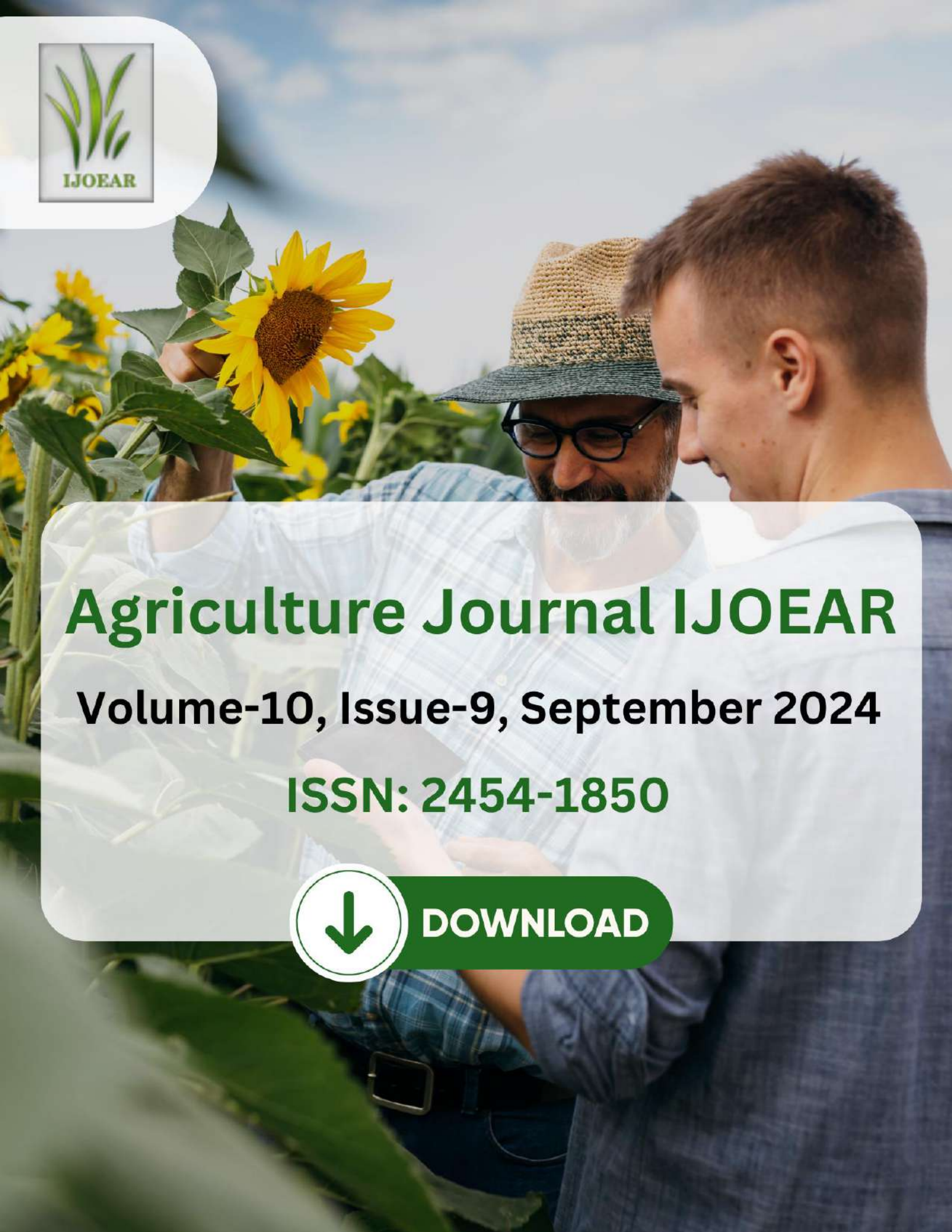

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Preface

We would like to present, with great pleasure, the inaugural volume-10, Issue-9, September 2024, of a scholarly journal, *International Journal of Environmental & Agriculture Research*. This journal is part of the AD Publications series *in the field of Environmental & Agriculture Research Development*, and is devoted to the gamut of Environmental & Agriculture issues, from theoretical aspects to application-dependent studies and the validation of emerging technologies.

This journal was envisioned and founded to represent the growing needs of Environmental & Agriculture as an emerging and increasingly vital field, now widely recognized as an integral part of scientific and technical investigations. Its mission is to become a voice of the Environmental & Agriculture community, addressing researchers and practitioners in below areas.

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Environmental science and regulation, Ecotoxicology, Environmental health issues, Atmosphere and climate, Terrestric ecosystems, Aquatic ecosystems, Energy and environment, Marine research, Biodiversity, Pharmaceuticals in the environment, Genetically modified organisms, Biotechnology, Risk assessment, Environment society, Agricultural engineering, Animal science, Agronomy, including plant science, theoretical production ecology, horticulture, plant, breeding, plant fertilization, soil science and all field related to Environmental Research.

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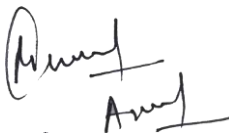
Agriculture, Biological engineering, including genetic engineering, microbiology, Environmental impacts of agriculture, forestry, Food science, Husbandry, Irrigation and water management, Land use, Waste management and all fields related to Agriculture.

Each article in this issue provides an example of a concrete industrial application or a case study of the presented methodology to amplify the impact of the contribution. We are very thankful to everybody within that community who supported the idea of creating a new Research with *IJOEAR*. We are certain that this issue will be followed by many others, reporting new developments in the Environment and Agriculture Research Science field. This issue would not have been possible without the great support of the Reviewer, Editorial Board members and also with our Advisory Board Members, and we would like to express our sincere thanks to all of them. We would also like to express our gratitude to the editorial staff of AD Publications, who supported us at every stage of the project. It is our hope that this fine collection of articles will be a valuable resource for *IJOEAR* readers and will stimulate further research into the vibrant area of Environmental & Agriculture Research.



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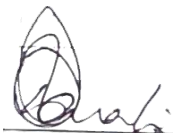

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Cereals or Basic Grains: Oats, Wheat, Barley, Rye, Triticale, Corn, Sorghum, Millet, Quinoa and Amaranth	Oilseeds: Canola, Rapeseed, Flax, Sunflowers, Corn and Hempseed
Pulse Crops: Peas (all types), field beans, faba beans, lentils, soybeans, peanuts and chickpeas.	Hay and Silage (Forage crop) Production
Vegetable crops or Olericulture: Crops utilized fresh or whole (wholefood crop, no or limited processing, i.e., fresh cut salad); (Lettuce, Cabbage, Carrots, Potatoes, Tomatoes, Herbs, etc.)	Tree Fruit crops: apples, oranges, stone fruit (i.e., peaches, plums, cherries)
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Dairy Sheep	Water Buffalo
Moose milk	Dairy product
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Silvopasture	Christmas tree cultivation
Maple syrup	Forestry Growth
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Harvesting equipment	Processing equipment
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Factors Limiting Rural Women Participation in Dairy Value Chain Activities in Zaria Local Government, Kaduna State, Nigeria

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Abstract— *This research aimed to evaluate the factors limiting rural women participation in dairy value chain activities in Zaria LGA of Kaduna State. Using a multi-stage sampling approach, 250 rural women were selected. Primary data were collected and analyzed with descriptive and inferential statistics to meet the research objectives. The findings indicated that the average ages of women who took part in the activity and the age of those who didn't was 39.2 and 42.1, respectively. Participants in the dairy value chain tend to have more years of experience compared to non-participants. with an average of 15.6 years, while non-participants had an average of 10.7 years. Additionally, the majority—60.0% of participants and 25.0% of non-participants were members of cooperatives. Logit regression analysis identified educational level, farm size, and cooperative membership were significant at the 5% level, while contact with extension agents was significant at the 1% level, whereas, marital status and access to credit were significant at 10% level. In terms of perceptions, women generally held positive views regarding their participation in the dairy value chain. Most perception statements received mean scores of 2.5 or above. For instance, the perception that dairy farming has improved their income (3.00), the belief that participation had enhanced their skills (3.08) and their family's nutrition has improved due to dairy farming (3.00). The respondents' main challenges include limited access to credit (75.2%), lack of technical knowledge (66.0%), time constraints due to household responsibilities (60.8%) and limited access to markets (50.8%). Based on these findings, recommendations were made that financial institutions and government programs should develop tailored credit facilities that address the specific needs of rural women in the dairy value chain.*

Keywords— Rural women, Dairy value chain, Nigeria, Kaduna State, Zaria LGA, Factors limiting participation, Socio-economic barriers, Gender-based discrimination, Dairy production, Agricultural sector.

I. INTRODUCTION

The dairy value chain in Nigeria is a vital component of the agricultural sector, significantly contributing to both the national economy and the livelihoods of rural communities. Nigeria's cattle population is estimated at over 20 million, making it one of the largest livestock producers in Africa (FAO, 2019). However, the country continues to import approximately 60% of its dairy needs due to inefficiencies within the local dairy value chain. This reliance stems from inefficiencies within the domestic

dairy value chain, which is plagued by low productivity, inadequate infrastructure, and fragmented market systems. The dairy sector in Nigeria is predominantly characterized by smallholder farmers who utilize traditional methods for milk production (Olaitan *et al.,* 2024a).

These methods, which are often low-yielding, result in average milk production rates of 1-2 liters per cow per day, significantly lower than the global average of 30 liters per cow per day (FAO, 2019). This low productivity is compounded by challenges such as poor animal husbandry practices, limited access to quality feed, and inadequate veterinary services. Additionally, the lack of cold chain infrastructure and processing facilities means that much of the milk produced is consumed locally or sold in an unprocessed form, preventing smallholders from accessing more lucrative, formal markets (Smith, Brown and Davis, 2023). As a result, the potential of the dairy sector to contribute to food security and economic growth remains largely untapped (Lai-Solarin *et al.,* 2024).

Beyond its economic implications, the dairy value chain is also integral to the livelihoods of millions of rural Nigerians, particularly women. In many rural communities, women play a pivotal role in dairy production, engaging in activities such as milking, processing, and marketing of dairy products (Thompson, Martinez and Wong, 2023). Planning, policies, and programs must take this into account in order for a nation to develop efficiently and sustainably (Oladejo, Olawuyi and Anjorin, 2022). According to Thompson *et al.* (2023), women's contribution to agricultural production in developing nations is therefore indisputable. Producing agricultural products is a labour-intensive and intricate operation. Women farmers are vital to the production and security of food in rural areas. Four out of every ten agricultural labourers globally are women, making up 70% of agricultural labourers, 80% of food producers, 100% of those who process staple foods, and 60 to 90% of those who market them (Smith *et al.,* 2023; Sennuga *et al.,* 2024a). This has led to a reevaluation of the significance of agriculture, with an emphasis on women's participation in agricultural activities, as well as its impact on industrialization and significance for peaceful development, political stability, and economic stability. However, their participation in the dairy value chain is often hindered by a range of socio-economic barriers. For instance, women typically have limited access to essential resources such as land, credit, and modern technology, all of which are critical for enhancing productivity and scaling operations (Olowogbon, Yisa and Ogunbile, 2021). Furthermore, socio-cultural norms and gender-based discrimination frequently limit women's decision-making power within households and communities, further constraining their ability to fully engage in and benefit from dairy-related activities. Even worse, a number of traditions prohibit women from joining cooperative organizations, which makes it more challenging for them to access financial resources and income (Olawuyi and Rahji, 2019; Olaitan *et al.,* 2024b).

This exemplifies the outdated notion that women are not farmers and men are. The full participation of women in agricultural production is hampered by this circumstance. Another problem is the difficulty in acquiring technology tools for employment that produces more, which restricts women's ability to earn money and take up business ventures. It is extremely difficult for women to secure credit facilities because the majority of them lack assets and are unable to offer collateral security to be used towards the acquisition of this sophisticated apparatus (Smith *et al.,* 2023). Their inability to assist in the accomplishment of more significant societal objectives stems from their need for assistance in obtaining the land required for automated farming. The majority of women in Nigeria's rural communities farm for subsistence (Odoh *et al.,* 2024).

Although most women are not permitted to own a significant amount of land or to have any access to land at all, it is believed that men would be more successful or have more access to property (Iliyasu *et al.,* 2023). Compared to men, women own less land overall, and the land they do own is typically smaller and less productive. Large-scale farming is out of the reach of women with knowledge and innovative ideas for agricultural production because of scarce or nonexistent land. Because of this, they work in small-scale farming and subsistence agriculture to support their family and make a pitiful living (Olowogbon *et al.,* 2021). Women's engagement in agriculture is decreasing despite Government's efforts to make farming more profitable and appealing to them, as more and more of them move to cities in pursuit of well-paying jobs. Women's involvement in the dairy value chain is influenced by a number of factors, including perceptions about agriculture, gender concerns, financial resources, and availability of land. In order to ensure self-reliance, food security, faster economic growth, and gender equality

in the study area, Nigerian leaders and their development partners must come up with creative strategies for making agriculture appealing to women (Ameh *et al.,* 2023). Unfortunately, information on these factors in Zaria Local Government Area of Kaduna was poorly understood and documented. The knowledge that was lacking was filled in by this study, enabling decision-makers to better understand how to increase young involvement in agriculture. This study aims to evaluate the factors limiting rural women participation in dairy value chain activities in Zaria Local Government, Kaduna State. To accomplish this, the following objectives are put forward:

a) Describe the socio-economic characteristics of the rural women in the study area.

b) Determine the socio-economic determinants of women's participation in the dairy value chain in the study area.

c) Establish how women perceptions influence their participation in dairy value chain in the study area.

d) Identify the constraints to women participation in dairy value chain in the study area.

II. LITERATURE REVIEW

2.1 Theoretical Framework:

2.1.1 Empowerment theory:

The Moser Gender Planning Framework by Caroline Moser served as the basis for this idea. This theory is founded on policy approaches to gender and development planning as well as Moser's conceptions of gender roles and gender demands (Moser, 1993). Via its policies aimed at solving the difficulties women confront in their subjugation within society, the idea addresses gender inequality. The policies that address gender inequality are listed below:

- **Welfare:** Focuses on addressing women's reproductive roles through top-down support, aiming to meet practical gender needs associated with that role.
- **Equity:** Aims to secure equal opportunities for women as active contributors to development, challenging traditional gender hierarchies.
- **Anti-poverty:** Seeks to boost the productivity of impoverished women by acknowledging their economic role and addressing their needs, especially in small-scale income-generating ventures.
- **Efficiency:** A Women In Development (WID) approach that prioritizes women's involvement in development to enhance overall effectiveness, equating participation with gender equity.
- **Empowerment:** Strives to foster women's self-reliance, addressing strategic gender needs through grassroots mobilization while recognizing their diverse roles.

This research, which attempts to solve the problem of gender disparity in society through its policies, is pertinent to the empowerment thesis. Equity and anti-poverty programs provide equal chances for men and women because they acknowledge the active role that women play in development. Subordination of women is further challenged by equity.

2.2 Conceptual Framework:

Figure 1 presents the conceptual framework for this study, exploring the relationship between the various factors (independent variables) that affect women's participation (dependent variables) in Zaria Local Government, Kaduna State. The conceptual framework was developed from the reviewed related literature. The independent variables (socio-economic and institutional characteristics) in this study are hypothesized to influence women participation in the dairy value chain. The dependent variable (women participation in the dairy value chain) measured in terms of the activities women were engaged in specifically dairy production and marketing. The intervening variables such as government policies, political interference, access to information and technology as well as cultural shifts affect the effects of the independent variable on the dependent variables.

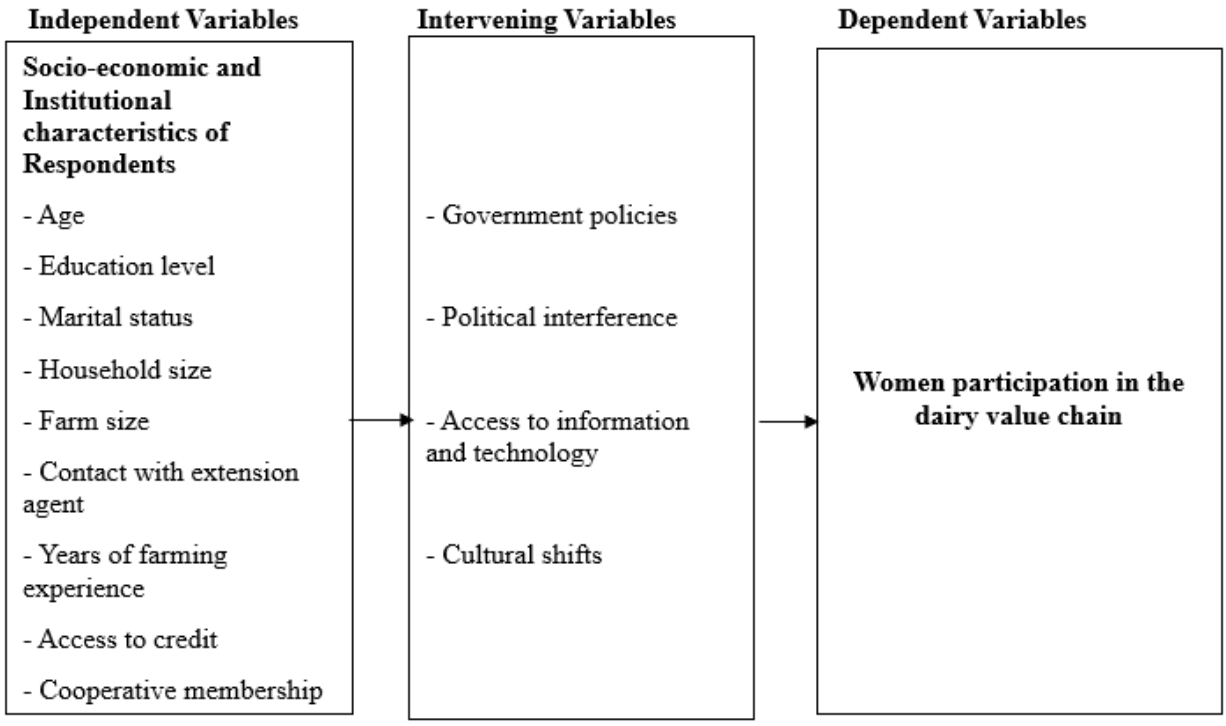

FIGURE 1: Conceptual framework of the study

III. MATERIALS AND METHODS

3.1 Study Area:

This study was conducted in the Zaria Local Government Area (LGA) of Kaduna State, Nigeria. Zaria is geographically positioned between latitudes 11°09'N and 11°13'N, and longitudes 7°39'E and 7°68'E. The LGA covers a total land area of approximately 300 square kilometres and has a population of 1,001,982 people (National Population Commission, 2006). The climate in Zaria is tropical, characterized by a distinct wet and dry season. The wet season, which lasts from May to October, is marked by heavy rainfall, beginning with minimal precipitation in April (0 mm) and reaching its peak at 816 mm in August. This is followed by a decline in rainfall, tapering to 150 mm in October and returning to near-zero levels from November through December. The dry season spans from November to April, contributing to the area's warm weather year-round.

The major ethnic groups in Zaria are the Hausa and Fulani, with significant populations of Yoruba, Igbo, and other ethnic groups. The local economy is predominantly agriculture-based, with staple crops such as guinea corn, millet, and sweet potato forming the backbone of subsistence farming. Additionally, cash crops like cotton, groundnut, and tobacco are widely cultivated, contributing to the local economy. Zaria is also known for its vibrant artisan sector, which includes traditional crafts such as leatherwork, dyeing, cap making, and various small-scale industries like print shops, furniture making, and textiles. This diverse economic landscape makes Zaria an important area for studying agricultural practices, including dairy farming, and understanding the socio-economic dynamics that influence rural livelihoods, particularly for women involved in the dairy value chain.

3.2 Population of the Study and Research Design:

The population of this study comprises rural women involved in dairy farming activities within the Zaria Local Government Area (LGA) of Kaduna State, Nigeria. This includes women who are engaged at various stages of the dairy value chain, such as production, processing, and marketing of dairy products. Additionally, the study considers other stakeholders who interact with these women, such as agricultural extension workers, local cooperative members, and community leaders, to gain a comprehensive understanding of the factors that influence women's participation in the dairy sector. The target population specifically focuses on women from the Hausa and Fulani ethnic groups, as they are predominantly involved in pastoral and

agricultural activities in the region. This population provides a critical lens through which to examine the socio-economic and institutional factors that impact women's involvement in the dairy value chain.

This study employs a mixed-methods research design combining both quantitative and qualitative approaches to gain a comprehensive understanding of the factors limiting rural women's participation in the dairy value chain in Zaria LGA. The quantitative component involves the use of structured questionnaires administered to a representative sample of rural women engaged in dairy farming activities. This approach allows for the collection of data on variables such as socio-economic status, access to resources, and levels of participation in the dairy value chain. The qualitative component involves in-depth interviews and focus group discussions (FGDs) with a purposive sample of women dairy farmers, agricultural extension workers, and community leaders. This approach is designed to explore the socio-cultural norms, institutional barriers, and personal experiences that influence women's participation in the dairy value chain. The qualitative data will be analyzed thematically, identifying recurring themes and patterns that provide a deeper understanding of the challenges faced by rural women in this sector. By integrating both quantitative and qualitative data, this mixed-methods design allows for a more robust and nuanced analysis, ensuring that the study captures both the measurable aspects of women's participation and the contextual, lived experiences that shape their involvement in the dairy value chain.

3.3 Sample Size and Sampling Techniques:

This study employs a multistage sampling technique to select a representative sample of rural women involved in dairy value chain activities within Zaria Local Government Area (LGA) of Kaduna State, Nigeria. This multistage sampling technique ensures that the sample is both representative and inclusive, reflecting the diversity of experiences and factors influencing rural women's participation in the dairy value chain across different parts of Zaria LGA. In the first stage, simple random sampling was used to select four wards from the total number of wards in Zaria LGA. The selected wards are Tudun Wada, Gyallesu, Kaura, and Dambo. This selection was made to ensure that the sample is geographically representative of different areas within Zaria LGA, capturing a diversity of socio-economic and cultural contexts.

Within each of these selected wards, specific communities were then chosen using purposive sampling. This was done to identify areas where dairy farming is a predominant activity, particularly among women. In Tudun Wada Ward, the communities of Dan-Madami and Ungwan Juma were selected due to their significant involvement in dairy farming, especially among the Fulani women who traditionally engage in this activity. In Gyallesu Ward, the Gyallesu and Ungwan Maigero communities were chosen for their strong agricultural practices, including dairy farming, supported by local cooperative groups. In Kaura Ward, Kaura GRA and Ungwan Kanawa were selected based on their well-established dairy farming practices, which are vital to the local economy. Finally, in Dambo Ward, the Ungwan Mai Gemu and Ungwan Zage communities were selected due to their active participation in dairy production and proximity to Ahmadu Bello University, which influences agricultural practices in the area. The selection of these communities was based on insights from local agricultural extension officers and community leaders, who provided detailed information about the prevalence of dairy farming activities.

In the final stage, systematic random sampling was used to select individual respondents within the chosen communities. A sampling interval was determined by dividing the total number of households involved in dairy farming by the required number of respondents per community. For example, if a community had 100 dairy farming households and the required sample size from that community was 25, every 4th household was selected. Within each selected household, one woman actively engaged in dairy activities was chosen to participate in the study. If more than one woman in a household was involved, simple random sampling, such as drawing lots, was used to select the respondent.

The 250 respondents were proportionally distributed across the selected wards and communities based on the estimated population of women involved in dairy farming in each area. Specifically, 70 respondents were selected from Dan-Madami and Ungwan Juma in Tudun Wada Ward; 60 respondents from Gyallesu and Ungwan Maigero in Gyallesu Ward; 60 respondents from Kaura GRA and Ungwan Kanawa in Kaura Ward; and 60 respondents from Ungwan Mai Gemu and Ungwan Zage in Dambo Ward.

3.4 Data Collection:

The primary instrument employed for gathering data in this research was a structured questionnaire. These questionnaires were administered to gather data, with the survey lasting approximately 1 hour and 9 minutes. The key themes explored in the survey encompassed the socio-economic characteristics of the rural women, the socio-economic determinants of women's participation in the dairy value chain, women perceptions in their participation, and the constraints to women participation in dairy value chain in the study area. To ensure the questionnaire's validity and reliability, it underwent pre-testing in a pilot study. This pilot test involved a small group of women not included in the main study sample. Through this pilot test, any ambiguities or issues in the questionnaire were identified, facilitating adjustments to enhance its clarity and effectiveness.

3.5 Data Analysis:

The data collected for this study were analyzed using a combination of descriptive and inferential statistical methods. Descriptive statistics, including percentages, frequency counts, and means, were utilized to address the objectives i and iv of the study. Objective (ii) was achieved by utilizing the logit regression model. For the objective (iii), a 4-point Likert scale was employed to assess the responses. The data analysis was facilitated by the IBM Statistical Package for the Social Sciences (IBM SPSS) software, version 24, which provided a comprehensive platform for both descriptive and inferential analysis, including the application of the logit regression model for deeper insights.

3.6 Model specification:

3.6.1 Model for Likert scale rating:

The study used a 4-point Likert scale to evaluate how respondents' perceptions influence their participation in dairy value chain. Specific responses were listed, and respondents were asked to rank their level of agreement with statements regarding the extent of their participation. The Likert scale ranged from "Very High Extent (VHE)" with a score of 4, to "Minimal Extent (MIE)" with a score of 1. The decision threshold was set at a mean score of 2.5, which served as the benchmark for interpreting the results. The scale was structured as follows:

- Very High Extent (VHE) – 4
- High Extent (HE) – 3
- Moderate Extent (ME) – 2
- Minimal Extent (MIE) – 1

The mean score for each item was calculated using the formula:

$$X_s = \frac{\Sigma(f\ X\ n)}{Nr} \quad (1)$$

Where:

Xs = Mean score

$\sum$ = Summation

F = Frequency of each response option (4, 3, 2, 1)

n = Likert numerical values assigned to the responses

Nr = Total number of respondents in each response category

3.6.2 Logit Regression Model:

A logistic regression model was applied to identify the factors that influence the participation of rural women in the dairy value chain within the study area. The implicit form of the Logit model is expressed as:

$$Y = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}) \quad (2)$$

The explicit form of the Logit model is given as:

$$Y=\beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + e \quad (3)$$

Where:

Y = Determinants of women's participation in the dairy value chain

X_1 = Age

X_2 = Years of experience in dairy farming

X_3 = Marital status

X_4 = Household size

X_5 = Education attainment

X_6 = Farm size

X_7 = Access to credit

X_8 = Cooperative membership

X_9 = Access to extension services

β_0 = Constant (intercept)

e = Error term

This model allows the study to analyze how various socio-economic and institutional factors impact the likelihood of participation among women involved in dairy activities, thereby providing insights into which factors are most significant in enhancing or limiting their engagement in value chain processes.

IV. RESULTS AND DISCUSSION

4.1 Socio-economic and Institutional Characteristics of Respondents:

The age distribution of respondents in Table 1 reveals that the majority of participants in the dairy value chain are aged between 30-39 years (45%), followed by those aged 40-49 years (35%). This age group is generally considered to be in their most economically active years, which aligns with their significant involvement in labour-intensive agricultural activities like dairy farming (National Population Commission, 2006). In contrast, non-participants were slightly older on average, with 40% in the 30-39 age range and 30% in the 40-49 range. The relatively higher mean age of non-participants (42.1 years) compared to participants (39.2 years) suggests that younger women are more likely to engage in dairy farming activities, possibly due to the physical demands and the potential for long-term economic returns (Olowogbon *et al*., 2021).

The result of marital status in Table 1 shows that a significant majority of both participants (70%) and non-participants (65%) in the dairy value chain are married. This finding aligns with previous studies that highlight the central role of married women in rural agricultural activities, where they often contribute to household income through farming (Thomson *et al*., 2023). The stability and support provided by marriage may encourage greater involvement in labour-intensive activities like dairy farming. Additionally, the presence of a spouse can provide additional labour and resources, which are crucial for sustaining dairy production. The proportions of widowed and divorced women were relatively low in both groups, indicating that marital stability may play a role in sustained agricultural engagement (Patel and Nguyen, 2024; Sennuga *et al.*, 2024b).

The result of household size in Table 1 reveals that the majority of participants in the dairy value chain have larger households, with 50% having 6-10 members and an average household size of 7.2 members. In contrast, non-participants tend to have smaller households, with 55% having 1-5 members and an average household size of 5.3 members. Larger household sizes among participants may contribute to the availability of labour for dairy farming activities, as family members often provide

the necessary workforce for labour-intensive agricultural tasks (Olawuyi and Rahji, 2019). The differences in household size highlight the importance of family labour in sustaining dairy farming operations, which is more pronounced among those actively participating in the dairy value chain.

The result on educational attainment in Table 1 indicates that 40% of dairy value chain participants have completed primary education, 30% have secondary education, and 10% have attained tertiary education, while 20% have no formal education. In comparison, among non-participants, 50% have primary education, 25% have secondary education, and 10% have tertiary education, with 15% having no formal education. These findings suggest that women with higher education levels are more likely to engage in the dairy value chain, likely due to better access to relevant knowledge and resources that facilitate their participation (Patel and Nguyen, 2024). The slightly higher educational levels among participants highlight the role of education in enhancing women's capacity to participate effectively in dairy farming.

The result of farming experience among respondents in Table 1 shows that participants in the dairy value chain tend to have more years of experience compared to non-participants. Specifically, 50% of participants have 10-19 years of farming experience, with an average of 15.6 years, while only 30% of non-participants fall within this range, with an average of 10.7 years. Additionally, 30% of participants have 20-29 years of experience, indicating a deeper engagement with agricultural practices over time. This suggests that greater farming experience may be associated with increased involvement in dairy activities, as experienced farmers are likely to have accumulated the necessary skills and knowledge to successfully participate in the value chain (Olawuyi and Rahji, 2019).

The result on farm size in Table 1 reveals that participants in the dairy value chain generally operate larger farms compared to non-participants. Specifically, 40% of participants manage farms ranging from 2-3 hectares, with an average farm size of 2.3 hectares. In contrast, non-participants have smaller farms, with 50% cultivating less than 1 hectare and an average farm size of 1.2 hectares. The larger farm sizes among participants suggest that access to more land may facilitate greater involvement in dairy farming activities, as larger plots can support more extensive agricultural operations, including the production of fodder for livestock (Ojo, Olawuyi and Dada, 2020; Abdulahi *et al.*, 2023). The significant difference in farm size between the two groups highlights the role of land availability in determining the level of participation in the dairy value chain.

The analysis of contact with extension agents in Table 1 shows that a higher proportion of participants in the dairy value chain have regular interactions with extension services compared to non-participants. Specifically, 55% of participants reported regular contact with extension agents, while only 20% of non-participants had similar interactions. Furthermore, 45% of non-participants reported having no contact with extension services, compared to only 15% of participants. This disparity suggests that regular access to extension services is closely associated with active participation in the dairy value chain, as extension agents provide crucial information, training, and support that enhance agricultural productivity (Oluwatusin, 2021).

The analysis of cooperative membership in Table 1 indicates that a significantly higher percentage of participants in the dairy value chain are members of agricultural cooperatives compared to non-participants. Specifically, 60% of participants reported being members of a cooperative, while only 25% of non-participants had similar memberships. Cooperative membership among participants provides access to shared resources, collective bargaining power, and essential support services, which are crucial for enhancing productivity and profitability in dairy farming (Adegboye, Adeoye and Yusuf, 2020). The lower membership rate among non-participants suggests that the absence of such networks may limit their access to the benefits and opportunities that cooperatives provide.

The result on access to credit in Table 1 reveals a substantial difference between participants and non-participants in the dairy value chain. Among participants, 45% reported having access to credit facilities, whereas only 20% of non-participants had similar access. This disparity highlights the importance of credit availability in enabling women to invest in and sustain their dairy farming activities. Access to credit provides the necessary financial resources for purchasing inputs, improving livestock management, and expanding production capacity (Adegboye *et al.*, 2020). The limited access to credit among non-participants suggests financial constraints that may hinder their ability to engage in or scale up dairy farming, thereby affecting their overall participation in the dairy value chain.

TABLE 1
SOCIOECONOMIC CHARACTERISTICS OF RESPONDENTS (n =250)

Characteristics	Participants (n=140)		Non-Participants (n= 110)	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Age				
20-29	21	15	22	20
30-39	63	45	44	40
40-49	49	35	33	30
50 and above	7	5	11	10
Mean	**39.2 years**		**42.1 years**	
Marital Status				
Married	98	70	72	65
Single	21	15	22	20
Widowed	14	10	11	10
Divorced	7	5	5	5
Household Size				
1-5	42	30	61	55
6-10	70	50	33	30
More than 10	28	20	16	15
Mean	**7.2 members**			
Educational Level				
No Formal	28	20	17	15
Primary	56	40	55	50
Secondary	42	30	28	25
Tertiary	14	10	11	10
Farming Experience (yrs)				
5-9	21	15	44	40
10-19	70	50	33	30
20-29	42	30	22	20
30 and above	7	5	11	10
Mean	**15.6 years**		10.7 years	
Farm Size (ha)				
Less than 1 ha	14	10	55	50
1-2 ha	49	35	33	30
2.1-3 ha	56	40	17	15
More than 3 ha	21	15	5	5
Mean	**2.3 hectares**		1.2 hectares	
Extension Contact				
Regular	77	55	22	**20**
Occasional	42	30	39	35
None	21	15	49	45
Cooperative Membership				
Yes	84	60	28	25
No	56	40	82	75
Access to Credit				
Yes	63	45	22	20
No	77	55	88	80

Source: Field study, 2024

4.2 Socio-economic determinants of women's participation in the dairy value chain:

The model statistics in Table 2 provide valuable insights into the overall performance and reliability of the Logit regression model used to analyze the socio-economic determinants of women's participation in the dairy value chain. The Likelihood Ratio Chi-Square (LR Chi^2) value is 45.67, which measures the goodness-of-fit of the model. This statistic tests whether the model with the independent variables fits the data significantly better than a model with only an intercept (no independent variables). The relatively high Chi-Square value indicates that the independent variables included in the model significantly improve the model's fit compared to a null model. The Pseudo R^2 value of 0.218 suggests that approximately 21.8% of the variance in women's participation in the dairy value chain is explained by the independent variables in the model. The model's overall P-Value is 0.0012, which is highly significant (well below the 0.05 threshold). This indicates that the model as a whole is statistically significant and that the independent variables collectively contribute to explaining the likelihood of women's participation in the dairy value chain. The model has a high negative Log likelihood of -72.45, which displays a good fit. This suggests that the explanatory variables in the calculated logit model effectively account for the probability of a respondent's involvement in the dairy value chain. Among the nine (9) factors tested, six factors had coefficients that were statistically meaningful: marital status, educational level, farm size, cooperative membership, access to credit, and extension contact. These factors are identified as important predictors influencing participation in the dairy value chain.

The analysis of marital status as a determinant of women's participation in the dairy value chain reveals that this variable is statistically significant at the 10% level, with a coefficient of 0.17 ($p = 0.06$). This indicates that married women are more likely to participate in dairy farming activities compared to their unmarried counterparts. The positive coefficient suggests that marital status may provide certain socio-economic advantages, such as increased household labor, financial stability, and support from spouses, which could facilitate greater involvement in dairy farming (Ojo *et al.*, 2020). This finding aligns with existing literature that highlights the role of marriage in enhancing women's economic activities, particularly in rural settings where household collaboration is crucial for managing agricultural tasks.

The analysis of educational level as a determinant of women's participation in the dairy value chain shows that it is statistically significant at the 5% level, with a coefficient of 0.20 ($p = 0.04$). This positive relationship suggests that higher levels of education increase the likelihood of women engaging in dairy farming activities. Educated women are more likely to access and utilize information, adopt improved agricultural practices, and navigate the complexities of the dairy value chain (Oluwatayo and Ojo, 2021).

