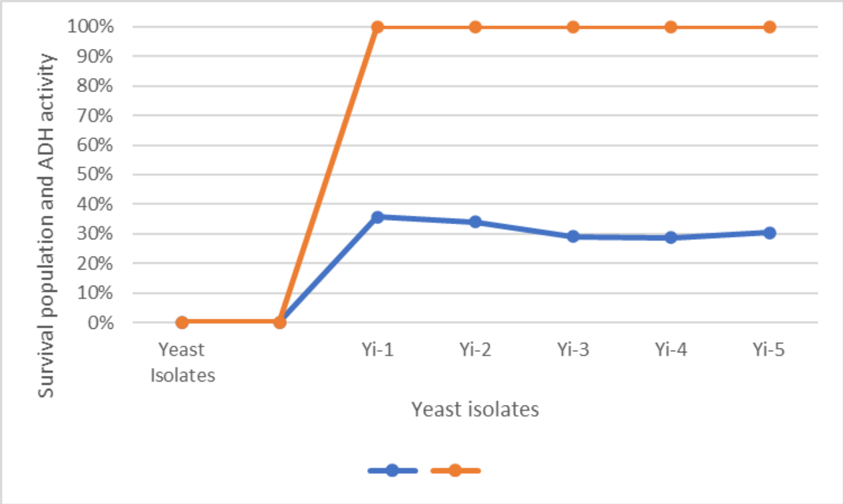


Fig.2 Osmotic stress tolerance and ADH activity of selected yeast spp.

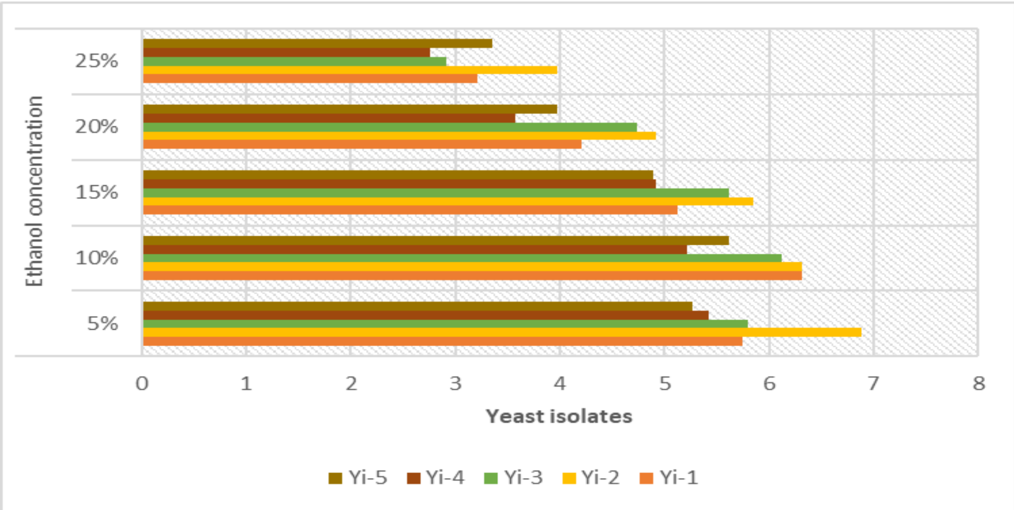
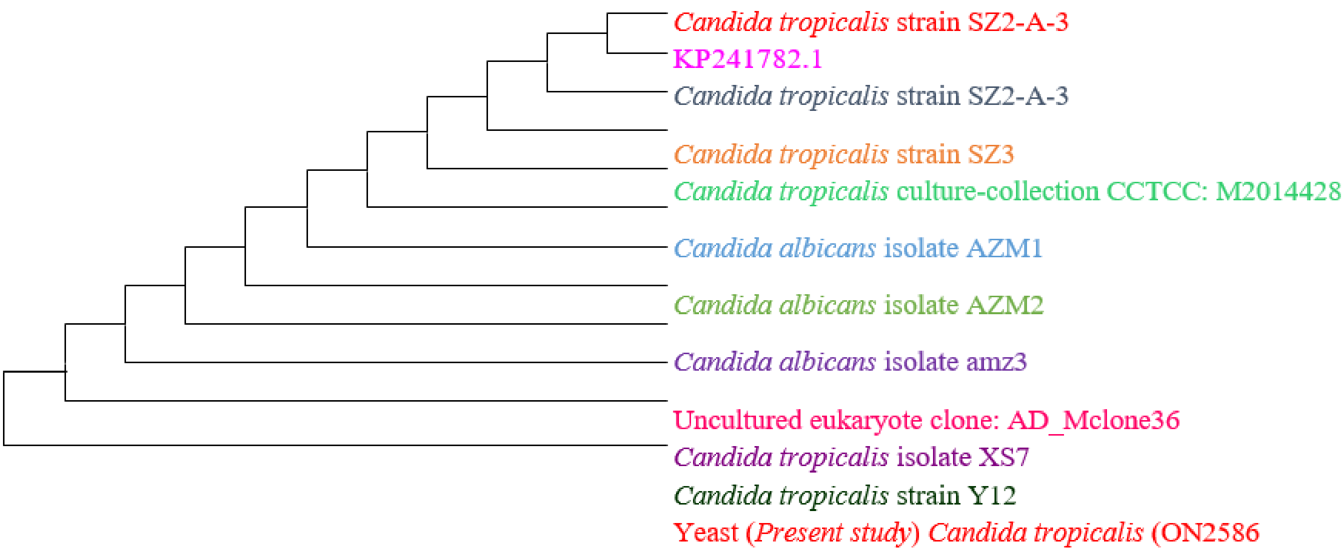


Fig.3 Exogenous ethanol tolerance of yeast spp.

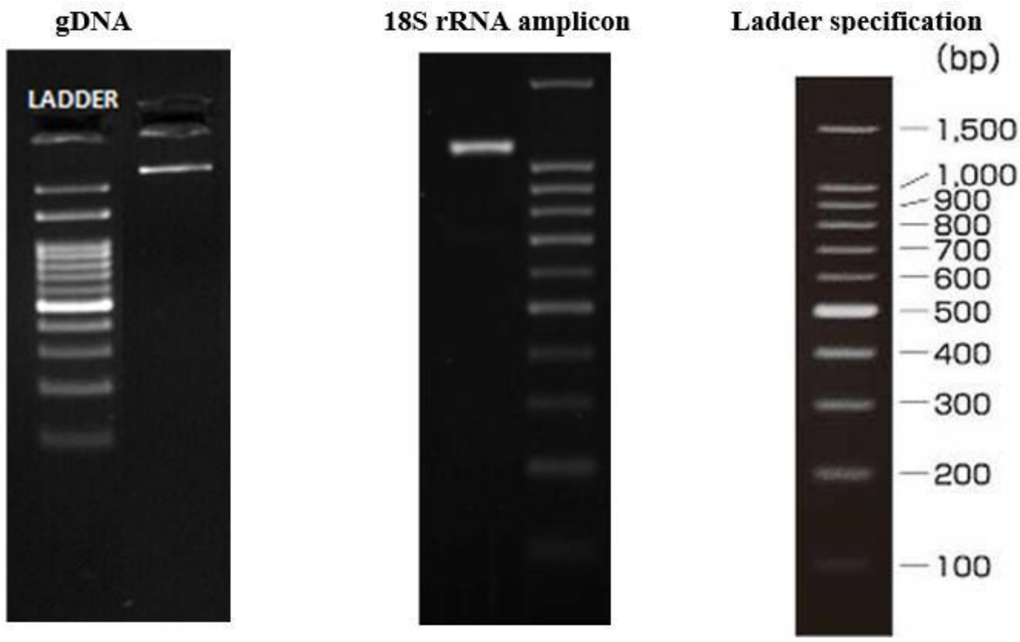
Nucleotide homology and phylogenetic tree analysis



Candida tropicalis

TTTATACAGTGAAACTGCGAATGGCTCATTAAAT
CAGTTATCGTTTATTTGATAGTACCTTACTACTTG
GATAACCGTGGTAATTCTAGAGCTAATACATGCT
TAAAATCCCGACTGTTTGGAAGGGATGTATTTATT
AGATAAAAAATCAATGTCTTCGGACTCTTTGATG
ATTCATAATAACTTTTCGAATCGCATGGCCTTGTG
CTGGCGATGGTTCATTCAAATTTCTGCCCTATCAA
CTTTCGATGGTAGGATAGTGGCCTACCATGGTTTC
AACGGGTAACGGGGAATAAGGGTTCGATTCCGGA
GAGGGAGCCTGAGAAACGGCTACCACATCCAAG
GAAGGCAGCAGGCGCGCAAATTACCCAATCCCGA
CACGGGGAGGTAGTGACAATAAATAACGATACA
GGGCCCTTTCGGGTCTTGTAATTGGAATGAGTAC
AATGTAAATACCTTAACGAGGAACAATTGGAGGG
CAAGTCTGGTGCCAGCAGCCGCGGTAATTCCAGC
TCCAAAAGCGTATATTAAAGTTGTTGCAGTTAAA
AAGCTCGTAGTTGAACCTTGGGCTTGGTTGGCCG
GTCCATCTTTCTGATGCGTACTGGACCCAACCGAG
CCTTTCCTTCTGGCTAGCCTTTTGGCGAACCAGGA
CTTTTACTTTGAAAAAATTAGAGTGTTCAAAGCA
GGCCTTTGCTCGAATATATTAGCATGGAATAATA
GAATAGGACGTTATGGTTCTATTTTGTTGGTTTCT
AGGACCATCGTAATGATTAATAGGGACGGTCGGG
GGTATCAGTATTCAGTTGTCAGAGGTGAAATTCTT
GGATTTACTGAAGACTAACTACTGCGAAAGCATT
TACCAAGGACGTTTTCATTAATCAAGAACGAAAG
TTAGGGGATCGAAGATGATCAGATACCGTCGTAG
TCTTAACCATAAACTATGCCGACTAGGGATCGGT
TGTTGTTCTTTTATTGACGCAATCGGCACCTTACG
AGAAATCAAAGTCTTTGGGTTCTGGGGGGAGTAT
GGTCGCAAG

gDNA and 18S Amplicon QC data:



IV. CONCLUSION

To conclude the present study, the bio-ethanol production from mixed fruit waste is one of the best choices of meeting the energy requirement. Fruit waste is, better substrate for microbial fermentation because it includes starch and sugars, which can be effectively transformed into bioethanol. *Candida tropicalis* (ON258632) used in the current study was superior to other strains for fermentation of fruit wastes, since, it produced both enzymes required for hydrolysis and fermentation; it is also concluded that, by using *Candida tropicalis* Yi-2 saccharification step can be skipped in bioethanol produced from fruit wastes.

ACKNOWLEDGEMENT

I would like to convey my profound gratitude to my teacher (Mr. SHARAN K Asst. prof. (AGM) & Ms. Nismal Aswin A Asst. prof. (AGM)), in addition to our principal and vice principal (Dr. K. Sekar. Professor of Horticulture & Dr. J. Raja Raja Cholan Associate Professor of Plant Breeding and Genetics), for providing me with the wonderful opportunity to conduct this incredible research on the topic of Agricultural Microbiology. and I learned so many novel concepts, for which I am thankful.

REFERENCES

[1] Cheesbrough, M. (2006). *District laboratory practice in tropical countries, part 2*. Cambridge university press.

[2] Chitranshi, R., & Kapoor, R. (2021). Utilization of over-ripened fruit (waste fruit) for the eco-friendly production of ethanol. *Vegetos*, *34*(1), 270-276.

[3] Fawole, M. O., & Oso, B. A. (2007). Laboratory manual of microbiology, spectrum book limited. *Ibadan, Nigeria*, 16-33.

[4] Guimarães, T. M., Moriel, D. G., Machado, I. P., Picheth, C. M., & Bonfim, T. (2006). Isolation and characterization of Saccharomyces cerevisiae strains of winery interest. *Revista Brasileira de Ciências Farmacêuticas*, *42*, 119-126.

[5] Hermansyah, H., Novia, N., Minetaka, S., & Satoshi, H. (2015). Candida tropicalis isolated from Tuak, a North Sumatera-Indonesian traditional beverage, for bioethanol production. *Microbiology and Biotechnology Letters*, *43*(3), 241-248.

[6] Kumar, S., Stecher, G., Li, M., Knyaz, C., & Tamura, K. (2018). MEGA X: molecular evolutionary genetics analysis across computing platforms. *Molecular biology and evolution*, *35*(6), 1547.

[7] Longhurst, T. J., Tung, H. F., and Brady, C. J. 1990. Developmental regulation of the expression of alcohol dehydrogenase in ripening tomato fruits. *Journal of Food Biochemistry*, *14*(6), 421-433.

[8] Osho, A. 2005. Ethanol and sugar tolerance of wine yeasts isolated from fermenting cashew apple juice. *African Journal of Biotechnology*, *4*(7), 660-662.

[9] Panse, V.G. and Sukhatme, PV, 1978 Statistical methods for agricultural workers, Indian Council of Agric. Res, New Delhi (India).

[10] Reddick, A. N. N. E. (1975). A simple carbohydrate fermentation test for identification of the pathogenic Neisseria. *Journal of Clinical Microbiology*, *2*(1), 72-73.

[11] Sar, T., Stark, B. C., and Akbas, M. Y. 2019. Bioethanol production from whey powder by immobilized *E. coli* expressing Vitreoscilla hemoglobin: Optimization of sugar concentration and inoculum size. *Biofuels*.

[12] Tambuwal, A. D., Muhammad, I. B., Alhaji, S., Muhammad, S., & Ogbiko, C. (2018). Morphological and biochemical characterization of isolated Aspergillus niger, Saccharomyces cerevisiae and Zymomonas mobilis from local indigenous sources. *GSC Biological and Pharmaceutical Sciences*, *5*(3), 078-085.

[13] Tamura K., Nei M., and Kumar S. (2004). Prospects for inferring very large phylogenies by using the neighbor-joining method. Proceedings of the National Academy of Sciences (USA) 101:11030-11035.

[14] Togarepi, E., Mapiye, C., Muchanyereyi, N., and Dzomba, P. 2012. Optimization of fermentation parameters for ethanol production from *Ziziphus mauritiana* fruit pulp using Saccharomyces cerevisiae (NA33). *International Journal of Biochemistry Research and Review*, *2*(2), 60.

[15] Vaughan-Martini, A., & Martini, A. (1993). A taxonomic key for the genus Saccharomyces. *Systematic and Applied Microbiology*, *16*(1), 113-119.

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Light intensity affects axillary bud quality of rubber mini-seedling budding CATAS73397

Jinglan Ruan[1,2,3], Zhennan Cha[1,2], Xuedan Gong[1,2], Xiying Jiang[1,2], Xianhong Chen[1, *], Jun Wang[1]

[1]Rubber Research Institute,Chinese Academy of Tropical Agricultural Sciences,Danzhou,Hainan,China
[2]Yunnan Agricultural University,Kunming, Yunnan, China
[3]Yunnan Province Huang Huasun Expert Workstation
Email: chenxhongjane@163.com (X. Chen).
*Corresponding author.

Received: 20 Nov 2024; Received in revised form: 19 Dec 2024; Accepted: 26 Dec 2024; Available online: 31 Dec 2024

Abstract**—***Rubber mini-seedling budding have the characteristics of short nursery cycle, low labor intensity, large number of seedlings per unit area, easy transportation and planting, well-developed taproot and intact root system, high post-planting survival rate, fast growth, strong tolerance to drought, wind and cold, and early tapping. The quality of rubber tree axillary buds is a key factor affecting the budding of rubber mini-seedling buddings, and there are many environmental factors affecting the quality of rubber tree axillary bud. Production practice shows that moderate shading is beneficial to the quality of rubber bud stick. However, there is still a lack of systematic research on the effect of light on the quality of rubber tree axillary bud. This study set up two treatments with 75% and 100% light intensity based on production practice to observe and analyze the phenology and axillary bud morphological indicators of rubber tree leaf whorl. The results showed that axillary buds of the 3rd leaf whorl had the highest quality under 75% light intensity. Suitable light intensity promotes axillary buds to grow more robustly. Taken together, light has a significant impact on the quality of rubber tree axillary bud. Suitable lighting is more conducive to improving the quality of rubber tree axillary bud and laying a good foundation for the subsequent growth and development of rubber mini-seedling budding.*

Keywords**—*****Hevea brasiliensis, light intensity, leaf phenology, axillary bud, quality***

I. INTRODUCTION

Rubber tree (*Hevea brasiliensis* (Willd. ex A. Juss.) Muell. Arg), a plant of the genus Euphorbiaceae, native to the Amazon River Basin in Brazil, is a typical tropical rainforest tree species and is currently the largest rubber-producing plant [1]. The stem is upright, the leaf scars are horseshoe-shaped, the three leaflets are mostly separated, and the latex is white. Axillary buds are one type of lateral buds, specifically referring to the fixed buds that arise from the leaf axils. They play an important role in the growth, development and reproduction of plants, not only promoting plant growth, but also closely related to plant biomass and crop yield [2]. The axillary buds are the origin point of lateral branches and 2ndary flower buds in rubber trees, and their healthy development plays a decisive role in the yield and quality of rubber trees.

As an important economic crop, the quality of rubber tree axillary buds is crucial for its reproduction and growth. Light, as one of the important environmental factors, has a significant impact on the growth and development of plants [3-5]. In the process of rubber budding, the quality of axillary buds directly affects the success rate of budding and the subsequent growth status of rubber trees. Among them, light intensity is one of the important environmental factors affecting the quality of axillary buds. Appropriate light intensity can promote the normal growth and development of axillary buds, achieving a good state in morphology, physiology, and other aspects, providing high-quality bud patches for high-quality rubber mini-seedling budding.

At present, there have been many studies on the effect of light intensity on the growth and development of rubber trees [6,7]. Although we know that environmental factors such as light have an impact on rubber bud grafting, different light intensities will have a corresponding degree of influence on the anatomical structure and growth of rubber tree leaves [8]. There are also studies on different types of bud and initial growth of scions conducted by Liu Zhongliang and others in rubber tree Yunyan 77-4 [9], establishment of axillary bud cell embryo regeneration system and induction of tender leaf callus tissue by Wang Taihua and others in rubber tree CATAS73397 [10], and the effect of different concentrations of colchicine by Zhao Qi and others on axillary bud germination rate of rubber tree clones [11]. However, the detailed dynamic changes in the growth indicators of rubber axillary bud under different light intensities are not yet fully understood, which makes it difficult to achieve precise control operations in the actual rubber mini-seedling propagation process. In view of this, the aim of this study is to conduct in-depth research on various growth indicators of mini-seedling buddings under different light intensities, analyze their intrinsic relationship with axillary bud quality, and determine the most suitable light intensity for axillary bud growth of rubber trees under different light intensities. This will further deepen our understanding of the mechanism of rubber mini-seedling budding propagation, improve budding quality, and promote the sustainable development of the rubber industry.

II. MATERIAL AND METHODS

Experimental site Experimental site is located in the demonstration base of rubber tree seedling budding in Danzhou City, Hainan Province (109.50E, 19.50N, 148.6 m altitude). Shading treatment was carried out using a shading net, and one light intensity was controlled to be 75%. The other experimental treatment had no shading, the light intensity was 100%, the light was good, and the environment was stable. The test material is the excellent variety of rubber tree CATAS73397, which is a high-yield variety bred by the Rubber Research Institute of China Academy of Tropical Agricultural Sciences. It has fast growth, high yield, strong wind resistance and cold resistance. Each experimental treatment concluded ten plants, three replicates, through the observation of phenology in each period of experimental treatment and cultivation of rubber tree, and the determination of phenotypic traits of axillary buds.

Phenological observation From July to August 2024, plants with good growth and consistency were selected for manual observation, and the duration, leaf color change and leaf growth dynamics of each phenological period (S1, bud-break stage, S2, elongating stage, S3, leaf-unfolding stage, S4, bronze stage Ⅰ, S5, bronze stage Ⅱ, S6, coloring stage, S7, light green leaf stage, S8, stable leaf stage, S9 mature leaf stage) were recorded. The leaf length and leaf width were measured by a transparent ruler, and the leaf color change was measured by chlorophyll meter (Jinkelida TYS-4N).

Axillary bud morphology observation At least 4 leaf whorls with good and consistent growth were cut, and stem diameter of each leaf whorl close node bud (the starting growth point of new leaf whorl) was measured with a vernier caliper. The plant height of each leaf was measured with a tape measure, and the leaf buds and scale buds on the 2nd, 3rd and 4th leaf buds were cut from the top down respectively. The number of leaf buds and scale buds on each leaf whorl was recorded. The length, width and thickness of axillary bud scar and the length and width of axillary bud eye were measured with vernier caliper. After the measurement, the leaf buds and scale buds on each leaf whorl were weighed fresh weight, and then placed on a ceramic tray and dried in a blast oven (Shanghai Yiheng DHG-9620A) to constant weight to calculate the moisture content.

Data processing and analysis Word Processing System (WPS) Excel 2018 and GraphPad prism 8.3.0 were used for data processing and chart drawing. Statistical analyses were performed with data processing system (DPS) statistical software package version 20.05 using student's t-test, one-way ANOVA followed by the Duncan's Multiple Range Test (SSR) to evaluate significant difference among different treatments at $P<0.05$, and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) for comprehensive analysis. All data were shown in the mean ± SD. Correlation heatmap analysis was evaluated on Tutools platform(http://www.cloudtutu.com), a free online data analysis website.

III. RESULT AND DISCUSSION

1 Plant growth

As shown in Fig.1A, leaf length of the 2nd, 3rd and 4th leaf whorl of CATAS73397 bud stick were significantly increased by 28.49% ($P<0.01$), 42.76% ($P<0.01$), and

47.32% (P<0.01), respectively, under 75% light compared with 100% light. As shown in Fig.1B, leaf width of the 3rd and 4th leaf whorl were significantly increased by 17.33% (P<0.01) and 26.66% (P<0.01), respectively, under 75% light compared with 100% light. The stem diameter of the 4th leaf whorl under 75% light was 9.85% smaller than that under 100% light (P< 0.05, Fig.1C). As shown in Fig.1D, leaf moisture of 2nd, 3rd and 4th leaf whorl under 75% light was significantly higher than that under 100% light by 6.00% (P < 0.01), 9.52% (P< 0.01) and 8.63% (P < 0.01), respectively, indicating that proper shading helps the growth of leaves. There was no significant difference in other parameters.