The analysis of farm size as a determinant of women's participation in the dairy value chain indicates that it is statistically significant at the 5% level, with a coefficient of 0.33 ($p = 0.02$). This positive relationship suggests that women who manage larger farms are more likely to be involved in dairy farming activities. Larger farm sizes provide the necessary space for cultivating fodder and raising livestock, thereby supporting more intensive and profitable dairy operations (Adesiji, Komolafe and Ajiboye, 2020).

The analysis of cooperative membership as a determinant of women's participation in the dairy value chain shows that it is statistically significant at the 5% level, with a coefficient of 0.64 ($p = 0.002$). This strong positive relationship indicates that women who are members of agricultural cooperatives are significantly more likely to participate in dairy farming activities. Cooperative membership offers women access to collective resources, such as financial services, training, and market information, which are crucial for enhancing productivity and profitability in dairy farming (Thomson *et al.*, 2023).

The analysis of access to credit as a determinant of women's participation in the dairy value chain reveals that it is statistically significant at the 10% level, with a coefficient of 0.26 ($p = 0.06$). This positive relationship suggests that women with access to credit are more likely to engage in dairy farming activities. Access to credit provides the financial resources needed for purchasing inputs, expanding operations, and investing in improved dairy practices, which are essential for scaling up production and enhancing profitability (Adesiji *et al.*, 2020). The significance of credit access in this context underscores its role as a critical enabler for rural women, allowing them to overcome financial constraints and participate more actively in the dairy value chain.

The analysis of contact with extension agents as a determinant of women's participation in the dairy value chain indicates a strong positive relationship, with the variable being statistically significant at the 1% level (coefficient = 0.710, $p = 0.004$). This result suggests that women who have regular contact with extension agents are significantly more likely to participate in dairy farming activities. Extension services provide essential information, training, and technical support that enhance women's knowledge and skills in dairy production, leading to increased productivity and engagement in the value chain (Oluwatusin,

2021). The high significance level of this variable highlights the critical role that extension services play in empowering women farmers and improving their agricultural practices.

TABLE 2
LOGIT REGRESSION TABLE SHOWING THE SOCIO-ECONOMIC DETERMINANTS OF WOMEN'S PARTICIPATION IN THE DAIRY VALUE CHAIN

Variable	Coefficient	Standard error	Z- value	P-value
Constant	-1.16	0.52	-2.23	0.02
Age	0.06	0.04	1.63	0.1
Marital Status	0.17*	0.09	1.87	0.06
Household Size	0.14	0.08	1.82	0.07
Educational Level	0.20**	0.1	2.03	0.04
Farming Experience	0.06	0.04	1.71	0.09
Farm Size	0.33**	0.13	2.41	0.02
Cooperative Membership	0.64**	0.24	3.14	0.002
Access to Credit	0.26*	0.14	1.86	0.06
Extension Contact	0.71***	0.25	2.89	0.004
Number of Observation	250			
LR Chi^2 (9)	45.67			
Pseudo R^2	0.218			
P-Value	0.0012			
Log likelihood	-72.45			

Source: Field Study, 2024

Note: ***, ** and * indicate significance at 1%, 5% and 10% probability level respectively

4.3 Perceptions of women on their participation in the dairy value chain:

The results from the Table 3 on women's perceptions of their participation in the dairy value chain reveal a blend of positive and negative sentiments by these women. A majority of the perception statements received mean scores above the decision threshold of 2.5, indicating positive views toward their involvement in dairy farming. However, several key areas were identified where the mean scores fell below 2.5, highlighting significant issues faced by the participants.

One of the most significant positive perceptions is that dairy farming has improved women's income, with a mean score of 3.00. This indicates that many women see their involvement in the dairy value chain as a crucial source of financial empowerment. This finding is consistent with existing literature that underscores the economic benefits of agricultural participation for rural women, particularly in sectors like dairy farming where income generation can be substantial (Oluwatayo and Ojo, 2021). The financial independence gained through dairy farming is a critical aspect of women's empowerment, contributing to their ability to support their households and make decisions regarding their finances.

The perception that participation in dairy farming has enhanced their skills is also strongly positive, with a mean score of 3.08. This suggests that women involved in dairy farming acquire valuable skills that are essential for their economic and social advancement. Skill acquisition is vital for improving productivity and efficiency in dairy farming, enabling women to better manage their operations and increase their output. The positive perception of skill enhancement aligns with studies that emphasize the importance of training and capacity building in empowering women farmers (Smith *et al.*, 2023). Another positive perception is the increase in social status that women experience as a result of their participation in dairy farming, with a mean score of 2.93. This reflects the broader social benefits of dairy farming, where women not only gain economically but also enhance their standing within the community. The increased social status is likely linked to the visibility and respect that comes with being a successful farmer, particularly in rural areas where agriculture is a central component of the community's livelihood (Akanbi, Akinbile and Adeniyi, 2021).

However, the table also highlights several areas of concern where the mean scores fell below the 2.5 threshold, indicating negative perceptions. For instance, the statement "My workload in dairy farming is manageable" received a mean score of 2.38, suggesting that many women find the demands of dairy farming to be overwhelming. This finding is consistent with previous

research that has documented the heavy workload borne by women in agriculture, which is often exacerbated by their household responsibilities (Akanbi *et al.,* 2021). The balance between farming duties and domestic chores remains a significant challenge for many women, affecting their overall well-being and capacity to fully engage in dairy farming activities.

The perception that "The income from dairy farming meets my financial needs" also scored low, with a mean of 2.25, indicating concerns about the sufficiency of earnings from dairy activities. This suggests that while dairy farming provides a source of income, it may not be adequate to fully support the financial needs of the women involved. Issues such as fluctuating market prices, access to markets, and production costs could contribute to this perception, highlighting the economic vulnerability that many women farmers face (Nwachukwu, Onyeka and Ibekwe, 2021). Infrastructural challenges were also evident, as seen in the statement "The infrastructure available supports my dairy farming activities," which received a mean score of 2.10. This low score indicates significant concerns regarding the availability and quality of infrastructure necessary for effective dairy farming, such as storage facilities, transportation, and access to water and electricity. Inadequate infrastructure can severely limit the efficiency and profitability of dairy operations, making it difficult for women to expand their activities and access larger markets (Nwachukwu *et al.,* 2021).

Additionally, the difficulties in accessing veterinary services and transporting dairy products to the market were highlighted by mean scores of 2.10 and 2.06, respectively. These challenges reflect practical barriers that women face in maintaining the health of their livestock and ensuring that their dairy products reach the market in good condition. Access to veterinary services is crucial for preventing and managing diseases in livestock, while efficient transportation is essential for minimizing losses and maximizing profits (Akanbi *et al.,* 2021).

TABLE 3
PERCEPTIONS OF WOMEN ON THEIR PARTICIPATION IN THE DAIRY VALUE CHAIN

S. No.	Perception Statements	VHE (4)	HE (3)	ME (4)	MIE (1)	Mean Score	Decision
1	Dairy farming has significantly improved my income	90	95	40	25	3	Accept
2	My participation in dairy farming has enhanced my skills	105	80	45	20	3.08	Accept
3	Dairy farming has increased my social status in the community	85	90	50	25	2.93	Accept
4	I am confident in managing my dairy farming operations	75	100	45	30	2.89	Accept
5	My family's nutrition has improved due to dairy farming	95	85	45	25	3	Accept
6	I have access to adequate resources for dairy farming	55	75	70	50	2.49	Reject
7	Dairy farming has made me more independent	80	85	55	30	2.83	Accept
8	I feel supported by my community in my dairy farming efforts	50	90	60	50	2.52	Accept
9	My workload in dairy farming is manageable	45	75	65	65	2.38	Reject
10	I have opportunities to grow and expand my dairy business	65	85	55	45	2.66	Accept
11	The income from dairy farming meets my financial needs	40	65	75	70	2.25	Reject
12	I can balance dairy farming with my household responsibilities	45	70	80	55	2.36	Reject
13	The infrastructure available supports my dairy farming activities	30	60	80	80	2.1	Reject
14	I face few challenges in accessing veterinary services	35	50	85	80	2.1	Reject
15	Transportation of dairy products to market is convenient	25	55	90	80	2.06	Reject
16	I have sufficient financial management skills for dairy farming	40	65	85	60	2.31	Reject

Source: Field survey (2024)

4.4 Constraints to women participation in dairy value chain:

The results presented in Table 4 illustrate the significant constraints faced by women in their participation in the dairy value chain. These findings shed light on the multifaceted challenges that hinder women's full engagement and potential in this sector. Limited access to credit emerged as the most prevalent constraint, with 75.2% of respondents identifying it as a major obstacle. This aligns with recent studies that highlight the persistent gender gap in access to financial services in agricultural settings (Smith *et al.*, 2023). The lack of collateral, limited financial literacy, and gender biases in lending practices often contribute to this disparity, severely limiting women's ability to invest in their dairy enterprises or expand their operations.

The second most reported constraint was the lack of technical knowledge, cited by 66% of the respondents. This finding underscores the gender disparities in access to agricultural education and extension services, a trend consistent with observations by Johnson and Lee (2022) across various agricultural subsectors. Limited technical knowledge can significantly impair women's productivity, efficiency, and ability to adopt new technologies in dairy farming.

Time constraints due to household responsibilities were identified by 60.8% of the respondents as a major barrier. This reflects the double burden faced by many women in rural areas, who must balance productive activities with reproductive and community roles (Garcia and Mahmood, 2024). The disproportionate allocation of domestic duties to women often leaves them with less time to engage in dairy-related activities or to pursue opportunities for skill development and market participation.

Limited access to markets was reported by 50.8% of the respondents. This constraint can be attributed to various factors, including restricted mobility, lack of transportation, and limited market information. Research by Thompson *et al.* (2023) has shown that such market access limitations can significantly reduce women's bargaining power and ability to capture value in agricultural value chains.

Cultural barriers and gender norms were identified as constraints by 45.2% of the respondents. This finding aligns with broader observations on the role of sociocultural factors in shaping women's participation in agricultural value chains (Patel and Nguyen, 2024). These norms can manifest in various ways, from restricting women's mobility to limiting their involvement in decision-making processes within the dairy sector. The lack of ownership of productive assets was cited by 38% of the respondents. This constraint is particularly significant in the context of dairy farming, where ownership of cattle and land is often crucial for participation and success. The gender asset gap in agriculture has been well-documented, with women consistently owning fewer and less valuable assets than men (Robinson and Ahmed, 2023; (Sennuga *et al.*, 2024b). Limited decision-making power was reported by 32.8% of the respondents. This constraint is closely linked to broader gender inequalities and can significantly impact women's ability to make strategic choices about their involvement in the dairy value chain. Research by Kumar and Wilson (2024) has demonstrated that enhancing women's decision-making power can lead to improved outcomes in agricultural productivity and household welfare.

TABLE 4
CONSTRAINTS TO WOMEN PARTICIPATION IN DAIRY VALUE CHAIN

Constraints	Frequency	Percentage
Limited access to credit	188	75.20%
Lack of technical knowledge	165	66.00%
Time constraints due to household responsibilities	152	60.80%
Limited access to markets	127	50.80%
Cultural barriers and gender norms	113	45.20%
Lack of ownership of productive assets	95	38.00%
Limited decision-making power	82	32.80%

Source: Field survey, 2024
Note: Multiple Response Allowed*

V. CONCLUSION AND RECOMMENDATIONS

This article provides a comprehensive analysis of the factors influencing rural women’s participation in the dairy value chain, focusing on socio-economic characteristics, determinants of participation, women’s perceptions of their involvement, and the constraints they face. The study reveals a complex interplay of factors that both enable and hinder women’s active engagement in dairy farming, with significant implications for their economic empowerment and overall well-being.

The socio-economic characteristics of the respondents showed clear distinctions between participants and non-participants in the dairy value chain. The respondents' socioeconomic characteristics demonstrated that the mean ages of participants and non-participants in the dairy value chain were 39.2 and 42.1 years, respectively. Participants generally had higher levels of education, with 40% having completed primary education compared to 50% of non-participants, and they also managed larger farms, with an average farm size of 2.3 hectares versus 1.2 hectares for non-participants. Additionally, participants were more likely to be members of agricultural cooperatives (60%) compared to non-participants (25%). These figures suggest that women who are better educated, possess larger landholdings, and have cooperative support are more likely to participate actively in dairy farming. On the other hand, non-participants tended to have smaller household sizes and lower levels of contact with extension agents, which may have limited their ability to engage in the dairy value chain.

The examination of socio-economic determinants through the Logit regression model identified several significant factors influencing women's participation in the dairy value chain. Marital status, educational level, farm size, cooperative membership, access to credit and contact with extension agents were all statistically significant determinants. Specifically, educational level (coefficient = 0.20, p = 0.04), farm size (coefficient = 0.33, p = 0.02), and cooperative membership (coefficient = 0.64, p = 0.002) were significant at the 5% level, while contact with extension agents (coefficient = 0.71, p = 0.004) was significant at the 1% level, whereas, marital status (coefficient = 0.17, p = 0.06) and access to credit (coefficient = 0.26, p = 0.06) were significant at 10% level.

In terms of perceptions, women generally held positive views regarding their participation in the dairy value chain. Most perception statements received mean scores of 2.5 or above, indicating a favourable outlook on their involvement. For instance, the perception that dairy farming has improved their income had a mean score of 3.00, and the belief that participation had enhanced their skills scored 3.08. These positive perceptions suggest that women feel empowered and see tangible benefits from their involvement in dairy farming. However, there were also negative perceptions identified, with lower mean scores in areas such as workload management (mean score of 2.38) and income sufficiency (mean score of 2.25). These findings underscore the dual nature of women's experiences in dairy farming, where empowerment and economic benefits are tempered by practical challenges related to workload, income, and infrastructure.

The study also identified several key constraints to women's participation in the dairy value chain. The most significant constraints were limited access to credit (reported by 75.2% of respondents), lack of technical knowledge (66.0%), time constraints due to household responsibilities (60.8%) and limited access to markets (50.8%). Other notable barriers included cultural barriers and gender norms (45.2%), lack of ownership of productive assets (38.0%), and limited decision-making power (32.8%). These constraints highlight systemic issues that limit women's ability to fully benefit from their participation in the dairy value chain. Addressing these barriers is essential for enhancing women's involvement and ensuring that they can maximize the economic and social benefits of their work in dairy farming. Based on the findings of this study, the following recommendations have been put forward:

i. Financial institutions and government programs should develop tailored credit facilities that address the specific needs of rural women in the dairy value chain. This could include offering low-interest loans, flexible repayment schedules, and providing financial literacy training to help women better manage their finances. Additionally, microfinance institutions could collaborate with cooperatives to ensure that women have access to group loans, which often come with lower collateral requirements and better terms.

ii. To overcome market access difficulties, women should be supported in forming or joining cooperatives that can collectively negotiate better prices and terms with buyers. Establishing market information systems that provide real-time data on prices and demand can help women make informed decisions about when and where to sell their products. Additionally, creating direct links between producers and retailers or consumers through farmers' markets or online platforms can reduce reliance on middlemen and increase profits.

iii. Continuous training and capacity-building programs are necessary to equip women with the skills required for successful dairy farming. Extension services should be expanded and tailored to address the specific challenges faced by women, such as low literacy levels and limited mobility. These services should also focus on business management, financial literacy, and the use of new technologies to improve productivity. Training sessions could be organized in collaboration with local cooperatives to ensure maximum participation.

iv. Programs aimed at changing societal attitudes towards women's roles in agriculture are essential for breaking down cultural barriers. These could include awareness campaigns and educational programs that promote gender equality

and highlight the economic benefits of women's participation in the dairy value chain. Engaging community leaders and male family members in these initiatives is crucial for fostering a supportive environment for women.

v. Support mechanisms that help women balance their farming and household responsibilities are essential. This could involve the introduction of community-based childcare services, promoting the use of time-saving technologies, and encouraging a more equitable division of labor within households. Educational programs aimed at raising awareness about the importance of shared household responsibilities could also be beneficial.

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Alleviating Poverty and Hunger through Irrigation Schemes in Nigeria: A Study Case of Lower Anambra River Basin Authority in Omor Anambra State

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Abstract— *Agricultural production in Nigeria is mainly carried out by subsistence farmers who depend heavily on rain-fed agriculture and use of rudimentary traditional methods for their production. But despite abundant water resources and rainfall in addition to wide diversity of ecological conditions with which Nigeria is blessed, the amount and timing of the rains are not adequate to meet the water requirement of the crops. This has led to low agricultural yields resulting to low income earning among farmers, diseases, hunger and malnutrition. Therefore, in order to meet national target on poverty reduction, and food security, the Federal Government of Nigeria embarked on establishment of irrigation facilities to make water available for agricultural production all the year round. One of such irrigation projects is the Lower Anambra-Imo River Basin Irrigation Project at Omor, in Ayamelum Local Government Area of Anambra State, Nigeria. This study was undertaken to investigate the contributions of Lower Anambra-Imo River Basin Irrigation Project in Omor, Anambra State, Nigeria; towards alleviating poverty and eradication of hunger and malnutrition. Primary data for this study was collected from 200 farmers who were randomly selected and given structured questionnaire designed to seek information in such areas as age, literacy level, and number of farm holdings, efficiency of irrigation water supply, and other challenges encountered by the farmers. The study revealed general switch from low-value subsistence farming to high-level market–oriented production resulting in increase in farmers' production, increased income, and provision of basic infrastructure such as roads, hospitals, schools in the area.*

Keywords— Irrigation; Rain-fed; Alleviation of Poverty and Hunger; Food Security and River Basin.

I. INTRODUCTION

Nigeria has a total area of is 923,768km^2 with a population of about 219,949,958 and estimated growth rate of about 2.4% per annum (NPC, 2017). According to World Bank, (2021) about 100 million of Nigerian population live in rural areas with average annual population growth of about 1.54%. The country has fertile soils and climate suitable for production of variety of crops that can provide enough food and raw materials for the industries that will alleviate hunger and poverty (FAO, 2012). Nigeria is also blessed with abundant water resources which include about 267 billion cubic metres of underground water, many rivers and streams, lakes and abundant rainfall in the southern part of the country; however, the amount and timing of rain falls are not adequate to meet the water requirement of crops (Ahameku, 2010; Umeghalu, *et al*., 2013). The country is well drained with a close network of rivers and streams (Iloeje, 1980; Ladokun, *et al.*, 2013). Figure 1, showing some major rivers and streams in Nigeria (FAO, 2015).

1.1 Nigeria's Surface River Basins:

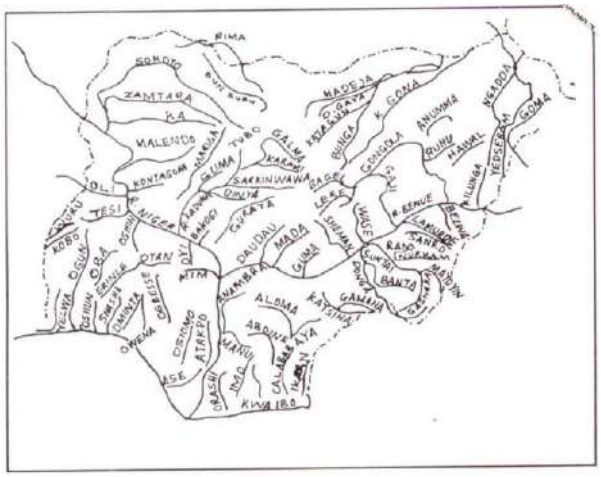

FIGURE 1: Map of Nigeria showing some major rivers. (Source: FAO, 2015)

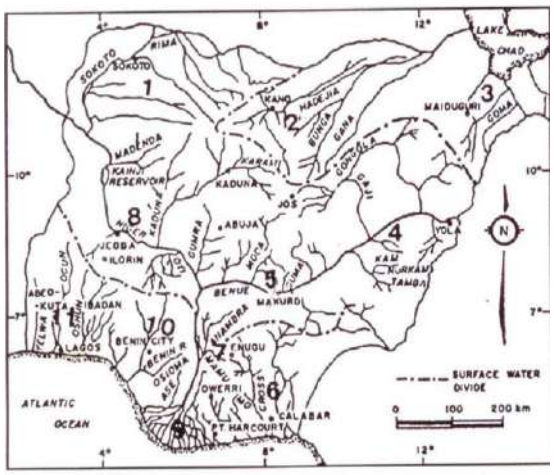

FIGURE 2: Nigerian's surface River Basins. (Source: FAO, 2012)

Nigeria is blessed with many rivers and streams. Among these numerous rivers and streams, are four principal surface water basins namely; the River Niger, the Lake Chad, the West Coast and the West Central also known as South-eastern Littoral Basin (Oshodi, 2006). These surface water basins are further subdivided into twelve river basins; the Benue, Delta and Cross River, the Imo – Anambra, Hadejia- Jam'are, Chad, Sokoto-Rima, Lower Niger, Upper Niger, Benin-Owena and Ogun-Osun River Basins.

Studies by Mahmood (1994) observed that over US$3billion had been invested on the construction of these irrigation and drainage projects that constitute over 300 dams and reservoirs. Figure 2, above shows river system in Nigeria and their organization into River Basins (FAO, 2016). The country is also endowed with over 79 million hectares of arable land of which only about 3.14 million hectares have potential to be irrigated (Okigbo, 1986; Eni, 2008).

1.2 Status of agriculture in Nigeria and pressure of increasing population:

Agricultural sector holds second position after oil and gas as the key to the development of the socio-economic and political life of Nigeria, contributing over 60% of her Gross Domestic Product (GDP), and employs over 70% of the country's economic active population. Regardless that more than half of the active population of the country are occupied in the agricultural sector, the sector could not produce enough food for the populace and raw materials to feed the industries. This is attributable to heavy reliance on rain fed agriculture, use of rudimentary traditional methods and techniques, shifting cultivation farming systems and subsistence farming which have led to low agricultural yields (World Bank, 2008; Ahameku, 2010; Umeghalu, *et al.*, 2013; Odigbo, 2016).

The pressure of population explosion and low agricultural yields has resulted to poverty and food insecurity in the country (Umeghalu *et al.*, 2013). Poverty is defined as a condition of lacking money and the necessities, such as food, water, education, healthcare, shelter and clothing needed to successfully live, which is often measured in terms of daily income of US$1.25 and US$2.0 (Akande, 2006; Ravallion, 1992). Thus, poverty is one of the global phenomena that have left the level of food insecurity in developing countries at alarming proportions. Poverty situation tends to worsen in reaches of a system where surface water availability is low, groundwater quality is poor, agricultural productivity is low and opportunities in the nonfarm sector are limited. Olatide*et al*. (1980) posited that, poverty remains a persistent feature of many developing countries, despite over a century of debate and action and over forty years of international aid to transform the livelihoods of the poor. The causes of poverty are complex and context-specific, but in general poverty tends to be linked with factors such as poor national economic performance, unequal distribution of income and political structures that render poor people powerless (Cohen and Reaves, 1995). According to World Bank (2000), Sub-Saharan Africa had an estimated poverty headcount of 47% in 1990 and 46.7% in 1998. United Nations (2015) also reported that overwhelmingly, the majority of people living on less than $1.25 a day reside in two regions of the World: Southern Asia and sub-Saharan Africa and they account for about 80% of global total extremely poor people. Furthermore, nearly 60% of the World's 1 billion extremely poor people live in just five countries: India, Nigeria, China, Bangladesh and Democratic Republic of Congo (UN, 2015). But in contrast, those regions such as the

Middle East, East Asia, who have the greatest proportion of cultivated land, have experienced the greatest poverty reduction, compliment to exploitation of irrigation (Lipton and Litchfield, 2002). Improvements in crop yield have been made possible by the development of hybrid and improved seed varieties used in combination with good water control and fertilizer application. It is important to note that one of the infrastructures which irrigation provides is access road. Bacha *et al.* (2011) noted in his studies, that farmers could easily access irrigation facilities, improve farm productivity and subsequently increase their household consumption.

1.3 Effect of Irrigation on agricultural production:

Irrigation has been regarded as a powerful factor in increasing crop productivity, enhancing food security, expanding opportunities for higher and more stable incomes and employment and for increasing prospects for multiple cropping and crop diversification. The role of irrigation in poverty alleviation has been focus of many international communities and groups in recent years. This is because many reviews have found strong direct and indirect relationships between irrigation and poverty (Hussain and Hanjra, 2004). Irrigation makes higher crop yield possible, less reliance on rain fed agriculture, and encourages agricultural production more than once in a year by providing water which is an integral element to food production. According to Bhattarai *et al*, (2002), irrigated agriculture significantly contributes towards generating rural employment and maintaining rural livelihoods. Furthermore, Unver *et al*, 2018) noted that irrigation enables smallholders to adopt more diversified cropping patterns and to switch from low value subsistence production to high value market oriented production. Food is available and affordable when agricultural production is increased.

In an effort to meet national target on poverty reduction, and food insecurity, the Federal Government of Nigeria realized the need to achieve a strategic balance through irrigation than the rain fed agricultural production that accounts for the bulk on Nigeria's agricultural production at lower cost per hectare but is more vulnerable to draught, floods and other impacts of climate change (Umeghalu and Okonkwo, 2012; Enete, 2014; FAO, 2015). It is imperative that to realize the country's agricultural potentials where agricultural production are based on rain fed cultivation, there is need to improve on methods of sourcing sufficient water for agricultural production to compliment whatever water that is naturally available. Expanding small-scale irrigation is one of the necessary steps or method in a larger movement towards more sustainable and equitable agricultural growth which will break the annual cycle of uncertainty and stagnation in securing local food systems and stable economic growth (FAO. 2013b; Liangzhi *et al.,* 2015). Therefore, it becomes pertinent to formulate policies and programmes that will solve the problem of insufficient water for agricultural production. In achieving this, the Federal Government of Nigeria therefore established the National Irrigation and Drainage Policy aimed to achieve sustainable growth and to enhance performance of irrigation, contributing fully to the goals of the Nigerian agricultural sector (FAO, 2015). Various water management projects which include construction of irrigation systems such as river basins, flood, sprinkler and surface water irrigation schemes were established. Thus, a well-developed irrigation system which would provide the boost that is required to make the leap from rain fed to grower led agricultural production in Nigeria (FOA, 2015).

World Bank (2008) noted that the high incidence of poverty in most developing world is attributable to heavy reliance on rain-fed agriculture, subsistence farming and exclusion from trade. However, irrigation brings a range of potential changes in agricultural production and even assures cropping and more secure food supply for basic needs which is often the priority of smallholder subsistence producers. Studies by Hussein et al., (2001), show that comparing agricultural production under rain-fed and irrigation setting, it was observed that poverty was much higher in settings without irrigation; and further shows that poverty incidence varies from 16% to 58% in irrigated settings and between 23% and 77% in rain-fed setting which shows that irrigation has significant impact on poverty. Irrigation encourages agricultural diversification as it makes growing variety of crops all the year round possible such as vegetables, okra and other products of market gardening. This reduces the likelihood of non-poor household becoming poor and poor households remaining poor (Michler and Josephson, 2017).

Northern part of Nigeria experiences lower rainfall with prolonged dry season. Shifting cultivation system of agriculture is predominant and crops cultivated in the region are rice, groundnuts, millet, sorghum, yam, cassava and maize. The southern part experiences average annual rainfall of between 2,000mm and 4,000mm, with shorter dry season is more suitable for cultivation of rice, root crops and maize. Tree crops such as cocoa, oil palm tree are also grown in this part of Nigeria. But regardless the heavy rainfalls in the southern part of the country, its unreliability in terms of onset, duration, intensity and amount for agricultural production calls for irrigation infrastructure to boost agricultural production, by minimizing the risks associated with rainfall unreliability (Onwualu, 2005; Abubakar, 2010; Faborode, 2001; Umeghalu, 2019).Irrigation can change the cropping timetable to take advantage of good weather conditions or avoid periods with hazards like heavy rainfall

or draught. FAO, (1999) reported that irrigation provides about 40% of World's food production on only 17% of total cultivated land.

1.4 Establishment of irrigation system in Nigeria:

In 2021, the Federal Government of Nigeria through the Federal Ministry of Water Resources reported that it has completed 10 more dams and 4 irrigation projects across 10 states in the country while six irrigation projects are on-going in 5 states meant to boost agricultural production and support the nation's quest for food insecurity by reducing farmers' dependency on rain-fed agricultural practices.

II. MATERIALS AND METHODS

2.1 The study area:

Omor is one of the communities in Ayamelum Local Government Area of Anambra State, Nigeria; and is located within Latitude 6º30"42.1884"N and Longitude 6º57'40.2372"E. The climate of Omor is typical equatorial and is influenced by two air masses namely: the North East Trade Winds which brings harmattan to the area, and the South West Monsoon Winds which brings rainfall to the area. The harmattan wind is felt between the months of November and March. During this period of harmattan, temperature of the area ranges between 40^0C in the day and 18^0C in the night. The area experiences the influence of South East monsoon winds between April and September and sometimes to October is responsible for precipitation averaging about 1000mm per annum (Iloeje, 1980). Although Omor is located within the Tropical Rain Forest Belt, however, anthropogenous activities through bush clearing for agricultural purposes, regular bush burning for games and overgrazing have contributed sufficiently to turn Omor's vegetation to Derived Savannah.

According to NPC (2017 and 2019), the population of Omor is put at 223,641 and 233,763 respectively. The climate and vegetation of the area provide suitable environment for production of variety of crops especially rice, cassava, yam, maize, potatoes and okra. Agriculture is the major occupation in Omor, engaging over 90 percent of her population. In Anambra State, Ayamelum Local Government Area is the major rice producer among the 21 local government areas that constitute Anambra State. Among these eight communities in that local government area, Omor is the largest rice producer being the largest producer of rice in Anambra State (Nwalieji, 2020).

In Omor, rice is cropped under upland, swamp and rain-fed lowland, and is dominated by small holder farmers who cultivate average of between one and two hectares of land. The cultivable land area of rice production in Omor is estimated to be about 8,500 hectares comprising the Lower Anambra Irrigation Project (LAIP), which covers about 5,000 hectares with net irrigable land area of 3,850 hectares and 1,150 hectares of non-irrigable/undeveloped areas (Nwalieji, 2020).

The Federal Government of Nigeria commenced the development of the Lower Anambra Irrigation Project at Omor in 1978 and completed the project in 1981 with the following major objectives:

a) To increase rice yield;

b) To double rice cropping in a year through irrigation;

c) To educate farmers modern techniques in rice production;

d) To eradicate hunger, poverty, disease and improve the standard of living of the communities within the project area;

e) To improve infrastructure within the project area and environment.

2.2 Data collection:

Primary data for this study was collected through field survey, scheduled-structured questionnaire prepared to collect information from farmers and the staff of the Lower Anambra Irrigation Project. The questionnaire was designed to seek information in following areas: age of participating farmers, literacy level, number of farm holdings for five consecutive cropping seasons, efficiency in supply of irrigation water, and challenges encountered by farmers. A total of 200 participating farmers were randomly selected for the study. Secondary data were obtained from the records of the Lower Anambra Irrigation Project, newspapers and collation of information from online publications.

III. RESULT AND DISCUSSIONS

3.1 Gender Distribution:

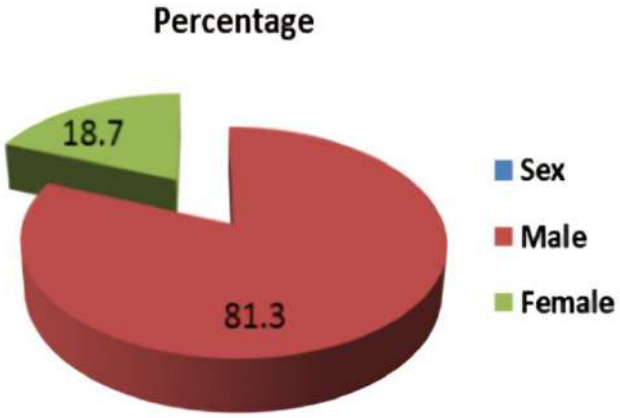

FIGURE 3: Graph showing percentage of gender distribution.

Data obtained shows that about 81.3% of the farmers are male while 18.7% are female as depicted in Fig. 3. This may be attributed to the fact that rice cropping is capital intensive. However, it was observed that women mainly engaged in provision of labour in areas of transplanting rice seedlings, fertilizer application, weeding, harvesting, threshing and winnowing of the paddy rice.

3.2 Supply of irrigation water to farmers:

TABLE 1
EFFICIENCY IN IRRIGATION WATER SUPPLY

S/N	Level of efficiency in water supply	Percentage of farmers
1.	Efficient water supply.	94
2.	Inefficient water supply.	6
	Total	100

About 94% of farmers interviewed responded affirmatively to efficient irrigation water supply to their paddy fields while 6% of the farmers complained that supply of irrigation water to their paddy field is not efficient as represented in Table 1. This may be attributed to long distance between their paddy fields to the source of irrigation water supply. Also, inadequate maintenance of the irrigation facilities may impede normal flow of irrigation water to some paddy plots. This often led to scramble for water especially during the dry season cropping. Inadequate supply of water especially during the dry season cropping may results to crop failure.

3.3 Education status of the farmers:

Fig. 4 below shows that, about 41.7% of the farmers obtained formal education;18.8% of the farmers have secondary school education; about 33.3% of the farmers are without formal education, while the remaining 6.2% of the farmers attained tertiary education. This shows that majority of the farmers acquired some level of education that can enhance their taking informed decisions on best farming techniques for their agricultural production. Although the number of farmers without formal education is high, they can improve their farming techniques from other educated farmers in the field.

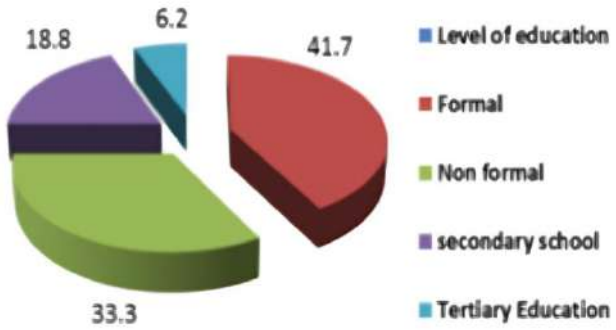

FIGURE 4: Literacy level of the farmers.

3.4 Trend of farmers' farm holdings for five consecutive cropping seasons:

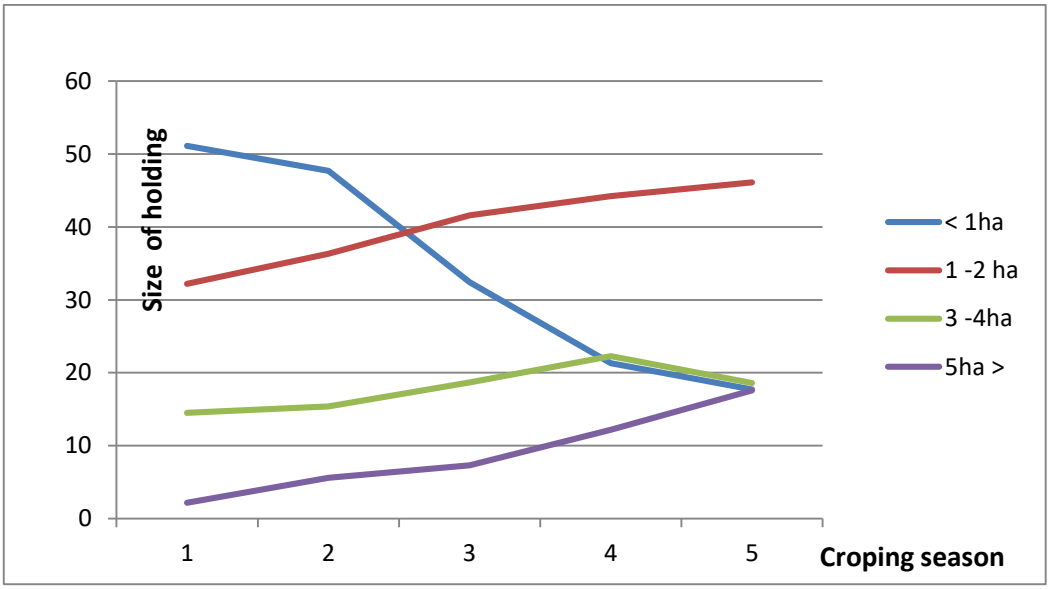

FIGURE 5: Trend of the farmers' farm holdings for five consecutive cropping seasons.