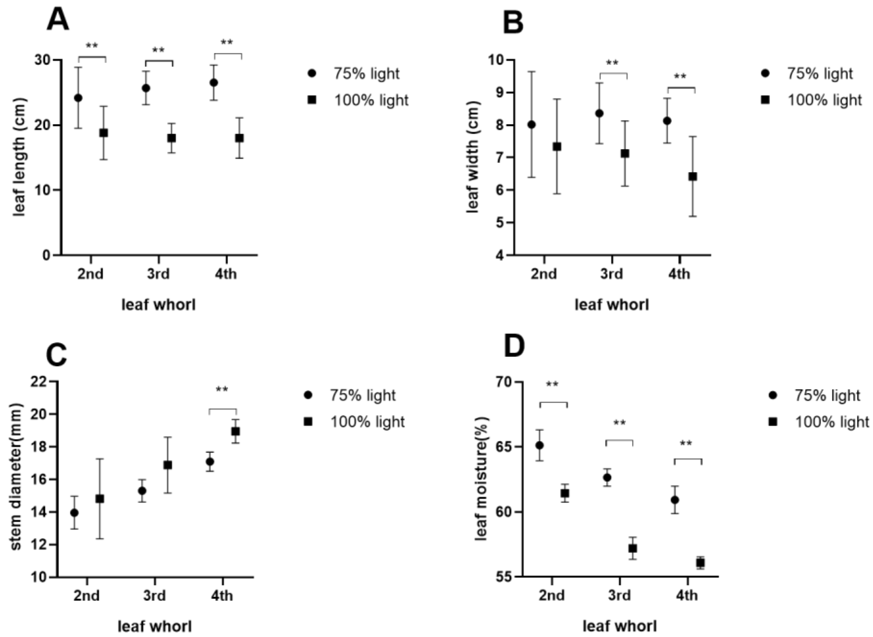


Fig.1 Plant growth performance at different leaf whorl under 75 % and 100 % light

2 Leaf phenology

As shown in Fig.2 and Fig.3A, compared with 100% light, the duration of leaf-unfolding stage and bronze stage I of CATAS73397 bud stick under 75% light was significantly shorter by 18.18% (P< 0.05) and 28.57% (P < 0.05), and the duration of coloring stage and mature leaf stage was significantly longer by 7.14% (P<0.01) and 57.14% (P<0.01), respectively. There was no significant difference in other leaf phenology periods.

2.1 Plant height

As shown in Fig.3B, plant height increase at leaf-unfolding stage and mature leaf stage of CATAS 73397 bud stick under 75% light was significantly 10.61% (P< 0.05) and 84.37% (P<0.05) higher than that under 100% light. There was no significant difference in other leaf phenology periods.

2.2 Leaf length As shown in Fig.3C, leaf length increase at bronze stage I and light green leaf stage of CATAS73397 bud stick under 75% light was significantly 43.53% (P<0.01) and 16.54% (P<0.01) shorter than that under 100% light, mature leaf stage was significantly 6.88% (P<0.05) higher than that under 100% light; There was no significant difference in other leaf phenology periods.

2.3 Leaf width As shown in Fig.3D, leaf width increase at bronze stage I, coloring stage and light green leaf stage of CATAS73397 bud stick under 75% light was significantly 51.23%, 10.98% and 20.45% shorter than that under 100% light (P<0.01), bronze stage II was significantly 9.49% shorter than that under 100% light (P <0.05), mature leaf stage was significantly 18.33% higher than that under 100% light (P < 0.01). There was no significant difference in other leaf phenology periods.

2.4 Leaf moisture As shown in Fig.3E, under 75% light, the leaf moisture of CATAS73397 was significantly 19.51% (P<0.05) lower than that under 100% light at coloring stage. There was no significant difference in other leaf phenology periods.

2.5 Leaf temperature As shown in Fig.3F, The leaf temperature of CATAS73397 under 75% light was significantly 2.01% (P<0.01) higher than that under 100% light at bronze stage II. Leaf temperature at mature leaf stage was significantly lower 2.42% (P<0.05) than that under 100% light; There was no significant difference in other leaf phenology periods.

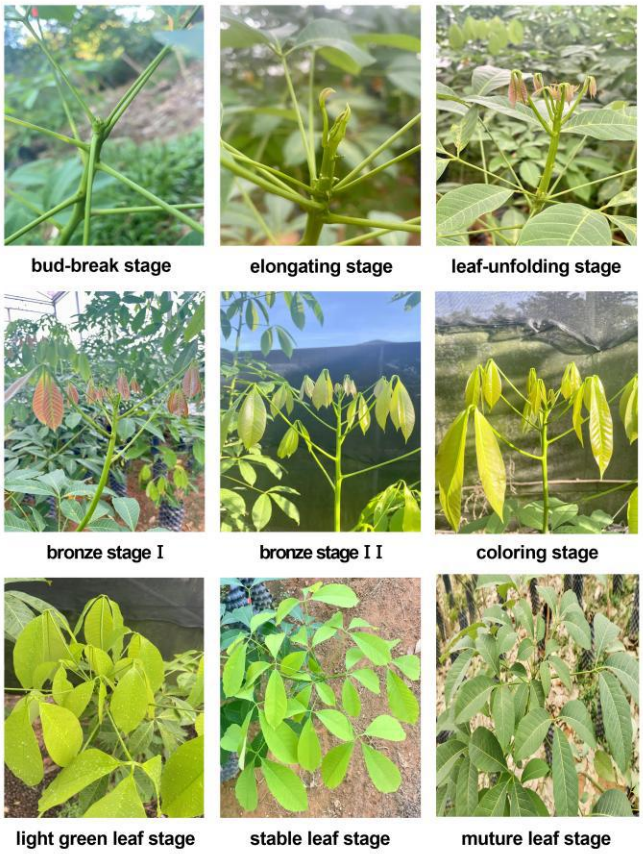


Fig.2 Leaf phenology of CATAS73397 rubber mini-seedling budding bud-stick

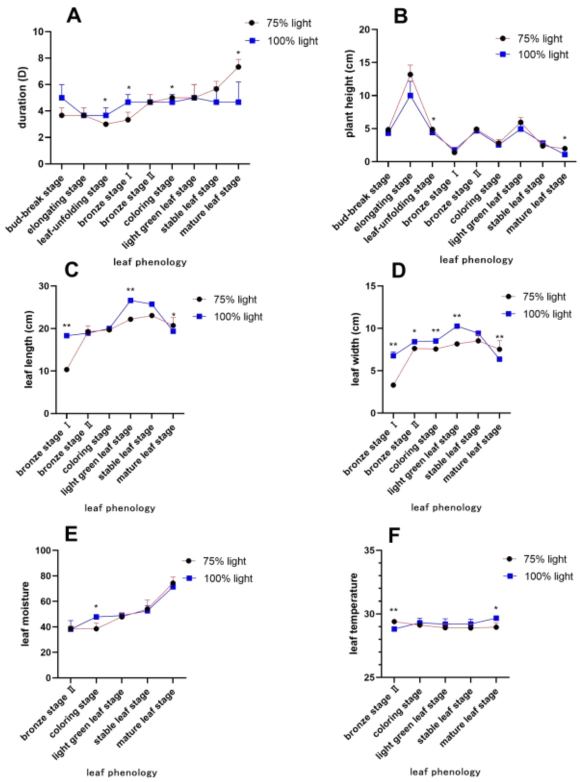


Fig.3 Change of phenology duration and leaf growth under 75 % and 100 % light

In general, although there was no significant difference in total phenological duration days and cumulative increase in plant height between 75% and 100% light, there were significant or extremely significant differences in duration days, increase in plant height, increase in leaf length, increase in leaf width, leaf moisture and leaf temperature among phenologically related leaves of CATAS 73397 bud stick.

3 Axillary bud quality

3.1 Different light intensities at the same leaf whorl

On the 2nd leaf whorl, the scale bud scar length (Fig. 4A), and leaf bud eye length (Fig.4G) were significantly increased by 41.30% ($P<0.01$), and 44.60% ($P<0.01$) respectively, under 75% light compared with 100% light. The leaf bud scar width was significantly 6.50% ($P<0.05$) higher than that under 100% light (Fig.4F). The scale bud eye width (Fig.4D) and leaf bud scar thickness (Fig. 4H) were significantly decreased by 14.58% ($P<0.05$) and 8.10% ($P<0.05$) compared with 100% light. There was no significant difference in other parameters.

On the 3rd leaf whorl, the leaf bud eye length (Fig. 4G, Fig. 5), were significantly increased by 33.09% ($P<0.01$), under 75% light compared with 100% light. The scale bud scar width (Fig.4B), leaf bud scar length (Fig.4E) and leaf bud scar width (Fig.4F) were significantly increased by 5.67% ($P<0.05$), 10.17% ($P<0.05$) and 0.66% ($P< 0.05$), respectively, under 75% light compared with 100% light. The scale bud scar length was significantly 19.34% ($P<0.01$) lower than that under 100% light. The leaf bud scar thickness (Fig.4H) and the scale bud moisture (Fig. 4I) were significantly lower than those under 100% light by 6.86% ($P<0.05$) and 4.09% ($P< 0.05$), respectively. There was no significant difference in other parameters.

On the 4th leaf whorl, under 75% light, the leaf bud scar thickness (Fig.4H) was significantly increased by 10.75% ($P < 0.01$). The leaf bud scar length (Fig.4E) and leaf bud eye length (Fig.4G) were significantly increased by 7.72% ($P < 0.05$) and 16.19% ($P < 0.05$) compared with 100% light. The scale bud scar length (Fig.4A), scale bud scar width (Fig. 4B), and scale bud eye length (Fig.4D) were significantly decreased by 22.54% ($P< 0.01$), 9.06% ($P<0.01$), and 39.45% ($P<0.01$) under 100% light, respectively. The scale bud moisture (Fig.4I) was 4.01% ($P<0.05$) lower than that under 100% light. There was no significant difference in other parameters.

In conclusion, the light intensity had significant effects on a number of morphologies and related indexes of CATAS73397 axillary buds. The indexes of different leaf buds increased or decreased to different degrees under the comparison of 75% light and 100% light, indicating that there were differences in the response of each leaf bud to light intensity. The CV difference of each index at the two light conditions reflects that the light intensity not only affects the value of the index, but also may affect its stability. It can be inferred that in the bud-stick cultivation process of this variety, the specific morphological index can be optimized by accurately regulating the light intensity for different leaf buds, so as to promote the overall growth and development. It can be seen that some indexes of leaf bud and scale bud have advantages under 75% light, which further indicates that reasonable light regulation is very important to balance the growth and development of different types of bud (such as leaf bud and scale bud).

3.2 Different leaf whorl on the same plant

3.2.1 75% light in the same plant

As shown in Fig. 6A, the scale bud scar length of the 2nd leaf whorl was significantly higher than that of the 3rd and 4th leaf whorls by 27.43% ($P<0.01$) and 40.88% ($P<0.01$), respectively.

As shown in Fig. 6B, the scale bud scar width of the 2nd leaf whorl was significantly smaller than the 3rd leaf whorl by 21.86% ($P<0.01$), and the 3rd leaf was significantly smaller than the 4th leaf whorl by 17.88% ($P < 0.01$).

As shown in Fig. 6C, the scale bud eye length of the 4th leaf whorl was significantly smaller than that of the2ndand 3rd leaf whorls by 48.12% ($P<0.01$) and 44.46% ($P<0.01$), respectively, and there was no significance between the 3rd leaf whorl and the 4th leaf whorl.

As shown in Fig. 6D, the scale bud eye width of the 2nd leaf whorl was significantly smaller than that of the 3rd leaf whorl by 41.25% ($P<0.01$) and significantly smaller than that of the 4th leaf whorl by 15.19% ($P < 0.05$), and the 3rd leaf whorl was significantly larger than that of the 4th leaf whorl by 18.45% ($P<0.01$).

As shown in Fig. 6E, the leaf bud scar length of the 2nd leaf whorl was significantly smaller than that of the 3rd leaf whorl by 12.96% ($P<0.01$), the 2nd leaf whorl was significantly larger than that of the 4th leaf whorl by 21.52% ($P<0.01$), and the 3rd leaf whorl was significantly larger than that of the 4th leaf whorl by 30.52% ($P<0.01$).

As shown in Fig. 6F, the leaf bud scar width of the 2nd leaf whorl was significantly smaller than that of the 3rd leaf whorl by 8.45% ($P<0.01$), and the 3rd leaf whorl was significantly larger than the 4th leaf whorl by 6.99% ($P< 0.01$).

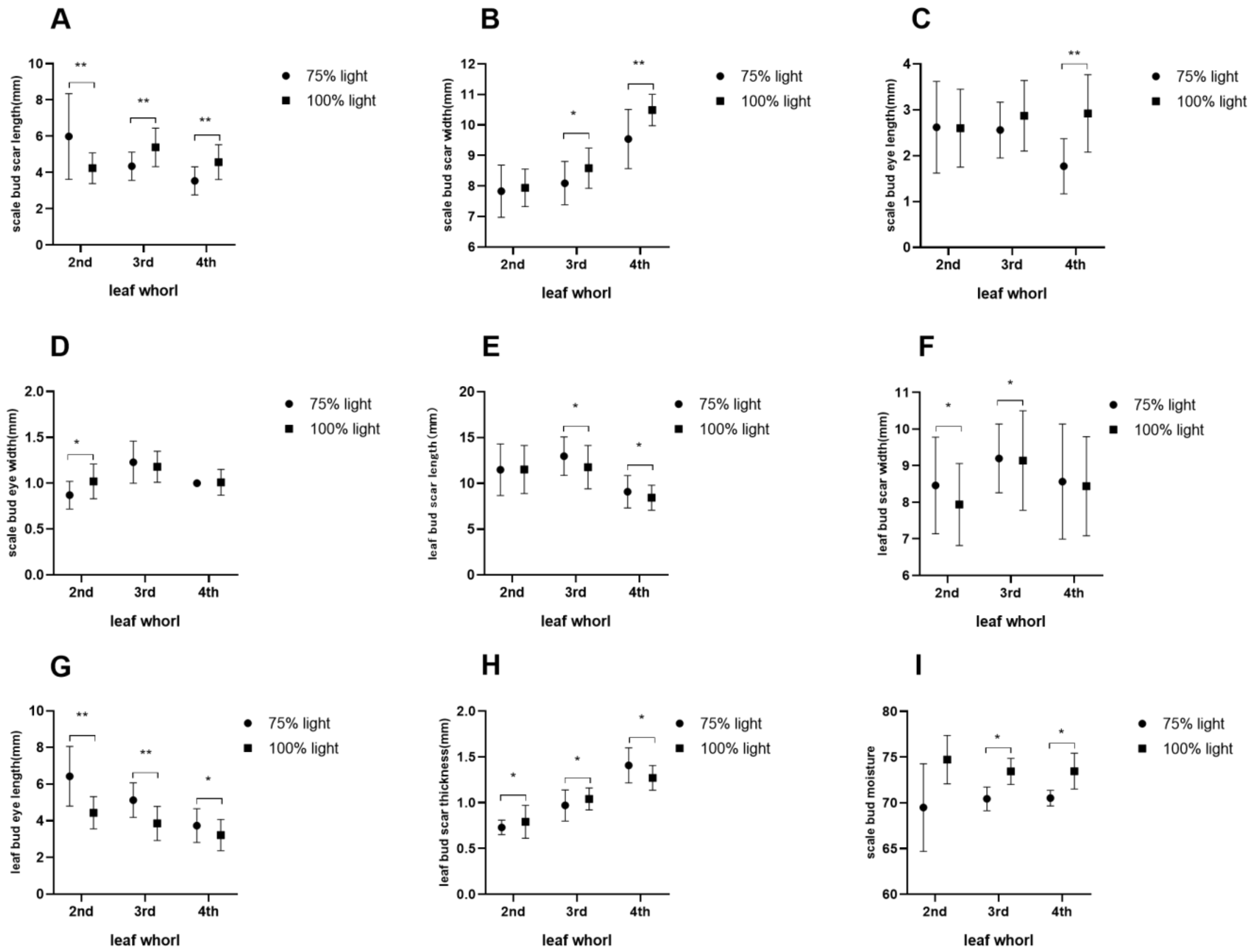


Fig.4 The axillary bud growth of the 2nd, 3rd and 4th leaf whorl under 75 % and 100 % light

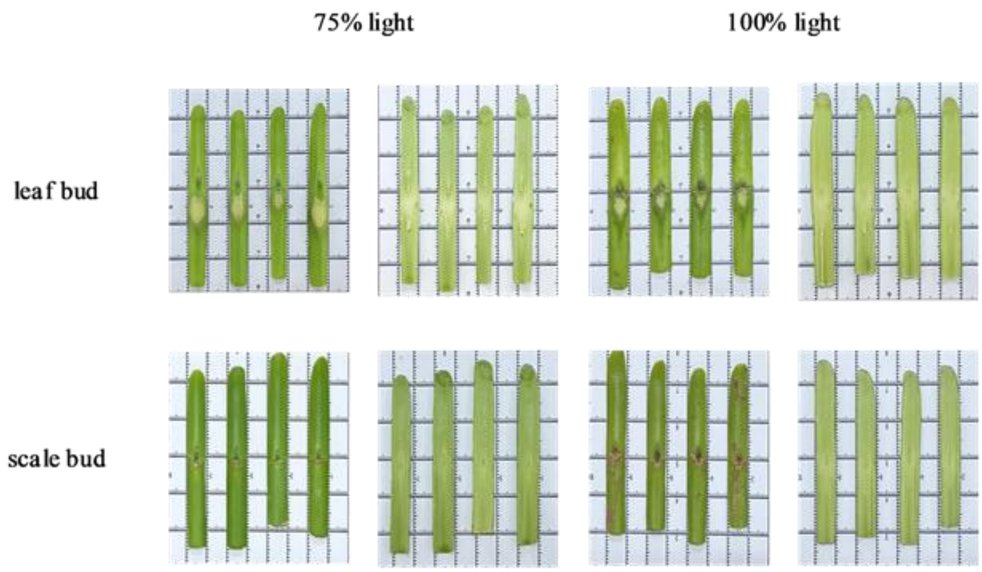


Fig.5 Positive and negative side view of leaf bud patch and scale bud patch on 3rd leaf whorl

ISSN: 2456-1878 (Int. J. Environ. Agric. Biotech.)
https://dx.doi.org/10.22161/ijeab.96.21

As shown in Fig. 6G, the leaf bud eye length of the 2nd leaf whorl was 18.26% (P<0.01) and 41.10% (P<0.01) higher than that of the 3rd and 4th leaf whorls respectively, and the 3rd leaf whorl was 27.94% (P<0.01) higher than that of the 4th leaf whorl. There was no significant difference in other parameters.

As shown in Fig. 6H, the scale bud scar thickness in the 2nd leaf whorl was 17.47% (P<0.05) higher than that in the 3rd leaf whorl, and the 3rd leaf whorl was 20.77% (P< 0.05) lower than that in the 4th leaf whorl.

As shown in Fig. 6I, the leaf bud scar thickness of the 2nd leaf whorl was significantly smaller than that of the 3rd and 4th leaf whorls by 33.16% (P<0.01) and 94.73% (P< 0.01), respectively. The 3rd leaf whorl was significantly smaller than that of the 4th leaf whorl by 43.42% (P< 0.01).

As shown in Fig. 6J, the number of scale buds in the 2nd leaf whorl was significantly lower than that in the 3rd leaf whorl by 40% (P<0.05), and the 3rd leaf whorl was significantly higher than that in the 4th leaf whorl by 28.57% (P< 0.05).

As shown in Fig. 6K, the leaf length of the 2nd leaf whorl was significantly smaller than that of the 4th whorl by 9.6 % (P<0.01), and that of the 3rd whorl was significantly smaller than that of the 4th whorl by 3.2 % (P< 0.05).

As shown in Fig. 6L, the leaf width of the 2nd leaf whorl was significantly higher than that of the 3rd and 4th leaf whorl by 2.96 % and 12.96 %, respectively, and the 3rd leaf whorl was significantly higher than that of the 4th leaf whorl by 9.89 %.

As shown in Fig. 6M, the leaf moisture of the 2nd leaf whorl was significantly higher than that of the 3rd and 4th leaf whorls by 4.67% (P<0.01) and 6.77% (P<0.01), respectively.

As shown in Fig. 6N, the stem diameter of the 2nd leaf whorl was 31.95% (P< 0.05) higher than that of the 3rd leaf whorl, and 41.89% (P<0.01) higher than that of the 4th leaf whorl from the top, the 3rd leaf whorl from top was significantly smaller than the 4th leaf whorl from top by 46.96% (P< 0.05).

3.2.2 100% light on the same plant

As shown in Fig. 6A, the scale bud scar length of the 2nd leaf whorl was significantly smaller than that of the 3rd leaf whorl by 27.13% (P<0.05), and was significantly larger than that of the 4th leaf whorl by 16.46% (P<0.01). The 3rd leaf whorl was significantly larger than the 4th leaf whorl by 34.29% (P<0.01).

As shown in Fig. 6B, the scale bud scar width of the 2nd leaf whorl was significantly smaller than that of the 3rd and 4th leaf whorls by 8.06% (P<0.01) and 32.12% (P< 0.01), respectively, and the 3rd leaf whorl was significantly smaller than that of the 4th leaf whorl by 32.12% (P<0.01).

As shown in Fig. 6C, there was no significance among the 2nd, 3rd and the 4th leaf whorl in the scale bud eye length.

As shown in Fig. 6D, the scale bud eye width of the 2nd leaf whorl was significantly smaller than that of the 3rd leaf whorl by 16.16% (P<0.01), and the 3rd leaf whorl was significantly larger than that of the 4th leaf whorl by 14.51% (P<0.01).

As shown in Fig. 6E, the leaf bud scar length of the 2nd leaf whorl was 28.08% (P<0.01) higher than that of the 4th leaf whorl, and the 3rd leaf whorl was 29.23% (P<0.01) higher than that of the 4th leaf whorl.

As shown in Fig. 6F, the leaf bud scar width of the 2nd leaf whorl was significantly smaller than that of the 3rd leaf whorl by 14.52% (P<0.01), and the 3rd leaf whorl was significantly larger than that of the 4th leaf whorl by 8.45% (P< 0.01).

As shown in Fig. 6G, the leaf bud eye length of the 2nd leaf whorl was 15.51% (P<0.01) and 30.00% (P< 0.01) higher than that of the 3rd and 4th leaf whorls, respectively, and the 3rd leaf whorl was 17.15% (P<0.01) higher than that of the 4th leaf whorl. There was no significant difference in other parameters.

As shown in Fig. 6H, the scale bud scar thickness in the 2nd leaf whorl was significantly lower than that in the 4th leaf whorls by 20.16% (P<0.01) and 20.52% (P<0.01), respectively.

As shown in Fig. 6I, the leaf bud scar thickness of the 2nd leaf whorl was significantly smaller than that of the 3rd and 4th leaf whorls by 30.96% (P<0.01) and 60.66% (P< 0.01), respectively. The leaf bud scar thickness of the 3rd leaf whorl was significantly smaller than that of the 4th leaf whorl by 22.68% (P<0.01).

As shown in Fig. 6J, the scale buds in the 3rd leaf whorl were 52% (P<0.05) higher than that in the 4th leaf whorl.

As shown in Fig.6M, the leaf moisture of the 2nd whorl was significantly higher than that of the 3rd and 4th whorls by 6.96% (P<0.01) and 8.83% (P<0.01), respectively.

As shown in Fig. 6N, the stem diameter of the 2nd and 3rd leave whorls was significantly larger than that of the 4th leave whorl by 19.61% (P<0.05) and 20.11% (P<0.05), respectively.

To sum up, it shows that even under the same light conditions, different leaf whorls have different responses to light, and their growth and development characteristics are not the same, and each leaf position has its own unique growth characteristics.

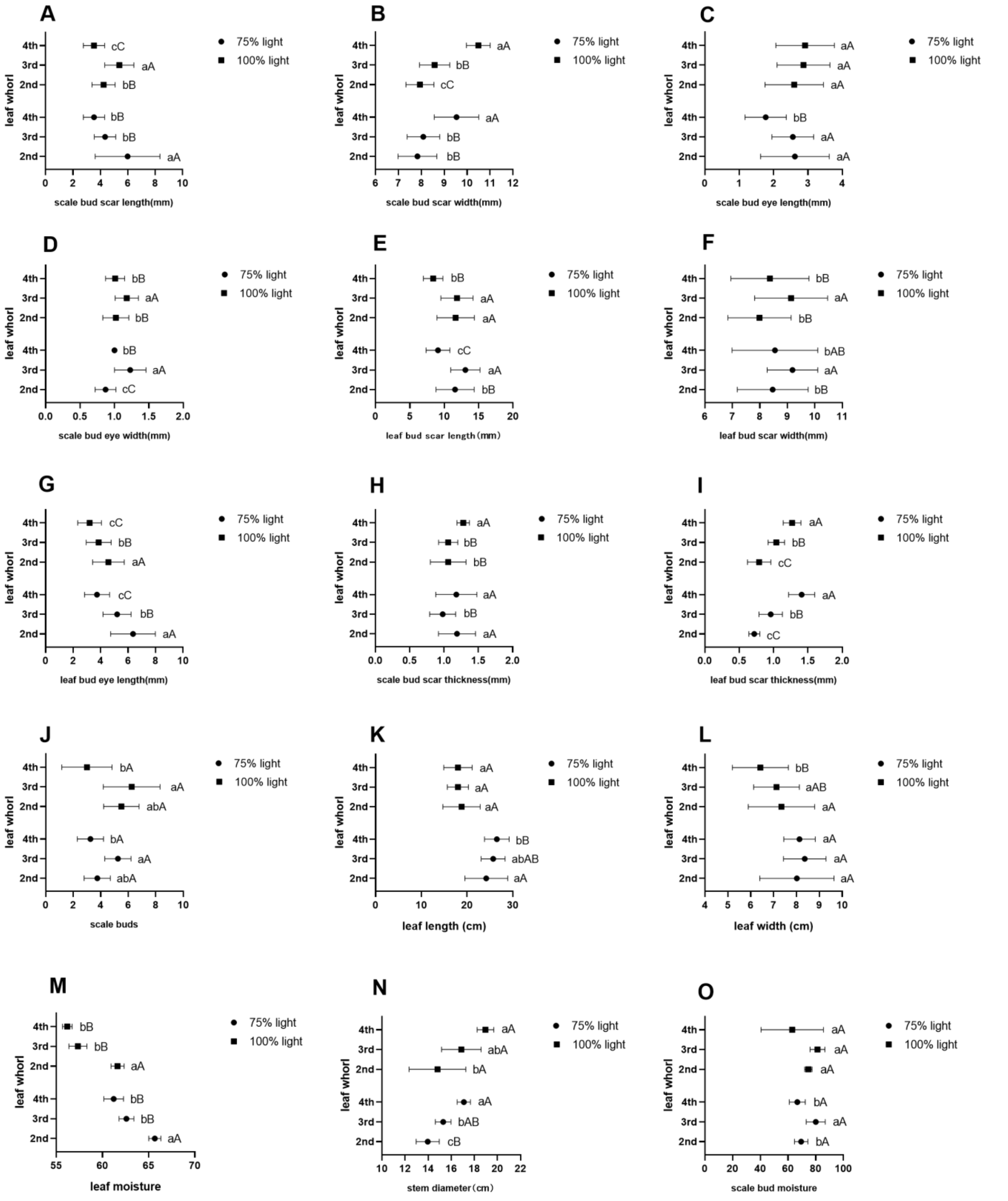


Fig.6 The quality of axillary buds at different leaf whorl on the same plant under 75 % and 100 % light

4 Coefficient of variation analysis

As shown in Tab.1, the coefficient of variation (CV) of leaf moisture of the 2nd, 3rd and 4th leaf whorl under 75% light were 32.87%, 24. 60% and 13.54%, while that under 100% light were 32.53%, 23.86% and 13.40%, respectively. The CV of scale bud moisture of the 3rd and 4th leaf whorl under 75% light, were 8.6% and 8.61%, while that under 100% light were 6.55% and 35.7%, respectively.

The CV of scale bud scar length of the 2nd, 3rd and 4th leaf whorl under 75% light were 39.49%, 17.9%, 21.94%, while that under 100% light were 19.96%, 19.75% and 21.94%, respectively. The CV of leaf bud scar length of the 3rd and 4th leaf whorl under 75% light were 16.26% and 19.17%, while that under 100% light were 19.78% and 16.78%, respectively.

The CV of scale bud eye length of 4th leaf whorl under 75% light were 33.86% and under100% light was 28.93%. The CV of leaf bud eye length of the 2nd, 3rd and 4th leaf whorl under 75% light were 25.66%, 19.58%, 24.28%, while that under 100% light were 25.12%, 23.67% and 26.78%, respectively. The CV of scale bud scar width of 3rd and 4th leaf whorl under 75% light were 8.79%, 10.14%, while that under 100% light were 7.75% and 4.92%, respectively. The CV of leaf bud scar width of 2nd, and 3rd leaf whorl under 75% light were 15.23%, 10.14%, while that under 100% light were 14.35% and 14.58%, respectively.

The CV of scale bud eye width was 17.14% under 75% light and 18.50% under 75% light. The CV of leaf bud scar thickness of the 2nd, 3rd and 4th leaf whorl under 75% light was 11.75%, 17.49%, 13.53%, while that under 100% light were 21.97%, 11.57% and 10.56%, respectively.

The CV of leaf length of the 2nd, 3rd and 4th leaf whorl under 75% light was 19.28%, 9.95% and 10.21%, while that under 100% light were 21.62%, 12.55% and 17.26%, respectively. The CV of leaf width of the 3rd and 4th leaf whorl under 75% light was 11.13% and 8.42%, while that under 100% light were 14.01% and 19.06%, respectively. It shows that sufficient light contributes to the growth of leaf width.

The duration CV under 75% light of leaf-unfolding stage, bronze stage Ⅰ, coloring stage and mature leaf stage were 0, 17.32%, 0 and 7.87%, while that under 100% light was 15.75%, 12.37%, 12.37% and 32.73%, respectively. It shows that proper shading is helpful for the rapid initiation of new leaf whorl, but it is not conducive to the completion of new leaf whorl phenology, suggesting that more light is needed in the later stage with the gradual increase of leaf area.

The CV of plant height increase at mature leaf stage was15.53% under 75% light and 14.32% under 100% light. CV of leaf length increase under 75% light was 2.44% at bronze stage Ⅰ, 0.45% at light green leaf stage and 1.10% at mature leaf stage, respectively, and that under 100% light was 2.19%, 1.64% and 0.81% respectively. The CV of leaf width increase under 75% light was 3.03% t bronze stage Ⅰ, 3.78% at bronze stage Ⅱ, 0.76% at coloring stage, 0.71% at light green leaf stage respectively, and that under 100% light was 6.66%, 1.37% , 1.18%, and 1.49%, respectively.

The CV of leaf temperature under 75% light was 0.53% at bronze stage II, 1.23% at mature leaf stage, and that under 100% light was 0.50%, 0.27%, respectively. The CV of leaf moisture at coloring stage was 11.67% under 75% and 2.09% under 100% light, respectively.

Table 1 Coefficient of variation (%) between significantly different parameters under two light intensities

parameter		75%light			100%light			parameter	leaf phenology	75%light	100%light
		2nd	3rd	4th	2nd	3rd	4th	duration	leaf-unfolding stage	0	15.75
moisture	leaf	32.87	24.6	13.54	32.53	23.86	13.4		bronze stage Ⅰ	17.32	12.37
	scale bud	-	8.6	8.61	-	6.55	35.7		coloring stage	0	12.37
bud scar length	scale bud	39.49	17.9	21.94	19.96	19.75	21.94		mature leaf stage	7.87	32.73
	leaf bud	-	16.26	19.17	-	19.78	16.78	plant height increase	mature leaf stage	15.53	14.32
bud eye length	scale bud	-		33.86	-	-	28.93	leaf length increase	bronze stage Ⅰ	2.44	2.19
	leaf bud	25.66	19.58	24.28	25.12	23.67	26.78		light green leaf stage	0.45	1.64
bud scar width	scale bud	-	8.79	10.14	-	7.75	4.92		stable leaf stage	1.10	0.81
	leaf	15.23	10.04	-	14.35	14.58	-	leaf width	bronze stage I	3.03	6.66

	bud							increase			
bud eye width	scale bud	17.14	-	-	18.5	-	-		bronze stage II	3.78	1.37
bud scar thickness	leaf bud	11.75	17.49	13.53	21.97	11.57	10.56		coloring stage	0.76	1.18
leaf length		19.28	9.95	10.21	21.62	12.55	17.26		light green leaf stage	0.71	1.49
leaf width		-	11.13	8.42	-	14.01	19.06	leaf temperature	bronze stage II	0.53	0.50
									mature leaf stage	1.23	0.27
								leaf moisture	coloring stage	11.67	2.09

5 Correlation analysis

5.1 Under 75% light, the 2nd, 3rd and 4th leaf whorl of scale bud

As shown in Fig.8A, leaves were significantly negatively correlated with leaf moisture ($p<0.01$). The scale bud moisture was significantly negatively correlated with the scale bud scar width and scale bud scar thickness, and the leaf moisture was significantly negatively correlated with plant height ($p<0.05$). There was a significant positive correlation between leaves and plant height ($p<0.01$). There was a significant positive correlation between scale bud eye length and scale buds ($p<0.05$). Fertilization and reasonable pruning measures can be taken to increase the scale buds, thereby promoting the growth of scale bud eye length, so as to have a positive impact on the scale bud eye width.

5.2 Under 75% light, the 2nd, 3rd and 4th leaf whorl of leaf bud

As shown in Fig.8a, leaves were significantly negatively correlated with leaf moisture ($p<0.01$). There was a significant negative correlation between the stem moisture and the of leaf bud scale eye length, the leaf bud scale thickness and the leaf buds, the leaf moisture and the plant height ($p<0.05$). There was a significant positive correlation between leaves and plant height ($p<0.01$). There was a significant positive correlation between the leaf bud eye width and the leaf bud eye length ($p<0.05$). It can be seen that when the stem moisture increases, the leaf bud eye length becomes smaller. Therefore, in the early management of the rubber bud grafting bud, reasonable irrigation and appropriate reduction of the stem moisture are beneficial to increase the leaf bud eye length.

5.3 Under 100% light, the 2nd, 3rd and 4th leaf whorl of scale bud

As shown in Fig.8B, there was a significant positive correlation between leaf moisture and stem diameter, plant height and scale bud moisture, scale bud eye length and scale bud eye width ($p<0.01$). There was a significant positive correlation between leaf width and scale bud scar thickness, scale bud scar length and scale bud scar width ($p<0.05$). There was a significant negative correlation between the stem moisture and the scale bud eye length and the scale bud eye width ($p<0.05$). Therefore, in the early management of rubber bud grafting, reducing the stem moisture is helpful to increase the scale bud eye length and width. However, the stem moisture should not be excessively reduced, so as not to have a serious negative impact on the overall growth of the plant.

5.4 Under 100% light, the 2nd, 3rd and 4th leaf whorl of leaf bud

As shown in Fig.8b, leaves were significantly positively correlated with plant height ($p<0.01$). There was a significant positive correlation between leaves and leaf bud eye length, plant height and leaf bud eye length ($p < 0.05$). There was a significant negative correlation between the leaf bud scar width and the leaf buds ($p < 0.01$). Under 100% light, the leaves are an important factor in their growth and development. The increase in the leaves will increase the plant height and the leaf bud eye length. However, the increase in the leaf bud will reduce the leaf bud eye width. In rubber mini-seedling budding operation, leaf bud size can be roughly judged by the naked eye.

It can be concluded from the correlation analysis results that scale buds and leaves increase, controlling the stem moisture content and the number of leaf bud is beneficial to increasing the length and width of the bud eyes. In the process of plant growth and development, various parts of the plant affect and restrict each other through a variety of physiological and morphological mechanisms to achieve overall growth and development, in order to provide better quality buds for rubber mini-budding.

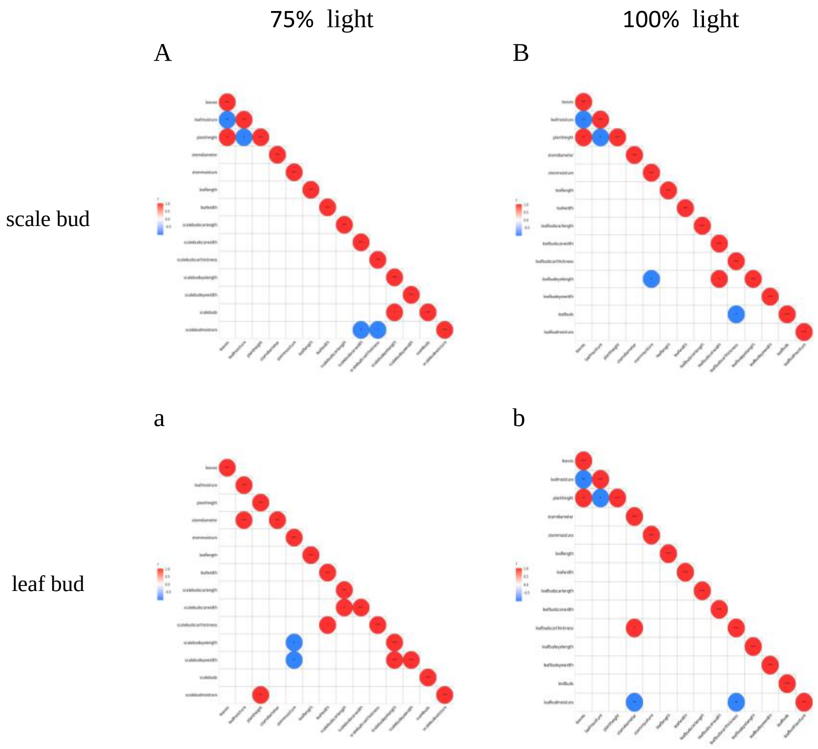


Fig. 8 Correlation analysis of leaf, stem, axillary bud and other indicators

6 Comprehensive analysis

As shown in Tab.2, taking stem diameter and plant height as low-optimal indexes, the TOPSIS method was used to analyze the leaves, leaf moisture, plant height, stem diameter, stem moisture, leaf length, leaf width, scale bud scar length, scale bud scar width, scale bud scar thickness, scale bud eye length, scale bud eye width, scale buds, scale bud moisture, leaf bud scar length, leaf bud scar width, leaf bud scar thickness, leaf bud eye length, leaf bud eye width, leaf buds, leaf bud moisture. The results are shown in Table 1. When considering the light intensity, the quality of axillary buds under 75% light was better than that under 100% light. When considering the bud leaf whorl, the best quality of axillary buds is the 3rd leaf whorl, followed by the 2nd leaf whorl, and finally the 4th leaf whorl; without considering the light intensity and leaf whorl position, axillary bud quality: 3rd-75% light > 3rd-100% light > 2nd-75% light > 2nd-100% light > 4th-75% light > 4th-100% light.

Table 2 Comprehensive analysis of TOPSIS method based on leaves, stems and axillary buds

The sorting index value of each sample				
Leaf whorl -light intensity	D+	D-	Statistic CI	Rank
3rd-75% light	0.3282	0.4364	0.5708	1
3rd -100% light	0.3697	0.4451	0.5463	2
2nd- 75% light	0.4075	0.4623	0.5315	3
2nd- 100% light	0.4209	0.353	0.4561	4
4th- 75% light	0.5045	0.3557	0.4135	5
4th- 100% light	0.5317	0.3429	03921	6

D+, distance to optimal vector. D-, distance to inferior vector. CI, approximation to the Optimal Vectors.

In the growth process of rubber bud-stick, first of all, in terms of light management, priority should be given to controlling the light intensity at about 75%, under this light condition, the leaf length, leaf width, leaf bud scar width, scale bud eye length, scale bud scar length and scale bud scar width were better than those under 100% light condition, thus effectively improving the quality of axillary buds and providing better bud resources for subsequent rubber bud grafting production. For example, when building a greenhouse or shading facility, precise regulation can be carried out according to this light ratio to promote the good development of axillary buds. This is different from Chen Qing 's study on the effects of five shading intensities (0, 50%, 70%, 80% and 90%) on the growth of rubber tree tissue culture seedlings in Hainan Province by artificial shading [12]. It is concluded that the nursery rate of rubber tree tissue culture seedlings under 90% shading is significantly higher than that of other groups. In the process of seed selection and seedling raising, the axillary buds from the 3^{rd} and 75% light conditions can be preferentially selected as the budding materials according to the results of axillary bud quality without considering the light intensity and leaf position, so as to improve the overall quality and growth potential of the seedlings, and lay a solid foundation for the later high-yield and high-quality production. It is consistent with the conclusion that the seedling growth of the seed seedlings obtained from the scale buds and axillary buds of the 3^{rd} canopy leaves in the bud grafting experiment of rubber tree seed seedlings with different leaves and different buds of different canopy leaves such as Xiaolong Sun is significantly higher than that of other treatments and controls [13].

IV. CONCLUSION

This study analyzed multiple quality evaluation indicators of rubber tree axillary buds. The results showed that different light intensities have a significant impact on the quality of rubber tree axillary buds, covering many aspects such as axillary bud phenotypic traits, moisture content, and photosynthetic physiological indicators. Appropriate light intensity is the key factor to ensure the high quality of rubber tree axillary buds. Based on the above indicators and the actual performance of the plant, it was determined that under 75% light intensity conditions, the axillary buds in the 3^{rd}-leaf whorl have the best quality. Therefore, during the growth process of rubber bud-stick seedlings, it is recommended to set the light intensity to 75%. For the propagation of rubber mini-seedling buddings through bud grafting, it is optimal to select bud-stick with three leaf whorls for bud grafting, and recommended for bud grafting according to leaf whorl position, which will optimize grafting technology and further improve the quality of rubber mini-seedling buddings. This can ensure that the mini-seedling buddings have high uniformity and neat forest appearance, and further solve the problem of labor consumption after transplanting in the field.

ACKNOWLEDGEMENTS

This work was supported by Hainan Provincial Natural Science Foundation of China(321QN335), the earmarked fund for China Agriculture Research System (CARS-34-YZ4), and Yunnan Province Huang Huasun Expert Workstation(202305AF150125).

REFERENCES

[1] Dongling Qi, Xiuquan Wang, Zhiyang Zhang, Yueqiu Huang. Current situation of Chinese natural rubber industry and development suggestions. Chinese Journal of Tropical Agriculture, 2013,33(02):79-87.

[2] Libing Li, Weitao Li, Yirou Liu, Yiyang Liu, Bo Bai, Feng Cui, Shubo Wan, Guowei Li. Research progress on branching formation and the main factors affecting branching number in plants. Journal of Plant Genetic Resources, 2024-12-04:1-14. DOI:10.13430/j. cnki.jpgr. 202403 15001.

[3] Juan Wei, Yonghong Ma, Ping Mao. Response to light intensity of cercidiphyllum japonicum seedlings. Journal of Tropical and Subtropical Botany, 2024-12-04:1-10. DOI:10.11926/jtsb.4923.

[4] Nan Chen, Xin Liu, Qin Wei, Xin Zhao. Effects of different light intensities on the content of 1,8-cineole in *Cinnamomum longepaniculatum*. Journal of Sichuan Forestry Science and Technology,2024,45(05):49-57.

[5] Zhi Jin, Li Ma, Xinsheng Wang, Siying Ou, Meng Guo. Effects of different light intensities on growth and flowering time of watermelon. South China Agriculture, 2024,18(19):21-25.

[6] Wenxiu Li, Yingquan Xu, Junjun He, Hualin Zhang, Ping Luo, Yunfeng Shi. Effects of different light conditions on cold tolerance and photosynthetic characteristics of *Hevea brasiliensis* under low temperature stress. Anhui Agric.Sci, 2023,51(04):92-94.

[7] Jianxiong Huang, Jian Pan, Lijun Zhou, Shuna Yuan, Weifu Lin. Effect of light deficiency on productivity of intercrops in rubber-cropagroforestry system. Chinese Journal of Eco-Agriculture, 2020, 28(5): 680-689.

[8] Liping Wei, Yaohua Tian, Huiping Zhou, Xiangshuai Yan, Yanxiong Gong, Huifang Yuan. The influence of shade treatment on leaf anatomical characteristicsand growth of different rubber variaties. Chinese Journal of Tropical Crops, 2019,40(01):45-53.

[9] Zhonglian Liu, Fanghui Guo, Quanbao Wang. Early growth test of different types of buds and scions of rubber tree Yunyan 77-4. China Tropical Agriculture, 2010, (03):43-46.

[10] Taihua Wang. Establishment of somatic embryo regeneration system in axillary buds of *Hevea brasiliensis* and callus induction of young leaves. HaiNan University, 2023.001206.

[11] Qi Zhao, Fengliang Zhang, Tian Yang, Yu Wu. Effects of different concentrations of colchicine solutions on axillary budding rate of *Hevea brasiliensis*. Tropical Agricultural Science & Technology, 2021,44(04):6-8.

[12] Qing Chen, Jun Zhou, Jun Wang, Weifu Lin. Effect of different shading on growth of tissue-culture *Hevea Brasilienis* Seedings. Fujian Journal of Agricultural Science, 2018,33(05):516-519.

[13] Xiaolong Sun, Hai Tian, Mingchun Gui, Ming Tang, Guoping Liang. Experiment of mini-seedling grafting with different buds from different budwoods of rubber trees. Tropical Agricultural Science & Technology, 2019,42(04):1-3+8.