Figure 5, represents the trend of increase in number of farm holdings by the farmers for five consecutive cropping seasons. It is shown that about 51.1% of the farmers commenced cropping with farm holdings less than 1 ha in the first cropping season. This number started declining progressively to 42.7%, 32.4%, 24.3% and 12.7% respectively from the second cropping season and subsequent seasons. Also it is observed that about 32.2% of the farmers that commenced cropping with between 1 and 2 hectares in the first cropping season increased their holding to 36.3% during the second cropping season and progressively to 41.6%, 44.2% and 46.1% respectively during the subsequent cropping seasons. While about 14.5% of farmers that started cropping between 3 and 4 hectares in the first cropping season also increased their holding to about 15.4% during the second cropping season and progressively increased to about 17.7%, 19.3% and 21.6% respectively in subsequent cropping seasons. It is found out too that in the first cropping season, about 2.2% of the farmers that commenced cropping with about 5 hectares also increased their holdings to about 5.6% in the second cropping season, and progressively increased to 8.3%, 12.2% and 19.6% respectively during subsequent cropping seasons.

IV. CONCLUSION

Observation from the study shows that there is significant increases in the number of farm holdings across board especially farmers with holdings less than one hectare and two hectares during the first cropping season. These increases in number of farm holdings indicate rise in farmers' revenue within the period under review which also translates to switching from low-value subsistence production to high-level market oriented production. Thus, rise in revenue also will translate to the following:

1) Rapid reduction in level of poverty and accelerated improvement in the standard of living of the farmers.
2) Increase in both holding and labour productivity.
3) Maintenance of food self-sufficiency and food security.

Challenges facing Lower Anambra irrigation Authority.

1) During the course of this study, it was found out that the distance between River Anambra from where the irrigation water is sourced to the paddy field in Omor community is several kilometres away. This causes enormous quantity of water loss in saturating the earthen canal through which water is conveyed to the paddy field. Thus, the cost of diesel for fueling the pumps that draw water from River Anambra into the canal before it flows gravitationally to the paddy fields is high, thus, exerting enormous financial pressure on the finance of the River Basin Authority. This often result to scarcity of water during the growing stage of the crops. Moisture stress affects overall paddy yield especially during the dry season cropping; and to avoid this situation, farmers resort to scrambling for water.

2) Inadequate maintenance of the authority's agricultural machines and equipment leading to their unavailability during the cropping season and delays in agricultural operations such land preparation, harvesting and threshing operations.

3) Corruption among the civil servants who engage in illegal land allocation to their cronies and often denying some genuine farmers the chance to participate. These practices led to the collapse of the irrigation and its eventual closure.

4) High cost of maintaining the irrigation canal conveying water to the paddy field has forced the River Basin Authority to scrap dry season cropping. This has resulted to drop in the farmers' annual revenue earning as the since they now crop only during the rains.

V. RECOMMENDATIONS

Food security cannot be attained by depending on rainfall for food production because of its timing. To achieve this government has pivotal role to play. The present status of agricultural practices whereby primitive methods are still at play should give way to exploitation of appropriate mechanization technologies. Thus government at all levels should assist farmers with the following:

1) Irrigation project is capital intensive and government has invested huge capital in establishing them in the country. There is therefore need to improve on supervisory roles over the investment especially on management of the established irrigation facilities.

2) Regular meetings and workshops should be organized between the management of the authority and participating farmers where problems confronting part shall be looked into and resolved for smooth running of the scheme.

3) Extension Workers should be employed to train and educate farmers on new farming techniques of using irrigation facilities especially their maintenance culture.

4) Farmers should be made or encourage to form co-operative societies to enable them secure loans and other incentives from government which will assist them to increase their holdings for increased production. This will enhance the chances of government to subsidize costs of farm inputs such as fertilizer, herbicides, pesticide etc.

5) there is need for re- establishment of tractor hiring scheme – This will increase farmers farm holding; timeliness of agricultural activities which will result to increased production of agricultural products for human and animal consumption as well making available sufficient raw materials for industries.

6) Holistic solution should be found thereby water from the Ezu River which flows nearby to gravitationally be supplying the paddy fields with water. This will save huge sum of money that would have order wise be spent on sourcing water from the far distant River Anambra.

7) Governments should ensure less involvement of politicians in the running of agricultural projects. Experiences have shown that facilities and inputs provided by government which are meant for farmers at subsidized rates do not reach the farmers. The facilities are diverted to their friends and cronies who often are not genuine farmers. The facilities are then resold to the farmers at exorbitant prices that are out of their reach. Secondly, experience has shown that politicians are fond of dumping programmes initiated by their predecessors resulting to policy inconsistences in agricultural programmes.

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Effect of Insecticides on Development and Adult Survival of *Trichogramma chilonis* (Trichogrammatidae: Hymenoptera)

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Abstract— *The effect of insecticides on development and adult survival of Trichogramma chilonis was investigated under laboratory condition. Insecticides tested were endosulfan, coragen, monocrotophos and deltamethrin+triazophos on following concentration i.e. 0.009%, 0.010%, 0.020%, 0.022% and 0.024%. Treating eggs with all the concentration of chemical insecticides caused death of the emerged adults within few hours post emergence when the treatment was carried out 4 days post parasitism or one day before adult emergence. The number of host eggs turned to black (the parasitoid larvae developed to pupae) varied according to timing of treatment. Adult emergence rate varied according to the used insecticide, the parasitoid stage and the generation. All the concentration of insecticides, with the exception of endosulfan and some cases coragen, adversely affected T. chilonis emergence from Corcyra cephalonica host eggs when exposed at 1st, 2nd, 3rd, 5th and 6th day of developmental stages (larval and pupal) of T. chilonis. Regardless of the developmental stage treated, none of the insecticides tested had a significant effect on the emergence and survival of T. chilonis male and a female significantly varied among insecticide treatments, and were significantly affected by the developmental stage of parasitoid when treated. Based on toxicity, deltamethrin+triazophos was the most toxic followed by monocrotophos, which was comparatively less toxic compounds to adult male and female T. chilonis. No parasitoids emerged from parasitized eggs treated with deltamethrin+triazophos in second generation.*

Keywords— Insecticides, Effect, Development, Survival, Trichogramma.

I. INTRODUCTION

Recently, integrated pest management strategy has recommended, minimizing the use of chemical pesticides. It is very important to study the side effect of insecticides on the natural enemies to exclude the ones that have detrimental effect on such natural enemies. *Trichogramma* spp. has been extensively used as biological control agent. During the past two decades, *Trichogramma* spp. wasps have been evaluated as biological control agents for pest suppression in different crops.

Numerous laboratory and field studies have shown that *Trichogramma* spp. wasps are highly susceptible to most broad-spectrum insecticides (Bull and Coleman 1985). Consequently, use of insecticides and *Trichogramma* spp. has historically been considered incompatible. In an attempt to combat insecticide resistance, conserve arthropod natural enemies, and reduce health risks, several new insecticides (e.g., tebufenozide, methoxyfenozide, spinosad) have been developed and tested against *T. exiguum* (Duttle *et al*. 1997, Harrison *et al*. 1997). Studies were conducted to assess the effects of selected insecticides on *T. chilonis* preimaginal development in Biocontrol laboratory S.V.P. Uni. of Agric. & Tech., Meerut,

II. MATERIALS AND METHODS

Fresh *Corcyra cephalonica* eggs (less than 24 h. old) were glued onto Trichocards, each contained nearly 300 eggs. These cards were placed in glass tubes. Newly emerged *T. chilonis* adults were transferred to the glass tubes containing *Corcyra* egg-cards and kept for 24 hrs. The exposed eggs were divided into five groups; the 1st group was treated with the tested insecticides 1st day after parasitism, 2nd group was treated 48 h after parasitism, 3rd group was treated 3rd day after parasitism, 4th group

was treated 5th days after parasitism, while 5th group was treated 6 days after parasitism (one day before adult emergence), while the 6th group was treated with water after parasitism to serve as a control**.**

The insecticides treated eggs were dried on paper-sheets for 15 minutes. All the five groups of insecticides treated eggs of *T. chilonis* were kept in glass tubes and checked daily for emergence of the adult parasitoids. Droplets of honey were scattered on the inner surface of the tube's walls as food for the adult parasitoid.

$$Percent\ of\ emergence = \frac{No.\ of\ wasp\ emerged}{Total\ No.\ of\ eggs\ in\ one\ cm2} \times\ 100 \quad (1)$$

Observations were made on the percent parasitization the fresh eggs were provided to these parasitoid @ 6:1 ratio and the number of parasitized eggs were recorded after 24, 48 and 72 hours. The percent parasitization was worked out by the following formula

$$Parasitization\ percent\ = \frac{No.\ of\ parasitized\ eggs}{Total\ No.\ of\ Corcyra\ eggs} \times\ 100 \quad (2)$$

Observations were made on the mortality was parasitoid wasp at Ist, 2nd, 3rd, 5th and 6th day after application of different concentration of insecticides. The percent mortality was worked out by the following formula

$$Mortality\ Percent\ = \frac{Total\ No.\ of\ adults\ dead}{Total\ No.\ of\ wasps} \times\ 100 \quad (3)$$

2.1 Biological aspects of the emerged parasitoids:

The following biological aspects were studied for the parasitoids emerged from treated parasitized eggs: average number of black eggs (containing parasitoids' pupae), emergence rate, longevity of adults, and female percentage. Each group was tested for the ability of emerged females to parasitize new untreated host eggs, (second generation (2nd G), and the previous biological aspects were determined for the second generation (if any).

2.2 Statistical analysis:

The experiment was conducted in a completely randomized design with six treatments five insecticides and a control (3 replicates for each treatment and 100 eggs for each replicate). Statistical analysis was achieved using the SPSS Software.

III. RESULTS AND DISCUSSION

3.1 Endosulfan 35% EC:

Different concentration i.e. 0.009, 0.010, 0.020, 0.022 and 0.024% of endosulfan was found to have considerable detrimental effect on the development of parasitoid inside the treated host eggs. The recorded values for the number of black eggs were (75.67, 78.33, 71.33, 75.0 and 74.33 for the first generation and 45.67, 38.33, 33.0, 32.33 and 29.67 for 2nd generation, compared to 76.33 for the control) at 1 day after parasitization for the eggs treated at 1, 2, 3, 5 and 6 days post parasitization, respectively. The respective values of the emergence rate for second generation decreased compared to 1st generation and the control, the recorded values were 58, 59.33, 60.0%, 61.0 and 62.67% on 1, 2, 3, 5 and 6 days post parasitization at 0.009% concentration compared to 75.33, 79.0, 77.33 and 78.67% for the control. As for comparing different concentration of insecticides with each other there were non-significant differences for the numbers of black eggs but significant differences between each other for emergence rates in first generation but in 2nd generation it was different (Table 1).

3.2 Monocrotophos 36 SL:

The number of black eggs of *T. chilonis* was slightly affected, but the emergence rate highly decreased compared to control. The recorded values on the emergence (31% and 23%) rate were for those treated one and two days post parasitism, while the emergence was recorded for those treated 3 and 5 days post parasitism compared to (78-85%) for the control. As for the second generation, the emergence rates were 39% and 40% when the treatment was one and two days post parasitism. It was noticed that in all the concentrations after 5th and 6th days of parasitization, number of adult emergence were maximum. As for the second generation, the emergence rates were only 30% and 31% when treatment was one and two days post parasitism at 0.009%, while at 0.024% conc. there was only 16-18% emergence recorded at 1st and 2nd day of parasitism (Table: 1). As for comparing different concentration of insecticides with each other there were non-significant differences for the numbers of black eggs but significant differences between each other for emergence rates in first generation, while in 2nd generation it was different (Table 1). At 1st, 2nd and 3rd day after parasitization of eggs there was found maximum deformities in second generation adults of *T. chilonis*, while at 5th and 6th day parasitized eggs had least. The maximum mortalities and deformities of adults were found highly concentrated doses of insecticides compared to the low concentrated.

TABLE: 1 (a)

NUMBER OF BLACK EGGS AND EMERGENCE RATE OF THE EGG PARASITOID *T. CHILONIS* TREATED WITH INSECTICIDES

Insecticides and Conc. (%)	Time of treatments after parasitism (days)											
	1st				2nd				3rd			
	No of black eggs		% Emergence		No of black eggs		% Emergence		No of black eggs		% Emergence	
	I st G	2nd G	I st G	2nd G	I st G	2nd G	I st G	2nd G	I st G	2nd G	I st G	2nd G
Endosulfan 35%EC												
0.009	75.67	45.67	58.00	33.33	70.00	50.33	59.33	36.00	69.67	51.33	60.00	39.67
0.010	78.33	38.33	51.33	31.00	69.33	44.33	56.00	33.33	72.67	47.67	52.33	37.00
0.020	71.33	33.00	45.33	29.33	80.67	37.67	47.33	30.33	83.00	43.00	47.33	33.33
0.022	75.00	32.33	38.67	25.00	68.67	34.00	40.33	27.33	80.67	36.33	41.00	32.00
0.024	74.33	29.67	32.67	19.33	71.67	30.00	35.67	21.33	72.00	32.67	37.00	27.33
Monocrotophos 36%SL												
0.009	79.33	38.67	49.67	30.00	74.33	39.67	50.00	31.67	79.33	44.00	52.00	39.33
0.010	69.67	36.67	46.67	25.00	69.67	37.33	48.33	29.00	75.00	39.33	48.33	36.00
0.020	72.67	34.33	40.67	19.00	71.00	34.00	42.33	24.33	82.33	36.67	42.33	33.00
0.022	73.33	29.67	33.33	18.33	76.33	30.33	40.00	20.00	77.00	39.00	40.00	29.67
0.024	73.33	27.33	26.33	16.67	76.33	28.67	33.67	18.00	72.00	29.33	33.67	26.67
Coragen												
0.009	80.33	39.00	52.33	33.00	77.33	40.00	58.00	31.00	78.67	52.33	55.67	41.00
0.010	72.67	35.33	47.33	31.00	75.33	37.00	53.00	32.33	78.33	48.33	52.67	34.33
0.020	81.00	33.33	40.67	26.00	76.00	32.33	46.00	31.00	75.33	41.00	46.33	31.33
0.022	71.67	31.33	36.33	18.67	74.67	30.33	39.33	28.33	74.00	35.33	39.67	27.67
0.024	77.00	27.00	33.33	18.00	80.67	24.33	33.33	25.00	73.67	30.33	33.67	23.33
Deltamethrin 1%+ Triazophos 35%EC												
0.009	70.00	0.00	4.00	0.00	76.67	0.00	2.00	0.00	73.33	0.00	2.00	0.00
0.010	74.67	0.00	1.00	0.00	76.00	0.00	0.67	0.00	75.67	0.00	1.00	0.00
0.020	73.67	0.00	0.00	0.00	76.00	0.00	0.00	0.00	66.67	0.00	0.00	0.00
0.022	70.00	0.00	0.00	0.00	78.67	0.00	0.00	0.00	71.00	0.00	0.00	0.00
0.024	68.00	0.00	0.00	0.00	72.67	0.00	0.00	0.00	74.67	0.00	0.00	0.00
Control												
Water spray	76.33	**76.33**	**77.67**	**73.33**	**73.33**	**74.67**	**75.33**	**75.67**	**73.33**	**75.33**	**79.00**	**77.33**
CD 5% SE (m)												

**** Mean of three replications***

TABLE: 1 (b)

NUMBER OF BLACK EGGS AND EMERGENCE RATE OF THE EGG PARASITOID *T.CHILONIS* TREATED WITH INSECTICIDES

Insecticides and Conc. (%)	Time of treatments after parasitism (hours)							
	5th				6th			
	No of black eggs		% Emergence		No of black eggs		% Emergence	
	Ist G	2nd G	Ist G	2nd G	Ist G	2nd G	Ist G	2nd G
Endosulfan 35%EC								
0.009	69.67	53.67	61.00	44.33	71.00	56.67	62.67	45.33
0.010	72.00	46.00	52.33	40.33	80.33	55.33	54.33	41.33
0.020	75.67	44.67	47.33	35.33	75.67	47.67	51.33	37.00
0.022	75.00	37.00	45.00	32.33	81.00	40.00	48.00	33.00
0.024	71.00	32.00	38.67	29.00	67.67	34.33	41.67	31.00
Monocrotophos 36%SL								
0.009	82.33	47.67	54.33	39.67	70.33	51.33	55.33	42.67
0.010	66.67	45.33	49.33	36.67	76.33	48.33	51.67	40.33
0.020	77.00	40.00	46.00	33.67	66.33	42.33	47.67	36.00
0.022	74.67	35.67	43.00	30.33	75.00	38.67	44.67	30.67
0.024	79.33	29.67	38.67	26.33	75.00	30.67	39.00	26.67
Coragen								
0.009	69.33	53.00	58.00	39.67	78.33	55.67	59.00	39.33
0.010	80.67	46.00	54.00	36.00	80.00	51.33	54.67	35.33
0.020	68.67	40.67	47.67	32.00	76.67	44.33	49.00	29.33
0.022	75.33	36.00	41.00	29.33	69.67	39.33	42.00	27.00
0.024	75.00	33.00	34.33	24.00	69.67	34.67	35.00	25.67
Deltamethrin 1%+ Triazophos 35%EC								
0.009	82.33	0.00	2.00	0.00	78.00	0.00	2.00	0.00
0.010	77.00	0.00	0.67	0.00	76.00	0.00	1.00	0.00
0.020	69.33	0.00	0.00	0.00	68.33	0.00	0.00	0.00
0.022	71.00	0.00	0.00	0.00	75.67	0.00	0.00	0.00
0.024	72.67	0.00	0.00	0.00	75.33	0.00	0.00	0.00
Control								
Water spray	**70.00**	**70.00**	**77.33**	**72.33**	**74.67**	**67.00**	**78.67**	**76.00**
CD 5% SE (m)								

**** Mean of three replications***

TABLE (2)

LONGEVITY (H) OF MALE AND FEMALE OF THE EGG PARASITOID *TRICHOGRAMMA CHILONIS* TREATED WITH FIVE INSECTICIDES. (n =20)

Insecticides and Conc. (%)	Time of treatments after parasitism (day)																			
	1st				2nd				3rd				5th				6th			
	Ist G		2nd G		Ist G		2nd G		Ist G		2nd G		Ist G		2nd G		Ist G		2nd G	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Endosulfan 35%EC																				
0.009	5	7	3	5	5	7	3	5	5	7	3	5	5	7	3	5	5	7	3	5
0.010	5	7	3	4	5	7	3	4	5	7	3	4	5	7	3	4	5	7	3	4
0.020	4	6	3	4	5	7	3	4	4	7	3	4	5	7	3	4	5	7	3	4
0.022	4	6	3	4	4	6	3	4	4	6	3	4	4	6	3	4	4	6	3	4
0.024	3	5	3	4	4	6	3	4	3	5	3	4	4	6	3	4	4	6	3	4
Monocrotophos 36%SL																				
0.009	4	6	4	5	4	6	4	5	4	6	4	5	5	7	4	5	5	7	3	5
0.010	4	5	3	5	4	6	3	5	4	6	3	5	4	6	3	5	4	7	3	4
0.020	3	5	3	5	4	5	3	5	4	6	3	5	4	6	3	5	4	6	3	4
0.022	3	5	4	5	3	5	4	5	3	5	3	4	4	5	3	4	3	5	3	4
0.024	-	-	-	-	3	5	-	-	3	5	-	-	3	5	-	-	3	5	-	-
Coragen																				
0.009	5	7	4	6	5	7	4	6	4	7	4	6	4	7	4	6	5	7	4	6
0.010	5	7	3	5	4	7	3	5	4	7	3	5	4	7	3	5	5	7	3	5
0.020	4	6	3	5	4	6	3	5	4	6	3	5	4	6	3	5	5	7	3	5
0.022	4	6	4	6	3	5	4	6	3	6	4	6	3	6	4	6	4	6	4	6
0.024	3	5	3	5	3	5	3	5	3	5	3	5	3	5	3	5	4	6	3	5
Deltamethrin 1%+ Triazophos 35%EC																				
0.009	3	4	-	-	4	6	-	-	5	7	-	-	4	7	-	-	4	6	-	-
0.010	3	4	-	-	4	5	-	-	4	6	-	-	4	6	-	-	3	6	-	-
0.020	3	4	-	-	3	5	-	-	4	6	-	-	4	5	-	-	3	5	-	-
0.022	-	-	-	-	3	5	-	-	4	6	-	-	4	5	-	-	4	6	-	-
0.024	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Control																				
Water spray	5	7	5	6	5	7	5	7	5	6	5	6	5	7	5	6	5	7	5	7

3.3 Coragen:

The emergence rate of *T. chilonis* on all concentration of coragen was very low (3-5%) and the emerged adults died within 6-12 hrs after emergence. It was noticed that all the five concentrations of coragen affects the egg parasitoid *T. chilonis* adult. Statistical analysis, showed highly significant differences of black eggs between the control and all the studied insecticides at 2nd generation but non-significant difference in 1st generation. As for comparing insecticides with each other there were non-significant differences for the numbers of black eggs (77-80) as well as emergence (52.33, 47.33, 40.67, 36.33 and 33.33) rates at 0.009, 0.01, 0.020, 0.022 and 0.024% concentration (Table 1). The respective values for the emergence rate for 2nd generation decreased compared to 1st generation and the control. In second generation, the emergence rate was 33% and 31% on one and two days post parasitism at 0.009% concentration, while at 0.024% conc. there was only 18-25% emergence recorded at 1st and 2nd day of parasitism (Table: 1). At 1st, 2nd and 3rd day after parasitization of eggs there was found maximum deformities in second generation adults of *T. chilonis*, while at 5th and 6th day parasitized eggs had least. The maximum deformities and mortality of adult wasps were found in highly concentrated doses of insecticides compared to the low concentrated.

3.4 Deltamethrin 1%+Triazophos 35%:

All the doses of Deltamethrin 1%+Triazophos 35% were significantly toxic to *T. chilonis*. The higher doses of chemical insecticide caused a highly decrease in the emergence rate, the recorded values were 0% - 2% compared to 77.33-77.67% for the control (Table: 1). Also this chemical caused death of the emerged adults within few hours post emergence (0–1 day) compared to (4–7 days) for the control so no data were recorded for the second generation. It is therefore, this chemical was recorded highly toxic to the *T. chilonis*. There was no mortality in untreated check.

IV. DISCUSSION

These findings are closely related to the findings of Chares *et al.* (2000), who reported that spinosad and prophenofos were the most toxic compounds to *T. exiguum* adults, followed by lambda cyhalothrin, cypermethrin, and thiodicarb. Plewka *et al.* (1975), also reported that some insecticides did not penetrate the host egg-chorion (*Sitotroga cerealella*), and *Trichogramma* spp. were affected only upon emergence from the eggs.

Adult *T. exiguum* emergence from *H. zea* eggs was significantly affected by insecticide treatment. Overall, parasitized eggs exposed to profenophos yielded the lowest percent emergence. Although insecticides are generally considered toxic to adult *Trichogramma*, preimaginal stages developing within host eggs appear to be well protected from many insecticides (Bull and House 1983, Bull and Coleman 1985, Li *et al*. 1986, Singh and Varma 1986, Brar *et al*. 1991, Coˆnsoli *et al*. 1998). Pyrethroids generally had a slight to moderate effect, whereas insect growth regulators and other selective compounds generally appeared to have no effect on emergence. For some insecticides, the effect on emergence appeared to be related to the progression of preimaginal development at time of exposure (Varma and Singh 1987, Coˆnsoli *et al*. 1998). Varma and Singh (1987) reported that in general, the disruptive effect of insecticides on *T. brasiliensis* Ashmead emergence decreased as parasitoids advanced in development.

The timing of insecticide exposure relative to preimaginal development (larval, prepupal, and pupal stages) did not have a significant impact on emergence for any of the insecticides tested. Profenophos (organophosphate) completely inhibited emergence and both pyrethroids (lambda cyhalothrin and cypermethrin) severely affected emergence for all three stages of exposure.

Possible explanations may be related to the species of *Trichogramma* and host eggs used as well as insecticide concentrations tested in each of the studies. The quality and overall fitness of *Trichogramma* heavily depends on the size of the host and the number of conspecifics that emerge with it (Bai *et al*. 1992)

We could found no published data concerning the effect of coragen on *Trichogramma* development or survival. However, Navarajan and Agarwal (1989) reported that the pyrethroids tested in their study (cypermethrin, fenvalerate, and deltamethrin) had relatively low residual toxicity to *T. brasiliensis* Ashmead while carbaryl (carbamate) had the highest residual activity.

V. CONCLUSION

Preliminary studies indicated that endosulfan and coragen had less adverse effect on preimaginal development or adult survival, indicating that these compounds are compatible with *T. exiguum* wasps. In response to the adverse effect of insecticides on preimaginal development in our study, it should be noted that eggs were completely drenched with an insecticide solution. Consequently, eggs received the maximum possible dose in our study. However, further research should focus on the impact of

insecticide exposure on *Trichogramma* parasitism and overall effectiveness under field conditions to determine the compatibility of *Trichogramma* wasps and insecticides. More emphasis should be placed on conserving or enhancing naturally occurring populations of *Trichogramma* as well as other natural enemies in field condition

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Trends and Challenges of Agriculture Marketing in India

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Abstract— *A sizable section of the population makes their living from agriculture, which is the foundation of the Indian economy. One of the main challenges facing the sector is marketing agricultural products, though. This research paper aims to address and comprehensively examine the numerous issues pertaining to agriculture marketing in India and its states. This study used secondary data from a number of sources, including the India state database, the Ministry of Statistics and Programme Implementation, the Government of India and the Ministry of Agriculture and Farmers Welfare, the Government of India. The Agricultural Produce Market Committee (APMC) Act and e-NAM (National Agriculture Market), two recent government policies and regulations aimed at reforming agriculture marketing, are also reviewed in this research paper. This research paper evaluates their efficiency in resolving the noted problems and makes recommendations for possible areas of development. The issues surrounding the marketing of agriculture in India and its states are thoroughly examined in this research paper. The main issues are highlighted, along with how they differ in different places and possible fixes. India's agricultural sector can become more resilient, effective, and profitable by addressing these problems, which will ultimately improve the lives of millions of farmers and support the country's economic expansion. India's agricultural market is evolving quickly, with different viewpoints emerging at the state and india levels. Enhancing farmers' livelihoods, implementing sustainable practices, and embracing technological innovations are the main priorities.*

JEL Classification: Q130, M31, M48, O3.

Keywords: Agriculture marketing, farmers, agricultural market, innovations, sustainable.

I. INTRODUCTION

Over time, India's agricultural sector has undergone a remarkable transformation, evolving from a largely subsistence-based industry into a vibrant and increasingly market-driven one. The past two years have seen brisk growth in the agriculture sector (Economic Survey, 2022-23). This sector, which employs the largest portion of the population, contributed a significant 18.8% to the country's Gross Value Added (GVA) in 2021–2022, with growth rates of 3.6% in 2020–2021 and 3.9% in 2021–2022 (Ramaswamy, 2022). A number of interrelated factors, such as shifting consumer preferences, technological advancements, policy changes, and globalisation, have driven this transformation in India's agricultural landscape. In addition to significantly impacting the livelihoods of millions, India's evolving agricultural market has positioned the country as a key player in the global agricultural market. Traditionally, Indian agriculture was characterised by small landholdings, antiquated farming methods, and a heavy reliance on monsoons. With a substantial portion of the population engaged in subsistence farming, food security was the primary concern. However, recent years have witnessed a noticeable shift towards a more market-oriented approach.

The growing understanding of agriculture as an essential part of the Indian economy has been one of the major forces behind this shift in perspective. It makes a sizable contribution to the GDP and job creation of the nation (Ministry of Agriculture and Farmers Welfare, 2022). A reevaluation of agriculture's place in the national development agenda has resulted from the realization that it can be a source of both prosperity and sustenance (Mukherjee, 2021). The agricultural landscape has changed significantly as a result of technological advancements and the adoption of modern agriculture (Singh & Pal, 2020; World Bank, 2021).

Agriculture market in India and the number of farmers using it: Agriculture plays a significant role in India's economy, contributing approximately 16–17% of the nation's Gross Domestic Product (GDP) (Ministry of Finance, 2022). Over half of

India's population relies on agriculture for their livelihood, making it the largest employer in the country. In fact, 58% of the labour force is employed in agriculture and related industries (National Sample Survey Office, 2021).

India's agricultural market is crucial for ensuring food security, producing essential crops like wheat and rice that form the backbone of the nation's food supply. The government purchases grains from farmers to distribute through the Public Distribution System (PDS) and other welfare programs, ensuring food accessibility across the country (Food Corporation of India, 2022). For millions of farmers nationwide, the agriculture market serves as their primary source of income, with the prices they receive for their produce significantly impacting their livelihoods. The National Agricultural Market (e-NAM) initiative aims to provide farmers with better access to markets. By offering a unified electronic trading platform, e-NAM enables farmers to sell their produce across different markets and states, reducing the reliance on middlemen and ensuring better prices (Ministry of Agriculture and Farmers Welfare, 2022).

Moreover, India is a major exporter of various agricultural products, including rice, wheat, spices, and cotton, contributing significantly to the global agricultural market. These exports not only increase foreign exchange revenue but also provide farmers with additional income (Export-Import Bank of India, 2021).

By September 2021, over 1,000 wholesale markets (mandis) across 18 states and union territories had adopted the e-NAM platform, drawing increasing attention from farmers and traders alike (Ministry of Agriculture and Farmers Welfare, 2021). Millions of farmers were already selling their produce on the e-NAM platform, reflecting its growing influence. However, many small and marginal farmers in remote and rural areas continue to rely on traditional local markets or intermediaries to sell their produce, despite the expanded access to formal markets provided by programs like e-NAM (Kumar & Joshi, 2022). The extent of participation in formal agricultural markets varies significantly across different geographic regions.

The adoption of formal agricultural markets varies widely among Indian states and regions, with farmers in areas with well-developed agricultural infrastructure and market connectivity more likely to participate in these markets (National Sample Survey Office, 2021; Singh & Gupta, 2020). Several factors, including government regulations, technological advancements, and shifts in market dynamics, can influence the degree to which farmers utilize formal agricultural markets over time (Sharma, 2021). Although there are ongoing initiatives to increase farmers' access to formal markets, the widespread adoption of such markets may take time (World Bank, 2021).

1.1 Marketing Infrastructure

Farmers are frequently unable to obtain accurate market prices across various markets, leading them to accept whatever prices traders offer (Niti Aayog, 2021). To address this issue, the government regularly broadcasts market prices on radio and television, and newspapers also inform farmers about the latest price changes (Ministry of Information and Broadcasting, 2021). Despite these efforts, many poor Indian farmers sell their produce immediately after harvest, even though prices are typically very low at that time (Sharma & Gupta, 2022).

The extensive network of middlemen in the agricultural market has significantly reduced the proportion of profits that farmers receive (Kumar, 2020). India's transport infrastructure is severely lacking, with only a few villages connected to mandis by railways or paved roads. As a result, produce often has to be transported using cumbersome conveyances like bullock carts. This type of transportation is impractical for long distances, forcing farmers to sell their harvests in nearby markets, even if the prices are extremely low (World Bank, 2021). This issue is particularly problematic for perishable goods, which cannot be stored for long periods (Singh & Verma, 2021).

1.2 Problems in agriculture marketing:

The majority of farmers today are struggling financially and are unable to afford high-quality pesticides and seeds from High Yielding Varieties (HYVs), which results in poor productivity (P. Lalita et al., 2020). The situation is exacerbated by the fact that markets often sell goods at very low prices or prices continue to decline. Market middlemen also take a significant portion of the farmers' output without adding value, further diminishing farmers' incomes and forcing them to borrow money from these intermediaries while selling their produce at reduced prices (P. Lalita et al., 2020).

In many villages, farmers lack access to proper storage or warehousing facilities. Due to inadequate storage options, 15 to 30 percent of agricultural produce is destroyed annually by pests or weather conditions (Nalange et al., 2019). Consequently, farmers are often compelled to sell their excess produce immediately after harvest at very low prices, which are unprofitable. Extreme poverty and limited access to appropriate credit facilities prevent most Indian farmers from waiting for better prices

(K. Manoj, 2018). This leads them to sell their produce under distress to local moneylenders and traders at significantly reduced prices (K. Manoj, 2018).

The current agricultural marketing system lacks sufficient storage facilities. The absence of proper storage means farmers must sell their products at low prices, as they cannot store them safely until market conditions improve. Inadequate and unscientific storage facilities contribute to substantial grain wastage, with pests causing about 20% to 30% of grains to be lost, costing farmers millions of dollars annually (Nalange et al., 2019).

The literature about the agricultural sector and its role in economic development are widely available. We have review them below

Prabhakara B.N. (2014), examines that the focus on market failure paved the way for market-driven liberalisation aimed at achieving "prices and institutions right." State-run marketing boards and producer marketing chains, which span from credit unions to farmer cooperatives to wholesale cooperatives, have emerged as a result. The state must devote all of its resources to bolstering the competitive marketing system before the producer can have access to market prices that are competitive.

Royce (2004), try to assess and explain that cooperative management authority is still limited because state agencies are still the primary suppliers of input and buyers of output. On-farm decision-making and member participation are significantly higher.

Ramkishen (2004) in his research paper, contended that the grower loses out on a good price for his produce during the peak marketing season due to inadequate food processing and storage, while consumers unnecessarily pay a higher price during the lean season.

Rajendran and Karthikesan (2014) conducted a study which revealed that small-scale farmers must be integrated into the market and educated about concepts such as supply and demand, which are fundamental to the economy, to prevent them from being excluded from the advantages of agricultural produce.

Thomas Sunny (2011) in his work “Growth and Composition of Indian Agriculture Exports during Reform Era," explains that the majority of countries rely heavily on Indian agricultural products for marketing, as they present significant opportunities. India's agricultural sector has grown significantly. The contribution of agriculture-related exports to the country's net exports had decreased significantly.

M. Vikram Kumar, Dr. P. Chenchu Reddy and A. M. Mahaboob Basha (2014), discusses the challenges faced by farmers in marketing their agricultural products in India. The paper highlights the importance of developing effective marketing strategies and information systems to help farmers sell their products at better prices. The authors suggest that the government should play a more active role in developing unique marketing strategies for the agricultural sector in India.

M. Selvaraj & M. Syed Ibrahim (2012) gives a thorough analysis of India's agriculture marketing situation as of right now. It covers a range of topics and difficulties facing the business, looks at how technology is affecting it, and offers case studies of creative marketing techniques in action. The report emphasises the significance of effective backward and forward integration with agriculture, which has produced production systems that are cost- and quality-competitive on a worldwide scale.

M. Shanmukh Raju, M. Rama Devy and P. V. Sathya Gopal (2022) A study in Andhra Pradesh assessed the knowledge of e-NAM registered farmers about the electronic trading portal. Most farmers were aware of registration and quality assaying fees and the ability to accept or reject bids. However, their overall knowledge level was moderate. Factors like education, extension contact, market orientation, income orientation, mass media exposure, risk orientation, and social participation were related to knowledge scores, collectively explaining about 59.90% of the variation. The study recommends providing training to enhance farmers' utilization of e-NAM.

Jaiprakash Bisena and Ranjit Kumar (2018) The paper reviews developments in Indian agricultural marketing with a focus on addressing challenges in implementing e-NAM, aiming to double farmers' income and reduce poverty in line with SDGs. The study identifies challenges in e-NAM implementation related to Infrastructure, Institution, and Information (3 I's) and recommends strengthening the supply chain with public-private interventions. It also suggests amending state APMC Acts to support e-tendering and raising awareness among farmers about the benefits of e-NAM.

Rakesh Rathore and Shubhaom Panda (2019) paper explain Agricultural marketing is of utmost importance to India's economy, providing employment for 65% of the workforce. This field encompasses primary, secondary, and terminal market functions. The paper delves into government initiatives and the growing demand for food products. Regulatory measures under the

Agricultural Produce Market Committee (APMC) Act promote both market regulation and contract farming. The electronic National Agriculture Market (e-NAM) is a significant force behind market modernization and integration.