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Determination of Wheat Evapotranspiration using the Earth Engine Evapotranspiration Flux (EEFLUX)

Vishal Pandey [1*], S.A. Kadam[2*], S.D. Gorantiwar[3] and M.G. Shinde[4]

[1*]Senior Research Fellow (IDE), Smart Irrigation Project, MPKV, Rahuri, Maharashtra, India
[2*]Associate Professor (IDE), MPKV, Rahuri, Maharashtra, India
[3]Head, Agricultural Engineering, MPKV, Rahuri, Maharashtra, India
[4]Professor (SWCE), MPKV, Rahuri, Maharashtra, India

Received: 23 Nov 2024; Received in revised form: 18 Dec 2024; Accepted: 24 Dec 2024; Available online: 31 Dec 2024

***Abstract*— *In this study an automated Earth Engine Evapotranspiration Flux (EEFlux) was used to produce actual evapotranspiration (ETa) estimates for rabi wheat, compared against the FAO-56 approach using ground-measured weather data. Eight cloud-free Landsat images from the 2020-2021 rabi season were processed in METRIC-EEFlux, producing ETa values ranging from 0.95 mm to 4.07 mm, with an average of 2.41 mm. Conversely, the FAO-56 method estimated ETa values between 0.64 mm and 4.80 mm, averaging 2.58 mm. Cumulative ETa for wheat was 290 mm (EEFlux) and 336 mm (FAO-56). The comparison showed moderate agreement (IA = 0.67), with EEFlux underestimating by 13.69% relative to FAO-56. EEFlux-ETa had an RMSE of 0.93 mm/day and NRMSE of 0.33. The findings suggest that EEFlux can achieve more accurate ET estimates with frequent satellite imagery, improved weather data, and automated ETrF adjustments, necessitating further validation across multiple years to confirm its general applicability.*

Keywords*— *Actual evapotranspiration; EEFlux; FAO-56; Landsat; Wheat

I. INTRODUCTION

Accurate estimation of actual crop evapotranspiration (ETa) holds great significance in both irrigated and dryland agricultural practices. Traditionally, various experimental methods have been employed to gauge ETa, such as lysimeters, the Bowen ratio, eddy covariance (EC), scintillometer (SC), and the soil water balance method. Empirical approaches, like the FAO-56 and ASCE methods, are also utilized. Nonetheless, these techniques exhibit limitations when applied to broader regions characterized by diverse land surfaces. To address this issue, innovative methods relying on surface energy balance and remote sensing data have been developed.

Several remote sensing-based models and algorithms, including Two-Source Energy Balance (TSEB) (Kustas & Norman, 1996), Atmosphere-Land Exchange Inverse (ALEXI) (Anderson et al., 1997), Surface Energy Balance Algorithm for Land (SEBAL) (Bastiaanssen et al., 2005; Bastiaanssen W.G.M. et al., 1998), Simplified Surface Energy Balance Index (S-SEBI) (Roerink et al., 2000), Surface Energy Balance System (SEBS) (Su, 2002), North American Land and Data Assimilation System (NLDAS) (Cosgrove et al., 2003), disaggregated ALEXI model (DisALEXI) (Norman et al., 2003), and Mapping Evapotranspiration at High Spatial Resolution with Internalized Calibration (METRIC) (Allen et al., 2007), have been harnessed for regional ETa estimation. Among these, METRIC is widely used, albeit it demands substantial data preprocessing and manual calibration.

To streamline this process, the Google Earth Engine Evapotranspiration Flux (EEFlux) platform was conceived to automate the application of the METRIC algorithm, simplifying data entry and calibration. EEFlux leverages Landsat imagery and gridded weather data to estimate ETa at the field scale, generating intermediate product maps like surface temperature, albedo, reference evapotranspiration, and crop coefficient maps.

Nonetheless, the automated nature of ETa estimation through EEFlux justifies a thorough assessment, particularly for specific regions and crops. Prior research indicates that while EEFlux generally provides reasonably accurate results, it may occasionally overestimate or underestimate ETa due to the automation processes, utilization of spatial weather data, and factors such as elevated wind speeds and residual soil evaporation. Overestimation can occur during the crop's maturity stage when the majority of energy is dedicated to heating the atmosphere rather than transpiration. Furthermore, EEFlux's performance has not been extensively scrutinized in Indian conditions or with non-irrigated crops.

This study seeks to evaluate the efficacy of METRIC-EEFlux in estimating ETa in India, taking into account the unique challenges and environmental conditions specific to the region.

II. MATERIALS AND METHODS

Study Sites

The research study was carried out in the Climate Smart Block established within the Centre for Advanced Agriculture Science and Technology focused on Climate Smart Agriculture Water Management, Mahatma Phule Krishi Vidyapeeth, Rahuri, during the rabi season. The study area is located at 19° 19' 19.70" N latitude and 74° 39' 27.27" E longitude, with an elevation of 527 meters.

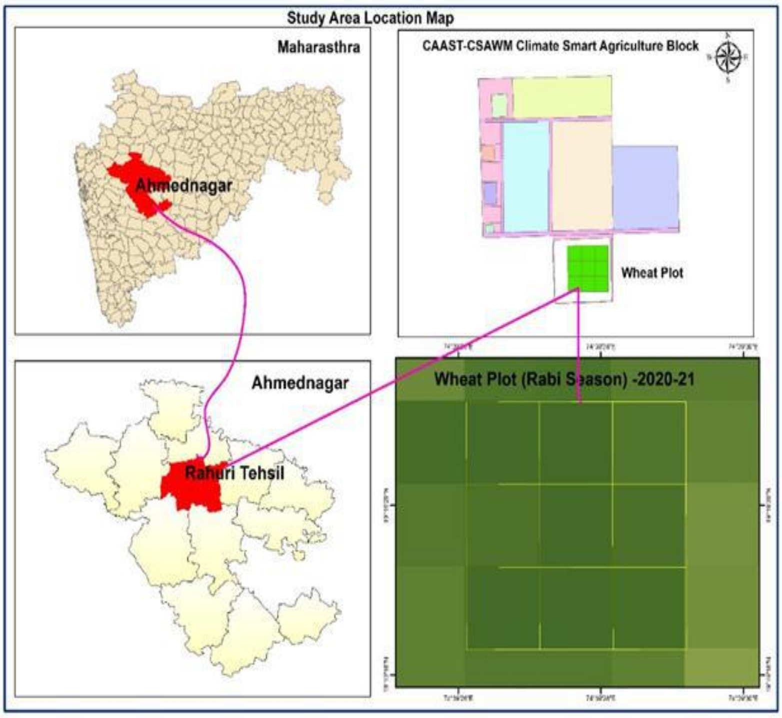


Fig.1. Location of Research Site

This research was conducted during the 2020-2021 agricultural season. Wheat (Triticum aestivum L.), specifically the Phule Samadhan variety, was the focus of the study. This investigation was carried out during the Rabi growing season, with the crop sown at a spacing of 22.5 cm using line sowing. The sowing date was December 6, 2020, and the crop was harvested on April 4, 2021, leading to a total crop duration of 120 days. Surface irrigation was employed as the method of watering, and a fertilizer dose of 120:60:40 N, P2O5, K2O (kg/ha) was applied.

Satellite Data Acquisition

Table 1 Details of the EtrF data products from METRIC – EEFlux (Satellite images) used in the study with year, acquisition dates, day of the year (DOY), Days after planting (DAP), Landsat satellite, and path/row for 2020-2021 rabi season.

Year	Acquisition date	DOY	DAP	Satellite	Path/Row
2020	December 17	352	12	Landsat 8	147/46
2021	January 02	2	28	Landsat 7	147/46

	January 18	18	44	Landsat 8	147/46
	February 03	34	60	Landsat 8	147/46
	February 19	50	76	Landsat 8	147/46
	March 07	66	92	Landsat 7	147/46
	March 23	82	108	Landsat 7	147/46
	April 04	98	124	Landsat 8	147/46

Within the scope of this research study, a total of eight clear sky images were deliberately chosen for examination, Table 1. These specific images were selected due to their comprehensive temporal coverage, ensuring cloud-free conditions for analysis. Subsequently, the chosen images underwent processing using the EEFlux - Google Earth Engine Evapotranspiration flux platform to yield essential data products, namely EtrF and EEFlux- ETa.

Field Data Collection

The daily ETr values estimated with ASCE Penman Monteith method with seasonal average value. The crop coefficient (Kc) values estimated using polynomial equation developed with lysimeter data.

Methods

1. **Estimation of actual evapotranspiration (ETa)**

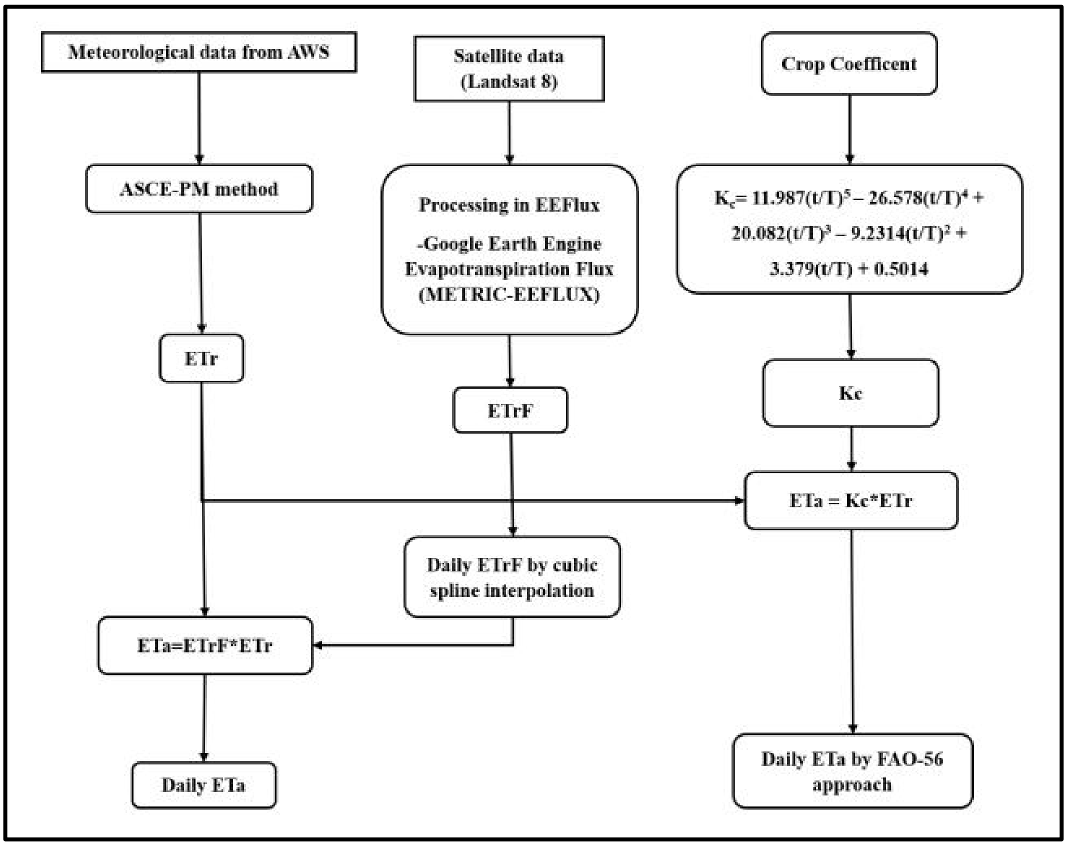


Fig.2 Methodology flowchart of actual evapotranspiration (ETa) estimation

The ETrF values derived from Landsat satellite data using EEFlux application, during the wheat crop growth period. Ultimately, the daily ETa values calculated using EEFlux were compared with respect to daily ETa by the FAO-54 approach with the help of statistical formulas. The detail of the workflow is explained in (Figure 2) flow chart.

1.1 Estimation of crop evapotranspiration (ETa) using FAO-56 approach

FAO-56 methodology (Allen et al., 2007)(Allen et al., 1998) was used to estimate actual crop evapotranspiration (ETa). The estimated actual crop evapotranspiration termed as FAO56-ETa. The crop evapotranspiration is estimated using equation ETa = Kc x ETr.

Where,

ETr = reference crop evapotranspiration (mm/day);

Kc = single crop coefficient that averages crop transpiration and soil evaporation;

The daily crop coefficient for wheat crop was estimated with the functions developed using the lysimeter data (Patil, 2007).

The crop coefficient values are calculated using the function presented in equation;

$Kc=11.987*(t/T)^5 -26.578*(t/T)^4+20.082*(t/T)^3 -9.2314*(t/T)^2+3.379*(t/T)+0.5014$

Where, t = day considered T = total crop duration

1.2 Estimation of actual evapotranspiration (ETa) by EEFlux

EEFlux, or the Google Earth Engine Evapotranspiration Flux, is a specialized application of the METRIC algorithm. It was employed to generate precise evapotranspiration (ET) maps by processing Landsat imagery within the Google Earth Engine infrastructure, focusing on the creation of ETa maps for individual Landsat scenes. EEFlux closely follows the operational METRIC model's approach, functioning as a comprehensive surface energy balance model that provides valuable estimates for key parameters, including net radiation (Rn), sensible heat flux (H), and soil heat flux (G). ETa values were derived as the difference within the surface energy balance equation, as originally established by Allen and colleagues in 2007. In the context of this study, ETa values computed using the METRIC-EEFlux approach were denoted as EEFlux-ETa.

Extraction of ETrF

In this study, Landsat images were processed using Earth Engine Evapotranspiration Flux (EEFlux / METRIC version 0.20.2). ETrF data from METRIC-EEFlux were downloaded for analysis. Mean EtrF values for wheat crops were extracted using a 3 x 3-pixel area (90 x 90 m rectangle) centered on field boundaries in QGIS 2.18.6. Daily EtrF values were derived using cubic spline interpolation. Daily EEFlux-ETa was calculated based on equation $ET_a = ET_rF \times ET_r$ and compared with ETa estimates using the FAO-56 approach for the 2020-2021 growing season. Seasonal ETa was determined by summing daily ETa values within the growing season.

III. RESULTS AND DISCUSSION

This study, carried out during the 2020-2021 season, focused on crop evapotranspiration and crop coefficient using the Earth Engine Evapotranspiration Flux application. It involved estimating reference evapotranspiration (ETr), actual crop evapotranspiration (ETa), crop coefficient based on lysimeter data (Kc), as well as estimating ETa using EEFlux-derived fraction reference evapotranspiration (EtrF).

Estimated Reference Evapotranspiration values

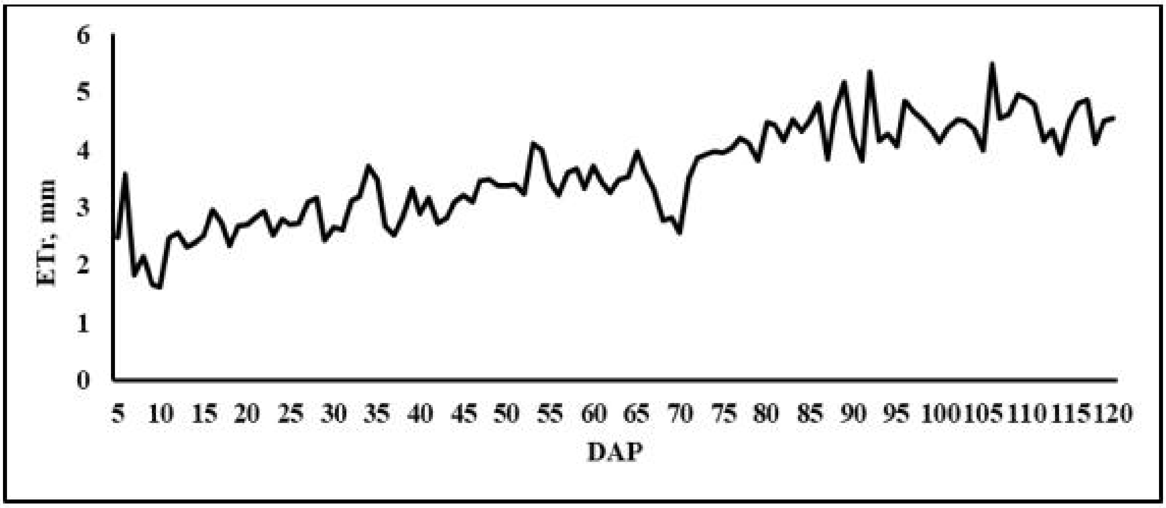


Fig.3 Stage wise ETr (mm) for wheat crop during the 2020 and 2021 growing seasons

Reference evapotranspiration was estimated using the ASCE Penman Monteith Method with data from the Automatic Weather Station at CAAST CSAWM Climate Smart Research Block during the 2020-2021 wheat growing season. Daily ETr values, depicted in Figure 3, demonstrate variations ranging from 1.61 mm to 5.50 mm over the wheat growth period, with an average of 3.57 mm.

Stage wise Crop Coefficient values

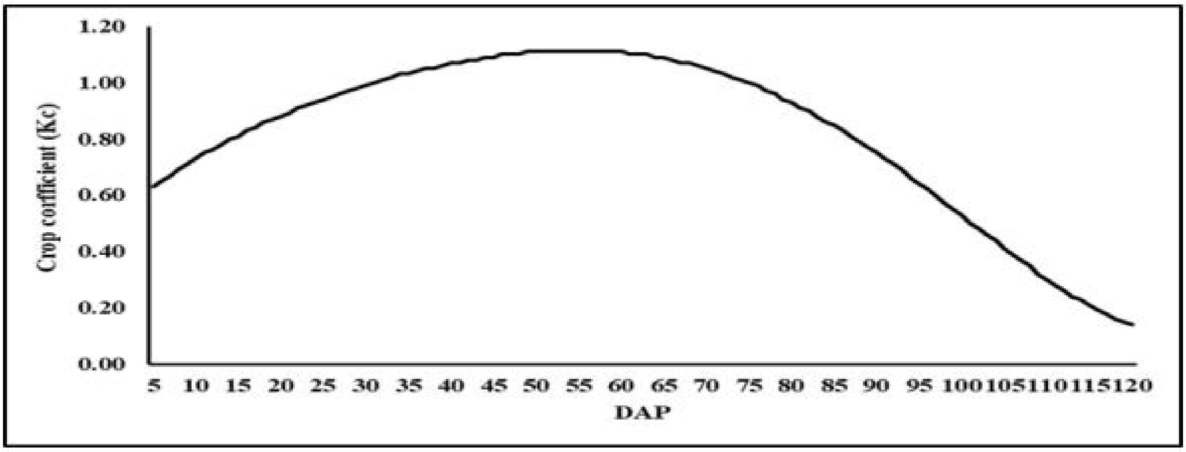


Fig.4 Stage-wise Kc estimated for wheat crop during the 2020 and 2021 growing seasons

Daily crop coefficient (Kc) values were determined using a polynomial equation based on lysimeter data and soil water balance. Stage-wise Kc values were averaged over each respective stage duration. The daily Kc values are visually represented in Figure 4, demonstrating a range from 0.14 to 1.11 during the wheat growth period, with an average seasonal value of 0.81. Estimated Daily FAO-56-ETa (mm)

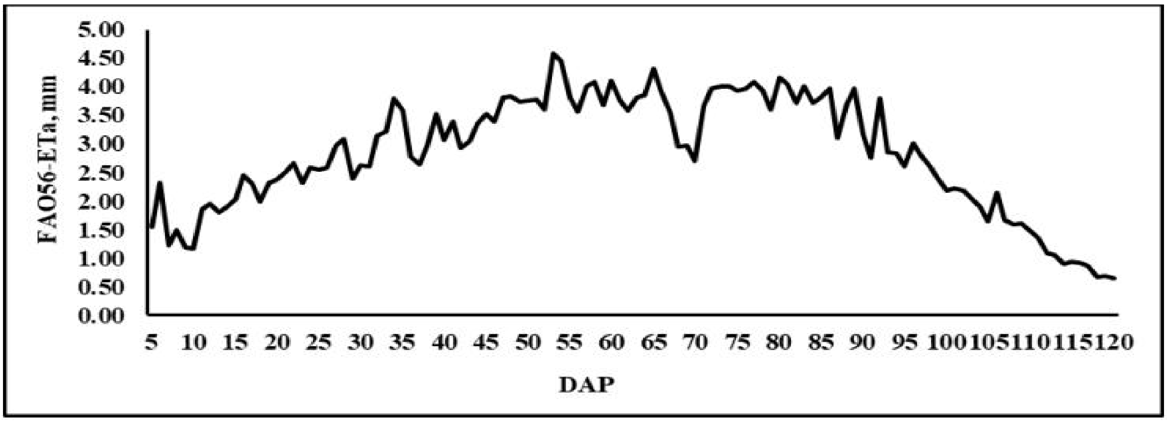


Fig.5 Daily FAO56-ETa (mm) estimated for rabi wheat growing season of 2020- 2021

Daily ETa values were estimated using the FAO-56 approach, calculated as the product of reference evapotranspiration and crop coefficient, denoted as FAO56-ETa. These values are visually displayed in Figure 5. The data reveals that FAO56-ETa varies from 0.64 mm to 4.80 mm throughout the wheat growing period, with an average value of 2.58 mm. The total seasonal ETa accumulates to 336 mm.

Daily ETrF derived from Landsat-8 satellite data

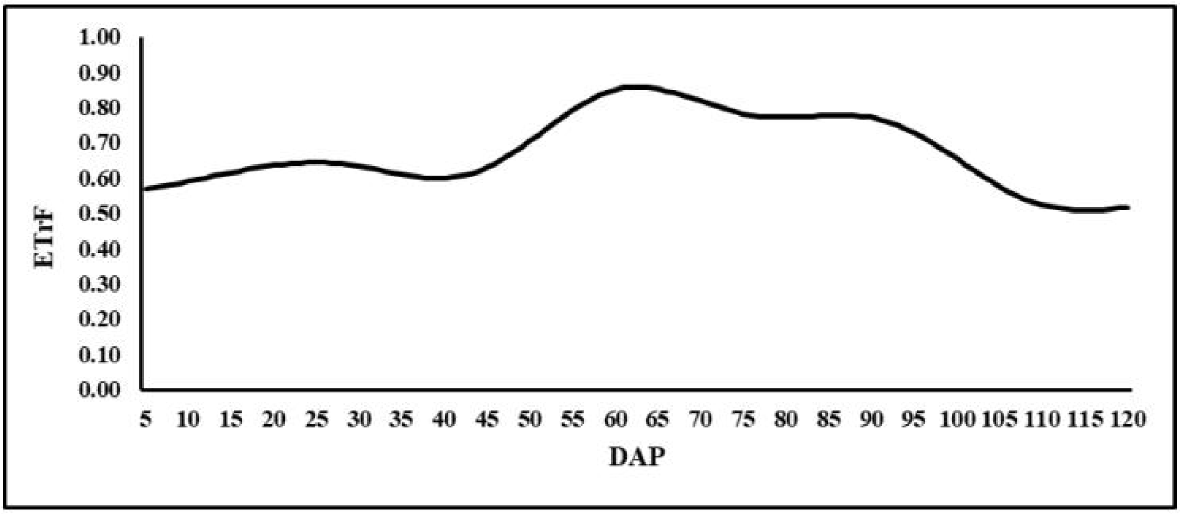


Fig.6 ETrF profile during crop growing period of wheat (2020-2021)

ETrF values, equivalent to the crop coefficient, were extracted from Landsat satellite data through the EEFlux (Google Earth Engine Evapotranspiration Flux) application for available dates within the wheat crop's growth period. These daily ETrF values are visually represented in Figure 6. Notably, ETrF varies from 0.51 to 0.86 throughout the wheat growing period, with a seasonal average of 0.67.