The primary objective of this study is to identify the perception and present situation of agriculture marketing system in India and outline the issues in agriculture marketing in India, the another objective is to measures for improvement in agriculture marketing in India and participation of farmers in e-NEM.

II. RESEARCH METHODOLOGY

2.1 Source of Data:

Secondary Source of data has been used in the present research paper. The data used for the research has been extracted from reports generated from official website of Agricultural Markets and other published sources. This study carried based on secondary data such as books, journals and periodicals etc. For fulfilment of objectives, the researcher had a review of various published papers to assess and explore the contribution and implications of Agricultural Marketing on Indian economy. The basic Statistical tools and descriptive analysis is used in the research paper to define the objective of research.

The Compound annual Growth Rate (CAGR) of state-wise value of output of Indian economy has been estimated by using an extensively accepted exponential model, $y = ab^t e^u$. The Compound annual Growth Rate (CAGR) is usually estimated by using the following semi-log functional form:

$$\ln(y) = \ln(a) + t\ln(b) + u \quad (1)$$

Where, y represents dependent variable whose growth rate is to be estimated; t represents independent variable (time) and u represents disturbance or error term. Moreover, 'a' and 'b' are the parameters to be estimated. The CAGR in per cent term is estimated as:

$$CAGR = \{Antilog(b) - 1\} * 100 \quad (2)$$

III. RESULT ANALYSIS AND DISCUSSION

Agri-tech solutions, e-commerce, and digital platforms are becoming more and more prominent in Indian agriculture marketing. These trends provide market access and efficiency, but they also present certain obstacles, such as the need for policy support, infrastructure gaps, and digital literacy. For the agricultural marketing landscape to undergo a long-lasting and inclusive transformation, these gaps must be closed.

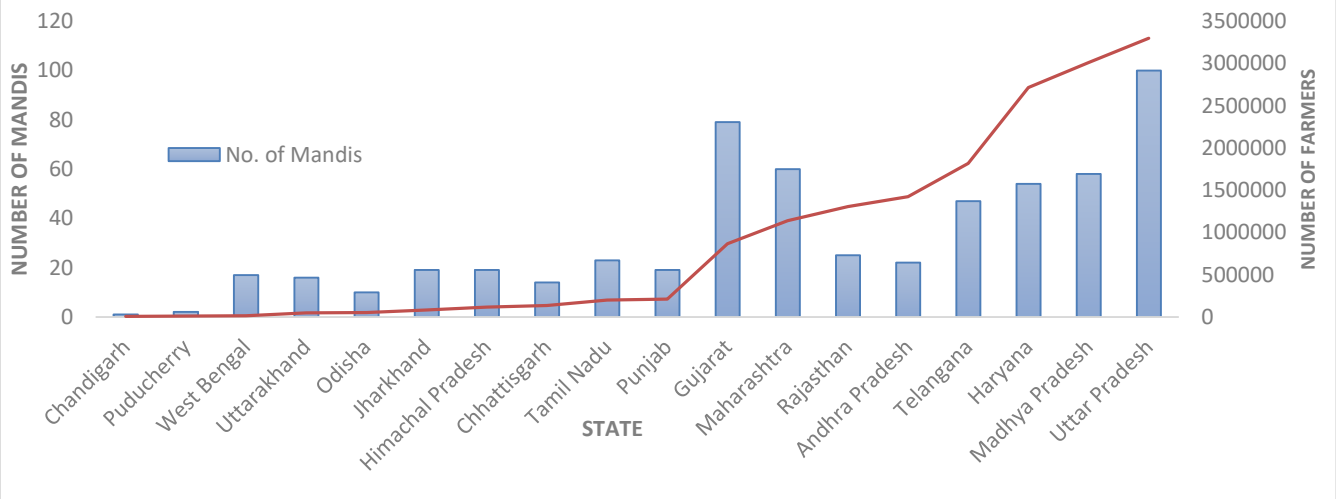

FIGURE 1; Selected State-wise Number of Mandis Integrated and Farmers Registered under National Agriculture Market (e-NAM) in India (As on 31.10.2019)

Source: Author's calculation based on database of Ministry of Agriculture & Farmers Welfare, Govt. of India.

The figure 1 presented in this study as shown in Figure 1 illustrates the integration of mandis (marketplaces) and the registration of farmers, under the National Agriculture Market (e NAM) in selected states of India up until October 31, 2019. The figure presents a bar chart with the x axis representing the states and the y axis representing the count of mandis and registered farmers. The bars colored in blue indicate the number of mandis while the orange bars represent the count of farmers registered

under e NAM. According to the figure Uttar Pradesh stands out as having the number of mandis under e NAM followed by Gujarat and Maharashtra. On the contrary Chandigarh has recorded a number of integrated mandis. In terms of farmer registrations under e NAM Uttar Pradesh again leads with a number, followed by Madhya Pradesh and Haryana. Conversely Chandigarh has reported fewer farmers being registered under e NAM. Overall this figure emphasizes how e NAM has made progress in integrating mandis and farmers across states in India. However it also indicates that there is still room, for increasing both integration and farmer registrations under e NAM particularly in states that currently have lower levels of integration.

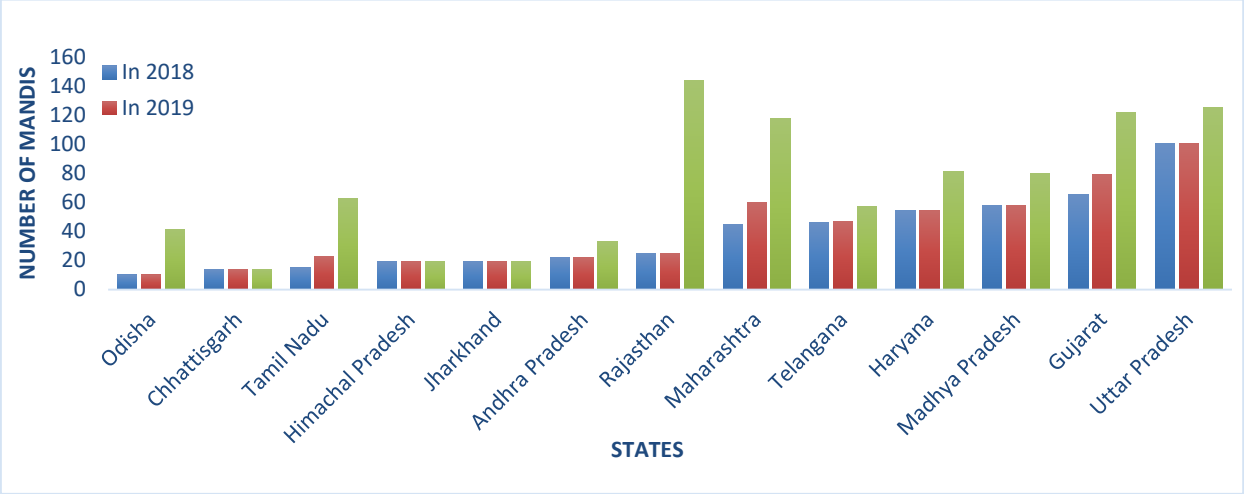

FIGURE 2: Selected State-wise Number of Mandis from the year of 2018, 2019 and 2022 in India.

Source: Author's calculation based on database of Ministry of Agriculture & Farmers Welfare, Govt. of India.

Figure 2 showing the number of mandis in a few Indian states during a three-year period. The number of mandis in 2018, 2019, and 2022 is represented by the blue, orange, and green bars, respectively. When comparing the number of mandis in various states throughout time, the figure is helpful. For instance, Uttar Pradesh (100) has the most mandis in 2018, followed by Gujarat (65), and Madhya Pradesh (58). In contrast, Tamil Nadu and Chhattisgarh had 14 and 15 mandis each, while Odisha had the fewest (10). The image also shows how the number of mandis has changed throughout time. For instance, the number of mandis in Rajasthan increased significantly from 25 in 2018 to 144 in 2022. In the same way, Maharashtra had 45 mandis in 2018 but 118 by 2022. All things considered, the figure offers a concise and clear depiction of the number of mandis in the various Indian states throughout time, making it an invaluable tool for scholars and decision-makers who wish to comprehend the workings of the country's agricultural markets. In summary, the figure indicates that e-NAM has achieved significant progress in the integration of mandis throughout India's many states. The graph also emphasises how important it is to keep pushing e-NAM and broadening its use nationwide, particularly in areas with lower integration levels.

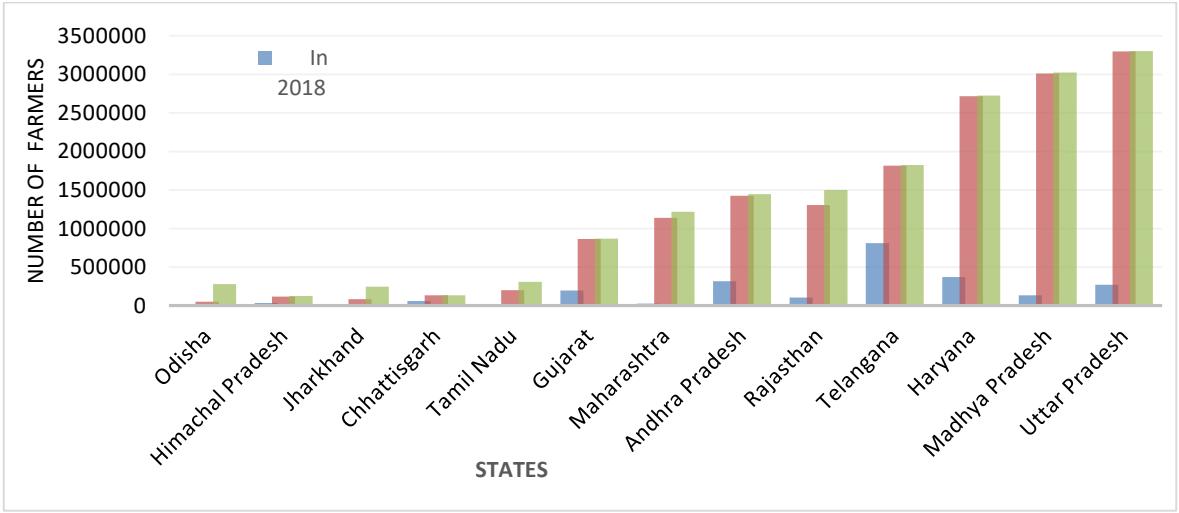

FIGURE 3: Selected State-wise Number of farmers Registered under National Agriculture Market (e-NAM) in India

Source: Author's calculation based on database of Ministry of Agriculture & Farmers Welfare, Govt. of India.

The number of farmers registered in each of India's states under the National Agriculture Market (e-NAM) is seen in Figure 3. Through the e-NAM internet platform, farmers may sell their goods directly to consumers, cutting out middlemen and associated costs. Figure 3 displays the statistics for the following years: 2018, 2019, and 2022. The chosen states are displayed on the x-axis, while the number of registered farmers is displayed on the y-axis. With more than 8.1 million farmers enrolled on the e-NAM platform in 2018, Telangana was the state with the most registered farmers. Uttar Pradesh, Andhra Pradesh, and Haryana were some of the other states having a large, registered farmer population. Most states saw increases in the number of registered farmers between 2018 and 2019, with Uttar Pradesh, Madhya Pradesh, and Haryana experiencing the biggest increases. Nonetheless, a few states, including Chhattisgarh and Tamil Nadu, do not appear to have seen a notable rise in the number of farmers who are registered. A forecast for 2022 is also included in the data in Figure. The forecast indicates that most states will continue to see increases in the number of registered farmers; Uttar Pradesh is estimated to have more than 3.5 million registered farmers by 2022. All things considered, Figure offers insightful data on farmers' acceptance and usage of the e-NAM platform across several Indian states.

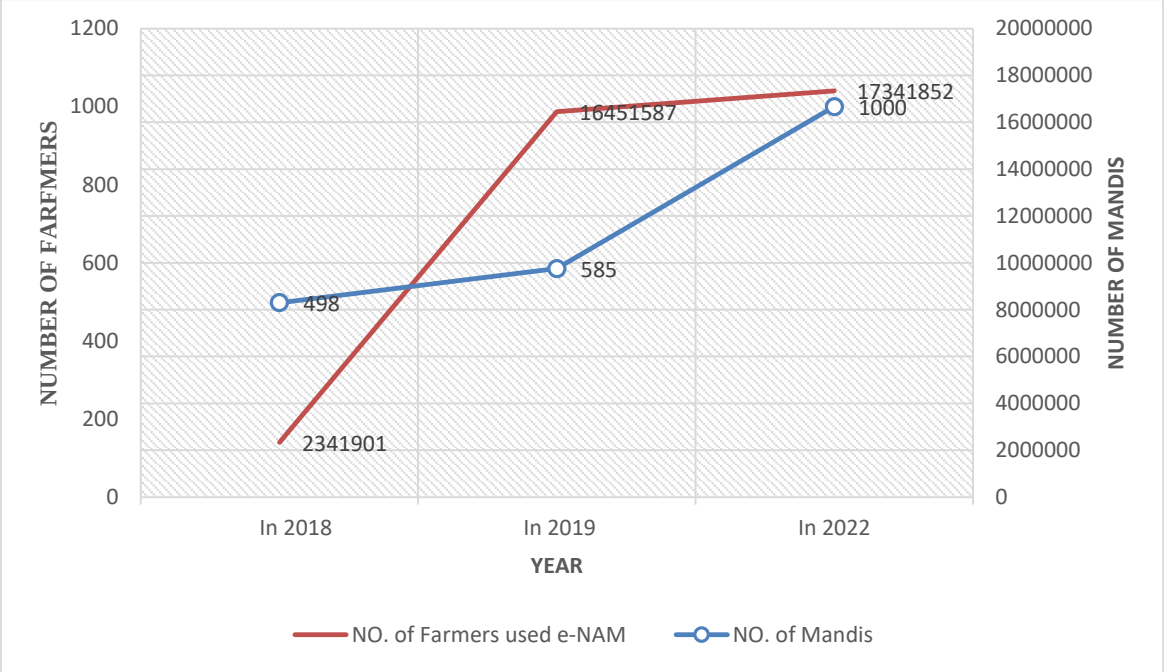

FIGURE 4: Trends of No. of Farmers used E- NAM and No. of Mandis during 2018, 2019 and 2022
Source: Author's calculation based on database of Ministry of Agriculture & Farmers Welfare, Govt. of India.

The figure 4 displays the trends of number of mandis integrated under e-NAM and the number of farmers using e-NAM in India in the years 2018, 2019, and 2022.Illustrates how e-NAM has significantly advanced the integration of farmers and mandis throughout India's many states. Nonetheless, there remains ample opportunity to augment the quantity of farmers and mandis included via e-NAM, particularly in states with reduced integration thresholds. As depicted in the picture, the number of farmers using e-NAM grew from 2.3 million in 2018 to 16.5 million in 2019 and then to 17.3 million in 2022. Comparably, from 498 in 2018 to 585 in 2019, and then to 1,000 in 2022, there were more mandis integrated under e-NAM. The graph shows how e-NAM has integrated farmers and mandis throughout India's many states, achieving notable success in this regard. Still, it indicates that there is more room to grow the number of farmers and mandis covered by e-NAM, particularly in states with lower integration levels. Ultimately, the graph indicates that e-NAM has been effective in enhancing price discovery, removing middlemen, and giving farmers more access to markets. The data also emphasizes the necessity of ongoing initiatives to improve e-NAM's visibility and expand its national reach.

TABLE 1

STORAGE INFRASTRUCTURE PROJECTS IN INDIAN STATES AND WOMEN BENEFICIARY IN YEAR OF 2022

States/UTs	No. of Women Beneficiaries	Capacity Created (MT)	Subsidy Released (Rupees in Lakh)
Andhra Pradesh	569	2779574.17	15556.25
Assam	45	140557.06	1468.71
Bihar	127	204881.51	1203.72
Chhattisgarh	37	45396.54	832.03
Gujarat	1461	1209118.26	7190.16
Haryana	281	1976707.53	13974.54
Himachal Pradesh	7	6173.83	74.7
Jammu and Kashmir	1	5000	25
Jharkhand	6	29046.3	121.52
Karnataka	652	809480.92	3960.38
Kerala	2	3625.25	18.26
Madhya Pradesh	1289	5862112.62	29113.33
Maharashtra	285	676958.44	2044.33
Meghalaya	2	5155.28	34.36
Odisha	86	220039.27	1119.61
Punjab	144	1255759.68	9558.92
Rajasthan	294	967144.49	4856.87
Tamil Nadu	123	567811.02	2828.7
Telangana	185	1088998.38	7476.21
Uttar Pradesh	96	506688.53	4136.58
Uttarakhand	96	336796.58	1872.14
West Bengal	22	53462.65	296.47
India	5809	18750488.34	107762.8

Source: Author's calculation based on database of Ministry of Statistics and Programme Implementation, Govt. of India.

The table 1 explains about storage infrastructure projects in various Indian states and union territories in the year 2022. For each state or union territory, the data includes the number of women beneficiaries, the storage capacity created in metric tonnes (MT), and the subsidy released in Indian Rupees (Lakh). With 569 women beneficiaries, Andhra Pradesh has the largest number, suggesting a major impact on women in the state. With only one or two, states like Jammu and Kashmir, Meghalaya, and Kerala have the fewest number of female beneficiaries. With a storage capacity of more than 5.8 million metric tonnes, Madhya Pradesh is the state with the largest contribution to the nation's storage infrastructure. The state also received the largest amount of subsidies, totaling more than 29,000 lakh rupees, which reflects the government's significant investment in the state's storage infrastructure. Kerala, Meghalaya, Jammu and Kashmir, and Himachal Pradesh have comparatively smaller storage capacities, most likely as a result of their less intensive agricultural and storage needs. Due to their smaller-scale projects, Kerala, Himachal Pradesh, and Jammu and Kashmir have received the least amount of subsidies. 5,809 women will have benefited from these storage infrastructure projects in India overall by 2022, demonstrating the cumulative effect on women's lives throughout the nation. The significant increase in storage facilities is indicated by the 18,750,488.34 MT total storage capacity created in India. A total of 107,762.8 Lakh Rupees have been released as subsidies in India, demonstrating the financial support given at the national level.

TABLE 2

CAGR OF STATE-WISE VALUE OF OUTPUT FROM AGRICULTURE AND ALLIED SECTORS IN INDIA

States/UTs	CAGR 2011-2016	CAGR2019-2021
Andaman & Nicobar Islands	0.658	4.97
Andhra Pradesh	6.162	6.66
Arunachal Pradesh	3.309	10.31
Assam	3.423	1.636
Bihar	1.73	3.253
Chandigarh	1.259	4.264
Chhattisgarh	3.69	3.782
Delhi	-8.321	-0.362
Goa	1.888	2.775
Gujarat	1.933	3.015
Haryana	0.76	3.456
Himachal Pradesh	5.055	1.892
Jharkhand	0.768	3.099
Karnataka	1.044	10.319
Kerala	-1.869	-0.668
Lakshadweep	7.911	-3.579
Madhya Pradesh	6.84	3.598
Maharashtra	-0.315	4.367
Manipur	1.198	0.222
Meghalaya	6.374	3.269
Mizoram	27.118	-2.487
Nagaland	2.611	1.425
Odisha	1.189	4.301
Puducherry	1.963	-0.24
Punjab	0.537	2.575
Rajasthan	3.815	5.544
Sikkim	-2.916	3.622
Tamil Nadu	4.501	5.986
Telangana	-1.416	9.271
Tripura	6.186	3.746
Uttar Pradesh	1.43	2.261
Uttarakhand	-0.27	1.868
West Bengal	1.86	2.734
India	2.218	4.207

Source: Author's calculation based on database of Ministry of Statistics and Programme Implementation, Govt. of India.

Table 2, shows the Compound Annual Growth Rate (CAGR) of the value of output from agriculture and allied sectors in various states and union territories (UTs) in India for two distinct time periods: from 2011 to 2016 and from 2019 to 2021. The CAGR in the Andaman and Nicobar Islands increased dramatically from 0.658 in 2011–2016 to 4.970 in 2019–2021, demonstrating robust growth in the agricultural and related sectors. Andhra Pradesh has maintained a comparatively high growth rate—6.162 and 6.660 CAGR-over the course of both time periods in order to support this growth. With the second-highest CAGR of 10.310 in 2019–2021, Arunachal Pradesh has demonstrated significant growth among the states. Urbanisation has created challenges for Delhi's agriculture sector, whose CAGR improved from -8.321 to -0.362. Encourage aquaponics,

rooftop gardens, and urban farming to make the most of available space. Create effective food supply networks to guarantee the city has a steady supply of fresh produce.

A few states and union territories, including Andaman & Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, and Bihar, experienced a rise in compound annual growth rate (CAGR) between the previous and subsequent periods. This suggests that agriculture and related industries are expanding in a positive direction. Certain states, like Rajasthan, Gujarat, and Haryana, had growth rates that were steady throughout both times, if not particularly high. This suggests that their agricultural output has stabilised. In the later period, the CAGR decreased in states like Tamil Nadu and Karnataka. Sustained growth depends on comprehending the causes of these oscillations. States with decreasing or negative CAGR in their agricultural sectors included Delhi and Kerala. Their agricultural output has been impacted by urbanisation and other factors. Significant growth in the agriculture and related sectors is indicated by the notably high CAGR values in the later period for states like Goa, Karnataka, Meghalaya, and Telangana. While Sikkim and Lakshadweep's performance improved in the later period, it was still relatively low when compared to other states. Earlier, these states had negative CAGR values.

In order to effectively target interventions, policymakers and stakeholders must conduct a thorough analysis of the unique factors influencing growth in each region. Climate, infrastructure, adoption of new technologies, market accessibility, and policy support are just a few of the variables that greatly influence how well the agriculture sector performs in each state and UT.

IV. CONCLUSION AND RECOMMENDATIONS

This research paper concludes by highlighting notable advancements and accomplishments in India's agricultural integration and storage infrastructure. In terms of integrated mandis and registered farmers, Uttar Pradesh, Gujarat, and Maharashtra have emerged as leaders, highlighting the advancements achieved by the e-NAM initiative in fostering integration within the agricultural sector. The somewhat lower figures in Chandigarh, however, highlight the necessity of ongoing initiatives to improve integration and raise farmer registrations, especially in areas where participation is still low. The research paper also sheds light on the dynamic landscape of mandi integration in India, with notable increases in the number of integrated mandis in states like Rajasthan and Maharashtra over the years. This underscores the importance of sustaining and expanding e-NAM's reach across the country, with a particular focus on areas where integration levels are still lagging. Between 2018 and 2022, the number of farmers using e-NAM increased significantly from 2.3 million to 17.3 million, which is indicative of the program's important role in integrating farmers and mandis. A further indication of the benefits of e-NAM, such as better price discovery, less dependence on middlemen, and improved market access for farmers, is the rise in integrated mandis from 498 to 1,000. Even though significant progress has been made, there is still opportunity for growth, particularly in states with lower levels of integration.

The impact of the projects on women, with Andhra Pradesh leading the way in terms of the number of women beneficiaries, indicates that the state's women are benefiting from these initiatives, which may also be enhancing their prospects for employment and agriculture. Nonetheless, there are clear regional differences in the number of female recipients, storage capacity, and subsidies received, which highlights the need for more focused efforts to include women in these kinds of projects, especially in states like Kerala, Jammu and Kashmir, and Meghalaya. With a storage capacity of more than 5.8 million metric tonnes and the largest amount of subsidies received, Madhya Pradesh has made a remarkable contribution to the country's storage infrastructure, demonstrating the government's significant investment in this vital sector. By 2022, an estimated 5,809 women's lives will have been positively impacted by storage infrastructure projects, underscoring the important role these programmes play in empowering women in agriculture and storage. There has been a significant expansion of storage facilities in India, resulting in the creation of 18,750,488.34 metric tonnes of total storage capacity and the release of significant subsidies. This helps greatly with the nation's agricultural and storage needs in addition to addressing regional disparities. The significance of storage infrastructure projects and agricultural integration, as well as how they can empower women, reduce regional disparities, and help the country's agriculture industry. The government's dedication to enhancing India's agricultural and storage infrastructure is evident in the substantial investments and accomplishments in these fields, which will eventually improve the country's economy and people's quality of life.

The research paper suggests that policymakers and government must conduct a thorough analysis of the unique factors influencing growth in each region to effectively target interventions. The study recommends concentrating on states with less influence and smaller populations, such as Jammu and Kashmir, Himachal Pradesh, and Kerala, to implement smaller-scale storage infrastructure projects. The study also suggests that policymakers and stakeholders must continue to focus on improving the sector's performance through targeted interventions.

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The Impact of Cultural Factors on the Sustainability of Agricultural Mechanization in Anambra State, Nigeria

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Abstract— *Agricultural machines and equipment have become the most effective instruments used extensively to boost agricultural production. Astronomical population increase in the country without corresponding increase in food production has led to massive importation of agricultural machineries by the Federal and State governments with the aim to mechanize agricultural practices and boost agricultural production. However, agricultural machinery whether they are power units, field implements, processing equipment or pumps cannot perform their duties indefinitely. Like any other machines, they break down from time to time. The high frequency of tractor breakdown are caused by environmental factors, unskilled operators, poor repair and maintenance culture, age of the machines and high cost of spare parts. Various researchers had noted that proliferation of tractor in the country makes widespread and high incidence of un-serviceability of farm tractors, gross underutilization of farm tractors, and frequent breakdown of tractors amongst other problems which is the hallmark of tractor hiring services in Nigeria. The study shows that poor maintenance culture of these agricultural machines and implements results to their unavailability for the works they are meant for, which affects timeliness of agricultural operations and mechanization programmes of the sector. It is recommended that preventive repair and maintenance should be adopted to make the machines and implements always available and prolong their useful life. The work aims to study the effect of poor culture of repair and maintenance of agricultural machines and equipment on mechanization of agriculture in Anambra State if Nigeria.*

Keywords— Repair and Maintenance; Mechanization; Agricultural Machines and Equipment.

I. INTRODUCTION

1.1 Repair and Maintenance of Agricultural Machines and Equipment:

Agricultural machines and equipment have become the most effective instruments used extensively to boost agricultural production. Tractors for instance are capable of working long hours under adverse conditions if certain precautions are taken. Tractor is of very important in as it is a major source of power in agricultural operations (Abubakar et al., 2013; Dahab et al., 2016; Gautuam and Shrivasta, 2017). According to Onwualu et al., (2006), agricultural machinery whether they are power units, field implements, processing equipment or pumps cannot perform their duties indefinitely. Like any other machines, they break down from time to time. They canbe used virtually for all agricultural operations ranging from land clearing operations to land preparations, harvesting, transportation and processing of agricultural products. However, tractor ownership demands considerable amount of capital investment; quite unlike using hand tools and animal drawn implements. Tractors require special management ability and skills as well as adequate service support facilities. Various authors including Onwualu *et al.*(2006) and Umeghalu (2022) have noted that the use of farm machines has increased in Nigeria without corresponding programme for training technicians on their repair and maintenance culture. There are insufficient repair and maintenance facilities to support efficient and economic tractor exploitation at farm level. This according to Onwualu *et al.* (2006) has resulted to the average life of agricultural machines and implements to become shorter because farmers find it difficult to maintain or repair as when due.

Odigboh, (2016), pointed out that some of the problems facing tractor and equipment hiring schemes in Nigeria are as follows: adverse environmental factors, improper use of machines, poor maintenance culture, age of the machines, high cost of spare parts, lack of proper record, poorly cleared farm lands, lack of ecological or survey data, size of farm holdings, absence of infrastructural facilities, inadequate training of operators, lack of technical management, absence of local content, untrained repair and maintenance crew. Umeghalu (2022), posited that poor maintenance culture is an attitude or way of life which sadly lacking towards maintenance of anything maintainable whether machinery, equipment, office furniture, building or factory. Thus, poor maintenance culture has become a widely recognized plague that is negatively affecting both public and private facilities in Nigeria.

Onwualu et al. (2006) pointed out that agricultural machine, whether they are power units, field implements, processing equipment, or pumps, cannot perform their duties indefinitely. Like other machines, they breakdown from time to time. Although introduction of tractor hiring programme in Nigeria was laudable however, the desired result was far from being achieved because of bad operational management, absence of financial autonomy, frequent change of policy by government amongst others. Anazodo (1987) had noted that proliferation of tractor in the country makes widespread and high incidence of un-serviceability of farm tractors, gross underutilization of farm tractors, frequent breakdown of tractors amongst other problems the hallmark of tractor hiring services in Nigeria. These tractors were imported into the country for a wide range of farm operations; from land preparation to planting, harvesting, on-farm processing, haulage of agricultural products for storage and to the markets (Kienzle *et al.*, 2013; Umeghalu *et al.*, 2012; Yakubu and Enaboifo, 2010).

1.2 Repair of Agricultural Machineries and Equipment:

Repair is a set of operations performed to eliminate defects to ensure safe operation before scheduled overhaul. Repair can be divided into minor and major repairs. While minor repair refers to small jobs such as brake problem, servicing of engine, tyre replacement, etc; major repairs refer to jobs such as replacement of sleeves or reboring cylinders, replacement of crankshaft etc.

1.3 Maintenance of Agricultural Machinery:

A set of compulsory operations specified in the relevant documents, which are carried out to keep the machine available throughout the machine or equipment's service life is often referred to as maintenance (Onwualu, 2005; Spiridanov, 1990). However, many authors have given several definitions of maintenance. Omofehinshe *et al*. (2015a) defined maintenance as an action taken to prevent a device or component from failing or to repair normal equipment degradation experienced with the operation of the device to keep it in proper working order.

Caring for agricultural machines and equipment is necessary to prevent wear and tear and reduce the time lost due to machine breakdowns. Satisfactory performance is the rule rather than the exception. Also, when agricultural machine or equipment is well maintained, its useful life will fully be realized. The effective use of agricultural machine is considerably dependent on its maintenance management culture. Maintenance is imperative to retain an item or restore it to acceptable condition or standard (Oni, 1999; Kutucuoglu *et al*., 2001; Cholasuke *et al*., 2004). What sometimes makes organizations fail is bad planning by the management. Onwualu (2005) reported that every strategic plan needs to be kept in place based on mission, vision and goals of the organization. In Nigeria, maintenance management practices are not effectively carried out. Agricultural machines and equipment have a lot of mechanical and electrical component and besides this; they work in hash environment and therefore needed to be subjected to regular maintenance to prolong their useful life (Odigbo, 1986; Onwualu, 1997). There is therefore need to have budgetary plan for maintenance of these machines and equipment (Odusanya, 1996). A system of scheduled preventive maintenance and repair must be established for farm machines and equipment to ensure their highly productive work, prevent premature wear and failure. This system involves a number of measures necessary to keep machines constantly available.

1.3.1 Classification of Maintenance:

Maintenance can further be classified as breakdown maintenance and preventive maintenance. Breakdown maintenance is the steps taken to rectify a faulty machine or a broken down machine with intention to bring it back to normalcy. It can occur due to the unpredictable failures of components, which cannot be prevented or gradual wear and tear of machine or equipment parts, which can be eliminated to a large extent by regular inspections. Breakdown maintenance is carried out only when the machine cannot carry out its function any longer.

1.3.2 Preventive Maintenance:

Preventive maintenance is any step taken to prevent troubles before they occur (Onwualu,1996; Dodson 1994; Nkakin and Etenero, 2016). The key to preventive maintenance is the tractor operator. There is a great deal of difference between an operator and a person who merely operates a tractor. A tractor operator is one who is familiar with the tractor.

A careful tractor operator needs correct information, experience, and desire to succeed with preventive maintenance. The practice of preventive maintenance usually comes about as a result of experience gained in operating and maintaining the tractor. These experiences are often costly because of the high cost involved in unnecessary repairs.

1.4 Effect of Non-availability of Agricultural Machinery on Agricultural Production:

Agricultural operations are time specific. Timeliness is important in all its operations. A faulty agricultural machine is not available to perform its regular operations. This will seriously affect the farmer's operations and eventually his agricultural output. Failures of national policies and programmes on mechanization of agriculture in the country are attributable to absence of strategic plans for agricultural machines and equipment repair and maintenance. Strategic plans have a long-term focus and it addresses issues related to the organization's business objectives. Maintenance strategy is an integrated system that is needed by corporate management to highlight the significance of a particular piece of equipment that impacts on particular types of repair and maintenance work (Adama and Onwualu, 2010; Lahiri *et al*., 2008).

Nigeria is endowed with about 79 million hectares of arable land and less than half of which is under cultivation and highly diversified ecological conditions suitable for the production of a wide range of agricultural products (Eni, 2008). It is estimated that her potential for crops, livestock and fishery remain enormous, especially buoyed by water supply level of about 267 billion cubic meters of underground water: an annual rainfall range of 300mm to 400mm, and potential irrigable area of 3.14 million hectares with only seven percent of which is utilized (Eni, 2008). These enormous numbers of hectares require large number of agricultural machines and implements to be cultivated.

1.5 Mechanization of Agriculture in Nigeria:

1.5.1 Programmes by Governments to boost food production:

Ogbulafor (1999) reported that prior to Nigeria independence in 1960, agriculture contributed more than 70 percent of the Gross Domestic Product (GDP) and was the country's leading foreign exchange earner. Today agriculture's contribution to GDP hovers around 40 percent and was even as low as 20 percent at a point. Thus, agriculture's share of foreign earning, have been crowded out by that of crude oil. Farm settlements were established by the Okpala administration in Eastern Region at Omasi, EhaAmufu, Ikom, Igbariam, Ohaji, and Boli where mechanized farming was practiced. Most of agricultural operations were mechanized. Tractors were employed for tillage, haulage and spraying of chemicals, bulldozers were used for land clearing operations, construction of roads etc. The result of these was that food and agricultural raw materials were surplus both for human and animals' consumption, also raw materials were abundant for the industries and enough remained for exportation.

However, following the oil boom of the 1970's in Nigeria, agricultural industry commenced to witness drastic decline due to heavy investment in developing the infrastructure associated with oil sector (Nwuba, 2008). Also, the youths who are strong and useful for agricultural production in the rural areas where agriculture is practiced started to massively migrate to urban centers for employment; thus leaving the tough agricultural production for the aged who are no stronger enough for agricultural production (Odigboh, 2008; Musa et al., 2011). Other debilitating factors which combined in making Nigeria's agricultural output uncompetitive in both the domestic and international markets significantly reduced the attraction of agriculture as a sustainable source of livelihood and viable business include low output, policy inconsistencies, inefficient and outmoded production techniques, low quality produce, heavy post-harvest losses, absence of access to quality agricultural inputs, limited value addition and facilities for credit, irrigation, processing and storage facilities, inadequate extension services and unskilled labor force (Onwualu *et al.,* 2006; Kienzle *et al.,*2013; Umeghalu *et al.,* 2012; Yakubu and Enaboifo, 2010).

Notwithstanding all these obstacles, Adesina (2011), noted that Nigeria still has the potential for not only, meeting her growing food needs but also to become an agro-powerhouse for the sub region and the world at large. It is arising from the above factors that the agriculture sector's performance is not impressive. Moreover, the steady increase in population of the country has called for urgent measures to increase food supply to avert famine.

Onwualu et al. (2006) defined agricultural mechanization as the development, introduction and use of mechanical assistance of all forms and at any level of technological sophistication in agricultural production (Onwualu et al., 2006; Adama, 2013, Jekayinka et al., 2015). Thus, the governments commenced to formulate policies and programmes at various times to address these challenges militating against agricultural sector such as: the 1975- 79 Operation Feed the Nation (OFN) of the Murtala Mohamed and Olushegun Obasanjo military administration, the Land Use Decree promulgated by the government to enhance land acquisition processes and the (1979-1983) Green Revolution introduced by Shehu Shagari administration. Under these programmes, various models of tractors and implement were imported by the Federal Government and sold to farmers at subsidized prices. However, most of these imported tractors and implement did not suit our local environment which was not taken into consideration during manufacturing. Other reasons include lack of spare parts, poor maintenance culture, age of the tractors and implement.