Estimated Daily EEFlux-ETa (mm)

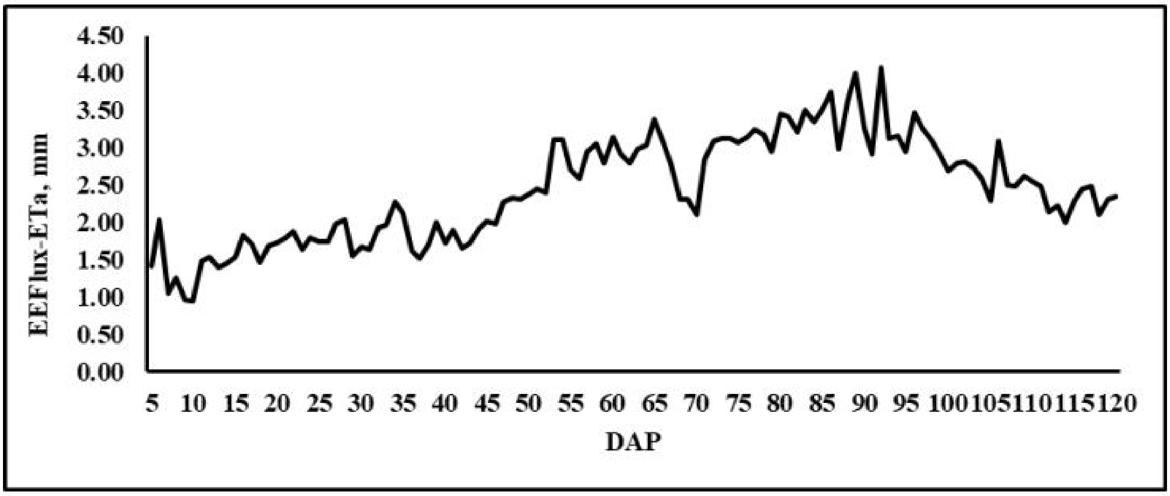


Fig.7 EEFlux-ETa during crop growing period of wheat (2020-2021)

EEFlux (Google Earth Engine Evapotranspiration Flux) was utilized to estimate ETa, referred to as EEFlux-ETa. EEFlux calculates ETa using Landsat satellite data and local weather information. EEFlux-ETa values are illustrated in Figure 7. The data shows that EEFlux-ETa ranges from 0.95 mm to 4.07 mm across the wheat growing season, with an average of 2.41 mm. The total seasonal ETa estimated by EEFlux amounts to 290 mm.

Comparison of EEFlux-ETa and FAO56-ETa

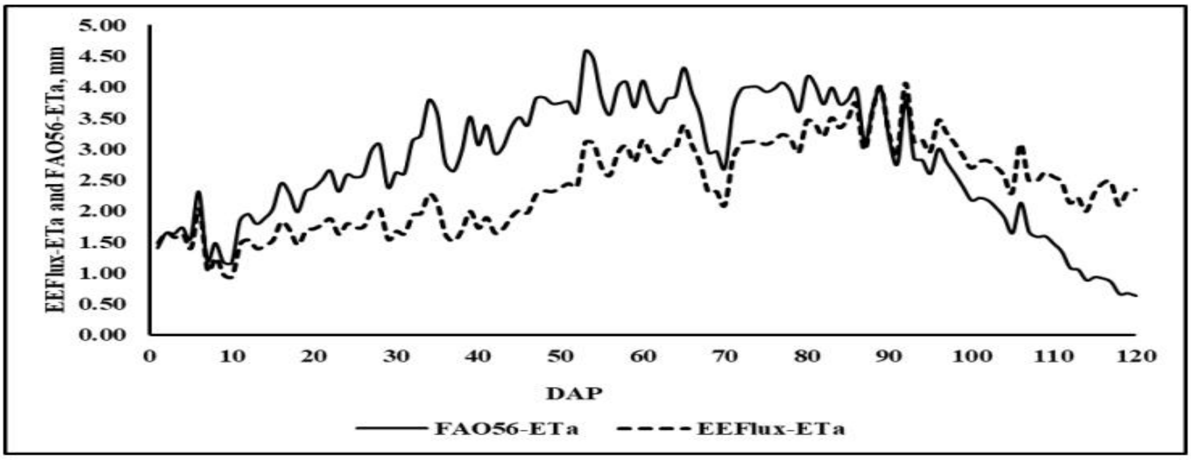


Fig.8 Comparison of EEFlux-ETa and FAO56-ETa during wheat crop growth period during 2020-2021

Figure 8 displays the Comparison of EEFlux-ETa and FAO56-ETa during wheat crop growth period during 2020-2021.

Daily rates exhibit significant variability throughout the growing season, with larger differences between EEFlux-ETa and FAO56-ETa observed on a daily scale. These disparities are most pronounced during the initial and late season stages. In the maturity stage, the majority of energy is allocated to heating the atmosphere rather than transpiration. Post-harvest, ET decreases abruptly, a phenomenon not captured by any method for seasonal ET, resulting in larger differences in ETa. These findings align with previous research comparing measured and estimated ETa. Khan et al. (2019) noted departures ranging from -4.7% to 25.5% for cumulative ET estimates with METRIC-EEFlux across various crops, with larger discrepancies in low ET conditions. Ayyad et al. (2019) reported a 36% overestimation of ETa by EEFlux in Egyptian agriculture compared to the SEBS model, while Duijndam (2016) observed errors ranging from 4% to 176% in EEFlux cumulative ETa estimates in semi-arid regions compared to flux tower measurements. Kadam et al. (2021) reported a 23% underestimation of ETa with EEFlux for winter wheat in dryland fields.

Table 2. Statistical comparison of EEFlux ETa and FAO-56 ETa

Statistical Parameter	Value
Index of Agreement (IA)	0.67
Root Mean Square Error (RMSE)	0.93 mm/day
Normalized root mean square Error (NRMSE)	0.33mm /day

EEFlux-ETa was rigorously compared to FAO56-ETa, employing root mean square error (RMSE), normalized root mean square error (NRMSE), and the index of agreement (IA). The statistical analysis, presented in Table 2, provides a comprehensive overview of ETa comparisons between EEFlux and the FAO-56 approach. Figure 9 visually illustrates the comparison between EEFlux-ETa and FAO56-ETa.

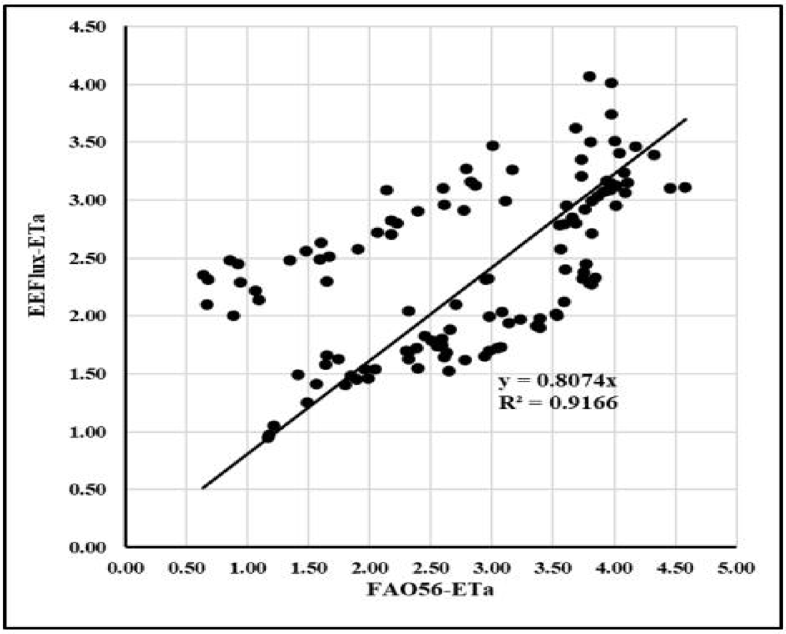


Fig.9 Statistical comparison of EEFlux-ETa and FAO56-ETa during wheat crop growth period during 2020-2021

The IA-index, registering at 0.67, along with a slope of 0.81, indicates a moderate to good correlation between the estimated EEFlux-ETa and FAO56-ETa, supported by an R^2 value of 0.92. Notably, the RMSE reveals a minimal bias, falling below 1 mm/day (RMSE=0.93 mm/day) for wheat. A corresponding NRMSE of 0.33 mm/day confirms this. Discrepancies observed in ETa estimations between EEFlux and the FAO-56 approach can be attributed to potential errors or bias in ETrF derived from satellite data and Kc estimates drawn from lysimeter data.

Comparison of Kc and EtrF during different growth stages

Table 3 Percent deviation of ETrF from Kc estimated using Lysimeter data

Stage	Duration (days)	Kc	ETrF	% Deviation
Initial	15	0.68	0.58	14.74
Development	25	0.96	0.63	35.02
Mid-Season	50	1.02	0.77	24.83
Late-Season	30	0.44	0.60	-45.93

The study calculated the average values of Kc and ETrF at various developmental stages of wheat crop, namely, initial (15 days), development (25 days), mid-season (50 days), and late-season (30 days). The stage-wise average Kc values were found to be 0.68, 0.96, 1.02, and 0.44 during the initial, development, mid-season, and late-season stages, respectively. Similarly, the stage-wise average ETrF values (representing Kc derived from Landsat satellite data) were 0.58, 0.63, 0.77, and 0.60 during the corresponding stages.

The study also determined the percentage deviation of ETrF from Landsat satellite data compared to Kc estimated using lysimeter data, resulting in deviations of 14.74%, 35.02%, 26.83%, and -45.93% for the initial, development, mid-season, and late-season stages, respectively. These daily departures of ETrF values from lysimeter-based Kc estimates are visually presented in Figure 10.

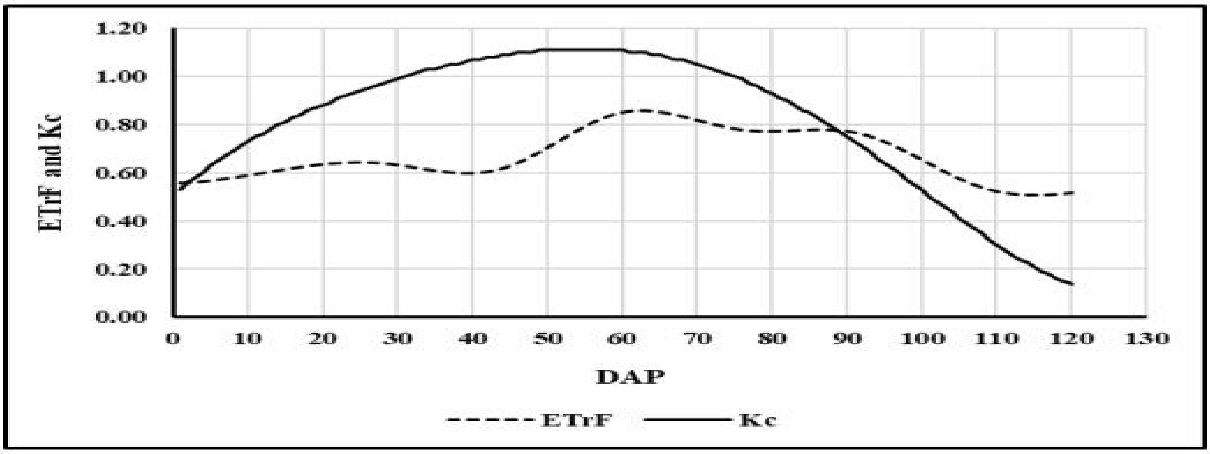


Fig.10 Statistical Comparison of daily ETrF and Kc during wheat crop growing season of 2020-2021

In the study conducted during the Rabi season of 2020-2021, the Earth Engine Evapotranspiration Flux (EEFlux) application showed a 13.69% underestimation of ETa compared to the FAO-56 approach. Additionally, the study revealed a moderate to good correlation between ETa estimated by EEFlux and the FAO-56 approach, with an R^2 of 0.92, IA of 0.67, RMSE of 0.97 mm/day, and NRMSE of 0.33. These findings support the potential use of EEFlux and Google Earth Engine for estimating wheat ETa. However, further assessments across multiple years and locations are necessary to determine its broader suitability for regional ETa estimation.

IV. DISCUSSION

This research explores the estimation of actual crop evapotranspiration (ETa) for wheat crops during the Rabi season. The study involves the assessment of ETa using two different approaches: the FAO-56 method and the EEFlux application in the Google Earth Engine platform. The analysis focuses on daily ET values and their seasonal variations, considering various factors such as crop coefficients (Kc) and reference evapotranspiration (ETr) values.

The findings highlight substantial variations in daily ETr values, Kc during the wheat crop's growth period. Comparisons between the two ETa estimation methods, FAO-56 and EEFlux, reveal an underestimation of ETa by EEFlux, approximately 13.69% on a seasonal basis. The statistical assessment demonstrates a moderate to good correlation between EEFlux and FAO-56-derived ETa, with strong R^2 values and acceptable error metrics.

This research topic underscores the significance of accurate ETa estimation methods for agricultural water management, particularly in regions cultivating wheat during the Rabi season. It opens the door for further investigations into improving the precision and applicability of EEFlux in estimating ETa for various crops and across multiple locations and years. The outcomes have potential implications for optimizing irrigation strategies and enhancing water resource management in agriculture.

Overall, this study reveals a 13.69 % underestimation of EEFlux-ETa compared to ETa estimated via the FAO-56 approach for wheat in the 2020-2021 Rabi season. Notably, a moderate to good correlation was observed between ETa estimates derived from EEFlux and the FAO-56 approach, with a maximum R^2 value and RMSE below 1.00 mm/day. These findings underscore the potential of EEFlux for accurate ETa estimation. However, further research across various years and locations is essential to ascertain its broader suitability for regional ETa estimation.

AUTHOR CONTRIBUTIONS

Conceptualization- S. A. Kadam; Methodology- S. A. Kadam, Vishal Pandey and S. D. Gorantiwar; Validation- M. G. Shinde;Formal analysis- S.A. Kadam and Vishal Pandey; Data curation- M. G. Shinde; Writing—original draft preparation, Vishal pandey; Writing—review and editing, S. A. Kadam, M. G. Shinde and Vishal Pandey; Supervision- S. D. Gorantiwar.

DECLARATION

All authors have read and agreed to the published version of the manuscript.

REFERENCES

[1] Allen, R. G., Tasumi, M., Morse, A., Trezza, R., Wright, J. L., Bastiaanssen, W., Kramber, W., Lorite, I., & Robison, C. W. 2007. Satellite-Based Energy Balance for Mapping

Evapotranspiration with Internalized Calibration (METRIC)—Applications. *Journal of Irrigation and Drainage Engineering*, ***133***(4), 395–406.

[2] Anderson, M. C., Norman, J. M., Diak, G. R., Kustas, W. P., & Mecikalski, J. R. 1997. A two-source time-integrated model for estimating surface fluxes using thermal infrared remote sensing. *Remote Sensing of Environment*, ***60***(2), 195–216.

[3] Bastiaanssen, W. G. M., Noordman, E. J. M., Pelgrum, H., Davids, G., Thoreson, B. P., & Allen, R. G. 2005. SEBAL Model with Remotely Sensed Data to Improve Water-Resources Management under Actual Field Conditions. *Journal of Irrigation and Drainage Engineering*, ***131***(1), 85–93.

[4] Bastiaanssen W.G.M., M. Meneti, R.A. Feddes, & Holtslag, a a M. 1998. A remote sensing surface energy balance algorithm for land (SEBAL). *J. Hydrol.*, ***212–213***(1), 198–212.

[5] Cosgrove, B. A., Lohmann, D., Mitchell, K. E., Houser, P. R., Wood, E. F., Schaake, J. C., Robock, A., Marshall, C., Sheffield, J., Duan, Q., Luo, L., Higgins, R. W., Pinker, R. T., Tarpley, J. D., & Meng, J. 2003. Real-time and retrospective forcing in the North American Land Data Assimilation System (NLDAS) project. *Journal of Geophysical Research: Atmospheres*, ***108***(22).

[6] Kadam, S. A., Stöckle, C. O., Liu, M., Gao, Z., & Russell, E. S. (2021). Suitability of earth engine evaporation flux (Eeflux) estimation of evapotranspiration in rainfed crops. *Remote Sensing*, ***13***(19).

[7] Kustas, W. P., & Norman, J. M. (1996). Use of remote sensing for evapotranspiration monitoring over land surfaces. *Hydrological Sciences Journal*, ***41***(4), 495–516.

[8] Norman, J. M., Anderson, M. C., Kustas, W. P., French, A. N., Mecikalski, J., Torn, R., Diak, G. R., Schmugge, T. J., & Tanner, B. C. W. 2003. Remote sensing of surface energy fluxes at 101-m pixel resolutions. *Water Resources Research*, ***39***(8).

[9] Pandey, V., & Firake, N. N. 2020. Economic Viability of Red Cabbage Production under Varying Environment and Ferti-Irrigation Regimes. *International Journal of Current Microbiology and Applied Sciences*, ***9***(4), 1965–1969.

[10] Roerink, G. J., Su, Z., & Menenti, M. 2000. S-SEBI: A simple remote sensing algorithm to estimate the surface energy balance. *Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere*, ***25***(2), 147–157.

[11] Su, Z. 2002. The Surface Energy Balance System (SEBS) for estimation of turbulent heat fluxes. *Hydrology and Earth System Sciences*, ***6***(1), 85–99.

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Optimizing Watering Strategies: Enhancing Zucchini (*Cucurbita pepo* L.) Growth and Yield Through Phase-Specific Water Management

Dian Nugraha Harry Putra[1*], Eko Widaryanto[2], Anna Satyana Karyawati[2]

[1]Master Student at Departement of Agronomy, Faculty of Agriculture, Brawijaya University, Malang, Indonesia
diannugrahaharryputra@gmail.com
[2]Departement of Agronomy, Faculty of Agriculture, Brawijaya University, Malang, Indonesia.

Received: 13 Nov 2024; Received in revised form: 15 Dec 2024; Accepted: 21 Dec 2024; Available online: 31 Dec 2024

***Abstract*— *The primary issue in zucchini cultivation is water availability. As a member of the Cucurbitaceae family, zucchini is notably sensitive to water supply, which can significantly influence plant growth and productivity. Each growth phase of the plant has specific water requirements that must be met for optimal development. The aim of this study was to determine the optimal watering management, tailored to the growth stages of zucchini, ensuring sustainable cultivation practices. The study was designed using a randomized block design (RBD) with 12 treatments. Four levels of watering management, based on field capacity (40%, 60%, 80%, and 100%), were applied in combination with two main growth phases (vegetative and generative). The treatments were repeated three times, resulting in 36 experimental units. The findings of this study indicate that treatments $V_{40}G_{60}$, $V_{40}G_{80}$, and $V_{60}G_{60}$ led to a decrease in both growth and yield of zucchini plants. These included growth parameters such as plant length, number of leaves, number of male flowers, number of female flowers, plant fresh weight, and plant dry weight. Furthermore, the $V_{40}G_{60}$ treatment significantly reduced yield parameters, including fruit weight and plant yield.*

***Keywords*—Field capacity, Watering management, Water stress, Zucchini.**

I. INTRODUCTION

Zucchini (*Cucurbita pepo* L.) is a high-value horticultural crop recognized for its significant economic and nutritional potential. In Indonesia, the market price of zucchini can reach up to Rp 40,000 (±2.51 USD) per kilogram, reflecting its premium status in the agricultural sector [1]. This substantial economic value is attributed to its increasing consumer demand, particularly in upscale dining establishments and premium retail outlets such as supermarkets [2]. The surge in its popularity is further supported by the dissemination of information via social media platforms, especially among younger generations who are increasingly adopting health-conscious lifestyles and dietary trends [3]. From a nutritional perspective, zucchini is a rich source of essential micronutrients and bioactive compounds. It contains B-complex vitamins, vitamin C, vitamin A, and dietary fiber, which play crucial roles in maintaining metabolic homeostasis, regulating blood sugar levels, and supporting overall health. Furthermore, it is an excellent source of potassium, an electrolyte critical for cardiovascular and muscular function [4]. Zucchini also stands out as a low-calorie food, providing only 14 kcal per 100 g, coupled with a remarkably high-water content of 96.5%, making it a suitable dietary choice for individuals aiming to manage weight or adopt a calorie-restricted diet [3]. These attributes, combined with its culinary versatility, contribute to its growing prominence as a staple in health-oriented dietary regimens.

The high economic value of zucchini can be attributed to the growing demand that is not matched by adequate domestic production. Limited cultivation insights and practices are among the primary factors contributing to the low production rates and the limited number of zucchini producers in Indonesia [1]. Moreover, zucchini remains an imported horticultural commodity in Indonesia, adding to its market exclusivity [5]. The significant market value of zucchini presents an opportunity for urban agriculture, as it does not require extensive land for cultivation. This characteristic makes zucchini suitable for production in residual spaces or home gardens, thereby leveraging limited urban land for agricultural purposes [6]. However, one of the main challenges in zucchini cultivation is its water requirement, particularly in arid or dryland areas. As a member of the *Cucurbitaceae* family, zucchini is notably sensitive to water availability, which can significantly impact plant growth and productivity [7]. Addressing these water management challenges is crucial for the successful and sustainable cultivation of zucchini in such regions.

Water scarcity potentially disrupt critical physiological processes in plants, such as photosynthesis, nutrient absorption, and fruit development, ultimately leading to reduced yields. Some researches conducted by [8,9,10] have demonstrated that water stress can decrease crop yields by up to 40%. This issue is particularly pressing in the context of urban farming, where resource efficiency is paramount. Hence, a deeper understanding of zucchini responses to water scarcity is essential to developing more effective and sustainable cultivation strategies.

Research has shown that timely irrigation during specific growth phases can significantly enhance crop yields [11]. Water demand typically increases during the peak growth stages, particularly during flowering and fruiting phases [12]. Therefore, understanding the growth phases and their duration is crucial for planning irrigation schedules, including both the timing and quantity of water application. By investigating the effects of watering management on zucchini growth and yield, this study aims to provide actionable recommendations for efficient water resource management. These insights could contribute to improving zucchini productivity while supporting sustainable agricultural practices, particularly in urban farming systems.