1.5.2 Tractor and Equipment Hire Scheme:

In line with tractor and equipment hiring scheme policy guidelines, Anambra State Government established Anambra State Tractor Hire Agency (ASTRAC) to enhance mechanization of agricultural practices in the State as a unit of the Agricultural Services Department in the State Ministry of Agriculture and Natural Resources. The tractor and equipment hiring outfit was laden with the following mandate:

1) To provide tillage operations for mechanized agricultural practices in the state in order to boost agricultural production.
2) To create enabling environment for Public Private Participation (PPP) in tractor and equipment hiring ventures.
3) To procure and maintain tractors and equipment and hire same to farmers in the state at subsidize rates.

All these programmes and policies were aimed at increasing agricultural products through mechanized systems. However, these government agricultural mechanization policies and programmes were fraught with abuses and corruption by the politicians who exploited the chances to enrich themselves. Also the rural component of agricultural production was not considered during the formulation of the policies. Under these policies, various models of tractors and implement were imported by the Federal Government and sold to farmers at subsidized prices. However, most of these imported tractors and implement did not suit our local environment which was not taken into consideration during manufacturing. The success of any policy or programme in agricultural production must take into cognizance the local variables such as soil, vegetation, climate, local farming system, culture, crops etc before coming up with the design for appropriate mechanization of agriculture in Nigeria (Odigbo, 1986).

One of these programmes was the introduction of Tractor and Equipment Hiring Scheme.

II. MATERIALS AND METHODS

2.1 Description of study area:

Anambra State lies approximately between $6^{0}20'$ North and $7^{0}00'$ East (en.m. Wikipedia org.) The State is an agrarian state, and is one of the states in South- East geo-political zone of Nigeria. The state occupies an area of about $4{,}844km^2$, with population estimated at about 11.4 million in 2020 (ANSG). The state is bounded in the North by Kogi and Enugu States and in the East by Imo and Abia States, on the South-East by Delta State. The State is generally low-lying without remarkable hills. The climate of the state is typically equatorial climate with two distinct seasons namely: rainy and dry seasons. The rainy season is often characterized by heavy thunderstorm and lasts between the months of April and October. At times, the wet season arrives as early as March and lasts till November (Oboli, 1975). The mean annual rain fall varies between 2250mm and 1500mm north of the zone. A bimodal rainfall pattern with a brief drop in rain fall known as "August Break" is often noticed in the State. Dry season starts from November and lasts till March. Annual potential evapotranspiration (PET) in the area stands between 1425mm and 1625mm. The State has an average maximum temperature range of $32^{o}c$ and average annual mean temperature of about $27^{o}c$ (Iloeje, 1971; Oboli, 1975).

More than 70 percent of the population in the study areas is resource poor farmers who grow between 0.5 to 5.0 hectares of farm holding in their crop dominated form of agriculture and often keep some livestock such as goats, pigs, sheep and poultry under a free range system.

FIGURE 1: Map of Anambra State showing Anambra West Local Government Area.

2.2 Methods of Data Collection:

Survey trips were made to the six predominant farming local government areas in the State namely: Ogbaru, Ayamelum, Orumba South, Awka South, Anambra East and Anambra West Local Government Areas for primary data collection. These areas are often referred to as the food basket zones of the State. The structured questionnaires were mainly administered to tractor operators in the field who are associated with tractors performance and challenges facing the scheme. Age of respondents and educational status, years of experience, nature and frequency of machinery breakdown, nature of repairs and maintenance, availability of spare parts, annual number of request for tractors services by farmers, cost of each farm operation, accessibility to farm machineries.

Secondary data were obtained from the records kept by the administrative office of Anambra State Agricultural Development Project (ADP) and from the State Ministry of Agriculture at Awka. Both the primary and secondary data collected were analyzed before reaching at the conclusion and suggestion offered in this study.

III. RESULTS AND DISCUSSION

3.1 Age of respondents:

TABLE 1

SHOWING AGE BRACKET OF THE RESPONDENTS.

S/No	Age (yrs.).	No. Of respondents	Percentage (%)
1.	20-30	15	15
2.	31-40	39	39
3.	41-55	46	46
		100	100

Table 1, shows that about 15% of tractor operators are within the age limit of between 20 and 30 years; about 39% of the operators are within the age bracket of 31 and 40 years while those between 41 and 55 years old are about 46%. This indicates that majority of the tractor operators are advanced in age and have enough experience as tractor operators.

3.2 Educational status of the respondents:

TABLE 2

SHOWING EDUCATIONAL STATUS OF THE RESPONDENTS.

Education	Educational status	Percentage
None	0	0
Primary	27	27
Secondary	61	61
Tertiary	12	12
Total	**100**	**100**

Table 2, indicates that all the tractor operators are educated. About 27% of the operators obtained primary school education, about 61% of the respondents acquired secondary school education while the remaining 12% of the respondents have tertiary education. This implies that the tractor operators are educated which will enhance their ability to read and understand necessary instructions that can enable them operate agricultural machines and equipment.

3.3 Years of Experience as Tractor Operator:

TABLE 3

SHOWING YEARS OF EXPERIENCE OF THE TRACTOR OPERATORS

S/No	Experience of Tractor Operators (Yrs.)	No. Of respondents.	Percentage of Respondents (%).
1	5– 10	21	21
2	11 – 20	43	43
3	20 – 30	36	36
		100	100

From data obtained during the study as shown in Table 3 above, about 21% of the operators have between 5 and 10 years of experience; about 43% of the respondents have between 11 and 20 years of experience while about 36% of the respondents have between 20 and 30 years of experience as tractor operator. Thus with majority of the operators above 40 years of age, it indicates that most of them have sufficient experience in tractor operating.

3.3.1 Inventory of the ADP tractors and implement between 2015 and 2018:

TABLE 4

SHOWING INVENTORY OF THE ADP TRACTORS AND IMPLEMENT FROM YEAR 2015 TO 2018:

Year	Machineries.	Total number of items purchased.	Functional machines & equipment	Non-functional Machines & Equipment
2015– 2018	Fiat tractors.	30	18	12
	Styr tractors.	50	33	17
	Disc plough	45	25	20
	Disc harrows	45	15	30
	Disc ridgers	24	9	15
	Trailers	14	9	5
	Planters	7	2	5
	Rice Threshers	25	15	10

Source: Administrative Office of ADP, Awka.

The inventory of Anambra State Agricultural Development Project Tractor and Equipment Hiring Service Unit is shown in Table 4 above. The table shows that between 2015 and 2018, the agency had 30 tractors consisting of different brands of Fiat tractors out of which 18of them are functional while 12 are faulty. Eight of the tractors require engine overhaul and four others require replacement of various spare parts and minor maintenance. Also, the Agency acquired 50 Styr tractors of different brands out of which 33 of them are functional while the rest 17 (seventeen) tractors have broken down. Furthermore, a good number of tractors were purchased by the State Government which was sold off to the public in fulfillment of government initiative to cede some tractors to farmers to encourage Public Private Participation (PPP) in the agricultural mechanization programme.

3.3.2 Status of Implement:

Also as shown in Table 4 above, out of 45 disc plough purchased, only 25 are functional while 20 are non-functional. Out of the 45 disc harrows purchased only 15 of them are available while 30 are faulty. The 24 disc ridgers purchased, only 15 are functional while the remaining 9 are faulty. The 7 seed planters owned by the outfit, only 2 of them are functional while 5 are faulty. The establishment had initially 25 rice threshers, however, the study shows that only15 of them are available while the remaining 10 are faulty; also out of the 14 trailers purchased by the outfit to enhance transportation of agricultural produce, only 9 of them are available while the remaining 5 are fault.

3.4 Frequency of tractors and equipment breakdown:

Table 5 below shows the frequency of tractors and equipment breakdown. The survey reveals that the frequency of the Agency's machinery breakdown and failure are relatively high and this can be attributed to several factors, such as: poor maintenance culture, unfavourable environmental condition, inadequate training of the operators, lack of spare parts, poorly cleared land on which the machines work, and lack of modern workshop and tools. Most of the imported machineries are refurbished and were not accompanied with their journals specifying their maintenance schedule. Moreover, the maintenance of the tractors are usually delayed or are never carried out at all especially when they are hired out to contractors who are more interested in their profit margin. As such, the machines are only maintained or repaired only when they breakdown. Scheduled periodic maintenance is not carried out on the machines resulting to unavailability of the tractors during most part of cropping period.

TABLE 5

NATURE AND FREQUENCY OF THE AGENCY'S TRACTOR AND EQUIPMENT BREAKDOWN.

Machines component	Frequency of break-down	Causes of breakdown	Average duration of breakdown	Replacement	Source of spare parts	Maintenance Nature	Average cost of repair (N'000)
Tractor steering ram oil leakage, hydraulic system failure	Not frequent	Hose blockage dirt in oil and inadequate maintenance	15-30days	Lack of spare parts	Imported	Break-down	50 and above
Worn out Clutch Plate/ Finger/ Release bearing	As above	Environmental factors.	As above	Lack of specialized tools	As above	As above	As above
Tyres bearing, fuel lift pump	Frequent	Stumps vibration, poor maintenance	As above	As above	As above	As above	As above
Disc plough bearing, disc bolt and blades disc hub	Frequent	Stumps environmental factors, poor maintenance& poorly cleared lands.	As above	As above	As above	As above	As above
Disc harrows, blades, bolts, disc bolts	Frequent	As above	As above	As above	As above	As above	As above
Disc harrows, blades, bolts, disc bolts	Frequent	As above	As above	As above	As above	As above	As above

Source: Administrative Office of ADP, Awka.

IV. CONCLUSION

The study shows that the services of Anambra State Tractor Hire Agency are poised to make positive impact on mechanization of agricultural practices in the state. The percentage of farmers who benefited from the services of the Agency significantly influenced the overall increase of farm output as well as increased farmers' farm holdings and income alike.

However, services like processing, storage and packaging are yet to be adequately addressed which would further boost agricultural productivity in the state.

The slow response to maintenance of tractors and equipment is still weighing down the operational capacity of the hire outfit leading to delay in agricultural operations at the instance of frequent breakdown of its machinery during the cropping season. This has pronounced disruption in the production programme of farmers thus, reducing the farmers overall output. Most agricultural operations are time specific.

V. RECOMMENDATIONS

1) The policy framework on which the Agency was established, like the subsidy regime should be strengthened with better understanding with all the critical stakeholders to provide for better implementation.
2) The existing workshops for repair and maintenance of the machines should be made more functional by adequately providing them with comfortable accommodation, tools, skilled and youthful personnel, spare parts and adequate funding by government.
3) Mobile workshops should be established in all the zones where the tractors are deployed to work. In this way, minor repairs and maintenance can be effected in the field without having to run to the workshops which may be far located. This will put the tractors and equipment in better form to perform more work especially during the cropping season while down time is minimized.
4) A good culture of preventive repairs and maintenance scheduled should be adopted to achieve prolonged machine service life and availability.
5) Government should purchase more tractors and equipment for the Agency to enable it serve more farmers per unit time within the cropping season as agricultural operations are time specific.
6) Government should adopt policies that allow farmers to hire tractors directly from the agency instead of hiring through contractors who are only interested in their profit margin at the expense of the fitness of the tractors.
7) Tractor operators should regularly be trained on the basic repair and maintenance requirement of the tractors they operate especially when new brand of tractors are introduced to the fleet.
8) Local blacksmiths should be trained in the act of forging and fabrication of some of the most frequent damaged implement which could not easily be sourced or supplied by sales agents or the manufacturers.
9) Importation of agricultural tractors and equipment should be based on local environment, availability of spare parts, experience of operators, cost of repair and maintenance.
10) Government should revive the moribund tractor assembly plants in the country for easy and available spare parts.

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Sustainable Farming Practices: Soil Health Cards as a Tool- A book Chapter

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Abstract— *The Indian economy and society depend heavily on agriculture. Approximately two thirds of the nation's people make their living either directly or indirectly from agriculture. The innovations of the Green Revolution in the 1960s made it possible to achieve food production self-sufficiency and transformed a nation experiencing a food deficit into one experiencing a food surplus. This resulted in a rebirth of agriculture centred on the adoption of intensive farming supported by the use of manures, fertilisers, pesticides, and assured irrigation, as well as high-yielding seed varieties. Chemical fertilisers were more well-liked by the high-yielding cultivars, and they eventually became a staple of Indian agriculture. Water conservation and effective usage, as well as soil health maintenance, are critical to the future food security of the planet. The largest source of nutrients for humans still comes from soils. Soil health is a direct indicator of human health.*

The focus of agricultural research has shifted recently to emphasize both food and nutritional security. The primary cause of the imbalance is thought to be the overuse of N fertilisers and the relatively low use of P and K fertilisers. In addition, India's fertilizer use has been rising over time. Nurturing the soil has become essential to improve its health and productivity. The Indian government introduced the soil health card programme in this regard. This is intended to encourage the implementation of fertiliser recommendations based on soil tests, which will help to sustainably maintain soil productivity while simultaneously increasing crop production.

Keywords— Agriculture, Indian Agriculture, Soil Health, Soil Testing, Soil Fertility, Soil Nutrition, Sustainable Agriculture, Food Security, Nutritional Security.

I. INTRODUCTION

The Soil Health Card scheme was launched by Government of India in 2015 andis endorsed by the Department of Agriculture and Co-operation under the Ministry of Agriculture and Farmers Welfare, Government of India. Under the programme, farmers receive soil health cards (SHCs) from the government that include crop-specific recommendations for the nutrients and fertilisers needed for every individual land holding. The goal of this is to assist farmers in increasing output by using inputs wisely. The Soil Health Card Scheme offers a qualitative evaluation of soil health and the necessary reclamation actions for soils which cause problems.

In addition to providing information on the specific nutritional status of each farmer's soil, the soil health card makes recommendations regarding the amount of fertiliser and soil amendments each farmer should use to preserve the long-term health and productivity of his or her soil. The programme aims to provide around 14 crore farmers nationwide with soil health cards every three years. It is being implemented through the Department of Agriculture of all the State and Union Territory Governments.

1.1 The stated objectives of soil health card scheme are as follows:

- To provide soil health cards, every three years, to all farmers in the nation, containing all the information related to fertilisation procedures that address nutritional deficiencies.
- To improve the functioning of Soil Testing Laboratories (STLs) by enhancing their capacity, including agricultural

students, and establishing a strong connection with the State Agricultural Universities (SAUs) and Indian Council of Agricultural Research (ICAR).

- To diagnose soil fertility-related limitations using universally standardised sample methodologies across all states.
- Examining and creating fertiliser suggestions at the block level in the districts that are being targeted.
- To develop and encourage soil test based nutrient management in the area for enhancing nutrient use efficiency
- To strengthen the ability of innovative farmers and employees at the area level to promote nutrient management techniques.

1.2 The unique features of SHC scheme are:

- ✓ Single, uniform, web-based software for generation of Soil Health Card in uniform format across the country in 22 local languages
- ✓ Sample tracking and alerts to farmers through SMS
- ✓ Automatic Fertilizer Recommendation calculations and micronutrient suggestions
- ✓ Fertilizer recommendations for Horticultural crops, based on age/ crop stage of the crop
- ✓ Organic carbon based fertilizers recommendations
- ✓ National database on soil health
- ✓ Dashboard
- ✓ Linkages to land record applications of states
- ✓ Integration with Common Service Centre (CSCs) portal for CSCs to enter data
- ✓ Interface for displaying Soil Health Card in Umang and Krishi Suvidha mobile Apps
- ✓ Various types of nutrient status reports
- ✓ Calculator for fertilizers dosages
- ✓ Success stories

II. SOIL HEALTH CARD PORTAL

The Soil Health Card Portal (http:// soilhealth.dac.gov.in) project was launched by Hon'ble Minister of Agriculture & Farmers Welfare on 15th July, 2015. The Soil Health Card Application is a work flow-based technology created by the National Informatics Centre that makes it easier for farmers nationwide to generate Soil Health Cards in a consistent and standardised manner. Soil samples are collected from fields of farmers on grid basis; 10 ha grid in rainfed areas and 2.5 ha grid in irrigated areas. The concerned officials record the samples' data and location details in the Application site, and an ID is produced specifically for each soil sample.

The developed mobile application can also be used to send the sample details. The mobile application automatically measures the latitude and longitude of the location where samples are taken, ensuring the accuracy of the data and the validity of the sample collection. Mobile application does not require net connectivity during sample details entry from the fields. As soon as internet connectivity is established, data is pushed and stored on the server.

The samples are tested in the labs and the test results are entered by the respective Soil Testing Lab officials. Based on the available nutrients in the soil, the crop-wise required quantity of nutrients are calculated using Soil Testing Crop Response developed by ICAR method or General Fertilizer Recommendations given by State Governments/ SAUs (State Agricultural Universities). The application then computes the appropriate crop-wise fertiliser quantities based on the required nutrients and prints the results on the Soil Health Card. The card also suggests the soil amendments that are required to eradicate micronutrient deficits.

2.1 Soil Health Card:

A soil health card is an in-depth report designed for a particular field that details the fertility status of the soil along with other significant soil factors that impact crop productivity. In addition to information on soil health, it also offers recommendations for applying fertilisers and amendments based on soil tests. Details in a Soil Health Card include-

- ✓ Information regarding Soil Fertility.
- ✓ Dosage of fertilizer application in crops.
- ✓ Information on soil amendments of saline or alkaline soil.
- ✓ Recommendation on integrated nutrient management.

2.2 How and where to get the Soil Health Cards

Farmers can simply bring representative soil samples from their farms to the closest Krishi Vigyan Kendra or State Agriculture University District Soil Testing Laboratory (STL). The sample can also be deposited to the Agriculture supervisor, Assistant Agriculture Officer for testing and to obtain the SHC. After analysis of the samples and interpretation, the recommendation made for the particular soil/field by the subject specialist. The State Agricultural University's Krishi Vigyan Kendra soil testing laboratory, along with the district soil testing laboratory, prepare the SHC, which farmers can either collect up in person or can send to their address.

2.3 Process of Soil Health Analysis and Distribution of Soil Health Cards

1. **Norms for Sampling**
   - ✓ Soil samples are drawn in a grid of 2.5 ha in irrigated area and 10 ha in rain- fed area with the help of GPS tools and revenue maps.
2. **Collection of Soil Samples**
   - ✓ Soil samples are typically collected twice a year, following the harvesting of the Rabi and Kharif crops, respectively, or when there is no standing crop in the field.
   - ✓ The sample is collected by the State Government using personnel from their Department of Agriculture or an external agency. The local agriculture and science college students may also be involved by the state government.
   - ✓ Soil Samples are collected by a trained person from a depth of 15-20 cm by cutting the soil in a "V" shape. A portion of it is often taken as a sample after being fully mixed and collected from the field's four corners and centre.
   - ✓ The selected samples are coded and sealed in a bag. The soil test laboratory receives it after that for examination.
3. **Soil Testing**
   - ✓ Soil samples are tested as per the approved standards for all the 12 parameters.
4. **Soil test report and printing SHC Portal**
   - ✓ After analysis, test results and relevant recommendations are uploaded into SHC portal (www.soilhealth.dac.gov.in). The reports are available to the general public.
   - ✓ Information on the progress of collecting and distributing soil samples, MIS reports, studies focused on farmers, Soil Maps, technical documentation and recommendations, access to mobile applications, and more are available on the SHC Portal.

III. SOIL HEALTH CARD MOBILE APPLICATION:

Soil Health Card Mobile application was launched on the occasion of World Soil Day – 5th December 2017 in *Jhajjar*, Haryana. This app was developed by *Krishitantra*, is a useful tool for managing soil health data, collecting soil samples, and conducting testing for Village Level Entrepreneurs (VLEs) and Soil Testing Laboratories (STLs).

- ✓ It makes visiting farmers' locations and scanning QR codes for soil sample collection easier. This guarantees precise sample collection while streamlining the procedure.
- ✓ It facilitates simple farmer registration and plot surveying, giving users the ability to effectively monitor and control the status of soil samples.
- ✓ It integrates with third-party soil-test service providers, enabling users to conduct tests using their preferred provider's apps. Subsequently, the soil test findings can be effortlessly entered into the system by government laboratories, guaranteeing smooth data administration.
- ✓ In addition, it provides a number of other helpful features like access to FAQs and user manuals, the ability to submit and track claims for soil testing services, and bilingual support.

3.1 Progress of SHC Scheme:

- In Cycle- I (2015 to 2017), 10.74 crore and in Cycle- II (2017 to 2019), 12.19 crore grid based Soil Health Cards have been distributed to farmers.
- In Model Village Programme (2019-20), 23.71 lakh and during the year 2020-21, 11.52 lakh land holdings based Soil Health Cards have also been distributed to farmers.

The "Development of Model Villages Programme (MVP)" pilot project was launched in 2019–20, which came after cycles I and II of the Scheme. Under this project, farmers were encouraged to work together to collect samples and evaluate their potentially cultivable soil. One village per block was adopted for land holding based soil testing and organization of larger numbers of demonstrations in the adopted villages.

3.2 Soil Health Card (SHC) Scheme progress in year 2023-2024:

Since, 2014-15, total 8272 Soil Testing Labs (1068 Static Soil Testing Labs, 163 Mobile Soil Testing Labs, 6376 Mini Soil Testing Labs and 665 Village Level Soil Testing Labs) have been established across the country.

- Challenges with Soil Health Card Scheme
- Inadequate soil testing infrastructure.
- The Soil Health Card does not include microbiological activity or moisture retention, two crucial components.
- Many farmers are unable to comprehend the information and, as a result, are unable to implement the advised procedures.
- A few crucial indications are missing, such as agricultural history, soil moisture or water resources, soil colour and texture, slope, depth, and microbiological activity.
- A lack of coordination between farmers and agricultural extension agents.
- Soil variability has no bearing on the number of soil samples per unit area.
- Only soil colour is listed under physical and biological attributes on the soil health card, which focuses mostly on chemical nutrient indicators

Soil Health Card scheme has been merged in Rashtriya Krishi Vikas Yojana (RKVY) cafeteria scheme as its one component under name 'Soil Health & Fertility' from the year 2022-23.

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Effects of Glyphosate on Yield and Shelf Life of Yam: A Case Study in Wulensi in the Nanumba Traditional Area, Ghana

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Abstract— *This study was undertaken to elucidate the effect of glyphosate on the soil mycoflora of yam farms and yam rots as a follow up on a previous study which suggested that glyphosate use had no effect on yam rots as held by farmers. This study was set up at the field level and in the laboratory to investigate these concerns. Two yam varieties; "laribako" and "olodo" were grown in a replicated control trial design under the conditions of chemical weed control (use of glyphosate) and manual weed control in three replicate sites in the Wulensi traditional area of the Nanumba south district. The transient effect of glyphosate on fungal population and diversity were determined by serial dilution method on Cooke's media. Combined methods of soil plate fungi isolation and food poison was used to determine the effect of normal and double the normal rate of glyphosate application on fungal population and diversity. Fungal species belonging to the genera Aspergillus, Fusarium, Mucor, Penicillium, Rhizopus, Rhodotorula and Trichoderma were isolated. The positive control (fungicide) totally inhibited fungal growth. Generally, there were no significant differences ($P \leq 0.05$) among the fungal population recorded for the glyphosate treated soils and the negative control (water). The glyphosate treated soil initially recorded a lower fungal population, which subsequently increased with passing days. The recorded fungal population ranged from 3.6×10^5 to 7.7×10^5 CFU/g for 10 days old glyphosate treated soil and non-treated soil respectively. The normal and double the normal rate of glyphosate application did not significantly ($P \leq 0.05$) affect the fungal population among the various treatments, but influenced fungal diversity over a short period of time. The study revealed after the storage period, that there was no difference ($P > 0.05$) in rots between yam treated with glyphosate herbicide and yam manually weeded. The study further revealed that glyphosate application at the recommended rate had no adverse effect on the mycoflora of the soil under consideration; hence did not distract the natural mycoflora of the soil which could have resulted in the proliferation of fungal pathogens causing yam rot.*

Keywords— fungi, glyphosate, herbicide, soil, yam.

I. INTRODUCTION

The commercialization of farming in Ghana coupled with the dwindling numbers of farm level workers, has led to the adoption of herbicides in crop production. Yam farmers in particular, have over the years, relied on herbicides for weed control on their farms. Despite the huge relief brought to the yam subsector through the use of herbicides, there are concerns regarding the quality of yam under the use of herbicides. A section of the public believes that the use of these herbicides makes the yam tuber susceptible to rots.

Yam tuber rot a major post-harvest challenge in yam production reduces the quality and quantity of stored yam tubers: resulting in huge economic losses. Among the various varieties of yam, tubers of Laribako have been documented as the most susceptible to rot (Wumbei et al.,2019; Demuyakor et al., 2013). Yam tuber rot pathogenic fungi including *Aspergillus flavus, A. niger, A.*

oryzae, Botryodiplodia theobromae, L. theobromae, Fusarium culmorum, F. oxysporum, F. moniliforme, Penicilium spp, *Rhizoctonia solani, Rhizopus stolonifera* and *Sclerotium rolfsii* (Wumbei et al., 2022; Dania et al., 2020). These fungi are normal mycoflora of soil but under certain conditions have the potential of becoming opportunist plant pathogens. Since yam tubers develop in the soil, several soil microbes including fungi exist on yam tuber skin as normal mycoflora, some of which may become pathogenic causing yam tuber rot during storage.

Herbicide application has the potential of influencing plant disease development by either enhancing the resistance or susceptibility of plants to diseases (Hammerschmidt, 2018). Also, the application of a herbicide such as glyphosate may reduce the population of beneficial soil microbes and increase that of soil borne pathogens which can facilitating the risk of disease development in crops where glyphosate was previously applied; especially, when the plants are planted too soon after glyphosate application (Hammerschmidt, 2018). The rate at which glyphosate is applied can influence its effect on plant cultivated on glyphosate applied lands (Van Bruggen et al., 2021). Researchers have evaluated the normal and double the normal rate of glyphosate application on soil microbial community and concluded that, although the composition of soil microbes may be disrupted, the microbial community seem to recover within a short period of time (Vázquez et al., 2021; Lupwayi et al., 2020). The long-term application of glyphosate in no-till systems only caused minor changes in soil microbial communities which seem to recover with time (Lupwayi, et. al., 2020; Arango et al., 2014). According to Kepler et al. (2020) and Spinelli et al. (2021) glyphosate application does not make crops susceptible to diseases, especially when the crops are planted a few days after application of glyphosate. This is because glyphosate does not persist in soil as residue since it is readily degraded by some soil microbes (Spinelli et al., 2021, Haney et al., 2000).

An initial study was conducted to assess the impact of glyphosate application on yam tuber storability. This was conducted using a replicated control trial design with two yam varieties in three locations in the Wulensi traditional area, the result of which was suggestive that the herbicides are not responsible for yam rots. The current study is therefore a repetition of the earlier study with an aspect of soil health analysis using fungi as bioindicator to determine if the application of glyphosate distorted the normal ecology of mycoflora in BBN, NKG and SDB soils in favour of pathogenic once aiding in yam tuber rot.

1.1 Objectives:

The main objective of the study was to determine if the use of herbicides contributes to yam tuber rots. The other objectives were to determine the influence of herbicides use on the yield of yam and whether the use of herbicides can lead to residue problems in yam.

II. MATERIALS AND METHODS

The research adopted a mixed method approach. It included a field trial and laboratory analysis. The purpose of the field trial, was to investigate the effect of the glyphosate herbicide on yam rots while the purpose of the laboratory analysis was to determine if there is any effect of the glyphosate herbicide on the soil microflora of yam farms.

2.1 Study Area:

The field experiment was conducted in Wulensi (Figure 1) in the Nanumba south district (8^0 39'N 0^0 01'W) in the Northern region of Ghana. The study area experiences unimodal rainfall of 1,268 mm per annum with most of the rain falling within 6 months *i.e.* between May and October with a peak in August and September. Temperatures are usually high ranging between 29 and 40 ^{0}C.

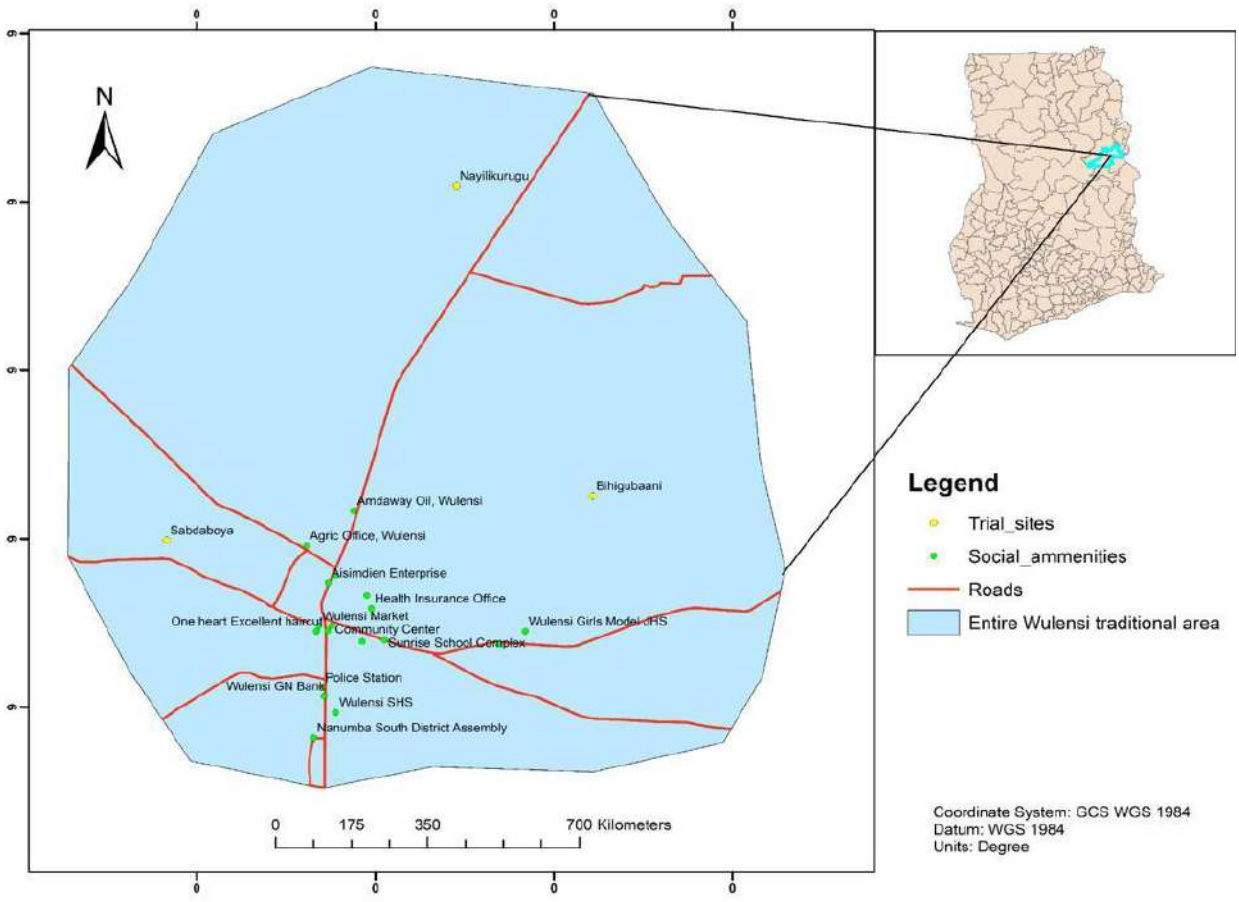

FIGURE 1: Study area

2.2 Field Trial:

The field experiment was conducted using a replicated cotrol trial design (Figure 2). Two yam varieties; "laribako" an early maturing variety and "olodo" a late maturing variety were used in the experimental set up. These yam varieties are widely grown by farmers of the area, but "laribako" is most preferred (Wumbei et al., 2019). Four treatments in three replicates were evaluated in tandem. They were grown following good agricultural practices such as: correct site selection, good land preparation, early planting and good spacing and staking. Three sites were purposefully selected in the Wulensi traditioal area. These sites include "Bihigubaani" in Wulensi east, "Nayilikurugu" in Wulensi North and "Sabdaboya" in Wulensi West. At each of the three sites, two treatments (plots treated with herbicides) and two controls (plots manually weeded) were evaluated, thus giving a total of six treatments and six controls. At each of the sites, the design was arranged in such a way that the treatment plots were placed on the down slope of the land while the control plots were placed on the upper slope of the land as in Wumbei et al., 2019. This, in essence, was to avoid pesticides contamination of the control plots during runoff.

BBN

LC	OC
LS	OS

NKG

LC	OC
LS	OS

SDB

LC	OC
LS	OS

FIGURE 2: Experimental Design

BBB = Bihigubaani, NKG = Nayilikurugu, SDB = Sabdaboya, LC = Laribako control, LS = Laribako sprayed, OC = Olodo control, OS = Olodo sprayed

2.3 Soil sample collection for the determination of microflora:

Soil sampling was done according to the method of Ackerson (2018) with some modification. For each field under study, composite soil sample was obtained along a "W" pattern path. The soil sample was obtained at a depth of 15 cm with a hand trowel. At each of the sub soil location, crop residue and other debris were removed before the sample was collected. Five sub soil samples each of volume 1000 cm^3 were collected at equidistance on each side of the "W" pattern path; resulting in a total of 20 sub soil samples per field. These sub soil samples were then pooled together in a bucket to obtain a single composite soil. This was then mixed thoroughly with a hand trowel to obtain a homogeneous mixture. About 1000 cm^3 of the homogeneously mixed soil sample was kept into a sample bag, labelled and taken to the Spanish Laboratory of the University for Development studies.

2.4 Media preparation:

Cooke's media was formulated by a mixture of 10 g of glucose, 5 g of peptone, 1 g of KH_2PO_4, 0.5 g of $MgSO_4.7H_2O$, 0.035 g of Rose Bengal, 0.35 g of amoxicillin, 15 g of agar and 1000 ml of distilled water. The mixture was thoroughly mixed on a hot electric plate with a magnetic stirrer. It was then autoclaved at 121^oC at 1.02 kg/cm^3 for 15 minutes.

2.5 Determination of fungal population:

Fungal population was determined using the serial plate dilution method (Bisen, 2014). One gram of the soil sample was added to 9 ml of sterile distilled water in a test tube and agitated for 2 minutes on an orbital shaker to give a homogeneous soil suspension. This was then serially diluted to10^{-3} and used for the study. One milliliter of the 10^{-3} diluted soil suspension was poured into a Petri dish (9 mm diameter) and 20 ml of molten Cooke's media added. The mixture was then swirled for the uniform spreading of the soil suspension in the medium. This was then inoculated at room temperature for 5 days for fungal growth. Each treatment was replicated thrice. The occurrence of each fungal species and colony forming units were determined with the formulae (Bisen, 2014):

$$\text{Occurrence (\%)} = \frac{Average\ number\ of\ colonies\ of\ a\ species}{Average\ number\ of\ colonies\ of\ all\ the\ fungal\ species} \times 100 \quad (1)$$

$$\text{Determination of CFUs/g dry soil} = \frac{Average\ number\ of\ colonies}{Dry\ weight\ of\ soil} \times Dilution\ factor \quad (2)$$

The fungi that grew were each sub-cultured on fresh Cooke's medium. The sub culturing continued until pure cultures of each fungus isolate obtained.

2.6 Effect of glyphosate application rate on soil mycoflora:

This was determined by a combination of the soil plate method (Bisen, 2014) for isolating fungi from soil and the conventional food poisoned method. About 0.0015 g of the soil sample was poured into a Petri dish. To this 5 ml of glyphosate at the normal and double the normal application rates were added separately to the soil sample and 20 ml of molten Cooke's media added, swirled and allowed to solidify. The plates were then incubated at room temperature for 7 days for fungal growth. The positive and negative control plates were amended with sterile distilled water and the synthetic fungicide (mancozeb 640g/kg + metalaxyl 80g/kg WP) respectively.