II. METHOD

The research was conducted from September to November 2024 located at Tlogo Indah St. No. 44, Tlogomas, Lowokwaru District, Malang City, East Java Province. The research area is geographically located at -7°56'17.6"S and 112°36'06.9"E. The elevation of the research area is at an altitude of 675 meters above sea level with an average temperature of 23-31°C, an average rainfall of 1,250 mm year^{-1}.

This study was conducted using a randomized block design (RBD). There were 12 treatments of water availability levels at each growth phase of zucchini plants referring to soil Field Capacity (FC) and repeated 3 times to obtain 36 experimental units. The treatments detailed:

$V_{40}G_{60}$: 40% FC in vegetative phase and 60% FC in generative phase

$V_{40}G_{80}$: 40% FC in vegetative phase and 80% FC in generative phase

$V_{40}G_{100}$: 40% FC in vegetative phase and 100% FC in generative phase

$V_{60}G_{60}$: 60% FC in vegetative phase and 60% FC in generative phase

$V_{60}G_{80}$: 60% FC in vegetative phase and 80% FC in generative phase

$V_{60}G_{100}$: 60% FC in vegetative phase and 100% FC in generative phase

$V_{80}G_{60}$: 80% FC in vegetative phase and 60% FC in generative phase

$V_{80}G_{80}$: 80% FC in vegetative phase and 80% FC in generative phase

$V_{80}G_{100}$: 80% FC in vegetative phase and 100% FC in generative phase

$V_{100}G_{60}$: 100% FC in vegetative phase and 60% FC in generative phase

$V_{100}G_{80}$: 100% FC in vegetative phase and 80% FC in generative phase

$V_{100}G_{100}$: 100% FC in vegetative phase and 100% FC in generative phase

The level of water supply is carried out in conditions of water shortages at field capacity and at normal water requirements at field capacity.

$$\text{Field Capacity} = \frac{\text{Soil FC weight} - \text{Oven dry soil weight}}{\text{Oven dry soil weight}} \times 100$$

Water treatment is done using a measuring cup based on the calculation results of watering on field capacity of 40% (1.08 L), 60% (1.62 L), 80% (2.16 L) and 100% (2.7 L) at a soil weight of 10 kg.

$$\text{Maximum water added to reach field capacity} = \frac{\text{FC moisture content} - \textit{air dry soil weight}}{100\%} \times \text{soil weight (10kg)}$$

Watering management treatments during the vegetative phase of zucchini commenced from the initial planting until 50% of the plant population had formed flowers (23 days after planting, DAP). Once 50% flowering was achieved, watering management treatments transitioned to the generative phase, covering 24–50 DAP. The observed parameters in this study were categorized into growth and yield metrics. Vegetative properties included the observation of plant height (cm) and number of leaves, assessed at 35 DAP. Generative properties included the observation of number of flowers, fruit weight (g/fruit and g/plant), fresh plant biomass (g/plant), and dry plant biomass (g/plant), all measured at harvest (50 DAP).

III. RESULT

3.1 Vegetative properties

The variation in watering managements at different growth stages of zucchini plants significantly affecting plant height at 35 DAP (Table 1). Plant length in the $V_{100}G_{100}$ treatment was longer by 40.16%, 39.54%, and 33.41% compared to the $V_{40}G_{60}$, $V_{40}G_{80}$, and $V_{40}G_{100}$ treatments. The $V_{100}G_{100}$ treatment was also 35.19%, 30.24%, and 15.23% longer than the $V_{60}G_{60}$, $V_{60}G_{80}$, and $V_{60}G_{100}$ treatments. In addition, the $V_{100}G_{100}$ treatment was 31.10% longer than $V_{80}G_{60}$, although not significantly different from $V_{80}G_{80}$ and $V_{80}G_{100}$, with an average length of 61.54 cm. Significant differences were also seen with the $V_{100}G_{60}$ treatment, which was 16.09% longer, but not significantly different from $V_{100}G_{80}$.

Table.1: The Effect of Watering Management During Vegetative and Generative Phases on the Length of Zucchini Plant at 35 DAP

Watering treatments	Length of plant (cm plant^{-1})
$V_{40}G_{60}$	47.01 a
$V_{40}G_{80}$	47.22 a
$V_{40}G_{100}$	49.39 ab
$V_{60}G_{60}$	48.74 ab
$V_{60}G_{80}$	50.59 ab
$V_{60}G_{100}$	57.18 b
$V_{80}G_{60}$	50.26 ab
$V_{80}G_{80}$	59.49 bc
$V_{80}G_{100}$	63.60 bc
$V_{100}G_{60}$	56.76 b
$V_{100}G_{80}$	62.03 bc
$V_{100}G_{100}$	65.89 c
HSD 5%	8.341
CV (%)	5.150

Note: number followed by the same letter in the same column represent non-significant result based on the 5% HSD test. HSD = honest significant difference, CV = coefficient of variation.

The watering management treatments showed significant result on the variable of the number of leaves. The leaf number parameter at 35 days after transplanting (DAP) showed that the $V_{100}G_{100}$ treatment had the highest number of leaves, with 15.83 in number. This was significantly higher than the $V_{40}G_{60}$, $V_{60}G_{60}$, $V_{80}G_{60}$, and $V_{100}G_{60}$ treatments, with increases of 23.38%, 20.20%, 17.26%, and 14.46%, respectively. Compared to the $V_{40}G_{80}$, $V_{60}G_{80}$, and $V_{80}G_{80}$ treatments, the increases were 21.77%, 15.80%, and 11.48%, respectively, but there was no significant difference with $V_{100}G_{80}$. Furthermore, compared to the $V_{40}G_{100}$ and $V_{60}G_{100}$ treatments, the increases were 18.75% and 11.71%, respectively, but no significant difference was observed with $V_{100}G_{100}$ watering management treatment.

Table.2: The Effect of Watering Management During Vegetative and Generative Phases on the Number of Leaves of Zucchini Plant at 35 DAP

Watering treatments	Number of leaves
$V_{40}G_{60}$	12.83 a
$V_{40}G_{80}$	13.00 a
$V_{40}G_{100}$	13.33 ab
$V_{60}G_{60}$	13.17 ab
$V_{60}G_{80}$	13.67 ab
$V_{60}G_{100}$	14.17 b
$V_{80}G_{60}$	13.50 ab
$V_{80}G_{80}$	14.20 b
$V_{80}G_{100}$	15.50 c
$V_{100}G_{60}$	13.83 ab
$V_{100}G_{80}$	15.17 bc
$V_{100}G_{100}$	15.83 c
HSD 5%	1.168
CV (%)	5.920

Note: number followed by the same letter in the same column represent non-significant result based on the 5% HSD test. HSD = honest significant difference, CV = coefficient of variation.

3.2 Generative properties

The analysis of variance showed that the watering management treatments during the vegetative and generative phases significantly affected the number of male and female flowers. For the number of male flowers in the $V_{80}G_{100}$ treatment produced 7,890 male flowers, showing increases of 33.95%, 31.50%, and 29.13% compared to the $V_{40}G_{60}$, $V_{40}G_{80}$, and $V_{40}G_{100}$ treatments, respectively. However, no significant differences were found when compared to the $V_{60}G_{60}$, $V_{60}G_{80}$, and $V_{60}G_{100}$ treatments (average of 6.74), as well as the $V_{80}G_{60}$, $V_{80}G_{80}$, and $V_{80}G_{100}$ treatments (average of 7.52), and the $V_{100}G_{60}$ and $V_{100}G_{80}$ treatments (average of 7.72).

Table.3: The Effect of Watering Management During Vegetative and Generative Phases on the Number of Flowers of Zucchini Plant at 35 DAP

Watering treatments	Number of male flowers	Number of female flowers
$V_{40}G_{60}$	5.890 a	3.310 a
$V_{40}G_{80}$	6.000 a	3.300 a
$V_{40}G_{100}$	6.110 a	3.280 a
$V_{60}G_{60}$	6.890 ab	4.440 b
$V_{60}G_{80}$	6.780 ab	4.480 b
$V_{60}G_{100}$	6.560 ab	4.440 b
$V_{80}G_{60}$	7.670 b	4.670 b
$V_{80}G_{80}$	7.560 b	4.590 b
$V_{80}G_{100}$	7.330 b	4.780 b
$V_{100}G_{60}$	7.780 b	5.000 b
$V_{100}G_{80}$	7.670 b	4.890 b
$V_{100}G_{100}$	7.890 b	5.110 b
HSD 5%	1.216	1.116
CV (%)	11.93	11.62

Note: number followed by the same letter in the same column represent non-significant result based on the 5% HSD test. HSD = honest significant difference, CV = coefficient of variation.

For the number of female flowers based on the $V_{100}G_{100}$ treatment resulted in 5,110 female flowers, with increases of 54.38%, 54.84%, and 55.48% compared to the $V_{40}G_{60}$, $V_{40}G_{80}$, and $V_{40}G_{100}$ treatments, respectively. However, no significant differences were observed when compared to the $V_{60}G_{60}$, $V_{60}G_{80}$, and $V_{60}G_{100}$ treatments (average of 4.45), as well as the $V_{80}G_{60}$, $V_{80}G_{80}$, and $V_{80}G_{100}$ treatments (average of 4.68), and the $V_{100}G_{60}$ and $V_{100}G_{80}$ treatments.

The watering management treatments had a significant effect on both the fruit weight and yield. The $V_{100}G_{100}$ watering management treatment exhibited a fruit weight of 393.0 g, which was significantly higher, showing increases of 28.47%, 28.30%, and 13.32% compared to the $V_{40}G_{60}$, $V_{40}G_{80}$, and $V_{40}G_{100}$ watering management treatments, respectively. Compared to the $V_{60}G_{60}$ watering management treatment, there was an increase of 25.11%, but no significant differences were observed when compared to the $V_{60}G_{80}$, $V_{60}G_{100}$ (average of 373 g), $V_{80}G_{60}$, $V_{80}G_{80}$, and $V_{80}G_{100}$ (average of 382.8 g), or the $V_{100}G_{60}$ and $V_{100}G_{80}$ (average of 384.1 g) watering management treatments.

The $V_{100}G_{100}$ watering management treatment yielded 883.9 g per plant, showing significant increases of 117%, 108%, and 64.44% compared to the $V_{40}G_{60}$, $V_{40}G_{80}$, and $V_{40}G_{100}$ watering management treatments, respectively. Compared to the $V_{60}G_{60}$, $V_{60}G_{80}$, and $V_{60}G_{100}$ watering management treatments, the increase was 89.39%, 43.81%, and 32.10%, respectively. This yield was 54.60% higher than that of the $V_{80}G_{60}$ treatment, but no significant differences were observed when compared to the $V_{80}G_{80}$, and $V_{80}G_{100}$ (average of 752.3 g), or the $V_{100}G_{60}$ and $V_{100}G_{80}$ (average of 696.7 g) watering management treatments.

Table.4: The Effect of Watering Management During Vegetative and Generative Phases on the Weight of Fruit and Yield of Zucchini Plant at 50 DAP

Watering treatments	Weight of fruit ($g\ fruit^{-1}$)	Yield ($g\ plant^{-1}$)
$V_{40}G_{60}$	305.9 a	406.0 a
$V_{40}G_{80}$	306.3 a	424.6 a
$V_{40}G_{100}$	346.8 b	537.5 ab
$V_{60}G_{60}$	314.1 ab	466.7 ab
$V_{60}G_{80}$	367.9 bc	614.6 b
$V_{60}G_{100}$	378.1 bc	669.1 b
$V_{80}G_{60}$	365.7 bc	571.7 ab
$V_{80}G_{80}$	390.5 c	720.2 bc
$V_{80}G_{100}$	392.3 c	784.5 bc
$V_{100}G_{60}$	376.0 bc	666.7 b
$V_{100}G_{80}$	392.2 c	726.7 bc
$V_{100}G_{100}$	393.0 c	883.9 c
HSD 5%	38.15	178.3
CV (%)	7.560	9.630

Note: number followed by the same letter in the same column represent non-significant result based on the 5% HSD test. HSD = honest significant difference, CV = coefficient of variation.

The fresh plant weight observations in the 50 DAP showed that the $V_{100}G_{100}$ watering management treatment exhibited a significantly higher, with increases of 39.06%, 37.31%, and 22.51% compared to the $V_{40}G_{60}$, $V_{40}G_{80}$, and $V_{40}G_{100}$ watering management treatments, respectively. When compared to the $V_{60}G_{60}$ and $V_{60}G_{80}$ watering management treatments, the fresh plant weight increased by 24.16% and 15.89%, respectively, although no significant difference was observed when compared to the $V_{60}G_{100}$ watering management treatment. The $V_{100}G_{100}$ watering management treatment also had a 16.89% higher weight than the $V_{80}G_{60}$ treatment, but no significant differences were found when compared to the $V_{80}G_{80}$, and $V_{80}G_{100}$ watering management treatments (average of 545.3 g). No significant differences were observed when compared to the $V_{100}G_{60}$ and $V_{100}G_{80}$ watering management treatments (average of 544.7 g).

The $V_{100}G_{100}$ treatment was 80.37% heavier than the $V_{40}G_{60}$ treatment, although no significant differences were found when compared to the $V_{40}G_{80}$, and $V_{40}G_{100}$ treatments. No significant differences were observed when compared to the $V_{60}G_{60}$, $V_{60}G_{80}$, and $V_{60}G_{100}$ treatments (average of 34.51 g), as well as with the $V_{80}G_{60}$, $V_{80}G_{80}$, and $V_{80}G_{100}$ treatments (average of 39.81 g). The $V_{100}G_{100}$ treatment also showed no significant differences when compared to the $V_{100}G_{60}$ and $V_{100}G_{80}$ treatments (average of 41.06 g).

Table.5: The Effect of Watering Management During Vegetative and Generative Phases on the Fresh Weight and Dry Weight of Zucchini Plant at 50 DAP

Watering treatments	Fresh weight of plant (g tan^{-1})	Dry weight of plant (g tan^{-1})
$V_{40}G_{60}$	417.6 a	26.24 a
$V_{40}G_{80}$	422.9 ab	27.57 ab
$V_{40}G_{100}$	474.0 ab	32.77 ab
$V_{60}G_{60}$	467.7 ab	31.03 ab
$V_{60}G_{80}$	501.1 b	34.37 ab
$V_{60}G_{100}$	533.5 bc	38.13 b
$V_{80}G_{60}$	496.8 b	33.40 ab
$V_{80}G_{80}$	530.3 bc	41.30 b
$V_{80}G_{100}$	560.3 bc	44.73 b
$V_{100}G_{60}$	532.0 bc	37.79 b
$V_{100}G_{80}$	557.5 bc	44.34 b
$V_{100}G_{100}$	580.7 c	47.33 b
HSD 5%	77.23	11.21
CV (%)	6.910	10.33

Note: number followed by the same letter in the same column represent non-significant result based on the 5% HSD test. HSD = honest significant difference, CV = coefficient of variation.

IV. DISCUSSION

Water is a critical component in the plants physiological processes, including photosynthesis, transpiration, and nutrient transport. Insufficient watering in plants, especially zucchini, significantly impact the plant growth and development, including plant length. In the age of 35 DAP, the watering treatment at 100% field capacity in both the vegetative and generative phases ($V_{100}G_{100}$) resulted in a significant increase of 40.16% and 39.53% compared to the treatment with 40% vegetative phase and 60% generative phase watering ($V_{40}G_{60}$), as well as the treatment with 40% vegetative phase and 80% generative phase watering ($V_{40}G_{80}$). This is supported by research that was done by [13], which indicates that plants experiencing water deficiency undergo stress that can inhibit growth, including plant length. In the cited study, a 40% field capacity watering treatment caused a 32% reduction in soybean plant length. When plants experience water stress, the plant ability to absorb carbon dioxide (CO_2) from the atmosphere is reduced. This leads to a decrease in photosynthetic efficiency, ultimately affecting plant growth, including the ability to increase its length [14]. The importance of proper watering in zucchini cultivation is further supported by studies on tomato plants, where water stress resulted in a decline in total plant biomass as an adaptation strategy to survive drought conditions. Furthermore, plants experiencing water stress tend to reduce the number of leaves and leaf surface area to minimize water loss through transpiration, which can lead to a decrease in overall plant length [15, 16].

Inadequate watering in zucchini plants can significantly impact the number of leaves, which is an important indicator of plant productivity. Optimal watering management at 100% field capacity during the vegetative and generative phases ($V_{100}G_{100}$) resulted in an increase of 23.38% and 21.80%, respectively, compared to the treatment with 40% vegetative phase and 60% generative phase watering ($V_{40}G_{60}$), as well as the treatment with 40% vegetative phase and 80% generative phase watering ($V_{40}G_{80}$). Water serves as a medium for nutrient transport and is essential in photosynthesis, both critical for plant growth. Water shortage causes plants to adapt by reducing leaf number or slowing down their growth as a response to environmental stress. Zucchini plants that experiencing water deficiency show a significant decrease in leaf number, especially under severe water stress (25% field capacity) [14, 17]. The reduction in leaf number is a strategy for conserving water. Adjusting leaf number and surface area is an adaptive strategy plants use to reduce water loss through transpiration, which ultimately affects plant biomass [16, 18]. Research that was done by [19] also indicates that drought stress negatively impacts the growth and leaf number of tomato plants. Overall, water deficiency significantly affects the reduction in leaf number, which, in turn, impacts photosynthesis, growth, and crop yield.

Water availability plays a crucial role in the physiological processes of plants in growing flower, as part of plants transition from vegetative phase to generative phase. Plants experiencing water deficiency can alter their flowering patterns, potentially reducing the number of flowers produced. Watering management in terms of male flower number showed significant differences, with the treatment of 100% field capacity during the vegetative and generative phases ($V_{100}G_{100}$) resulting in a 33.95% increase compared to the treatment with 40% vegetative phase and 60% generative phase watering ($V_{40}G_{60}$). In terms of female flower number, significant differences were observed with the 100% field capacity watering during the vegetative and generative phases ($V_{100}G_{100}$), showing a 55.79% increase compared to the treatment with 40% vegetative phase and 100% generative phase watering ($V_{40}G_{100}$). Water deficiency can disrupt the flowering process, reducing the number of both male and female flowers formed. Research that was done by [20] demonstrated that water stress in cucumber plants led to a decrease in flower number due to reduced energy for the flowering process. Water stress impacts cucumber plant to grow and produce, as well as in the flowering phase. A reduction in flower number can decrease the number of fruits produced, affecting yields through the disruption of the flower and fruit formation [21, 22].

Water deficiency leads to a reduction in fruit weight of plants, which in turn affects the overall yield. The watering management treatment with 100% field capacity during both the vegetative and generative phases ($V_{100}G_{100}$) resulted in significantly larger fruit weights, with increases of 28.47% and 28.30%, respectively, compared to the treatment with 40% field capacity during the vegetative phase and 60% during the generative phase ($V_{40}G_{60}$), as well as $V_{40}G_{80}$. In terms of plant's yield, the $V_{100}G_{100}$ treatment also showed a 117% and 108% increase compared to other treatments. Water stress can significantly impact yield of zucchini [17]. Based from the study, plants subjected to water stress exhibited a notable decrease in fruit weight. Adequate water availability is crucial for supporting optimal fruit growth. Water stress reduced both the weight and size of zucchini fruits, with a decrease of up to 37% in plants watered with 50% field capacity [14]. Water deficiency impedes fruit growth and leads to a reduction in overall yield. Water stress, particularly in zucchini plants, affects both the quality and quantity of the fruit produced [23, 24].

Water deficiency can lead to a reduction in the fresh weight of plants, which in turn affects the overall yield. The analysis of variance presented in (Table 5) shows that the treatment with 100% watering during both the vegetative and generative phases ($V_{100}G_{100}$) resulted in a 29.46% increase in fresh weight compared to the treatment with 40% watering during the vegetative phase and 60% during the generative phase ($V_{40}G_{60}$). Studies have shown that water stress affects the fresh weight of plants, as observed in cucumber plants, which experience a decrease in fresh weight due to less water shortage in the plant's tissue [25, 26]. This reduction is caused by the stress experienced by the plants, which reduces energy available for growth. Overall, adequate water availability is crucial for supporting optimal plant growth and increasing fresh weight [27]. Water stress in zucchini plants can significantly affect their dry weight. A decrease in dry weight occurs in water-stressed plants. The treatment with 100% watering during both the vegetative and generative phases ($V_{100}G_{100}$) resulted in a 47.11% increase in dry weight compared to the $V_{40}G_{60}$ treatment. The significant reduction in dry weight observed in water-stressed plants is related to the stress that reduces energy for growth [25, 26]. Overall, water stress negatively impacts the dry weight of zucchini plants, indicating that sufficient water availability is essential for supporting optimal growth.

V. CONCLUSION

Field capacity water application treatments $V_{40}G_{60}$, $V_{40}G_{80}$ and $V_{60}G_{60}$ decreased the growth and yield of zucchini plants which include growth parameters (plant length, number of leaves, number of male flowers, number of female flowers, plant fresh weight, plant dry weight). Additionally, the $V_{40}G_{60}$ treatment significantly reduced yield parameters (fruit weight g fruit^{-1} and fruit weight g tan^{-1}).

REFERENCES

[1] Hartati, T., SOndari, N., Abdullah, R., and Ulfah, I. (2022). Peningkatan Hasil Zukini (*Cucurbita pepo* L.) Varietas Zacky Z6 Akibat Pemberian Dosis Pupuk Kotoran Ayam Dan Konsentrasi Pupuk Hayati. *Jurnal Ilmiah Pertanian (ISSN : 2598-0327).* 10(2): 231-236.

[2] Hadi, P., Rizkian, F., and Rahayu, T. (2021). The Use of Organic and Anorganic Mulch on Zucchini (*Cucurbita pepo* L) Plant with Elephant Manure from Borobudur Temple. *Journal of Biodiversity and Biotechnology (ISSN 2808-3229).* 1(2): 46–49.

[3] Tejeda, L., Buendia-Monero, L., Villegas, A., Cayuela, J. M., Bueno-Gavila, E., Gomez, P., and Abellan, A. (2020). Nutritional and sensorial characteristics of zucchini (*Cucurbita pepo* L.) as affected by freezing and the culinary treatmen. *International Journal of Food Properties.* 23(1): 1875-1833. DOI:https://doi.org/10.1080/10942912.2020.1826512.

[4] Ashriyani, T., R. Sitawati dan S. N. Widyastuti. 2022. Pengaruh Pemberian Pupuk Bioboost terhadap Pertumbuhan dan Hasil Tanaman Zukini (*Cucurbita pepo* L.) Varietas Zacky Z-6. J. Ilm. Pert. 4(2): 63-72.

[5] Rosmiati, M., Putra, R. E., and Ruswandi, A. (2015). Insects Pollination of Zucchini Farming in Indonesia and their

Economic Importance. *Asian Journal of Plant Sciences (ISSN 1682-3974).* 14(2): 84-88. DOI: 10.3923/ajps.2015.84.88.

[6] Ikbal, A. M. D. P., Permanasari, P. N., Saitama, A., and Widaryanto, E. (2024). Sukini Urban Farming System (Cucurbita pepo L.) With Utilization of Household Waste Compost. *Jurnal Produksi Tanaman (ISSN: 2527-8452).* 12 (2): 71-79. Doi: http://dx.doi.org/10.21776/ub.protan.2024.012.02.01.

[7] Vasileva, E. S., and Chipilski, R. R. (2022). Identification and characterization of drought tolerant local populations of *Cucurbitaceae. Bulgarian Journal of Agricultural Science* 28(3):417-424.

[8] da Silva, A. C. C., de Almeida, W. F., Lima, L. A., de Oliveira, M. C., and Guimarães, A. L. (2018). Water use efficiency of different production techniques for zucchini. Acta Scientiarum (*ISSN: 1807-8621).* 41, E42604. DOI: 10.4025/actasciagron.v41i1.42604.

[9] Hao, S., H. Cao, H. Wang and X. Pan. 2019. Effects of Water Stress at Different Growth Stages on Comprehensive Fruit Quality and Yield in Different Bunches of Tomatoes in Greenhouses. *Int. J. Agric. Biol. Eng.* 12(3): 67-76. DOI: 10.25165/j.ijabe.20191203.4468

[10] Youssef, E. A. E. M. and M. M. A E. Baset. 2017. Study the Applications of Water Deficiency Levels and Ascorbic Acid Foliar on growth Parameters and Yield of Summer Squash Plant (*Cucurbita pepo* L.). *J. Agric. England*. 147-158

[11] Salam, R. H., Mulyati., H. Suheri dan E. Darmawan. 2023. Penerapan Berbagai Sistem Pengairan terhadap Pertumbuhan dan Hasil Tanaman Terung (*Solanum melogena* L.) di Lahan Kering Kabupaten Lombok Timur. J. *Agroteksos*. 33(2): 446-474.

[12] Miranda, F.R., R.S. Gondim, C.A.G. Costa. 2006. Evapotranspiration and crop coefficients for tabasco pepper (*Capsicum frutescens* L.). *Agricultural Water Management*. 82:237-246.

[13] Guntoro. W., H. Suhardjono dan I. R. Moeljani. Respon Tanaman Kedelai (*Glycine max* Merr.) terhadap Jumlah Air yang Diberikan. J. Ilmu. Pert. 2(3):15-28

[14] Sousa, H. C., and P. B. C. Cambissa. 2022. Gas Exchange and Growth of Zucchini Crop Subjected to Salt and Water Stress. *J. Agric. Ambiental*. 26(11):815-822

[15] Rahmat, B. P. N., N. Wicaksana dan S. Mubarok. 2021. Respons Dua Generasi Tomat Mutan Insensitif Etilen terhadap Cekaman Kekeringan. *J. Kultivasi.* 20(1): 25-37

[16] Santos, M. R. D. 2023. Establishment of Corn Plants Under Different Water Regiments. *J. Sci. Soc*. 12(7):20-41

[17] Dantas, M. V., G. S. D. Lima and H. R. Gheyi. 2022. Gas Exchange Hydrogen Peroxide and Saline Nutrient Solution in Hydroponic Zucchini Culture. J. *Agrarias*. 43(3):1679-1690

[18] Veloso, L. L. D. A., G. S. Lima and A. A. R. D. Silva. 2021. Attenuation of Salt Stress on the Physiology and Production of Bell Peppers by Treatment With Salicylic Acid. *Semina. Ciencias. Agrarias.* 42(5): 2751- 2768

[19] Rawal, R., J. C. Scheerens and S. Fenstemaker. Novel Trichoderma Isolates Alleviate Water Deficit Stress in Susceptible Tomato Genotypes. *J. Front. Plant. Sci*. 13(1):1-16

[20] An, S., S. W. Park and Y. Kwack. 2020. Growth of Cucumber Scions, Rootstocks, and Grafted Seedlings as Affected by Different Irrigation Regimes during Cultivation of 'Joenbaekdadagi' and 'Heukjong'. Seedlings in a Plant Factory with Artificial Lighting. *J. Agronom.* 10(2):1-17

[21] Pati, K., D. M. Anilabh and K. B. Tusar. 2015. Inheritance of Gynoecism in Cucumber (*Cucumis sativus* L.) Using Genotype GBS-1 as Gynoecious Parent. J. Genetika. 21(5):45-58

[22] Yamasaki, S. and K. Manabe. 2011. Application of Silver Nitrate Induces Functional Bisexual Flowers in Gynoecious Cucumber Plants (*Cucumis sativus* L.). *J. of the Japanese Scty for Horti. Sci*. 80(1):66-75

[23] Fernandes, A. O. and Suasa, G. 2022. Ionic Homeostasis, Biochemical Components and Yield of Italian Zucchini Under Nitrogen Forms and Salt Stress. *J. Bio. Brazilian*. 23(4):1519-1533.

[24] Roman, L., Rodriguez and J. Cesar. 2023. Saline-Water Irrigation and Plant Growth Regulator Application on Zucchini Fruit Yield and Quality. *J. Agr. Produc*. 16(11):83-95

[25] Barickman, T. C., C. Simpson and C. E. Sams. Waterlogging Causes Early Modification in the Physiological Performance, Carotenoids, Chlorophylls, Proline, and Soluble Sugars of Cucumber Plants. *J. MDPI*. 8(6):160-172

[26] Maluleke, M. K. 2022. Metabolite Profile of African Horned Cucumber (*Cucumis metuliferus* E.) Fruit Grown Under Differing Environmental Conditions. *J. Scitfc*. 12(37): 1-18

[27] Olguin, M. A. V., M. C. D. L. Fuente and A. B. Mendoza. 2020. Commercial and Nutraceutical Quality of Grafted Melon Cultivated Under Hydric Stress. *J. Hort. Sci*. 47(3):139-149.

International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-6; Nov-Dec, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Inulin fortified maize-based fermented beverage (*Rab*) affects lipid profile and blood pressure levels in Indian hyperlipidaemic subjects

Zahara Ali Shams*,[1], Nikita Wadhawan[2]

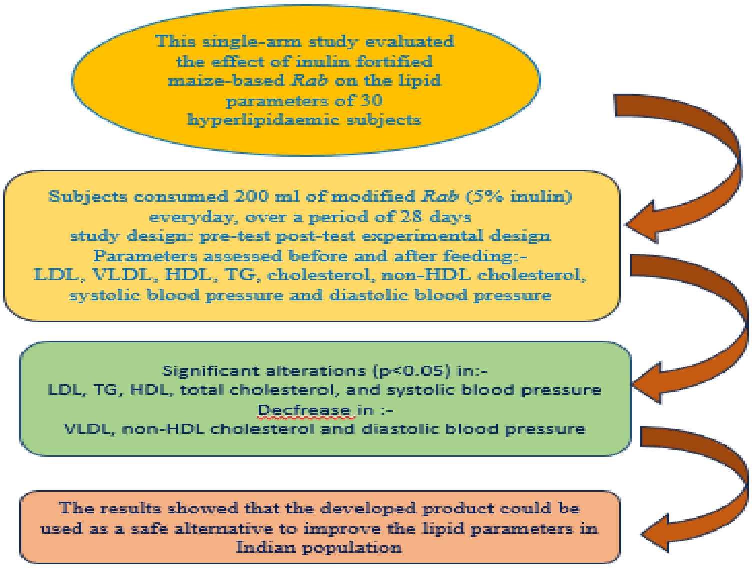
[1]Research scholar, College of Community and Applied Sciences, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India;
[2]Associate professor, College of Dairy and Food Technology, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India
*Corresponding Author: zahara227@gmail.com; Orcid id: 0000-0002-5118-2129

Received: 17 Nov 2024; Received in revised form: 19 Dec 2024; Accepted: 25 Dec 2024; Available online: 31 Dec 2024

***Abstract*— *This study evaluated the effect of inulin-fortified maize-based Rab on the lipid parameters of 30 hyperlipidemic subjects. The subjects consumed 200 ml of modified Rab (5% inulin) for 28 days. Anthropometric measurements, blood pressure, and lipid parameters were assessed at the beginning and end of the intervention. The data showed that the LDL, total cholesterol, and triglyceride levels were significantly reduced (p<0.05), HDL levels also increased significantly at the end of the intervention period (p<0.05). The results showed that the developed product could be used as a safe alternative to improve the lipid parameters in Indian population.*

***Keywords*— prebiotics, inulin, modified Rab**

Practical application: Adding inulin to traditional beverage would increase the adaptation and reach of the product. It might be an effective tool to prevent and manage dyslipidemia in rural and urban Rajasthan and connected regions



Graphical abstract

I. INTRODUCTION

Changes in lifestyle, dietary patterns, high-fat food, low level of physical activity, and sedentary lifestyle are the important factors that pose a fatal threat to human beings in the form of hyperlipidaemia, a common cardiovascular disease. Dyslipidaemia is the most important atherosclerotic risk factor. A review of population-based studies in India shows increasing mean total cholesterol levels. South Asians (SA) are at a higher risk for stroke and vascular dementia due to the disproportionate burden of diabetes, hypertension, and dyslipidemia. (Enas, Yusuf and Mehta 1992; Misra, Wasir, and Pandey 2005, Gupta and Gupta 2009, Singh, Dhamoon, and Alladi 2018)

Recent studies have reported that in India, high cholesterol is present among 25-30 per-cent of urban and 15-20 per-cent of rural subjects. This prevalence is lower than in high-income countries. The most common dyslipidaemia in India is borderline high LDL cholesterol, low HDL cholesterol, and high triglycerides (Shahi and Ranga 2000). Studies have reported that over a twenty-year period total cholesterol, LDL cholesterol, and triglyceride levels have increased among urban populations. Case-control studies have reported that there is a significant association of coronary events with raised apolipoprotein-B, total cholesterol, LDL cholesterol and non-HDL cholesterol and an inverse association with high apolipoprotein-A and HDL cholesterol. An increasing pattern with age was observed for hypercholesterolemia among urban males, females and rural females. The pervasiveness and magnitude of dyslipidemia in India is very high, urging for crucial lifestyle intervention strategies to avert and manage this important cardiovascular risk factor. In order to reduce the burden of this epidemic, it is essential to inculcate healthy lifestyle right from childhood (Enas 2001, Joshi et al 2024, Rao et al, 2015, Gupta 2017).

A study on the cholesterol levels among tribal population of Rajasthan state showed that 21.1% had borderline high cholesterol and 9.4% had high cholesterol. It was observed that males have higher cholesterol level as compared to females and working group has high level as compared to non-working group. Prevalence of low HDL-C level was found among urban females in Rajasthan (Bandana 2012, Agrawal, Varma and Gupta 2015).

Inulin is a non-digestible polysaccharide which break down in large intestine by particular gut microorganisms and proved to be beneficial for the growth and metabolism of gut microflora; specially, *Lactobacillus* and *Bifidobacteria*. In food industry it is used as fat replacer, sweet replacer, bulking agent, texture modifier, foaming agent, functional ingredient. It is generally commercialized in white coloured powder form, has no particular flavour or smell. Due to moderate water solubility, it is suitable for beverage industry. (Abou-Arab, Talaat and Abu-Salem 2011, Leyva-Porras et al 2014, Shams and Wadhawan 2021)

The study showed that addition of 2 percent inulin improved the viscosity, and melting properties of the yogurt significantly. It also significantly enhanced the viability of probiotic bacteria Lactobacillus acidophilus and Bifidobacterium lactis. (Rezaei, Khomeiri and Kashaninejad 2014)

Data have suggested that consumption of inulin in Human subjects improved the lipid profile. It was suggested that inulin supplementation 10g/day for 3 weeks could reduce triglyceride levels by 16% (Letexier, Diraison and Beylot 2003); 15g/day for 20 days could increase in 2.8% HDL-cholesterol (Alles et al 1999) whereas 5.5g/day for 10 weeks period did not significantly improve in lipid profile (Vulevic 2008). The consumption of inulin rich diet positively modulate total cholesterol, LDL -C and triglyceride levels in plasma of hyperlipidemic individuals but did not altered the plasma lipid profile in normolipidemic subjects (Guo et al 2012).

Hypertension is characterized by abnormally high blood pressure and regarded as one of the major public health issues worldwide. It is associated with the development of medical conditions like CVDs, myocardial infarction, cardiac failure, stroke, renal disease. In lower middle-income countries (LMICs) an increasing trend in prevalence of hypertension is observed. Being an LMIC, the scenario of hypertension in India is evidently crucial as 207 million persons were hypertensive and in 2016 around 1.63 million deaths in India were hypertension-related; therefore, called a silent killer. According to WHO World Health statistic Report 2012, 21 per-cent adult population has raised blood pressure. Hypertension contributes to 4.5 per-cent of the current global disease load, accounting for approximately 31 per-cent of global deaths (Kumar, Sharma and Sain 2017). In India, a representative study was performed on 1.3 million adults aged eighteen or above. The prevalence of hypertension in rural India ranged from 14.6 per-cent to 38.8 per-cent and in urban areas ranged from 17.6 per-cent to 62.7 per-cent, nationally. In Rajasthan state, the data showed 18.3 per-cent hypertension prevalence in rural areas and 26.1 per-cent in urban areas (Ghosh and Kumar 2019, Godara et al 2021, Bardhar, Khanna and Bardhar 2022, Longkumer et al 2023).

A cross-sectional study was performed in Udaipur city, Rajasthan, with aim of evaluating the prevalence of hypertension in Udaipur, Rajasthan. The data showed that 32.67 percent urban and 18.67 per-cent rural population had elevated levels of blood pressure. Among urban population, 87.76 per-cent led a sedentary lifestyle, 45.92 per-cent were overweight and 14.28 per-cent were obese (Godara et al 2021). A study performed by Patidar (2015) on a sample size of 600 in Udaipur city, Rajasthan suggested that 30.6 per-cent of the total population has hypertension.

Indian rural population depends on locally available food for nutrition and health. In India, 1000 of major and minor ethnic/ traditional foods and beverages are produced diversly. One of such beverages is called as *Rab* which is made up of combination of buttermilk and cereals like maize, pearl millet, wheat etc. It is served as cold or hot drink mainly as a breakfast in summer as well as winter season. *Rab* is a traditional fermented cereal-based soup like beverage of Rajasthani cuisine; prepared by cooking maize grits and flour in buttermilk for a long period (2 to 3 h). In rural areas of Rajasthan *Rab* is prepared and kept stored for 2 or 3 days in an earthen pot for consumption purposes. Investigations have been performed to standardize different cereal- based Rabs including maize-based (Soni and Arora 2000) sorghum-based (Pintu and Verma 2019), pearl millet-based (Dhankher and Chauhan 1987), wheat-based (Gupta and Nagar 2014, Gupta and Khetarpaul 1993), barley-based *Rabs* (Gupta, Khetarpaul and Chauhan 1992), soybean-based (Gupta and Nagar 2008).

Prior, studies have suggested the beneficial effect of inulin on the hyperlipidaemic subjects. But no scientific studies are focussed on the combination of traditional beverage (*Rab*) and inulin. Besides, there is no research work available that investigate the effect of the consumption of inulin fortified *Rab* on the lipid profile of hyperlipidaemia. Thus, the present study primarily concentrated on the effect of inulin fortified maize based Rab on the lipid parameters of hyperlipidaemic individuals.

II. METHODOLOGY

Subjects: This study was approved by the “Institutional Ethical Committee of Human Research”, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India. Written informed consent was obtained from all participants before inclusion.

Screening and inclusion

In total 30 hyperlipidaemic subjects from Udaipur city, Rajasthan, were identified and selected for the feeding intervention. The intervention was done for four weeks (28 days). Both male and female subjects participated in the study in 60:40 ratio. The inclusion criteria for the selection of the subject: willingness to participate and cooperate; age (>35 to < 55 year); serum cholesterol level >= 200mg/dl; no other degenerative diseases; and persons who are not taking any medication for hyperlipidemia.

Tool for personal interview

A well-structured interview schedule was prepared for this purpose. The schedule included background information, anthropometric measurement, blood pressure, food habits, biochemical parameters.

Intervention

All the participants were asked to consume 200 ml of modified maize-based *Rab* containing 5 percent inulin, daily for 28 days in the morning time during breakfast. No special diet modification or lifestyle modification was prescribed.

Blood pressure: a certified, automates, calibrated blood pressure measuring device was used to measure the systolic and diastolic blood pressure of all the participants before and after the commencement of the feeding period.

Pre and post blood analysis

Lipid parameters: cholesterol total, Low-Density Lipoprotein (LDL), High-Density Lipoprotein (HDL), Triglycerides (TG), Very Low-Density Lipoprotein (VLDL) and Non-HDL Cholesterol were checked a day prior to intervention. Post intervention testing of lipid parameters was done on the very next day of completion of intervention.

Statistical analysis for biochemical properties Mean+ SD values were calculated and to analyze the effect of consumption of modified Rab on the lipid profile and blood pressure paired ‘t’ test was applied.

III. RESULTS

The age of the selected participants ranged from 35 to 55 years. All the participants were non-smoker and non-alcoholic. None of the participants exercise daily. None of the participants had diabetes or any known heart disease. Ten of the subjects had family history of hyperlipidaemia. The pre-intervention, estimated mean value for LDL was 123.58 mg/dL, HDL was 35.21 mg/dL, TG, was 137.30mg/dL, VLDL mean value was 27.78 mg/dL, mean cholesterol total was 223.05 mg/dL, and mean of non- HDL cholesterol for 30 subjects was 152.31 mg/dL (Table 3). The post-intervention estimated mean value of LDL was calculated as 122.75 mg/dL, HDL as 35.78 mg/dL, TG as 136.62 mg/dL, Cholesterol total as 222.48 mg/dL, VLDL as 27.71 mg/dL, and Non-HDL cholesterol as 151.86 mg/dL (Table 3)

When the pre- and post-intervention values were compared, there was a significant decline in the values of LDL, triglycerides and total cholesterol at 1 per-cent level of significance (Table 3). The increase in the value of HDL was also found to be significant at 5 percent level of significance. The reduction in the values of VLDL and non-HDL cholesterol were found to be non-significant.

The decline in values of LDL was 0.67%, triglycerides was 0.80%, total cholesterol was 0.25%, VLDL was 0.25% and non-HDL cholesterol was 0.29%. The increase observed for the HDL was 1.61%. (Table 1)

Systolic Blood Pressure (SBP) data revealed a significant decrease in the post-intervention mean value as compared to the pre-intervention mean value at 0.1 per-cent level of significance, as shown in the Table 3. The mean of post diastolic blood pressure (DBP) slid down as compared to the pre-intervention DBP. Though, the difference between post and pre-intervention DBP mean was not found to be significant, nevertheless, the alteration revealed that the modified maize *Rab* did limit the increase in the DBP in the subjects. Modified maize-*Rab* induced 1 per-cent reduction in mean values of both SBP and DBP.

The post-intervention mean systolic blood pressure was found to be significantly reduced as compared to the pre-intervention mean, whereas the reduction in the post-intervention diastolic BP as compared to pre-intervention was not found to be significantly different. The distribution of the participants according to the blood pressure also changed. The pre-intervention data showed that 26.66 per-cent were in normal BP range, 43.33 per-cent were in prehypertensive stage and 30 per-cent were in the hypertensive stage. The post-intervention data suggested that though there is no change in the hypertensive stage, but there is a fall in the frequency of prehypertensive stage (36.66 per-cent) and increase in the normal range of BP as 33.33 per-cent respondents, post-trail (Table 2).

It is evident that the consumption of the modified *Rab* improves systolic blood pressure. Though it does not reduce the diastolic BP but indeed it prevents the rise in the diastolic blood pressure.

IV. DISCUSSION

In the present study, we imposed that consumption of the inulin-incorporated maize-based Rab (200 mL per day containing 10 g inulin) for 28 days duration did affect the levels of lipid parameters and blood pressure of the hyperlipidemic subjects. The developed beverage effectively reduced the values of low-density lipoprotein, triglycerides, and cholesterol levels, significantly. The level of the high-density lipoprotein also influenced by the consumption of the Rab. It did not significantly influence the VLDL and non-HDL cholesterol values but prevented the increase in these values. The mean SBP value significantly reduced after 28 days intervention period. The decline in the DBP value was not found statistically significant.

Previously, the effect of Inulin-incorporated food products and drinks on lipid profile have been studied in animals and in humans. Russo et al (2008) reported that consumption of inulin-enriched pasta resulted in the significantly altered HDL-cholesterol (P = 0.004), total cholesterol/HDL-cholesterol ratio (P = 0.006), triglycerides (P = 0.04), and Lipoprotein(a) (P = 0.02) concentrations. Nassar *et al* (2013), presented work on the assessment of effect of inulin on the metabolic changes produced by fructose rich diet in rats. The results showed significant increase in the serum HDL levels and significant decline in the serum levels of TG, LDL and total cholesterol due to inulin supplementation in the experimental animals concluding that the carbohydrate and lipid metabolic changes produced by the high fructose diet could be corrected by the consumption of inulin.

Yang et al (2018) also suggested the effect of inulin (9%) on the hepatic and total cholesterol levels in healthy mice. Miao et al (2021) also suggested the similar results in their research on the pregnant mice that ingestion of inulin type fructans (ITF) may alleviate the glucose and lipid metabolism disorders.

The study performed by Deng et al (2020) suggested that Inulin Type Fructans significantly decreased the VLDL levels in mice (fed with inulin for 12 weeks) whereas the HDL and LDL levels were not significantly altered. The contradictory results were presented in the study performed by Mistry et al (2018). It demonstrated that neither short chain inulin nor long chain inulin have any adverse effect on the metabolism of cholesterol in the experimental mice, even after raise in the generation of short chain fatty acids.

It is evident that the consumption of the modified *Rab* improves systolic blood pressure. Though it does not reduce the diastolic BP but indeed it prevents the rise in the diastolic blood pressure. Similar results were discussed by Castro-Sanchez et al (2017) and Becerril-Alarcón et al (2019) recommending that inulin supplementation significantly lower the systolic BP. It also reduced the diastolic BP but not significantly, thus it prevents increase in the diastolic Blood Pressure.

Cai et al (2018); Heil et al (2020) and Hess et al (2019), reported the positive effect of inulin on both the systolic and diastolic blood pressure. The review performed by Faghihimani et al (2021) suggested that the inulin supplementation only effectively reduces the systolic blood pressure in females but does not have any favorable effect on the male subjects.

Our data suggest that developed inulin fortified *Rab* has beneficial effects which protect against cardio vascular diseases by improving lipid profile and blood pressure levels. Adding inulin to traditional beverage would increase the adaptation and reach of the product. It might be an effective tool to prevent and manage dyslipidemia in rural and urban Rajasthan and connected regions.