2.7 Isolation of fungal pathogens from rotten yam tubers:

Laribako tubers with rot symptoms were thoroughly washed with tap water. About 3 mm^3 fragment tissues of yam tubers consisting of both healthy and diseases portions were obtained. These were surface sterilized by dipping them in 70% alcohol for 2 min, and then washed in three changes of sterile distilled water. The tissues were then blotted dry in a laminar air flow chamber. The tissues were then plated on Cooke's' media in a 9 cm Petri dish and then incubated under room temperature. The fungi that grew were subculture until pure cultures of each fungus obtained.

2.8 Identification of fungal species:

Each fungus was identified based on its cultural and morphological characteristics in comparison with criteria documented by Barnett and Hunter (2006). A binocular microscope was used for observing the morphology of each fungus.

2.9 Pathogenicity test:

Healthy yam tubers were washed under running tap water to remove all debris. The tubers were then surface sterilized by dipping them in Sodium hypochlorite for 1 min. after which they were washed in three changes of sterile distilled water, and then blotted dry in a laminar air flow chamber. A 5 mm cork borer was used to remove about 3 mm deep tissue from the yam tuber. A 5 mm mycelia disc of the test fungus was placed in the hole created in the yam tuber and the removed yam tissue replaced on it. The wound was then sealed with Vaseline. The inoculated yam tubers were then incubated for 14 days under room temperature for rot development. Rot development was assessed by a cross section cutting of the yam tuber along the inoculated disc. The control yam tuber was inoculated with 5 mm mycelia disc of Cooke's' media.

III. RESULTS

3.1 Hypothesis Tests:

A statistical analysis of one sample t-test was conducted to test the difference in rotting between glyphosate treated and manually weeded yam, the differences in rotting between the "laribako" and the "olodo" yam varieties, the difference in yield between herbicides treated and manually weeded yam, the difference in yield between the "laribako" and the "olodo" yam varieties and difference in soil microflora between glyphosate treated soils and control soils. The results of the analysis are presented in table 1.

TABLE 1
HYPOTHESIS TESTS

Test	Observed t	Degrees of Freedom	P value	Decision
No difference in rots between glyphosate treated and manually weeded yam	-1.387	5	0.224	Accept H_0: glyphosate does not have influence on yam tuber rots
There was significant difference in rots between "Laribako" and "Olodo" yam varieties	-3.371	5	0.02	Reject H_0: Yam variety has significant influence rots/shelf life
No difference in yield between herbicides treated yam and manually weeded yam	-1.732	5	0.144	Accept H_0: Herbicides do not have influence on the yield of yam
No difference in yield between "Laribako" and "Olodo" yam varieties	-0.655	5	0.542	Accept H_0: Yam variety has no significant influence on yield
No difference in microflora between glyphosate treated and manually weeded soils	-6.124	5	0.989	Accept H_0: glyphosate does not have influence on soil microflora on yam farms

3.2 Mycoflora of BBN, NKG and SDB soils before and after glyphosate application:

Several fungal species were isolated from the fields of BBN, NKG and SDB prior to glyphosate application for weed management before planting the yam crops and at the time of harvest after glyphosate was applied (Table 1). Significant differences ($P \leq 0.005$) were recorded among the percentage occurrences of the fungal species isolated for the different fields of BBN, NKG and SDB at the various times of sampling the soil (Table 1).

TABLE 1
OCCURRENCE OF FUNGI ON BBN, NKG AND SDB SOILS BEFORE AND AFTER GLYPHOSATE APPLICATION AT HARVEST

Fungi	Occurrence %							
	BBN			NKG			SDB	
	Before	After		Before	After		Before	After
Alternaria alternata	0.00^{a}	0.00^{a}		0.00^{a}	0.00^{a}		0.00^{a}	1.62^{ab}
Aspergillus flavus	0.00^{a}	0.00^{a}		5.14^{ab}	7.82^{a}		7.44^{ab}	7.38^{bc}
Aspergillus niger	13.40^{cd}	16.55^{e}		14.54^{cd}	16.38^{b}		13.86^{bc}	11.71^{cd}
Aspergillus oryzae	12.99^{cd}	14.70^{de}		22.23^{e}	0.00^{a}		17.81^{c}	21.51^{ef}
Aspergillus tamarii	12.61^{bcd}	13.10^{cde}		21.24^{de}	23.93^{bc}		0.00^{a}	0.00^{a}
Fusarium oxysporium	4.82^{abc}	6.77^{abc}		0.00^{a}	0.00^{a}		0.00^{a}	0.00^{a}
Fusarium poae	0.00^{a}	0.00^{a}		0.00^{a}	0.00^{a}		6.17^{ab}	6.92^{bc}
Mucor spp	0.00^{a}	0.00^{a}		3.05^{ab}	1.68^{a}		0.00^{a}	0.00^{a}
Penicillium citrinum	9.21^{bc}	0.00^{a}		0.00^{a}	0.00^{a}		0.00^{a}	0.00^{a}
Penicillium funicolosum	6.96^{abc}	8.25^{bcd}		0.00^{a}	0.00^{a}		15.77^{bc}	21.85^{f}
Penicillium glabrum	0.00^{a}	0.00^{a}		0.00^{a}	0.00^{a}		0.00^{a}	2.74^{ab}
Penecillium italicum	3.94^{ab}	6.35^{abc}		0.00^{a}	0.00^{a}		0.00^{a}	0.00^{a}
Penicillium variabile	4.81^{abc}	5.03^{ab}		8.69^{bc}	7.28^{a}		14.93^{bc}	10.36^{cd}
Rhizopus stolonifera	0.00^{a}	1.07^{a}		0.00^{a}	0.00^{a}		2.19^{a}	0.00^{a}
***Rhodotorula* spp**	19.06^{d}	16.56^{e}		0.00^{a}	17.51^{bc}		21.82^{c}	15.91^{de}
Trichoderma harzianum	11.80^{bcd}	11.62^{bcde}		25.10^{e}	25.40^{c}		0.00^{a}	0.00^{a}
F(pr)	**<0.001**	**<0.001**		**<0.001**	**<0.001**		**<0.001**	**<0.001**

Mean in the same column followed by different letter(s) are significantly different as determined by Tukey's multiple-range test.

3.3 Transient effect of glyphosate application on soil mycoflora:

Table 2 shows the effect of glyphosate application on soil mycoflora over a period of 20 days.

A higher CFU/g of fungi was recorded before glyphosate application treatment for each of the soil obtained from BBN (7.6×10^5 CFU/g), NKG (6.3×10^5 CFU/g) and SDB (7.7×10^5 CFU/g) than their respective treatments of 5, 10, 15 and 20 days after glyphosate was applied. For each of the soil samples, there was a progressive decrease in the recorded fungi CFU/g before glyphosate application up to 15 days after the application and an increase in fungi CFU/g at 20 days after glyphosate application. For each of the soil sample, the CFU/g recorded at 20 days after glyphosate application was lower than those recorded before the application. The BBN and SDB soil samples each recorded no significance difference ($P \leq 0.05$) for the treatments of before and at 5,10,15 and 20 days after glyphosate application. However, for the SDB soil sample, the CFU/g of fungi recorded for before glyphosate application (7.7×10^5 CFU/g) was not significantly higher than that of 20 days after application but both were significantly higher than those of days (4.5×10^5 CFU/g), 10 days (3.6×10^5 CFU/g) and days (4.3×10^5 CFU/g) after the application.

TABLE 2
EFFECT OF GLYPHOSATE ON SOIL MYCOFLORA OVER A PERIOD OF 20 DAYS

Treatment	Colony Count (CFU/g)		
	BBN	NKG	SDB
BGA	7.6×10^{5a}	6.3×10^{5a}	7.7×10^{5b}
5DAGA	5.0×10^{5a}	4.9×10^{5a}	4.5×10^{5a}
10DAGA	4.9×10^{5a}	5.0×10^{5a}	3.6×10^{5a}
15DAGA	5.4×10^{5a}	5.3×10^{5a}	4.3×10^{5a}
20DAGA	6.3×10^{5a}	5.4×10^{5a}	6.6×10^{5b}
F(pr)	**0.077**	**0.612**	**<0.001**

Mean in the same column followed by different letter(s) are significantly different as determined by Tukey's multiple-range test

Key: BGA = before glyphosate application, 5DAGA = 5 days after glyphosate application, 10DAGA = 10 days after glyphosate application, 15DAGA = 15 days after glyphosate application, 20DAGA = 20 days after glyphosate application.

3.4 Mycoflora present before and after glyphosate application:

Table 3 shows the transient effect of glyphosate application on the presence and absence of various fungal species before and after glyphosate application over 20 days period. Fourteen fungal species belong to the genera *Aspergillus, Fusarium, Mucor, Penicillium, Rhodotorula, Rhizopus* and *Trichoderma* were isolated from the soil before the application of glyphosate. Five days after the application of glyphosate, fungal species belonging to the genera *Aspergillus, Fusarium, Mucor* and *Rhodotorula* were isolated. Ten and 15 days after glyphosate application each recorded nine fungal species isolates belong to the genera *Aspergillus, Fusarium, Penicillium, Rhodotorula* and *Rhizopus* with the exception of *Trichoderma* which was not recorded for 10 days but 15 days after glyphosate application. At 20 days after glyphosate application, fourteen fungal species belonging to the genera *Aspergillus, Fusarium, Mucor, Penicillium, Rhodotorula, Rhizopus* and *Trichoderma* were isolated from the soil.

TABLE 3
MYCOFLORA PRESENT BEFORE AND AFTER GLYPHOSATE APPLICATION OVER A PERIOD OF 20 DAYS

Fungi	Treatment				
	BGA	5 DAGA	10 DAGA	15 DAGA	20 DAGA
Aspergillus flavus	+	+	+	+	+
A. niger	+	+	+	+	+
A. oryzae	+	+	+	+	+
A. tamarii	+	-	+	-	-
Fusarium oxysporium	+	+	-	+	+
F. poae	+	-	+	-	+
Mucor spp	+	-	-	-	+
Penicilium citrinum	+	-	+	-	+
P. funicolosum	+	-	-	+	-
P. italicum	+	-	-	-	+
P. variabile	+	-	+	+	+
Rhodotorula spp	+	+	+	+	+
Rhizopus stolonifera	+	-	+	+	+
Trichoderma harzianum	+	-	-	+	+

Key: + = present, - = absent, BGA = before glyphosate application, 5DAGA = 5 days after glyphosate application, 10DAGA = 10 days after glyphosate application, 15DAGA = 15 days after glyphosate application, 20DAGA = 20 days after glyphosate application.

3.5 Effect of glyphosate application rate on soil mycoflora:

Table 4 shows the effect of the normal and double the normal application on soil mycoflora. There was total fungal growth inhibition for the positive control treatments of BBN, NKG and SDB soils. For the BBN soil the highest and lowest fungal population mean were recorded for the negative control (162.67) and Gly@NAR (142.33) treatments. The fungal population mean recorded for the BBN negative control treatment (162.67) was significantly higher ($P \leq 0.05$) than those of Gly@NDAR (132.67) but not Gly@NAR (142.33). NKG soil recorded a higher fungal population for the negative control treatment (152.00), followed by Gly@NAR (139.67) and then Gly@NDAR (137.67). There were no significant differences ($P \leq 0.05$)

in the fungal population recorded for NKG soil for Gly@NAR (139.67), Gly@NDAR (137.67) and the negative control treatments. The least and highest fungal population for the SDB soil was recorded for the Gly@NDAR (136.67) and negative control (177.33) respectively.

TABLE 4
EFFECT OF RATE OF GLYPHOSATE APPLICATION ON SOIL MYCOFLORA (COLONY COUNT/PETRI PLATE)

Treatment	Colony count		
	BBN	**NKG**	**SDB**
Positive control	0.00^{a}	0.00^{a}	0.00^{a}
Gly@NAR	142.33^{bc}	139.67^{b}	165.67^{bc}
Gly@NDAR	132.67^{b}	137.67^{b}	136.67^{b}
Negative control	162.67^{c}	152.00^{b}	177.33^{c}
F(pr)	**< 0.001**	**< 0.001**	**< 0.001**

Mean in the same column followed by different letter(s) are significantly different as determined by Tukey's multiple-range test

Key: Gly@NAR=Glyphosate applied at normal rate, Gly@NDAR=Glyphosate applied at double normal rate

3.6 Yam tuber rot fungal pathogens:

The following fungi were isolated from the rotten *Laabako* tubers; *Aspergillus niger, A. flavus, Botryodiploidia theobromae, Fusarium oxysporium* and *Rhizopus stolonifer*. The pathogenicity test confirmed each of these fungi as pathogens causing the tuber rot of Laabako.

3.7 Yield and Tuber Loss Due to Rots:

Table 5 presents information on yield across the trial sites and tuber rots during storage. In terms of yield, on all the fields, the olodo variety slightly did better than the laabako variety, but within variety there was no significant difference ($P<0.05$) between the sprayed and not sprayed plots at all the trial sites (NKG, BBN and SDB). In terms of rots, laaako from all the fields recorded more rots at storage the olodo variety. Within each variety, the laaako not sprayed recorded more rots than laaako sprayed, while there was no significant difference ($P<0.05$) between olodo sprayed and olodo not sprayed, except at the BBN site where the controlled plot recorded 11% rots as against 0% rots of the sprayed plot.

TABLE 5
LEVELS OF ROTTING AD YIELD

TREATMENT	No of tuber/Plot @ harvest	No of tuber/ha @ harvest	Weight (kg/plot) @ harvest	Weight (kg/ha) @ harvest
NKG LNS	65	2275	117	4095
NKG LS	68	2380	92	3213
NKG ONS	64	2240	98	3427
NKG OS	70	2450	126	4410
BBN LNS	71	2485	105	3690
BBN LS	63	2205	113	3969
BBN ONS	46	1610	83	2898
BBN OS	84	2940	151	5292
SDB LNS	69	2415	93	3260
SDB LS	64	2240	86	3024
SDB ONS	53	1855	79	2755
SDB OS	64	2240	115	4032

TREATMENT	No of tubers/ha @ Storage	Weight (kg/ha) @ Storage	Percentage tuber loss in storage	Percentage weight loss in storage
NKG LNS	52	2366	20	42
NKG LS	60	2100	12	35
NKG ONS	64	2957	0	14
NKG OS	70	2940	0	33
BBN LNS	56	1960	21	47
BBN LS	53	1892	16	52
BBN ONS	41	1292	11	55
BBN OS	84	3450	0	35
SDB LNS	55	1887	20	42
SDB LS	61	1922	5	36
SDB ONS	53	2115	0	23
SDB OS	63	2712	2	33

NB: NKG = Nayilikurugu, BBN = Bihigubaani, SDB = Sabdaboya, LS = Laabako sprayed, LNS = Laabako not sprayed, OS = Olodo sprayed, ONS = Olodo not sprayed

IV. DISCUSSION

The general occurrence of similar fungal species isolated from the soils of BBN, NKG and SDA before the application of glyphosate to the fields and after the application at harvest time indicated that the application of glyphosate had innocuous effect on the soil mycoflora. This conforms to the findings of Kepler et al., (2020), Spinelli et al. (2021) and Benslama and Boulahrouf (2013) that applied glyphosate does not persist in soils as residue but rather have temporal effects on soil microbial community

Although more fungal species were recorded in the untreated glyphosate soil than the treated once, the number of isolated fungal species increased progressively from 5 to 20 days after the application of glyphosate. This showed that the applied glyphosate only had a temporal effect on the diversity of the soil mycoflora. Also, the no significant differences observed for the transient effect of glyphosate application on the colony forming units of the mycoflora of the untreated and the treated glyphosate soil over a period of 20 day indicated a recovery of the soil mycoflora with the passing of time. This confirmed the findings of Zain et al. (2013) that glyphosate application may have a temporary effect on soil mycoflora diversity which may recover within 10 to 20 days.

There were no significant differences between the fungal populations recorded for the normal and double the normal rate of glyphosate treated soil, implying that these rates of glyphosate application did not have a detrimental effect on the mycoflora of the soil. This supports the finding of Haney et al. (2000) that microbes have a high efficiency of degrading glyphosate to the extent that, even glyphosate application at excessive rates does not have adverse effect on soil microbial activities. the total inhibition of the soil mycoflora recorded for the synthetic fungicide treatment and the fungi occurrences recorded for the normal and double the normal rate glyphosate treated soils indicated that glyphosate did not have fungicidal activity on the soil mycoflora. This agrees with the report of Morjan et al. (2002).

Laabako generally recorded more tuber rot during storage than olodo. This supports the report that that Laabako tubers are more susceptible to rot during storage than those of olodo variety (Wumbei, 2019, Macdonald et al., 2013). The fungi *Aspergillus niger, A. flavus, Botryodiploidia theobromae, Fusarium oxysporium* and *Rhizopus stolonifer* isolated from the rotten Laabako tubers were the cause of the rot. These fungi have been documented as fungal pathogens that cause yam rot (Wumbei et al., 2019, Sowley and Eric, 2014). The only factor in this study which had significant influence ($P < 0.05$) on level of rots was the variety of the yam cultivated. The "olodo" variety recorded fewer number of rotten tubers than the "laabako" variety in terms of the level of rots. This results conforms with (Demuyakor et al., 2013, Wumebi et al., 2019) in which the laabako variety was observed to be a short storage variety compared to the "olodo" variety.

Since the mycoflora of the soils recovered to normalcy after the application of glyphosate within a short time, it implied that the applied glyphosate did not distort the natural balance of the soil fungi in favour of pathogenic once to cause the tuber rot. Several strains of fungi belonging to the general *Aspergillus, Fusarium, Mucor, Penicillium, Purpureocillium, Trichoderma*

and *Rhodotorula* are capable of degrading glyphosate in soil using it as S and/P source; hence, reducing glyphosate residue build up in soils (Spinelli et al., 2021; Kunanbayev et al., 2019; Carranza et al., 2017).

The result is in agreement with Wumbei et al., 2019, that the generally held view by farmers and the public that, the use of the glyphosate herbicide causes yam tuber rots is not true. In most instances the use of glyphosate seemed to have suppressing effect on tuber rots and in other instances, it seemed to be having enhancing effect on tuber rots. However, as can be seen in table 1, the t-test showed that there is no significant difference ($P > 0.05$) in terms of rots between yam treated with glyphosate and yam manually weeded. The also result conforms with previous studies that investigated pesticides disease interactions in which mixed results of both enhancing and suppressing effects were recorded (Altman & Rovira, 2009; Bradley et al., 2002b; Altman & Neate, 1990; Kawate et al., 2017; Lévesque & Rahe, 1992; Marks & Becker, 1990; Rodriguez-Kabana & Curl, 2003). Since it is established that the herbicides cannot be responsible for the yam tuber rots as observed in this study and Wumbei et al., 2019, the rots could be attributed to the rot causing pathogens which were isolated from both the soil and the rotten tubers, enhanced by physical/mechanical factors as have been widely published in literature (Elias & Eric, 2014; Ogaraku and Usman, 2008; Okigbo, 2005; Okigbo & Ikediugwu, 2000; Okigbo & Nmeka, 2005; Aboagye-Nuamah et al., 2005, Kwoseh et al., 2005, Cornelius, 1999, FAO, 2018).

V. CONCLUSION AND RECOMMENDATION

The application of glyphosate had no adverse effect on the mycoflora of the soil under consideration; hence did not distract the natural mycoflora of the soil which could have resulted in the proliferation of fungal pathogens causing yam tuber rot.

The greater number of rotten tubers recorded for Laabako than olodo shows that the rot was not facilitated by the applied glyphosate, but the susceptibility of Laabako tubers to rot.

The lack of difference in yield between glyphosate treated plots and manually weeded plots shows that weeds are an important factor affecting yield, but the method of weed control does not affect yield.

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Bacteriocin Production using Lactic Acid Bacteria Isolated from Ugba (*Pentaclethra macrophylla* Benth)

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Abstract— *Lactic acid bacteria (LAB) play vital roles in our everyday life such as in fermentation, preservation and production of wholesome foods. This work is aimed at studying the bacteriocin production of lactic acid bacteria from Ugba (a local condiment) sold in Anambra state. A total of 5 samples of Ugba each were purchased randomly from three locations in Anambra state. Lactic acid bacteria were isolated and characterized using standard microbiological procedures. The isolates were subjected to antimicrobial activities by disc diffusion method while bacteriocin production was achieved by culture on appropriate medium and partially purified by centrifugation method and then characterized. Antimicrobial activities using cell free supernatant and partially purified bacteriocin of the isolates against Escherichia coli, Staph. aureus and Candida albicans found in Ugba were equally assessed. The isolate that gave the highest zone of inhibition was identified by 16s rDNA sequencing and was selected for further assay. Biopreservative study of the choice isolate against Escherichia coli, Staph. aureus and Candida albicans which were extraneously introduced into the Ugba was conducted. A total of Six LAB isolates designated with codes were obtained based on their catalase spot test reaction. zones of inhibition ranging from 13-20mm, 12- 18 mm and 10-19mm were obtained against Escherichia coli, Staphylococcus aureus and Candida albicians respectively. The LAB isolate code A1 with the Best Antimicrobial Activity was identified as Lactobacillus plantarum. The bacteriocin produces by Lactobacillus plantarum (A) was slightly stable at 40 and 60°C with a continuous decrease at 80 and 100°C for 30 mins but totally lost the activity at 121 °C for 15 min. The effect of pH on partially purified bacteriocin showed maximum activity against Escherichia coli, Staphylococcus auerus and Candida albicians. at pH 5.0 (18 mm ,17mm and 15mm respectively) and a continuous decrease as the pH increased from 6 to 9. The antimicrobial activity of bacteriocin was lost after treatment with proteolytic enzyme: trypsin and pepsin. This study show that Lactobacillus plantarum isolated from ugba has great potential for exploitation in food safety and preservation as a result of its bacteriocin content. Thus this locally fermented food plays a dual role of protection from pathogenic agents as well as serving as a functional food. It is therefore recommended that everybody should begin to consume ugba on a regular basis.*

Keywords— Ugba, Lactic acid bacteria, Bacteriocin.

I. INTRODUCTION

Ugba also called 'Ukpaka' in Eastern part of Nigeria is an indigenous fermented food, rich in protein and produced by a solid state fermentation of seeds of African oil bean tree (*Pentaclethra macrophylla*), a perennial legume tree. It is a popular food delicacy in Nigeria especially among the Ibo ethnic group where it serves as snack or as a food condiment. It is an important food item for various traditional celebrations where it is mixed with slices of boiled stock fish, garnished with vegetables and consumed. The unfermented seeds are bitter to taste as a result of anti-nutrition substances inherent in them. The natural fermentation of the seeds still done at the domestic level renders the product nutritious, palatable and non-toxic.

Diverse groups of microorganisms including *Bacillus, Micrococcus, Leuconostoc, Staphylococcus, Enterobacteriaceae and lactic acid bacteria* (LAB) have been reported to play active roles in the process of ugba fermentation (Enujiugha 2009). They produce antimicrobial substances such as organic acids, diacetyl, hydrogen peroxide and bacteriocins (Ogunbanwo *et al*. 2003) which are alleged to be connected with the preservation of many fermented food condiments in Nigeria. The preservation and safety are currently the two major challenges of the food industry as huge economic losses are sustained yearly due to food

spoilage while many consumers have been reported to develop adverse sensitivity reactions to chemical based preservatives. The Lactic acid bacteria (LAB) which are used generally as starter cultures for food fermentation are considered as having the potential to bridge this gap (Budde *et al*. 2003; Delves-Broughton 2005). They produce antimicrobial compounds that demonstrate antagonism toward the closely related species. The LAB in 'ugba' improve fermentation and also enhance the product storage, quality and safety by restricting the spoilage microflora from spoiling the food condiment and at the same time eliminating the pathogens such as *L.monocytogenes, S. aureus and E.coli* (Alor and Okonkwo 2021).

Lactic acid bacteria (LAB) are heterogenous group of bacteria which play a significant role in a variety of fermentation processes. They ferment food carbohydrates and produce lactic acid as the main product of fermentation. In addition, their degradation of proteins and lipids and production of various alcohols, aldehydes, acids, esters and sulphur compounds contribute to the specific flavour development in different fermented food products.(Sindhu and Khetarpaul 2001)

While many scientific reports are available on 'ugba', such studies have thus far addressed mainly the microorganisms associated with the fermentation processes of the seed as well as systems for optimization of the fermentation conditions (Odibo *et al*. 2008). The effect of processing techniques on the nutritive quality of ugba has also been reported by Okonkwo and Alor 2021 while the proximate composition and properties of the seeds have also received modest scientific attention (Odibo *et al* 2008). There is presently, paucity of scientific information on the ecological contribution of the LAB and bacteriocins for the safety and bio preservation of the food condiments.

Bacteriocins are extracellularly produced primary compounds of bacterial ribosomal synthesis which have a somewhat narrow range of bactericidal activity (Caplice and Fitzgerald 1999). They are active against other bacteria despite varying greatly in the chemical nature and mode of action. Bacteriocins have significant advantage over the established antibiotics in being easily degraded by the digestive enzymes without the risk of interference with the normal tract ecology (Caplice and Fitzgerald 1999). Bacteriocin producing LAB have been generally recognized as safe (GRAS) status and have been shown to fortify the barrier function of the gut microflora as well as promote the non-specific improvement of the immune system of man and animals (Tome *et al*. 2008).

The problem of chemotherapy and its associated side effects together with multiple drug resistance by infectious agents has led to the search for local foods that can serve as functional foods with dual role of protection from pathogenic agents as well as high nutrient based diet. Hence ugba (*P macrophylla*) which is generally consumed particularly in southeast Nigeria is investigated for its role in the isolation of lactic acid bacteria for bacteriocin production.

II. MATERIALS AND METHODS

2.1 Sample Collection:

Five samples each of traditionally fermented ‘ugba’ were randomly purchased from different sellers at different locations in Anambra state. This include ‘Awka’, ‘Ontisha’. ‘Nnewi,’ representing the three senatorial zones, in Anambra state. All the samples were transported to Microbiology laboratory of Nnamdi Azikiwe University Awka and stored at 3±1°C for a maximum of 24 hours prior to analysis.

2.2 Isolation of Lactic Acid Producing Bacteria (LAB):

Ten gram of each sample was homogenized separately in a porcelain mortar and then transferred into 250 ml flask containing 90 ml of buffered peptone water as diluents. The samples were mixed thoroughly by agitation for 2 min before serial 10-fold dilution was made in 0.1 % peptone water. For the isolation of the LAB, 0.1 ml supernatant of appropriate dilution was inoculated into de Mann, Rogosa and Sharpe (MRS) agar plates containing 0.5% nystatin using pour plate method. The plates were incubated anaerobically at 30 °C for 48 hours and the isolates purified by successive subculture. (Enujiugha *et al.*, 2002).

2.3 Characterization and Identification of Lactic Acid Bacteria:

The morphological, biochemical and molecular characteristics of the isolates were determined using standard microbiological methods.

The antibiogram profile of the isolates was determined using the method of Vlková *et al*. (2006).

The molecular identification of the best LAB isolate with the best antimicrobial activity was done by 16s rDNA sequencing method. (Murray 2010).

2.3.1 Bacteriocin Production by the Lab Isolates:

Bacteriocin production was performed by growing the isolates in MRS broth at 30ºC for 48 hours. This was done according to the method of Joshi *et al.,* (2006). After incubation, the broth was centrifuged at 5000xg for 10mins to obtain a cell free supernatant. The cell-free supernatant was saturated with 60% ammonium sulphate. After stirring on a magnetic stirrer, it was kept undisturbed in the refrigerator at the temperature of 25^0c. Precipitates formed were collected by centrifugation at 10,000 x g for 10mins and redissolved in 20mmol sodium phosphate buffer with pH 6.0.

2.3.2 Sensitivity of the Bacteriocin to Various Treatments:

The CFS (cell free supernatant) was divided into 2.0 ml portions before subjecting them to treatments in organic solvents (chloroform and ethanol), proteolytic action (pepsin and trypsin) and heat in order to evaluate the effect of the different factors on the activity and stability of bacteriocin. The solvents and enzymes were filtered, sterilized through Millex GV 0.22 µm filters before the addition of CFS. The controls consist of distilled water and untreated CFS in 0.1 M phosphate buffer. The samples and controls were incubated at 30 °C for 2 hours before the remaining bacteriocin activity were determined by the agar-well diffusion (AWD) assay against the indicator strains. (Azizpour *et al.,* 2009).

2.3.3 Detection of Antimicrobial Activity of The Bacteriocin:

A modification of the agar-well diffusion (AWD) method was employed in this assay (Azizpour *et al*, 2009). A loopful of the indicator strains *E. coli, S. aureus* and *C. albicans* were inoculated separately into 5ml normal saline for 5h. Then sterilized nutrient agar was each seeded with 1.0 ml each of the indicator strains at a concentration of 10^8 CFU/ml gently mixed and then dispensed into sterile Petri-dishes. The plates were left to solidify under a laminar airflow. Thereafter, wells (8 mm diameter) were made in each of the plates using a sterile cork borer. A 0.1 ml of the CFS was introduced into the different wells and left for 1 h in a refrigerator to allow for diffusion of the metabolite before incubating at 30 °C. The plates were examined for the development of translucent halos in the bacterial lawn surrounding the wells after 24 h incubation. the haloes (zones of clearing) produced by the different strains were compared. The percentage bacteriocin activity were calculated from the diameter of zones of clearing measured after each treatment relative to the halos produced from the positive control (untreated CFS) against each target organism. (Azizpour *et al.,* 2009)**.**

2.4 Characterization of Bacteriocin:

2.4.1 Effect of Temperature on the antimicrobial activity of the Bacteriocin:

Test tubes containing 5 ml of the partially purified bacteriocin was overlaid with paraffin oil to prevent evaporation and then heated at 40, 60, 80, 100°C for 30 min, and at 121°C for 15 min. The heat-treated bacteriocin and the control were incubated at 37ºC for 2 h. The antimicrobial activity was determined by agar-well diffusion (AWD) assay against the indicator strains (Okpala *et al.,* 2003).

2.4.2 Effect of pH on the antimicrobial activity of the Bacteriocin:

A 5ml aliquot of the partially purified bacteriocin was transferred into test tubes and the pH values of the contents were adjusted to 2–9 individually, using 1 M NaOH and 1 M HCl. After allowing the samples to stand at room temperature (30ºC) for 2h, the antimicrobial activity of the bacteriocin and the control were determined by agar-well diffusion assay (Joshi *et al*., 2006).

2.4.3 Effect of proteolytic enzyme on the antimicrobial activity of the Bacteriocin:

Test tubes containing 5ml aliquot of the partially purified bacteriocin was treated with pepsin and trypsin (1 mg/ml) each. The test tubes with and without the enzyme (controls) were incubated for 2 h at 30 °C and heated for 3 min at 100°C to denature the enzyme. Both the controls and the bacteriocin were assayed for antimicrobial activity by agar well diffusion method (Joshi *et al*., 2006).

III. RESULTS

3.1 Isolation and Characterization of LAB from Ugba:

A total of 25 organisms were isolated and screened. Six LAB isolates were obtained based on their catalase spot test reaction and colony morphologies on De- Mann Rogosa and Sharpe (MRS) agar. Table 1 shows the lactic acid bacteria isolated from each homogenized ugba. The biochemical identification and characterization of the isolates using conventional methods are shown in Table 2. The results obtained shows that all isolates were gram positive, non-motile, catalase negative and have varying carbohydrate (sugar) fermentation profile which presumptively made them Lactic acid bacteria.

TABLE 1
NUMBER OF ORGANISMS ISOLATED FROM UGBA MADE FROM DIFFERENT LOCATIONS IN ANAMBRA STATE

Ugba purchase	Number of organism isolated	Number of lactic acid isolated	Isolate code
From Awka	7	2	A1, A2
From Nnewi	8	2	N1,N2
From Onitsha	10	2	O1,O2

TABLE 2
BIOCHEMICAL IDENTIFICATION AND CHARACTERIZATION OF THE LAB ISOLATES

Isolate code	Cultural Characteristics	Cell Morphology	Gram Reaction	Catalase Reaction	Motility	Gas from glucose	Glucose	Lactose	Sucrose	Fructose	Galactose	
A1	Punctiform, glistening, smooth whitish colony	coccobacilli	+	-	-	-	+	+	+	+	+	*Lactobacillus* sp
A2	circular raised cream white colony	cocci in tetrads	+	-	-	-	+	+	+	+	-	*Pediococcus* sp
N1	Circular, flat translucent whitish colony	cocci in pairs and short chains	+	-	-	-	+	+	-	-	+	*Leuconostoc* sp
N2	Circular, flat off white colony	cocci in chains	+	-	-	+	+	+	-	+	+	*Lactococcus* sp
O1	Punctiform, smooth raised cream colony	long rods in chains	+	-	-	-	+	+	+	+	-	*Lactobacillus* sp
O2	Circular, flat off white colony	cocci in tetrads	+	-	-	-	+	+	+	+	+	*Pediococcus* sp

3.2 Antibiogram of the LAB Isolates:

Some of the LAB isolates were sensitive to all the antibiotics except A1, O1, N1 which showed varying degrees of susceptibility to antibiotics such as Erythromycin, Streptomycin, Ciprofloxacin and Zinnacef as shown in plate 1.

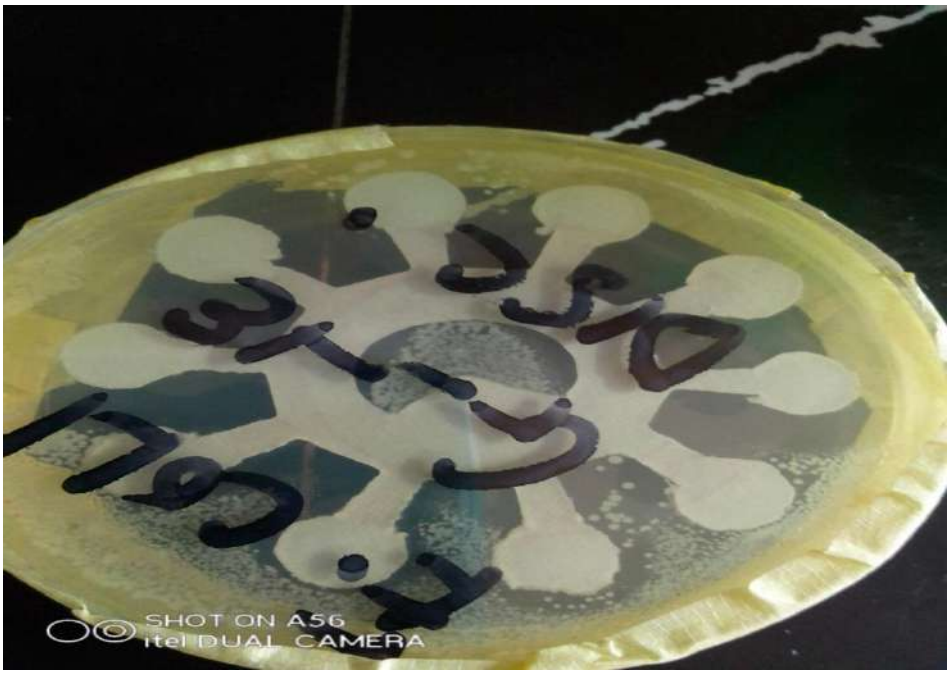

PLATE 1: Antibiogram of LAB isolate with designated code A1

Key: S = Streptomycin, SXT= Septrin, E = Erythromycin, PEF = Pefloxacin CN = Gentamycin APX =Amplicox, Z = Zinnacef, AM= Amoxicillin, R = Rocephin, CIP = Ciprofloxacin.

3.2.1 Antimicrobial Activities of the Cell Free Supernatant from the LAB Isolates against test organisms (*Escherichia coli, Staphylococcus aureus and Candida albicians)*.