V. CONCLUSION

Results of the current study have proven that the consumption of 200 ml inulin incorporated maize Rab (5% inulin), daily for 28 days may decrease the LDL, cholesterol, and triglyceride values in human. It also significantly increased in the level of high-density lipoprotein. Even though prior studies have reported that prebiotics could have beneficial effect on the lipid parameters, researches have also mentioned clashing results. Results from our study has supported that prebiotics have hypolipidemia effect on humans. Additionally, our study suggested that traditional beverage like Rab could be fortified with inulin (prebiotic) and used as a hypolipidemic beverage. This established that inulin incorporated maize Rab has the potential to be safely used as a nondrug option in the management of hyper lipidaemia, especially in Rajasthan and connected states of India. Thus, it is evident that consuming developed maize *Rab* resulted in the betterment of the health of hyperlipidemic individuals.

Table 1: Distribution of participants according to lipid profile

Lipid parameters	Pre-intervention	Post-intervention	(%) difference
LDL cholesterol			
<100 Optimal	Nil	Nil	Nil
100-129 Near optimal/above optimal	66.66%	66.66%	Nil
130-159 Borderline high	33.33%	33.33%	Nil
160-189 High	Nil	Nil	Nil
≥190 Very high	Nil	Nil	Nil
Total cholesterol			
<200 Desirable	Nil	Nil	Nil
200-239 Borderline high	86.66%	86.66%	Nil
≥240 High	13.33%	13.33%	Nil
HDL cholesterol			
<40 Low	76.66%	76.66%	Nil
>40 <60 normal	23.33%	23.33%	Nil
≥60 High	Nil	Nil	Nil

Table 2: Per-centage distribution of participants based on blood pressure

Blood pressure (mmHg)	Per-centage (%)		(%) Difference
	Pre-intervention BP_1	Post-intervention BP_2	
Normal (120/80)	26.66	33.33	25
Prehypertensive (120-139/80-89)	43.33	36.66	15.39
Hypertensive (> 140/90)	30	30	Nil

Table 3: Mean ± SD of lipid profile and blood pressure of participants

Blood parameters	Pre-intervention values	Post-intervention values	't' values	(%) Difference
LDL mg/dL	123.58±14.14	122.75±14.67	4.45**	0.67
HDL mg/dL	35.21±8.26	35.78±8.42	-3.26**	1.61
TG mg/dL	137.30±15.08	136.62±15.24	3.56**	0.80
Cholesterol total mg/dL	223.05±14.71	222.48±14.68	2.09*	0.25
VLDL mg/dL	27.78±4.95	27.71±4.9	0.43^{NS}	0.25
Non-HDL Cholesterol mg/dL	152.31±17.88	151.86±17.74	1.21^{NS}	0.29
Systolic Blood pressure (mmHg)	131.72±10.94	130.68±10.53	3.19***	0.78
Diastolic Blood pressure (mmHg)	88.43±5.73	87.9±5.5	1.76^{NS}	0.59

* = 5per-cent level of significance

** = 1per-cent level of significance

*** = 0.1per-cent level of significance

^{NS} = non-significant

ACKNOWLEDGEMENT

This research has been funded by the University Grant Commission, India (UGC-NET).

CONFLICT OF INTEREST

The authors declared that there is no conflict of interest regarding the publication of this article.

REFERENCES

[1] Enas, E. A., S. Yusuf, and J. L. Mehta. 1992. "Prevalence of coronary artery disease in Asian Indians." *American Journal of Cardiology* 70(9): 945-9.

a. doi: 10.1016/0002-9149(92)90744-j.

[2] Misra, A., J. S. Wasir, and R. M. Pandey. 2005. "An evaluation of candidate definitions of the metabolic syndrome in adult Asian Indians." *Diabetes Care* 28:398–403. doi: 10.2337/diacare.28.2.398.

[3] Gupta, R., and K. D. Gupta. 2009. "Coronary heart disease in low socioeconomic status subjects in India: "an evolving epidemic"." *Indian Heart Journal* 61(4):358-367.

[4] Singh, V., M. S. Dhamoon, and S. Alladi. 2018. "Stroke Risk and Vascular Dementia in South Asians." *Curr Atheroscler Rep* 20(9):43. doi: 10.1007/s11883-018-0745-7.

[5] Shahi, S. K., and S. Ranga. 2000. "Lipoprotein (a) and coronary artery disease in Indians." *Indian J Pathol Microbiol* 43(1):1-3.

[6] Enas, E. A. 2001. "Lipoprotein(a)is an important genetic risk for coronary artery disease in Asian Indians." *Am J Cardiol* 88(2):201-2. doi: 10.1016/s0002-9149(01)01659-9.

[7] Joshi, Shashank R., Ranjit M. Anjana, Mohan Deepa, Rajendra Pradeepa, Anil Bhansali, Vinay K. Dhandania, Prashant P. Joshi, et al. 2024. "Prevalence of Dyslipidemia in Urban and Rural India: The ICMR–INDIAB Study." *PLOS ONE* 5(2014): e96808. https://doi.org/10.1371/journal.pone.0096808.

[8] Mangala, Rao, Xavier Denis, Devi Padmini, Alben Sigamani, Faruqui Atiya, Gupta Rajeev, Kerkar Prafulla, et al. 2015. "Prevalence, treatments and outcomes of coronary artery disease in Indians: A systematic review." *Indian Heart J.* 67(4):302-10. doi: 10.1016/j.ihj.2015.05.003.

[9] Mradula, Gupta. 2017. "Development and evaluation of millet based probiotic beverage." PhD diss., Shoolini university of biotechnology and management sciences. http://hdl.handle.net/10603/204029

[10] Bandana, Sachdev. 2012. "Diet and lifestyle: its association with cholesterol levels among Nomad tribal populations of Rajasthan." *International Journal of Medicine and Biomedical Research* 1(2):124-130.

[11] Achu, Agrawal, Varma Kanika, Gupta Rajeev. 2015. "Lipid profle and prevalence of dyslipidemia in urban women of Jaipur district, Rajasthan, India." *Nutrition & Food Science* 45(3):412-422

[12] Azza A. Abou-Arab, Talaat H. A., and Abu-Salem F. M. 2011. "Physico-chemical Properties of Inulin Produced from Jerusalem Artichoke Tubers on Bench and Pilot Plant Scale." *Australian Journal of Basic and Applied Sciences* 5(5): 1297-1309.

[13] Leyva-Porras, C., López-Pablos, A.L., Alvarez-Salas, C., Pérez-Urizar, J., and Saavedra-Leos, Z. 2014. Physical Properties of Inulin and Technological Applications." in Polysaccharides, edited by Ramawat, K., and Mérillon, J.M. Springer, Cham. https://doi.org/10.1007/978-3-319-03751-6_80-1

[14] Shams, Zahara A., and Wadhawan Nikita. 2021. "Inulin a Crucial Component in Food Industry: A Review." *International Journal of Trend in Scientific Research and Development* 5(3):742-745, URL: https://www.ijtsrd.com/papers/ijtsrd38768.pdf

[15] Rezaei, R., M. Khomeiri, M. Aalami, and M. Kashaninejad. 2014. "Effect of inulin on the physicochemical properties, flow behavior and probiotic survival of frozen yogurt." *J Food Sci Technol* 51(10): 2809–2814. doi: 10.1007/s13197-012-0751-7

[16] Letexier D, F. Diraison, and M. Beylot. 2003. "Addition of Inulin to a Moderately High-Carbohydrate Diet Reduces Hepatic Lipogenesis and Plasma Triacylglycerol Concentrations in Humans." *Am. J. Clin. Nutr* 77:559–564.

[17] Alles, M.S., N.M. de Roos, J.C. Bakx, E. van de Lisdonk, P.L. Zock, J.G. Hautvast. 1999. "Consumption of Fructooligosaccharides Does Not Favorably Affect Blood Glucose and Serum Lipid Concentrations in Patients with Type 2 Diabetes." *Am. J. Clin. Nutr* 69:64–69.

[18] Vulevic, J., A. Drakoularakou, P. Yaqoob, G. Tzortzis, G.R. Gibson. 2008. "Modulation of the Fecal Microflora Profile and Immune Function by a Novel Trans-Galactooligosaccharide Mixture (B-GOS) in Healthy Elderly Volunteers." *Am. J. Clin Nutr* 88:1438–1446.

[19] Guo, Z., X. Liu, Q. Zhang, F. Tian, H. Zhang, Z. He-Ping, and W. Chen. 2012. "Effects of inulin on the plasma lipid profile of normolipidemic and hyperlipidemic subjects: a meta-analysis of randomized controlled trials." *Clinical Lipidology* 7(2): 215-222

[20] Kumar, U., O.P. Sharma, J. Goyal, and S. Sain. 2017. "Prevalence of hypertension among young adults in Jaipur district of Rajasthan, India." *International journal of community medicine and public health* 4(2):424

[21] Ghosh, S. and M. Kumar. 2019. "Prevalence and associated risk factors of hypertension among persons aged 15–49 in India: a cross-sectional study." *BMJ* 9: e029714. doi: 10.1136/bmjopen-2019-029714

[22] Godara, Ramesh, Mathews Elezebeth, Mini G.K., and Thankappan K.R.. 2021. "Prevalence, awareness, treatment and control of hypertension among adults aged 30 years and above in Barmer district, Rajasthan, India." *Indian Heart Journal* 73(2): 236–38. https://doi.org/10.1016/j.ihj.2021.02.007.

[23] Bardhar, S., A. Khanna. and N. Bardhar. 2022. "A study on the prevalence of hypertension and its associated risk factors in Gandhinagar urban PHC, Jaipur." *International Journal of Community Medicine and Public Health* 9(8):3159-3165

[24] Longkumer, Imnameren, Suniti Yadav, Sunanda Rajkumari, and Kallur Nava Saraswathy. 2023. "Trends in hypertension prevalence, awareness, treatment, and control: an 8-year follow-up study from rural North India." *Scientific Reports* 13(1):9910. https://doi.org/10.1038/s41598-023-37082-4.

[25] Patidar, Natwarlal. 2015. "A study on effect of life style risk factors on prevalence of hypertension among urban population of Udaipur city." *Internartional journal of current research* 7(4): 15168-15171.

[26] Soni, S.K., and J.K Arora. 2000. "Indian fermented foods:biotechnological approaches. In: Food processing: Biotechnological Applications." edited by Marwaha, S.S., and J.K. Arora, 143-190. New Delhi Asiatech. Pub. Inc.

[27] Pintu, R.K. and B.B. Verma. 2019. "Optimization of Rabadi-like sorghum based fermented milk beverage." *Journal of Agrisearch* 6 (4).

[28] Dhankher, N. and B.M. Chanuhan. 1987. "Technical note: preparation, acceptability and B vitamin content of Rabadi-a fermented pearl millet food.International journal of food science and technology," 22: 173-176

[29] Gupta, V., and R. Nagar. 2014. "Minerals and antinutrients profile of rabadi after different traditional preparation methods." *J Food Sci Technol* 51(8):1617-21. doi: 10.1007/s13197-012-0667-2.

[30] Gupta, M., and N. Khetarpaul. 1993. "Hydrochloric acid extractability of minerals from rabadi - a wheat flour fermented food." *J. Agric. Food Chem* 41(1): 125–127 https://doi.org/10.1021/jf00025a027

[31] Gupta, M., Khetarpaul, N. and Chauhan, B.M. 1992. Preparation, nutritional value and acceptability of barley rabadi – an indigenous fermented food of India. Plant Foods Hum Nutr.; 42:351–358. doi: 10.1007/BF02194096.

[32] Gupta, V. and Nagar, R. 2008. Physico- chemical and acceptability of rabadi (a fermented soyaflour product) as affected by cooking and fermentation time. Int J Food Sci Technol. 43:939–943. doi: 10.1111/j.1365-2621.2007.01551.x.

[33] Russo, F., G. Chimienti, G. Riezzo, G. Pepe, G. Petrosillo, M. Chiloiro, and E. Marconi. 2008. "Inulin-enriched pasta affects lipid profile and Lp(a) concentrations in Italian young healthy male volunteers." *European Journal of Nutrition* 47: 453–459.

[34] Nassar, S.E., G.M. Ismail, M.A. El-Damarawi, and A.A. Alam El-Din. 2013. "Effect of Inulin on Metabolic Changes Produced By Fructose Rich Diet." *Life Sci J* 10(2):1807-1814. http://www.lifesciencesite.com. 255

[35] Yang, J., S. Zhang, S.M. Henning, R. Lee, M. Hsu, E. Grojean, R. Pisegna, A. Ly, D. Heber, and Z. Li. 2018. "Cholesterol-lowering effects of dietary pomegranate extract and inulin in mice fed an obesogenic diet." *The Journal of Nutritional Biochemistry* 52: 62-69

[36] Miao, Miao, Yongmei Dai, Can Rui, Yuru Fan, Xinyan Wang, Chong Fan, Juan Mu, et al. 2021. "Dietary supplementation of inulin alleviates metabolism disorders in gestational diabetes mellitus mice via RENT/AKT/IRS/GLUT4 pathway." *Diabetology & Metabolic Syndrome* 13(1) https://doi.org/10.1186/s13098-021-00768-8.

[37] Deng, P., J.B. Hoffman, M.C. Petriello, C. Wang, X. Li, M.P. Kraemer, A.J. Morris, and B. Hennig. 2020. "Dietary inulin decreases circulating ceramides by suppressing neutral sphingomyelinase expression and activity in mice." *Journal of Lipid Research* 61(1): 45-53.

[38] Mistry, R.H., F. Gu, H.A. Schols, H.J. Verkade, and U.J.F. Tietge. 2018. "Effect of the prebiotic fiber inulin on cholesterol metabolism in wildtype mice." *Sci Rep* 8: 13238. https://doi.org/10.1038/s41598-018-31698-7

[39] Castro-Sánchez, F. H., D. A. Ochoa-Acosta, N. G. Valenzuela-Rubio, M. Domínguez-Rodríguez, J.A. Fierros-Valdez, and M.J. Vergara-Jiménez. 2017. "Inulin effect on weight loss and associated parameters with the development of cardiovascular disease in obese dyslipidemic subjects." *Austin J Nutr Metab* 4(1): 1044.

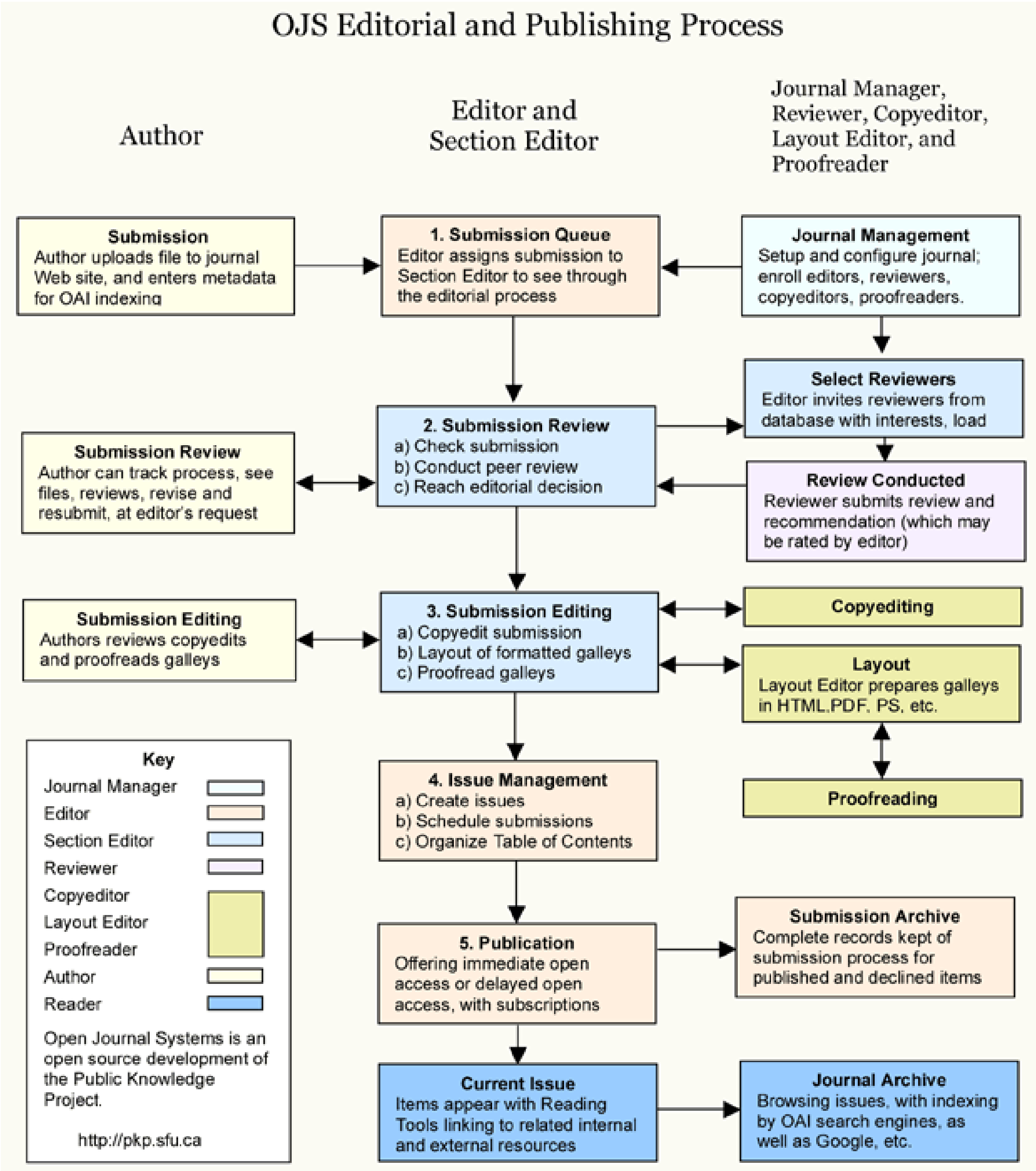
[40] Becerril-Alarcón, Y., S. Campos-Gómez, J.J. Valdez-Andrade, K.A. Campos-Gómez, D.Y. Reyes-Barretero, A.D. Benítez-Arciniega, R. Valdés-Ramos, and A.E. Soto-Piña. 2019. "Inulin Supplementation Reduces Systolic Blood Pressure in Women with Breast Cancer Undergoing Neoadjuvant Chemotherapy." *Cardiovasc Ther* 1:5707150. doi: 10.1155/2019/5707150.

[41] Cai, Xiaxia, Huanling Yu, Lan Liu, Tong Lu, Jingjie Li, Yacheng Ji, and Zhiyin Le, et al. 2018. "Milk Powder Co-Supplemented with Inulin and Resistant Dextrin Improves Glycemic Control and Insulin Resistance in Elderly Type 2 Diabetes Mellitus: A 12-Week Randomized, Double-Blind, Placebo-Controlled Trial." *Molecular Nutrition & Food Research* 62(24) https://doi.org/10.1002/mnfr.201800865.

[42] Hiel, Sophie, Marco A. Gianfrancesco, Julie Rodriguez, Daphnée Portheault, Quentin Leyrolle, Laure B. Bindels, Carolina Gomes Da Silveira Cauduro, et al. 2020. "Link between gut microbiota and health outcomes in inulin -treated obese patients: Lessons from the Food4Gut multicenter randomized placebo-controlled trial." *Clinical Nutrition* 39(12):3618–28. https://doi.org/10.1016/j.clnu.2020.04.005.

[43] Hess, Anne Lundby, Alfonso Benítez-Páez, Trine Blædel, Lesli Hingstrup Larsen, Jose Ramón Iglesias, Carmen Madera, Yolanda Sanz, and Thomas Meinert Larsen. 2019. "The effect of inulin and resistant maltodextrin on weight loss during energy restriction: a randomised, placebo-controlled, double-blinded intervention." *European Journal of Nutrition* 59(6): 2507–24. https://doi.org/10.1007/s00394-019-02099-x.

[44] Faghihimani, Zahra, Nazli Namazi, Samad Ghaffari, Mahnaz Rezaei Kelishadi, Shima Sharifi, Elyas Nattagh-Eshtivani, and Moloud Akbarzadeh, et al. 2021. "Effects of Inulin Type-Carbohydrates on blood pressure: a systematic review and meta-analysis." *International Journal of Food Properties* 24(1):129–39. https://doi.org/10.1080/10942912.2020.1858863.



~OJS Workflow~

Important links:

Paper Submission Link:

OJS:

https://ijeab.com/ojs/index.php/ijeab/about/submissions

https://ijeab.com/submit-paper/

Editorial Team:

https://ijeab.com/editorial-board/

Peer Review Process:

https://ijeab.com/peer-review-process/

Publication Ethics:

https://ijeab.com/publication-policies-and-ethics/

Author Guidelines:

https://ijeab.com/author-guidelines/

Join Us a Reviewer:

https://ijeab.com/join-us/

Journal Indexed and Abstracted in:

- Qualis-CAPES -Brazil
- Normatiza (Under Review)
- Bielefeld Academic Search Engine(BASE)
- Aalborg University Library (Denmark)
- WorldCat: The World's Largest Library Catalog
- Semantic Scholar
- J-Gate
- Open J-Gate
- CORE-The world's largest collection of open access research papers
- JURN
- Microsoft Academic Search
- Google Scholar
- Kopernio - powered by Web of Science
- Pol-Index
- PBN(Polish Scholarly Bibliography)Nauka Polaska
- Scilit, MDPI AG (Basel, Switzerland)
- Tyndale University College & Seminary
- indiana Library WorldCat
- CrossRef DOI-10.22161/ijeab
- Neliti - Indonesia's Research Repository
- Journal TOC
- Dimensions.ai: Re-imagining discovery and access to research
- Citeseerx
- Massachusetts Institute of Technology (USA)
- Simpson University (USA)
- University of Louisville (USA)
- Biola University (USA)
- IE Library (Spain)
- Mount Saint Vincent University Library (Halifax, Nova Scotia Canada)
- University Of Arizona (USA)
- INDIANA UNIVERSITY-PURDUE UNIVERSITY INDIANAPOLIS (USA)
- Roderic Bowen Library and Archives (United Kingdom)
- University Library of Skövde (Sweden)
- Indiana University East (campuslibrary (USA))
- Tilburg University (The Netherlands)
- Williams College (USA)
- University of Connecticut (USA)
- Brandeis University (USA)
- Tufts University (USA)
- Boston University (USA)
- McGill University (Canada)
- Northeastern University (USA)
- BibSonomy-The blue social bookmark and publication sharing system
- Slide Share
- Academia
- Archive
- Scribd
- SJIF-InnoSpace
- ISSUU
- Research Bib
- DRJI
- journal-repository

Platform & workflow by OJS / PKP

Infogain Publication

International Journal of English, Literature and Social Science (IJELS)