The cell free supernatants of the LAB isolates examined for antimicrobial activity against *Escherichia coli*, *Staphylococcus aureus and Candida albicians yielded* zones of inhibition ranging from 13-20mm, 12- 18 mm and 10-19mm respectively. The inhibition zones showed that all of the isolates have antimicrobial effect on the indicator microorganisms with isolate A1 having the highest zone of inhibition (20 mm for *Escherichia coli*,18 mm for *Staphylococcus sp* and 19mm for *Candida albicians)* as seen in Table 3.

TABLE 3

ANTIMICROBIAL ACTIVITY OF THE CELL FREE SUPERNATANT FROM LAB ISOLATES AGAINST *ESCHERICHIA COLI*, *STAPHYLOCOCCUS AUERUS* AND *CANDIDA ALBICIANS*

Isolate code	Zone of inhibition (mm) (Mean ± S.E)		
	Escherichia coli	Staphylococcus auerus	Candida albicians
A1	20.00±0.05	18.00±0.00	19.17±0.00
A2	15.15±0.03	12.10±0.01	15.00±0.00
N1	15.25±0.05	15.10±0.02	15.17±0.00
N2	16.00±0.00	16.28±0.03	16.00±0.00
O1	18.16±0.03	16.00±0.00	16.20±0.00
O2	15.00±0.01	12.22±0.02	10.6±0.00

3.2.2 Antimicrobial Activities of the Bacteriocin from the LAB Isolates against test organism (*Escherichia coli, Staphylococcus aureus and Candida albicians*)

The result obtained from the antimicrobial activities against *Escherichia coli*, *Staphylococcus aureus* and *Cadida albicians* as seen in table 4, showed that the isolate with designated code A1 had the highest zone of inhibition for *Escherichia coli* (18.36mm), *Staphylococcus auerus* (17.33mm) and *Candida albicians* (19mm) while the isolate with the code N1 and N2 had no inhibitory effect on the test organisms. Isolate O2 had no effect on *Escherichia coli* but had inhibition zones of 13.13mm 14.0mm on *Staphylococcus aureus* and *Candida albician* respectively. Also isolate O1 had zone of inhibition of 16.33mm for *Escherichia coli* and 11.00mm for *Candida albician* but no activity was detected for *Staphylococcus aureus.*

TABLE 4

ANTIMICROBIAL ACTIVITY OF THE BACTERIOCIN FROM THE LAB ISOLATES AGAINST *ESCHERICHIA COLI, STPHYLOCOCCUS AUERUS* AND *CANDIDA ALBICIANS*

Isolate code	Zone of inhibition (mm) (Mean ± S.E)		
	Escherichia coli	Staphylococcus auerus	Candida albicians
A1	18.36±0.03	17.33±0.01	19.00±0.00
A2	13.65±0.05	12.00±0.00	15.00±0.00
N1	NI	NI	NI
N2	NI	NI	NI
O1	16.33±0.03	NI	11.003±0.00
O2	NI	13.13±0.02	14.00±0.02

Key

NI= no zone of inhibition

The LAB isolate code A1 with the Best Antimicrobial Activity was identified as *Lactobacillus plantarum*

3.3 Characterization of the Bacteriocin of *Lactobacillus plantarum* (A1)

The sensitivity of the bacteriocin produces by *Lactobacillus plantarum* (A1) to various treatments were shown in table 6-8. The antimicrobial activity of the heat treated bacteriocin was found to be slightly stable at 40 and 60°C with a continuous decrease at 80 and 100°C for 30 mins. However, after incubation for 15 min at 121°C, there was complete loss of activity. The effect of pH on partially purified bacteriocin showed maximum activity against *Escherichia coli, Staphylococcus auerus and Candida albicians*. at pH 5.0 (18 mm ,17mm and 15mm respectively) and a continuous decrease as the pH increased from 6 to 9. The antimicrobial activity of bacteriocin was lost after treatment with proteolytic enzyme: trypsin and pepsin as seen in table 5.

TABLE 5

EFFECTS OF PH ON BACTERIOCIN FROM *LACTOBACILLUS PLANTARUM* (A1) AGAINST *ESCHERICHIA COLI, STAPHYLOCOCCUS AUERUS* AND *CANDIDA ALBICIANS*

pH	Inhibition zone diameter (mm)		
	Escherichia coli	Staphylococcus auerus	Candida albicians
2	7	5	6
3	11	10	9
4	15	14	13
5	18	17	15
6	10	9	8
7	8	7	6
8	5	4	5
9	3	NI	2
Control (without pH treatment)	18	17	18

Key

NI=No inhibition zone

TABLE 6

EFFECTS OF PROTEOLYTIC ENZYMES ON BACTERIOCIN FROM *LACTOBACILLUS PLANTARUM* (A1) AGAINST *ESCHERICHIA COLI*, *STAPHYLOCOCCUS AUERUS* AND *CANDIDA ALBICIANS*

Proteolytic enzyme	Inhibition zone diameter (mm)		
	Escherichia coli	Staphylococcus auerus	Candida albicians
Trypsin	NI	NI	NI
Pepsin	NI	NI	NI
Control (without Proteolytic enzyme)	18	17	16

Key:
NI=No inhibition zone

IV. DISCUSSION

Out of 15 isolates obtained from ugba, 6 Lactic acid bacteria were found and characterized (Tables 1 and 2). The presence of LAB in these samples is due to the lactic acid fermentation which is a principal production step. It also confirms the reports of Njoku and Okemmadu (2008) on the active roles lactic acid bacteria play in the spontaneous fermentation of ugba.

The susceptibility of the isolates tested against 10 different antibiotics in this research showed that six isolates were susceptible to all of the antibiotics used while the remaining four isolates (O1, A1 and N1) had varying degrees of susceptibility to antibiotics such as Erythromycin, Septrin, Ciprofloxacin, Zinnacef and Rocephine as shown in plates 1. LAB isolates with designated code O1, A1, N1 were resistant to Amoxicillin, Gentamycin, Streptomycin, Pefloxacin and Amplicox; and susceptible to Erythromycin and Ciprofloxacin. O1 was resistant to Septrin and susceptible to Rocephine and Zinnacef while A1 and N1 were resistant to Rocephine and susceptible to Septrin. These results are in agreement with the research conducted by Pundir *et al.* (2013) where all LAB isolates were sensitive to Erythromycin. *Lactobacillus plantarum* (A1) which gave the best antimicrobial and bacteriocin like activity was resistance to Amoxicillin, Gentamycin, Streptomycin, Pefloxacin, Amplicox, Zinnacef and Rocephin and was susceptible to Erythromycin, Septrin and Ciprofloxacin. This agrees with the reports of Zhou *et al.* (2005) who stated that Lactobacilli are usually sensitive to inhibitors of protein synthesis and more resistant to aminoglycosides. Resistance to common antibiotics by lactic acid bacteria could be intrinsic (naturally owned) or acquired (Mathur and Singh, 2005). Intrinsic resistance of lactic acid bacteria to many antibiotics is an advantage for isolates with bacteriocin genic/probiotic potential because it could be helpful for sustainable utilization of the strains in human intestinal microflora during antibiotic therapy (Ketema *et al*., 2010).

The cell free supernatants of the LAB isolates examined for antimicrobial activity against pathogenic bacteria *Escherichia coli*, *Staphylococcus auerus* and *Candida albicians* yielded zones of inhibition ranging from 13-20mm for *Escherichia coli*, 12- 18 mm for *Staphylococcus auerus* and for *Candida albicans* as seen in Table 3. The diameter of inhibition zones showed that all of the isolates have antibacterial effect on the indicator microorganisms. The highest diameter (20 mm for *Escherichia coli*, 18 mm for *Staphylococcus auerus and Candida albicians*.) was recorded for *Lactobacillus plantarum* (A1) which was the same with the report of Kaushik *et al.* (2009) where *Lactobacillus plantarum* had 20 mm zone of inhibition for *Escherichia coli*. However, this result was not in agreement with the reports of Mobolaji and Wuraola (2011), Adejumo *et al.* (2014) who reported no antagonistic effect on *Escherichia coli* and *Staphylococcus auerus by Lactobacillus. plantarum* while Oluwajoba *et al.* (2014) reported 15, 21 and 22 mm zone of inhibition for *Escherichia coli Staphylococcus auerus* and *Candida albicians respectively*. The antimicrobial activity exhibited by these LAB isolates may be due to decrease in pH, depletion of nutrients and production of antimicrobial compounds including bacteriocins and various organic acids such as lactic acid, acetic acid (Adejumo, 2014)

Bacteriocin from gram positive organisms such as lactic acid bacteria have attracted much attention and have been the subject of intensive investigation due to their ability to act as bio-preservative agents. The data obtained for *Lactobacillus plantarum* (A1) which showed the highest zone of inhibition against the target microorganisms in this study, is in agreement with that of Okpara *et al.* (2014) and Sankar *et al.* (2012) where the bacteriocin produced by *Lactobacillus. plantarum* was active against *Escherichia coli* giving an inhibition of 18mm. However this result did not agree with the reports by Falegan *et al.* (2014), Okoro *et al.* (2011), Ogunbawo *et al.* (2003), having zones of inhibition 7, 28, 8, 12 mm for *Escherichia coli* and 7mm for *Staphylococcus* auerus. The variations in the inhibition zones by the bacteriocin against *Escherichia coli* may be as a result of range of inhibition, assay method, concentration and purity of the inhibitor, the sensitivity of the indicator species, the density of the cell suspension used and the type of buffer or broth used (Sourau and Arijit, 2010). Also the variations in the inhibition zones by bacteriocins produced by

Lactobacillus. plantarum could also be as a result of the genetic diversity of *Lactobacillus plantarum* observed by Oguntoyinbo *et al.,* (2015).

The stability pattern of the bacteriocin produced by *Lactobacillus plantarum* was found to agree with the works of Joshi *et al.* (2006), Sankar *et al.* (2012) and Okpara *et al.* (2014) where there was a partial loss in activity as temperature was increased to 100ºC for up to 15mins and a complete loss of activity at 121°C. The thermo stability of bacteriocins is of great importance in its application in food system, especially when they are to be used together with pasteurization in a multiple hurdle approach to food preservation. The bacteriocin showed maximum activity against *Escherichia coli* at pH 5.0 (18 mm) after which the activity gradually decreased. This finding indicated that increased pH affected the stability of the bacteriocin. The antimicrobial activity of bacteriocin was lost after treatment with proteolytic enzyme: trypsin and pepsin. These results confirmed the proteinaceous nature of the bacteriocin. Studies done by Joshi *et al.* (2006), Elhag *et al.* (2015) revealed that bacteriocins of different LAB species lost their proteinaceous nature when treated with proteolyic enzymes.

The food borne pathogens isolated are the common pathogens that have been reported in works on microbiological analyses of Ugba by Ogbonna *et al.* (2011) and Gyar *et al.* (2014). These organisms of public health concern might have been introduced as a result of processing and packaging procedures such as poor handling and sanitation conditions. This could be due to the antimicrobial metabolites produced by *Lactobacillus plantarum*. These include many organic acids such as lactic, acetic and propionic acids produced as end products which provide an unfavourable acidic environment for the growth of many pathogenic and spoilage microorganisms. Acids are generally thought to exert their antimicrobial effect by interfering with the maintenance of cell membrane potential, inhibiting active transport, reducing intracellular pH and inhibiting a variety of metabolic functions (Ross *et al.,* 2002). Another possible explanation is the production of bacteriocins.

V. CONCLUSION

This study shows that *Lactobacillus plantarum* isolated from ugba has great potential for exploitation in food safety and preservation as a result of its bacteriocin content. Thus this locally fermented food plays a dual role of protection from pathogenic agents as well as serving as a functional food. It is therefore recommended that everybody should begin to consume ugba on a regular basis.

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Restoring Degraded Rangelands in Northern Kenya Using Buffel Grass

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Abstract— *This review paper seeks to explore the potential of buffel grass (Cenchrus ciliaris L.) in the fight against land degradation within arid and semiarid areas of the world, especially Kenya. Soil degradation impacts 1. 5 billion people globally and more than 60% of the Earth's land surface experience poverty, hunger, and environmental pollution. The current drought cases in ASAL countries, including Kenya, exhibit the need to develop effective land restoration approaches. Several studies have reported that Buffel grass has improved germination and initial growth rates, improved disease control, improved water use efficiency, and increased resistance to weeds, which makes it a tool that could significantly alleviate problems related to soil erosion, low soil fertility, and land degradation. This review integrates the literature and case study evidence and presents practical recommendations for policy makers, land owners and managers and all interested in land restoration. This study highlights how buffel grass can be incorporated into sustainable land management practices while considering risks to the environment.*

Keywords— Cenchrus ciliaris L., Drought tolerance, Controlled burns, Selective grazing, Carbon credits, Ecological stability.

I. INTRODUCTION

Currently, more than 40% of the Earth's land surface is experiencing degradation, and this percentage is increasing (Shao *et al*., 2024). Land degradation refers to the ongoing or prolonged depletion of natural resources on land. This poses a direct danger to the well-being of almost half of the world's population that depend on these land resources (UNCCD, 2022). Persistent land degradation will amplify the occurrence of poverty, hunger, and environmental pollution (Jiang *et al*., 2022). Areas that have been degraded will become more susceptible to disasters such as disease outbreaks, droughts, floods, or wildfires (UNCCD, 2022). As the world continues to suffers the impacts of climate change, a cyclical relationship between land degradation and poverty will become prevalent in several regions, particularly in arid environments (UNCCD, 2017). Degradation affects 12 million hectares of land each year, with estimates ranging from 10% to 20% of the world's drylands (James *et al.* 2013). A larger population in the Africa will be affected by this phenomenon as nearly half of Africa's population lives in dry and semiarid rangelands, which make up approximately 43% of the continent's total area according to James *et al.* (2013).

Approximately 65–70% of the rangelands in Sub-Saharan Africa are categorized as moderately to severely degraded, meaning that they have experienced a large decrease in plant cover, an increase in undesirable species, or both (Tamene and Le 2015). Kenya is among the nations most impacted by land degradation in terms of its degree, severity, and economic situation, as more than 80% of her landmass is inarable (Mganag *et al*., 2022). The North Kenya region is characterized by dry and semiarid conditions and has experienced delayed growth and underdeveloped economic conditions. Despite being the habit for 30% and 70% of humans and livestock, respectively, the area has long been plagued by poverty and drought which will be worsened by the continued degradation (Mganga *et al*., 2022). Land degradation in these areas is caused by climate change and poorly managed human activities, which accelerate desertification in these regions. Figure 1 below shows the land degradation status

of drylands according to the USDA Natural Resources Conservation Service, highlighting the critical need for targeted conservation efforts in these areas, including Kenya.

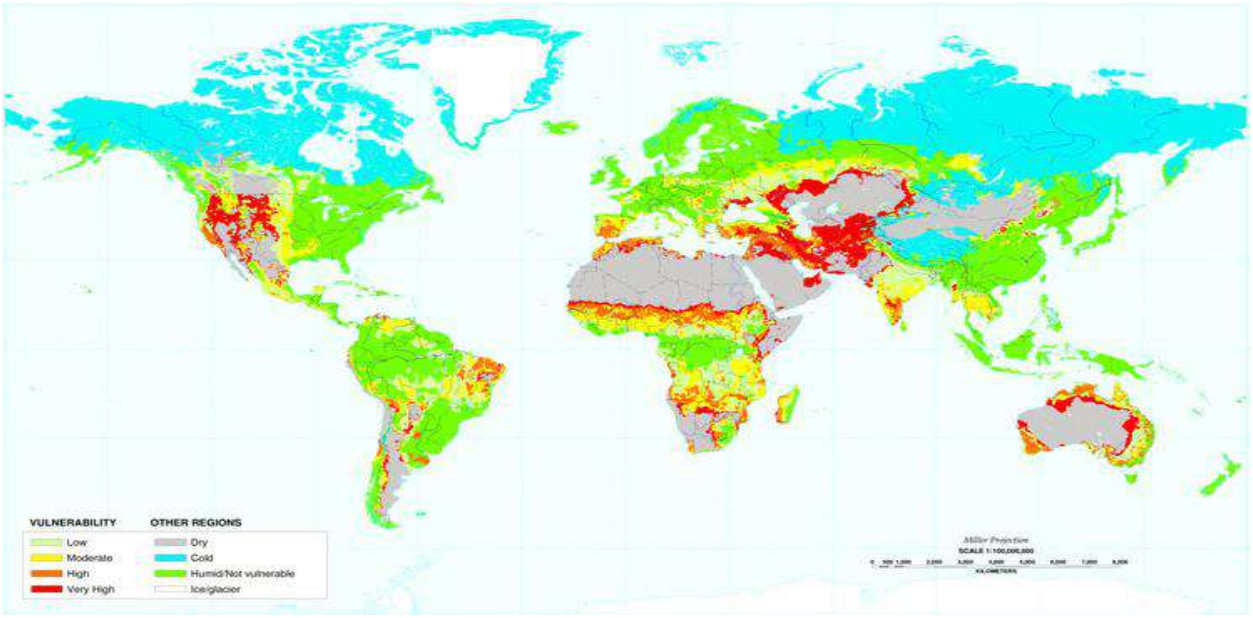

FIGURE 1: Vulnerability of Drylands to Land Degradation (Source: USDA Natural Resources Conservation Service)

In 2022, the Arid and Semi-Arid Lands (ASALs) counties of Kenya experienced unprecedented drought. This drought, which began at the end of 2020 and continued with five consecutive below-average rainy seasons, led to a significant increase in humanitarian needs according to the Office for the Coordination of Humanitarian Affairs (OCHA) ("Kenya 2022 drought response in review," 2023. The capacity of communities in the ASAL areas to cope was weakened by successive droughts, which led to a dramatic increase in food insecurity and severe malnutrition throughout the year. From January to December 2022, the number of individuals experiencing high acute food insecurity jumped eighty percent, rising from a projected 2.4 million in crisis (IPC Phase 3) or worse to approximately 4.4 million, with 1.2 million falling into emergency (IPC Phase 4) ("Kenya 2022 drought response in review," 2023. By December 2022, 2.5 million cattle had died due to the drought according to OCHA.

Approximately 885,000 children under five years of age and older than 115,700 women who were pregnant or nursing were projected to be acutely malnourished and in dire need of treatment by October 2022 ("Kenya 2022 drought response in review," 2023. In some regions, the incidence of acute malnutrition exceeds the emergency threshold. In addition to having to travel further to obtain food and water, women and girls saw an upsurge in gender-based violence, including sexual assault, early marriage, and female genital mutilation ("Kenya 2022 drought response in review," 2023. Reports of individuals seeking new livelihoods and aid in urban and peri-urban regions of the ASAL region increased, mostly from pastoralist groups. Additionally, in 2022, the United Nations High Commissioner for Refugees (UNHCR) reported that approximately 45,000 people seeking refuge in Kenya came from neighboring Somalia ("Kenya 2022 drought response in review," 2023. The socioeconomic dynamics of the ASAL regions are influenced to a greater extent by the adverse effects of severe climate events and droughts. Hence, finding appropriate strategies to reverse this trend and establish a thriving ecosystem is necessary.

Due to its extreme drought tolerance and ability to endure severe grazing, buffel grass (*Cenchrus ciliaris L.*) is extensively cultivated in tropical and subtropical dry rangelands worldwide. Buffel grass has been shown to have significant potential to mitigate soil erosion, enhance soil fertility, and restore degraded landscapes (Nkombe, 2016; Lebbink *et al*., 2021). This review explores the mechanisms through which buffel grass contributes to land restoration and the best practices for its management to reverse the land degradation problem in the Kenyan rangelands. Here, we review the available literature to explore the role of buffel grass in restoring degraded rangelands and highlights the socioeconomic benefits of Buffel grass cultivation, including its impact on local communities' livelihoods and resilience against climate change. By synthesizing the current research and case studies, this review aims to provide actionable insights for policymakers, land managers, and stakeholders involved in land restoration efforts in these fragile landscapes.

II. LITERATURE REVIEW

2.1 Extent and Impacts of Land Degradation:

Although the exact percentage of degraded land varies from country to country, 67% (16.1 million km2) of Sub-Saharan Africa's total land area is shown by FAO TERRASTAT data. Kenya experienced 13% land degradation, and the variations among counties are considerable (FAO, 2000; Kirui *et al*., 2021). Approximately 14 percent of Kenya's landmass is considered degraded according to GLASOD data (FAO, 2000). The estimates of land degradation in Kenya differ based on the source and calculation methodology (FAO, 2000). Approximately 17% of the nation and 30% of its arable land might be at risk of land degradation, according to a 2006 study by Bai and Dent. This degradation could be characterized as "places where both net primary production and rain-use efficiency are diminishing" (Kirui *et al*., 2021). More land is degraded in the east and northeast regions of Kenya; 12.3% of the land is severely degraded, 52% is moderately degraded, and 33% is susceptible to land degradation (UNEP 2022). According to Bai *et al*. (2008), in 1997, moderate land degradation affected approximately 64% of Kenya's total land area, while extremely severe degradation affected approximately 23%. The latter rose to almost 30% at the turn of the 2000s (Bai *et al*. 2008). A more recent study by Le *et al.* (2014) indicated that 31% of croplands, 46% of forested land, 42% of shrub lands, and 18% of grasslands in Kenya degraded from 1982 to 2006. The Kenya Soil Survey reported land degradation hazard areas, as shown in the figure below.

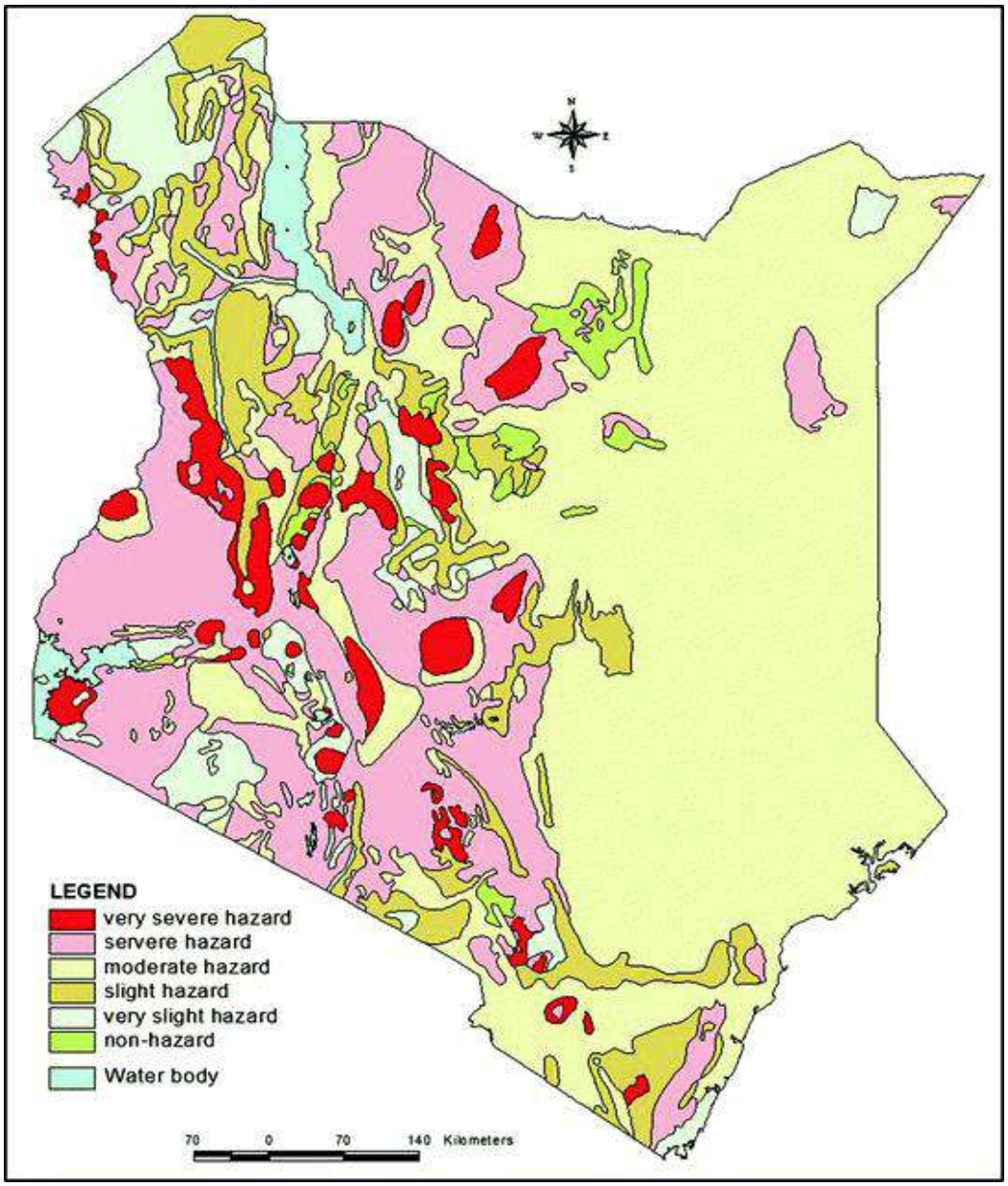

FIGURE 2: Land degradation hazard areas in Kenya. Source Based on Kenya soil survey

Figure 3 below shows some of the major causes of land degradation. Deforestation, desertification, rangeland degradation, wind and water erosion, soil fertility loss due to "soil nutrient mining," and soil erosion overall are the most significant land degradation issues in Kenya (UNEP 2022). In Kenya, the expansion of farming into marginal lands, such as in the drylands close to Lake Turkana and marginal agricultural land in the Eastern Regions, was a major contributor to land degradation. This degradation not only affects the ecosystem service supply, food security, and food pricing downstream but also affects other regions far from their sources.

Droughts impact the availability of water and feed, which hinders most livestock development operations in rangelands. During droughts, livestock productivity is severely limited due to insufficient conservation efforts and a lack of strategic feed reserve facilities. Prolonged drought events act together with other factors, such as the subdivision of pasture lands, and unsustainable land practices accelerate land degradation in these areas. Additionally, rangeland ecosystems are susceptible to a number of negative impacts caused by overgrazing (UNEP 2022). Many of the impacts are obvious right away, but others are subtle and may linger for a while. Soil, forage, water, and livestock interactions are all negatively impacted by overgrazing, which in turn disrupts rangeland systems. In only one year, overgrazing may cause tremendous damage to rangeland ecosystems (Gebrehiwot *et al*., 2022). In the long run, climate change will have detrimental effects on soil quality, native plant species, fodder production, weaning weights, and breeding rates, among other factors.

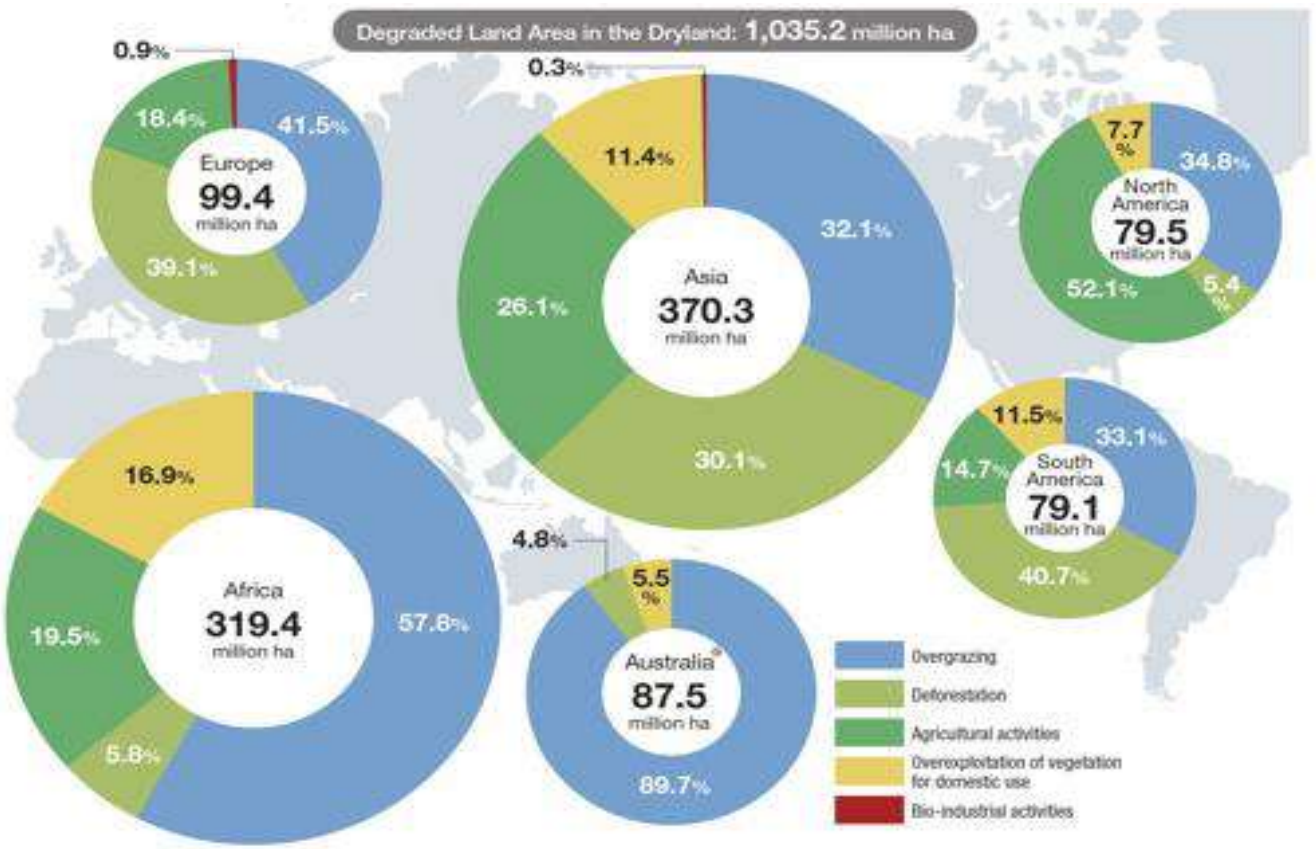

FIGURE 3: Causes of Land Degradation in Global Dry Ranges

The capacity for vegetation to absorb carbon decreases as landscapes degrade. Vegetation grows as a result of restoration strategies such as regenerative agriculture, natural forest regeneration, river restoration, regenerative grazing, reseeding with indigenous species, habitat conservation, and restoration of biodiversity. Soil organic carbon absorption increased by more than 10% after 20 years of landscape restoration, according to one Ethiopian study (Gebrehiwot *et al*., 2022). Because degraded land covers 75% of the world's usable land, restoration has a great chance of boosting carbon sequestration, which is an important measure in the fight against climate change. Additionally, restoring optimum pasture conditions is an important social and environmental goal for many governments, NGOs, and local community organizations. In the Kenyan rangelands, Buffel grass has the potential to act as a tool for pasture production and land restoration, hence enhancing the capacity of formerly degraded lands to sequester more carbon. Therefore, this species can be used to reseed disturbed areas as a native species owing to its adaptive nature and improve primary productivity in these rangelands.

2.2 Origin and distribution of Buffel Grass:

Buffel grass covers a large portion of the Earth's surface between 45 degrees north and south of the equator. Figure 4 shows the occurrence of these species throughout regions and nations. The grass was originally from the dry tropical and subtropical zones of western Asia and Africa, but it has since spread exotically to parts of Australia, the United States, Mexico, and South America (Marshal *et al*., 2012). Buffel grass is native to Kenya and other sub-Saharan Africa countries.

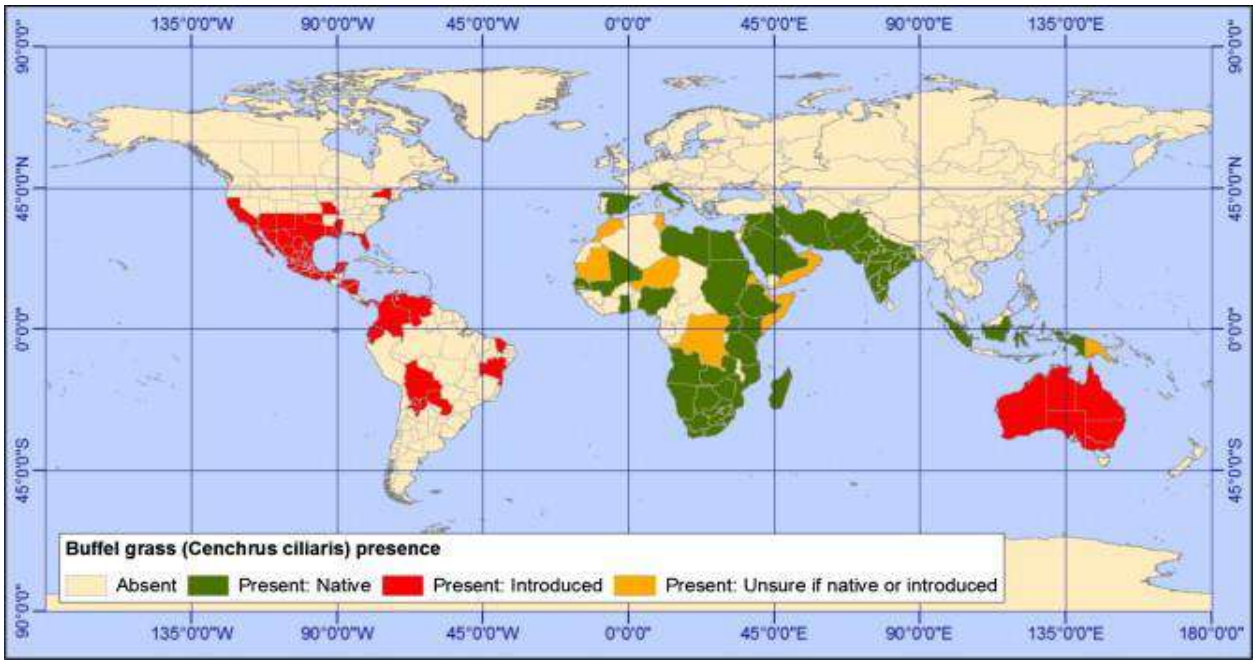

FIGURE 4: Buffel grass distribution according to Marshal et al., 2012

2.3 Nomenclature and morphology:

Buffel grass, scientifically known as *Cenchrus ciliaris L*., is a resistant perennial tussock grass that grows in dry tropical and subtropical regions. There is considerable taxonomic uncertainty surrounding this species due to its diverse morphological and physiological traits and extensive geographic range; thus, several synonyms have emerged. The physiological and morphological variations among buffel grass types have been the subject of several studies. For instance, height, leaf area, number of leaves on the main tiller, number of internodes covered by leaf sheaths, number of branches per plant, and number of reproductive branches per plant accounted for the majority (38.7%) of the morphological variance among the 20 Buffel grass accessions studied in a Pakistani study (Arshad *et al.,* 2007).

TABLE 1

The physiological and morphological variations among Buffel grass types according to Arshad *et al*. (2007)

Trait	Dimension
Height	20-150 cm
Stem thickness	1-3 mm
Leaf	1.5–30 cm long
	3–8 mm wide
Roots	Max 2.4 m deep
Flowering	3 months after germination
Ligules	0.5-2 mm
Inflorescences	Yellow–purple–gray

Both natural selection and the commercial introduction of novel strains to increase pastoral land production have contributed to the emergence of intraspecific diversity. Improvements in disease resistance, improved growth rates, and tolerance to various environmental circumstances have led to the development of cultivars with these traits (Arshad *et al*., 2007). As a result, it may be crucial for efficient land restoration to have knowledge about which strains are suitable for which conditions. However, there is a dearth of research in this area, particularly in the Kenyan context. It is possible to classify commercial cultivars as tall, medium, or short. Cattle production often involves tall cultivars, which may reach a height of 1.5 m because they thrive in environments with richer soils and more rainfall. Rhizomes form, and the leaves often exhibit a bluish-green hue (Arshad *et al*., 2007). Typically, smaller types (<90 cm) are better suited to soils with a lighter texture, less tolerance of floods, and poor rhizome growth (Arshad *et al*., 2007). These materials are often utilized for sheep production and erosion prevention. The majority of Buffel grass species are apomictic (Bray, 1978), yet there are a small number of sexually active species (Akiyama *et al*., 2005). Wind, waterways, and foot and animal movements are ideal routes for the rapid dissemination of seeds. Additionally, rhizomes and stolons are capable of vegetative reproduction in certain plant varieties (Arshad *et al*., 2007). Because of this, one may see a wide variety of plant types throughout the landscape, from thick monotypic stands to tiny groupings or even lone tussocks.

2.4 Establishment and Environmental Requirements for Growth:

The most basic requirements for a species' conditions may be determined by learning about its germination, growth, and development needs. The germination of seeds and seedling emergence are the most important life history phases for every plant community in dry environments (Hardegree *et al*., 2018). The germination rates and lifetime of Buffel grass seeds have been the subject of a great deal of research because of the widespread use of this species as a pasture. For seeds to germinate, the soil must be moist (Ward *et al.,* 2006). A minimum of 6.3 mm of rainfall, spread out over two days, is required for Buffel grass seeds to sprout from loam soils. Ward *et al*. (2006) conducted a greenhouse investigation meant to mimic the summer wet season in Tucson, Arizona, where buffel grass is common. The results showed that seedlings exposed to three or four days of continuous simulated precipitation had the greatest chance of fresh emergence on days three and four. After the fourth day, the likelihood of fresh emergence decreased significantly. The results showed that during the summer wet season in one of two years in Tucson, the factors needed for the development of 50% viable buffel grass occurred (Ward *et al*., 2006).

On average, the optimal duration for perennial grasses to germinate in central Australia is thought to be approximately every twelve months (Jensen *et al*., 2022). The enormous lifetime of Buffel grass's seed bank—which ranges from 2 to 30 years—helps the grass endure rare germination opportunities (Friedel *et al*., 2007). It is possible for seeds to remain viable even after 8 months of dormancy on earth (Marshal *et al*., 2012). Germination rates for buffel seeds are best achieved at approximately 30 °C/20 °C day/night, yet they can sprout at temperatures as low as 10-40 °C. These numbers were derived for light/dark changes, continuous darkness, and continuous light (Innes, 2022). Research on germination in potting mix, clay, and paper towelling environments revealed that germination rates were greater for the former two substrates (Bhattarai *et al*., 2008).

Like tropical C4 grasses, Buffel grass plants exhibit superior growth performance; greater biomass; greater height; and greater leaf length and breadth when exposed to higher levels of CO2 (Bhattarai *et al*., 2008). According to Innes (2022), a plant's CO_2 absorption and water usage efficiency peak at 30/20°C day/night air temperatures, and they decline with increasing temperature until they die at 45/35°C day/night. According to Innes (2022), the ideal temperature for photosynthesis is 35°C. Buffel grass is tolerant of nutrient-poor soils. Nonetheless, there is evidence that higher nitrogen levels enhance water use efficacy (WUE), crude protein yields, and dry fodder production, whereas higher phosphorus levels widen the shoot/root ratio (Marshall *et al*., 2012).

2.5 Adaptations of Buffel Grass:

The tropical savanna is a typical habitat for C4 grasses such as buffel grass, which thrive in the summer when temperatures are high and rainfall is heavy (Marshall *et al*., 2012). Further characteristics of this biome include open canopies and thick understorys of grass that provide fuel for fires. Extremely low soil moisture levels prevent seedling emergence and subsequent plant growth, leading to sparse vegetation in dry and semiarid habitats as well as low, unpredictable, and occasional rainfall (Innes, 2022). For a number of reasons, Buffel grass is the only grass in this category that can thrive in extremely dry environments (Marsh *et al.*, 2012). Its deep root system (which can reach depths of up to 2.5 meters in some soils) allows it to reach water sources more quickly and for longer than other native herbs and forbs (Ines, 2022). It has a number of other interesting traits, such as the ability to store carbohydrates at the base of its stems for later use, longer seed longevity, and opportunistic germination (Mganga *et al*., 2021). There may be less competition, disease, and predation for buffel grass in dry areas. In regard to water, light, and nutrients, for instance, anecdotal data suggest that native plants are outcompeted by buffel

grass in their habitat (Mganga *et al*., 2021). Paralid moths, which contribute to the decline of the species in tropical regions, as well as tropical diseases such as buffel blight (Magnaporte grisea), ergot, smut, rust, and blast, may have less of an impact on buffel grass in dry climates (FAO, 2011). In addition, the establishment and growth of this grass are affected by other factors, including climate, edaphic factors, topography and fire/disturbance.

2.5.1 Climate:

The climates in which buffel grass thrives are very varied. According to Innes (2022), it can withstand temperatures as high as 50 °C. However, Marshall *et al*. (2012) reported that these faults will not settle in areas where the mean yearly minimum temperature dips below 5°C. It can thrive in areas with yearly rainfall ranging from 250 mm to 2670 mm, and it can withstand a wide range of average rainfall (Innes, 2022). Compared to average yearly rainfall, temperature seems to be a more important constraint on the species' worldwide range. The impact of rainfall seasonality on the distribution of Buffel grass should not be examined in isolation from other factors, such as the likelihood of drought, tree survival, growth rates of woody vegetation, and disturbance probability.

2.5.2 Edaphic Factors:

Although Buffel grass may be grown in a variety of soils, it seems that certain types of textures are necessary for its long-term survival (Marshall *et al*., 2012). Soil types such as sandy, silty, and clayey soil promote seedling emergence; however, the rate of emergence decreases when the percentage of sand, silt, or clay approaches 100% (Marshall *et al*., 2012). Moreover, when planted in clay, silt, loam, or silty clay soils, plants progressively wilt and die (Mganga *et al*., 2021). Centre for Arid Zone Research (2001) and Van Devender and Dimmitt (2006) found that sandy and sandy loam soils are the favorites of grasses, although they can colonize loam soils as long as they have 90 days of summer growth and reasonably warm and dry winters (Cox *et al*., 1988).

According to Hoover *et al*. (2022), the ability of soil to hold moisture is usually associated with the significance of soil texture on plant development. Some Buffel cultivars have been engineered to resist floods, making them more suitable for heavy soils that contain moisture. When tropical regions' thick clay soils become too waterlogged for Buffel grass, they adapt to dry locations' lighter soils (Innes, 2022). As long as there is an adequate supply of nitrogen and phosphorus, the species may thrive even in less fertile soils (Mganga *et al*., 2021). According to Hoover *et al*. (2022), soil fertility might differ significantly depending on rainfall. In dry areas, Buffel grass may require particularly fertile soil to grow. When there is an abundance of manganese and aluminum in the soil, Buffel grass will not grow (Smith *et al*., 2021). Soils with a pH between 7 and 8 work best for seed dispersal according to research conducted in Tanzania (Cook, 2007).

2.5.3 Topography:

The elevation range of Buffel grass may be anywhere from sea level to 2,000 meters. Grass often takes root in landscape depressions on a smaller scale (Marshall *et al*., 2012). Depressions provide a moist place for establishment and shelter from grazing, which is especially important in dry regions. C4 species, on the other hand, are physically unable to dominate closed-canopy ecosystems and instead prefer open, light-filled environments.

2.5.4 Fire and disturbances:

According to Innes (2022), buffel grass contributes to a higher fuel load, which in turn causes more frequent and powerful fires than what dry landscapes normally experience. Resurfacing initially on ash beds creates a self-reinforcing feedback loop that permanently changes the invading system (Mganga *et al*., 2021). The deep-penetrating root system and long lifespan of individual tussocks allow Buffel grass to resprout from preexisting tussocks after fire, which is one of several physiological traits that allows it to react so rapidly to rain and fire (Novak *et al*., 2021). One study showed that Buffel grass cover doubles following a fire (Marshall *et al*., 2012), and there is some evidence suggesting that aboveground biomass recovers faster after more severe fires (Innes, 2022). According to Innes (2022), the amount of disturbance needed for establishment could be influenced by the competitiveness of nearby flora. The initial effect of fire is to lessen competition from nearby plants and to slow the recruitment of young woody plants; this prevents the landscape from recovering and leaves it open to quick colonization by fast-growing species such as buffel grass. According to Mganga *et al.* (2021), after a fire, Buffel grass may be able to quickly take advantage of the soil's temporarily increased available phosphorus. While further study is needed to corroborate this, we have shown that once established, it may not need disruption to spread, and we think that rhizomes might play a role in this.

III. RESULTS AND DISCUSSIONS

3.1 Ecological Benefits:

The capacity of buffel grass to adapt to higher temperatures, endure, and provide profitable grazing makes it an essential pasture species for rangeland regions, and this ability may become even more significant under climate change conditions. Given the potential decline of other plant species due to climate change, biochar has the potential to become a significant soil stabilizer in arid regions. One documented application of grass in rangelands is erosion prevention and soil stabilization (Marshall *et al*. 2012). By stabilizing the soil through its extensive root system, Buffel grass decreases the likelihood of wind and water erosion. The large root network of this species helps bind soil particles, which in turn prevents soil loss and keeps the soil fertile, according to studies by Kimiti *et al*. (2017). By restocking native seed banks, boosting carrying capacity, improving primary production, and increasing plant cover, active restoration approaches may help mitigate soil erosion in semiarid rangelands of Africa (Mganga *et al*., 2021).

For instance, prior research has shown that seeding *C. ciliaris* seeds into a degraded African rangeland results in low-cost erosion barrier grass restoration (Kimiti *et al*., 2017). Therefore, herbaceous cover was greater even in areas where other types of grass were unable to take root. Enclosures reseeded with *Euphausia superba* and *C. ciliaris* in a semiarid rangeland in Kenya boosted biomass output by a factor of up to 10 (Mganga *et al*., 2021). Because of its high biomass output, sorghum leaves behind an abundance of litter, which breaks down and enriches the soil with nutrients. Soil organic carbon levels and general soil health are both enhanced by this procedure.

Perennial grasses native to rangelands in Africa can be used for ecological restoration for several reasons. First, they are already well adapted to their environment. Second, they are efficient seeders and dispersers of seeds (Wright *et al.,* 2021). Third, these plants undergo high tillering and nutrient translocation to protect themselves from herbivory and fires. Finally, they can be used as a source of additional income by selling hay and seeds. Grazing exaptation is an adaptation that occurs in C4 perennial grasses found in African rangelands because these grasses are drought resistant (Wright *et al*., 2021). A thicker root rhizosheath and a widespread network of fine roots are the techniques by which C4 grasses withstand drought (Mganga *et al*., 2021). An abundance of roots in the top 0–30 cm of soil allows these grasses to make the most of the infrequent and light rainfall (Marshall *et al*., 2012). The extensive root structure of grass increases soil porosity, which in turn promotes water penetration and retention. In dry areas, when water is scarce, this is very helpful. During dry seasons, improved water retention helps to retain plant cover and ecosystem production. Because C. ciliaris L. can root up to 2.4 meters deep, it is able to access deeper layers of soil for water intake (Marshall *et al*., 2012).

The reclamation of degraded pasture areas has led to extensive and fruitful use of buffel grass. For instance, mechanical treatments and the introduction of kapok bush (*Aerva javanica*), buffel grass, and birdwood grass (*Cenchrus setiger* Vahl) during restoration in the 1960s greatly improved conditions in the Ord River watershed in western Australia (Friedel *et al*., 2006). Active soil erosion had mostly eased by 2002, large gully systems had stabilized to some extent and were anticipated to improve further as ground cover increased, and large colonies of introduced *Cenchrus spp*. dominated the most vulnerable and severely degraded regions. Perennial grasses, both native and imported, formed a thick ground cover throughout much of the region. There have been effective uses of buffel grass for land reclamation on pastoral land in central Australia, where rainfall is much lower, as was the case for Bastin in 1991 according to Friedel *et al*. (2006). The article mentions its usage for revegetation and erosion control in parks and reserves, as well as for dust control at the Alice Springs airport and in the vicinity of many Aboriginal communities. After being rehabilitated using Buffel grass, central Queensland's postmining area has been put back into pastoral use (Bisrat *et al*. 2004). These case examples indicate the successful utilization of buffel to restore and reclaim degraded lands, resulting in ecologically thriving landscapes with substantial economic and social benefits.

3.2 Management Practices:

3.2.1 Establishment Techniques:

The successful establishment of Buffel grass involves site preparation, seed selection, and planting methods. Planting Buffel grass requires the same soil preparation as planting any other crop, plus an additional procedure of ensuring that the seedbed is either mechanically firmed or has settled down (Wied *et al.,* 2020). It is sufficient to use relatively shallow tillage to obtain soil aggregates with a medium texture, absorb organic matter residues, and eradicate weeds (Cook, 2007). To compact loose seedbeds, one might use a roller or be "cultipacked." Additionally, it has been established that buffel grass can be effectively grown in a variety of planters. Used on very uneven terrain, track-type tractor exhaust tack seeders disperse the material in a

random fashion. If not overgrazed, six or seven harvests may continue to occur on well-fertilized buffel grass (Cook, 2007). Fertilizer is effective on Buffel grass, as it is effective on the majority of grass species. Soil analysis is necessary prior to implementing a fertility program. Potassium is seldom necessary in Buffel grass regions due to the high levels of natural potassium in most soils.

3.2.2 Grazing Management:

Buffel grass is a valuable forage resource for livestock. However, overgrazing can lead to its decline and consequent land degradation. In regard to livestock and environmental goals, grazing management is key for achieving a balance between pasture quantity and quality. The profitability of farms that rely on pasture for animal feed will also improve. Compared to a poorly grazed pasture, a well-grazed pasture has greater productivity, lifespan, and feed quality (Rhodes *et al*., 2023). Grazing managers need to be able to time the movement of animals between paddocks, evaluate the different phases of pasture development, and set significant benchmarks for pasture. Overgrazing or selective grazing may eliminate valuable species from a paddock, and leaving livestock there for too long can lead to erosion and deterioration of the pasture. However, a shift in pasture composition, poor utilization rates, or an increase in waste may result from undergrazing or excessive rest, which in turn reduce feed quality (digestibility and protein content). One beneficial management strategy that is gaining popularity is regenerative grazing, which typically entails a combination of rotational grazing and selective rest to hasten landscape regeneration.

Multiple studies conducted in Australia in the last few years have shown that regenerative grazing strategies may enhance ecological conditions, including plant richness and variety. According to McDonald *et al*. (2019), strategic-rest grazing resulted in considerably greater total ground cover and animal output per hectare than did continuous grazing management. According to McDonald *et al*. (2019), compared to continuous grazing, increasing the amount of rest relative to grazing time resulted in increased plant biomass, vegetation cover, animal weight growth, and animal output per hectare. Lawrence *et al*. (2019) noted that under short-duration grazing, there was an approximately 19% increase in the ground cover of perennial species, with higher-value forage species being more abundant. Research conducted by Kisambo *et al*. (2023) on buffel grass highlighted the substantial impact of clipping management on important morphological and production parameters across rangeland grass ecotypes. The findings of the present study also indicated that the grass ecotype produced the best results when clipped at 10- and 15-centimeter intervals and with 4-week and 12-week delays between cuts. In grazing fields with native grasses, the most productive defoliation strategies occur either moderately or at low frequencies.

3.3 Potential Challenges:

Buffel grass has been linked to a decline in native plant diversity and abundance, a reduction in tree recruitment, and an increase in fire severity that alters the structure of woodlands in the rangeland region. Invertebrates, reptiles, and native mammals all exhibit a decrease in variety because of this change (Marshall *et al*. 2012). These issues will likely worsen as a result of increased density and the use of buffel grass as an infill material due to climate change. Compared to fire and unpredictable rainfall, Buffel grass competition was the strongest predictor of native biodiversity loss in 28-year-long studies (Mganga *et al*. 2021). Buffel has a direct impact on the survival of several native plant species, including those that are at risk of extinction. In addition to influencing species and faunal assemblages, buffer invasion alters the structure and composition of vegetation, which may increase the likelihood of extinction (Innes, 2022). Buffel planting in dry and semiarid areas has had a detrimental effect on local plant and animal species diversity according to substantial evidence. Preventing the introduction of new genetic material, increasing control efforts in areas where the plant is scarce (which may include confinement), and setting up quarantine barriers to stop intrusions into nature reserves are all possible approaches to management (Innes, 2022). Controlling its proliferation and balancing its usage with the protection of local plants need effective management measures. Furthermore, the large biomass of Buffel grass might increase the vulnerability of drought-prone regions to fire (Kisambo *et al.,* 2023; Rhodes *et al*., 2023). The capacity of Buffel to change invaded habitats into dense swards and enhance fire connectivity in formerly sparsely or patchily vegetated regions allows it to increase the frequency, severity, and extent of fires; this makes it a transformer species. Controlled burns and firebreaks are two fundamental fire management methods that are vital for reducing this risk.

IV. CONCLUSION

Buffel grass (*Cenchrus ciliaris L.*) has significant potential for preventing land degradation in arid and semiarid regions, especially in Kenya. Due to its tolerance to drought and high ability to withstand overgrazing, it is useful for reestablishing degraded soils, controlling soil erosion and improving soil fertility in many rangeland landscapes. Moreover, there are

socioeconomic advantages associated with growing Buffel grass, including an enhanced standard of living for people in the region in the wake of climate change. The features of high adaptability, fast growth rates, and well-developed root systems help grass establish more hostile conditions and enhance the existing stocks of carbon and ecosystem stability. However, Buffel grass should be adopted very carefully because the impact of this grass on native wildlife and the balance of ecosystems could be rather negative. Although Buffel grass can enhance the quality of degraded lands, it has certain disadvantages, such as elevating the level of fire intensity and putting pressure on indigenous species. However, management practices could play a critical role in optimizing the use of buffel grass as a forage and in restoring land in addition to reducing the negative impacts caused by its utilization.

V. RECOMMENDATIONS

Integration into Sustainable Land Management (SLM) Strategies: County governments and national land use agencies should include buffel grass in SLM measures where vulnerability to degradation is most likely to occur. The relevant authorities should develop guidelines and best practices that will enhance its benefits while minimizing its negative impacts on the environment.

Capacity Building and Education: Local communities and farmers as well as landowners should be educated on the advantages and disadvantages of growing Buffel grass. Another recommendation is to strengthen the participation of communities in the restoration of land, thus supporting more of their views and local knowledge on land management.

Balancing Conservation and Utilization: County and national governments should develop strategies to balance the use of Buffel grass with the protection of native biodiversity. Additionally, the planting of buffel grass together with other native plants should be promoted to improve the stability and variety of the ecosystem.

Policy and Regulatory Frameworks: Policies and legal instruments should be established concerning the use of buffel grass, especially for land restoration. Additionally, collaboration with relevant government departments, NGOs, and local people to achieve sustainable land management efforts is recommended.

Climate adaptation and mitigation: Identify areas that include buffel grass in other climate action approaches, such as climate change adaptation and mitigation, since the plant is capable of enhancing carbon sequestration. Authorities should explore opportunities for carbon credits and other incentives to promote the use of buffel grass in land restoration efforts.

Therefore, even though buffel grass is very effective for land restoration and as a forage in arid and semiarid landscapes, it must be used cautiously, with a special focus on ecological consequences. Hence, through the use of research and partnerships, Buffel grass can help in reclaiming degraded landscapes and providing resilience against the effects of global climate change.

STATEMENTS AND DECLARATIONS

The authors declare that there are no conflicts of interest. The authors alone are responsible for the accuracy and integrity of the paper content.

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Exploring the Potential for Sustainable Potatoes as a Crop for Northern Ghana

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Abstract— *The Irish potato (**Solanum tuberosum**) belongs to the solanaceae family of flowering plants. It is a staple food in many parts of the world and an integral part of much of the world's food supply. The Irish potato is a critical crop in terms of food security in the face of population growth and increased hunger rates. Despite the potential for the potato as an important food and income security crop, very little effort has been made in Ghana to adopt and integrate it into the food production system. It is against this backdrop, that this study was designed to investigate the potential for introducing Irish potatoes as a new crop for Ghana. In this study, certified seed of three Irish potato varieties (Maris Peer, Mayan Rose and Nadine) was imported from Scotland (UK) and planted in July under rainfed conditions. The study was implemented in a four-block randomized complete block design in three replicate sites in the northern region (Nebilyili, Yapalsi and Wulensi). The planting was done on both ridges and on flat land. The crops were monitored till harvesting. Generally, the yield was poor, with a maximum of 3.1MT/ha. Among the varieties, Nadine performed better than Mayan Rose and Maris Peer, although there was no significant difference (P > 0.05) between varieties. Among the three sites that were used for the trial, there was significant difference (P < 0.05) between Wulensi and the other two sites with the Wulensi site performing better. There was also no significant difference in yield between potato planted on ridges and those planted on flat land. Fungal species belonging to the genera Aspergillus, Fusarium and Penicillium were isolated from the healthy and rotten Irish potato tubers. Also, fungal species belonging to Alternaria, Aspergillus, Fusarium, Mucor, Penicillium and Trichoderma were isolated from the root system of the Irish potato crops. Based on the findings, we conclude that, Irish Potato can be grown as a food crop in Ghana, if the necessary agronomic conditions are provided.*

Keywords— Irish Potato, Exploring, Potential, Food security, Northern Ghana, fungi.

I. INTRODUCTION

The potato (*Solanum tuberosum*) belongs to the Solanaceae family of flowering plants. First domesticated in the Andes mountains of South America, it is a staple food in many parts of the world and an integral part of much of the world's food supply (Spooner et al., 2014). The potato is the world's most important root and tuber crop. It is grown in more than 125 countries and consumed almost daily by more than a billion people (FAO, 2019). Hundreds of millions of people in developing countries depend on potatoes for their survival. Potato cultivation is expanding strongly in the developing world, where the potato's ease of cultivation and nutritive content have made it a valuable food security and cash crop for millions of farmers. Developing countries are now the world's biggest producers and importers of potatoes and potato products (FAO, 2009). As of 2014, potatoes were the world's 4th most consumed food crop after maize, wheat, and rice (CIP, 2019; Johnson & Cheein, 2023.). Potato is a critical crop in terms of food security in the face of population growth and increased hunger rates (CIP, 2019).

Potatoes yield abundantly with little effort, and adapt readily to diverse climates as long as the climate is cool and moist enough for the plants to gather sufficient water from the soil to form the starchy tubers (Ensminger et al., 1994). One hectare of potato can yield two to four times the food quantity of grain crops. Potatoes produce more food per unit of water than any other major crop and are up to seven times more efficient in using water than cereals (CIP, 2019). The yield of calories per acre (about 9.2

million) is higher than that of maize (7.5 million), rice (7.4 million), wheat (3 million), or soybean (2.8 million) (Adepoju et al., 2010, Ensminger & Ensminger., 1994).

Today, potato production and consumption are booming worldwide, with ever greater quantities being processed for the convenience food and snack industries, while its importance as a subsistence crop continues to expand. Many developing countries are eager to enter the lucrative emerging markets for potatoes and potato products, but to do so needs a major assessment of the productivity, profitability and sustainability of their potato subsectors. For example, potato yields in the developing world average around 10 to 15 tonnes per hectare, less than half of the average yields achieved by farmers in Western Europe and North America (FAO, 2009).

The development of a vibrant, profitable and sustainable potato subsector in developing countries depends on measures to overcome a number of persistent constraints. Those measures include improvements in the quality of planting material, potato varieties that have reduced water needs, greater resistance to insect pests and diseases, and resilience in the face of climate changes, and farming systems that make more sustainable use of natural resources (FAO, 2009).

Despite the potential for the potato as an important food and income security crop in developing countries and the eagerness of many developing countries in adopting and integrating potatoes into their crop production systems, no such effort has been made in Ghana, despite the fact that, there are visible food and income security challenges in the country (Darfour and Rosentrater, 2016).

It is against this backdrop, that this 18-month feasibility study was designed to investigate the potential for introducing Irish potatoes as a new crop to northern Ghana, and to the country at large. In this study, to maximize the chances of success we used novel seed potato varieties (Maris Peer, Mayan Rose and Nadine) developed by the Sarvari Research Trust, with the following characteristics: i) Late blight and virus resistance; ii) Vigour to suppress weed growth; iii) Natural sprout suppression properties in storage; iv) Drought tolerance and v) Reduced reliance on expensive chemical inputs.

The objective of the study was to assess the potential for growing and storing Irish potatoes in northern Ghana.

II. METHODOLOGY

The feasibility study was executed between July and November, 2021. The study was implemented in a four-block replicated complete block design (RCBD) with three potato varieties (Mayan Rose, Maris Peer and Nadine) and replicated in three sites ('Yapalsi', Nebilyili and Wulensi) in Karaga, Gushegu and Nanuma South districts respectively. Besides variety and location as factors, planting method (on ridges and on flat land) was another factor. Below is the trial design (Table 1).

TABLE 1
TRIAL DESIGN

BLOCK A	MRR	MRF	MPR	NDF	MPF	NDR
BLOCK B	NDR	MRF	MPF	MPR	MRR	NDF
BLOCK C	MRR	MRF	MPF	NDF	MPR	NDR
BLOCK D	MPF	MRR	NDR	NDF	MRF	MPR

NB: MRR = Mayan Rose Ridged, MRF = Mayan Rose Flat, MPR = Maris Peer Ridged, MPF = Maris Peer Flat, NDR = Nadine Ridged and NDF = Nadine Flat

The RCBD is widely used in field experimentation and very appropriate when one is collecting quantitative data, such as yield, and requires a rigorous s comparison between treatments. The two cornerstones of the RCBD are *replication* (i.e., repetition) and *randomization.* These allow for the accommodation of any variability in the local environment and to determine the probability of the differences in results between treatments being real or simply due to chance (Gomez & Gomez, 1984). The main purpose of blocking is to reduce experimental error by eliminating sources of heterogeneity such as soil fertility or field slopes (CIP, 2006).

For this study, where three Irish potato varieties and two planting regimes were tried, one acre land with four replicate blocks was cultivated at each site. Each block contained six treatment plots with size of a plot being approximately $40m^2$ (Table 1). The treatments are: Mayan Rose on ridge (MRR), Mayan Rose on flat land (MRF), Maris Peer on ridge (MPR), Maris Peer on flat land (MPF), Nadine on ridge (NDR) and Nadine on flat land (NDF). This brings the total of plots per trial site to 24. Each treatment appeared ones and randomly in every block.

2.1 Land Preparation:

Growing potatoes requires extensive soil preparation (Asia Farming, accessed on 20th Septemer, 2019). Therefore, in this trial, the land preparation was done at two levels of ploughing and ridging. The first ploughing was done to clear the land of all standing vegetation (grass, crop stubble and shrubs). In cases where there were still standing vegetation after the first ploughing, they were cleared manually. The second ploughing (harrowing) was done to roll the soil to produce the fine tilth that is required for growing of potato. After the second ploughing, ridges were made manually, on which the planting was done.

2.2 Planting:

Generally, seed requirement depends on the cultivar and soil type. In potato cultivation, seed required per hectare is 1,300 to 2000 kg (Asia Farming, accessed on 20th September 2019). In this trial, 1000 kg of each of the three potato varieties were planted across the three sites, implying approximately 333 kg of each variety per plot. Planting was done at a spacing of 60 cm (inter row) and 30 cm (intra row) and at a depth of 10 cm. Planting was done at a time that there is sufficient moisture in the soil (not wet) and the soil temperature is not above 22 ^{o}C. Planting was done on both ridges and on flat land to measure if there is any effect of ridging on the yield potential. The main issue encountered was the fact that the Maris Peer variety from arrival at the airport in Ghana to the time of planting suffered a lot of rotting. Samples of the rotten/dead plants were taken to the Laboratory for the isolation of the associated fungal species.

FIGURE 1: Planting

Maris Peer **Nadine** **Mayan Rose**

FIGURE 2: Potato seed on arrival from the UK

2.3 Fertilizer Application:

Before the fertilizer administration, soil analysis was conducted at each of the trial sites (Table 2) to determine the level of fertility of the soil, which in turn informed the NPK ratios to adopt. Fertilizer (NPK) application was done at planting at the rate of 300kg/ha, 550kg/ha and 200k/ha respectively for nitrogen, phosphorous and potassium. Aside the NPK, foliar-fertilizer (Croplift) was also applied at the rate of 2L/ha.

TABLE 2
RESULTS OF SOIL ANALYSIS

LAB NO	SAMPLE ID	pH (H2O 1:2:5)	% (O.C)	% N	P mg/Kg	K mg/Kg	Cmol+/kg (Ca)	Cmol+/kg (Mg)	Cmol+/kg (CEC)	TEXTURE		
										% SAND	% SILT	% CLAY
245/20	N1	6.51	1.014	0.1	8.11	71	4.8	3	9.62	59.92	30.32	9.76
246/20	N2	6.78	1.2285	0.12	9.48	76	4.6	2	8.55	63.92	28.32	7.76
247/20	N3	6.73	1.5405	0.15	12.36	79	4.6	3	9.63	65.92	26.32	7.76
248/20	N4	6.8	1.248	0.12	9.78	77	5.4	1.2	8.57	65.92	26.32	7.76
249/20	W1	6.86	1.1115	0.11	9.65	72	2.4	0.8	5.05	71.92	22.32	5.76
250/20	W2	6.86	1.1895	0.12	9.97	73	3.2	0.4	5.47	71.92	18.32	9.76
251/20	W3	6.65	1.1115	0.1	9.38	72	2.6	0.4	4.85	71.92	18.32	9.76
252/20	W4	6.64	1.3845	0.13	11.64	78	2.8	0.2	5	73.92	19.32	6.76
253/20	Y1	6.56	1.0725	0.11	9.77	69	3.4	0.4	5.57	73.92	20.16	5.92
254/20	Y2	6.53	0.7995	0.07	7.29	58	1.6	0.4	3.49	73.92	22.16	3.92
255/20	Y3	6.59	1.3065	0.13	10.67	76	5	2.2	9.15	75.92	20.16	3.92
256/20	Y4	6.42	0.819	0.08	8.96	67	3.4	3.4	8.52	75.92	20.16	3.92

2.4 Weeding:

Weeding is one of the important intercultural operations that was conducted throughout the trial, albeit manually. First weeding was carried out when the plants were about 20 cm high and the second weeding was carried out three weeks afterwards. Alongside the weeding operations, earthing up was carried out to keep the soil loose for proper development of tubers and for the protection of the developing tubers from direct contact with the sun, which could lead to greening of the tubers.

2.5 Pests/Disease Monitoring:

The potato like many other crops in the Solanaceae family, is susceptible to many pests and diseases (CIP, 2019, Hillary & Otieno, 2019, Okonya et al., 2016; Okeyo et al., 2019). The common pest of the potato include: Colorado potato beetle (*Leptinotarsa decemlineata*), Potato tuber moth (*Phthorimaea operculella),* Leafminer fly (*Liriomyza huidobrensis*) and Cyst nematodes (*Globodera pallida* and *G. rostochiensis*). The common diseases of potato include: Late blight, caused by *Phytophthora infestans,* Bacterial wilt and Potato blackleg (bacterial infection). Increasing potato production while protecting producers, consumers, and the environment requires an integrated approach encompassing a range of strategies: encouraging natural pest predators, breeding varieties with pest/disease resistance, planting clean seed, rotating with other crops, and organic composting to improve soil quality

Raising potato varieties that are pest/disease resistant is one of the ways to increase potato production while protecting producers, consumers and the environment (CIP, 219). Although, the potato varieties used in this trial are relatively resistant to diseases and pests, efforts were made to scout for potential pests and diseases that might attack the crop in the trial areas. This was to assist the project to come out with integrated and sustainable approaches to addressing pests and diseases in subsequent projects to scale up the production of Irish potato in Ghana.

FIGURE 3: Checking plants for symptoms of disease & Disease condition observed on the field

2.6 Fungal Isolation:

2.6.1 Media Preparation:

The Potato Dextrose Agar (PDA) (Oxoid, UK) was prepared by suspending 39 g of PDA powder in 1000 cm^3 of distilled water. To this 150 mg of amoxicillin was added to suppress bacteria growth and the mixture stirred on hot electric plate to dissolve the solutes. This was then autoclaved at 121 ^oC at a pressure of 1.03 kg/cm^3 for 15 minutes. About 20 ml of the molten PDA was then poured into a 9 cm diameter Petri dish to solidify.

2.6.2 Isolation of fungi from root system of Irish potato crops:

The root of the Irish potato crop varieties was thoroughly washed with running tap water to remove soil particles and dead loose root tissues. Pieces (fragments of 0.5 cm long) of the root system were obtained. These were then surface sterilized with 70 % alcohol for 1 minute, and then washed in three changes of sterile distilled water. The fragments were then blotted dry with sterile tissue paper. The pieces were then inoculated on PDA in Petri dish and then incubated at room temperature (28 ± 2 ^oC) for fungal growth. The mycelia that grew were sub cultured until pure cultures of the fungi isolate were obtained.

2.6.3 Isolation of fungi from healthy and rotten Irish potato tubers:

Both healthy and Irish potato tubers with rot symptoms were washed under running tap water to remove any debris on them. Pieces (0.5 cm^3 fragments) of tissues were obtained from the heathy Irish potato tubers. Also, pieces (0.5 cm^3 fragments) of tissues consisting of both rotten and healthy portions were obtained from the Irish potato tubers with rot symptoms. The pieces obtained from the heathy and rotten Irish potato tubers were each surface sterilized with 70% alcohol for 1 minute, washed with three changes of sterile distilled water and then blotted dry with sterile tissue paper. Five pieces of the tissues obtained from the healthy and rotten tubers were each inoculated separately at equidistance on PDA in a Petri dish. This was then incubated at room temperature for fungal growth. The grown fungi were sub cultured until pure cultures of each isolate obtained. Each treatment was replicated three times. The occurrence of the fungal isolates was determined with the formulae;

$$\% \text{ occurrence of fungi} = \frac{number\ of\ tissues\ infected\ by\ a\ fungus}{Total\ number\ of\ tissues\ plated} \times 100 \quad (1)$$

2.7 Identification of fungus isolate:

Slides of pure culture mycelia were observed under the microscope to determine its morphological characteristics. The fungus was then identified using its morphological and cultural characteristics as documented (Campbell 2013; Samson and Van Reenen-Hoekstra, 1988).

2.8 Pathogenicity test:

Healthy Irish potato varieties (Maris Peer, Mayan Rose and Nadine) were washed under running tap water and then surface sterilized with 70% alcohol. A 5 mm corkborer was used to remove a cylindrical core from the tuber to create a hole. A 5 mm disc of the test fungus mycelia was placed into the hole and the cylindrical core placed back. The wound was then sealed with Vaseline and the inoculated Irish potato tubers incubated under room temperature (28 ± 2°C) for 14 days. The tubers were then cut transversely through the inoculated spot and examined for rot symptoms.

2.9 Harvesting and Storage:

The potato varieties used come to maturity and ready for harvesting after 3 months of sowing. The crop becomes ready for harvesting when leaves turn into yellow colour and there is easy separation of the tubers from their stolons (CIP, 2019). When these signs were observed, harvesting was done manually by the use of hoes. During harvesting, care was taken so as not to cause injury to the tubers. After harvesting, the potato tubers were weighed, labeled and stored in well protected storage environment, under airy and cool conditions to prevent sprouting.

III. DATA COLLECTION AND ANALYSIS

3.1 Evaluation parameters:

Once the trials have been established, the following data were collected during the growing season in accordance with established procedures by the International Potato Centre (CIP, 2006):

- Number of plants per plot: this data will be collected 45 days after planting
- Plant habit: this data was collected 45 days after planting
- Plant vigor: this data was collected 45 days after planting
- Flowering stage: this data will be collected 60 days after planting
- Senescence stage: this data will be collected 90 days after planting
- Disease and pest damage
- Number/weight/size tubers per plot
- Internal defects at harvest
- Tuber quality in storage
- Climate data.

Plant habit and flowering and senescence stages were measured using scales described by Gomez (2006) while Plant vigor was evaluated using a scale from 1 to 9 where "1" is assigned to least vigorous plants and "9" describes very vigorous plants.

Scouting was done during the growing period to record pest and disease incidences. This was done by just counting pest and disease incidences recorded by treatment plots.

At harvest, the tubers were graded into 3 categories and the weights and numbers of tubers in each category were recorded. The categorization was done according to CIP (2006) as follows:

>45 and <45

- Category I: commercial, tubers weighing 200-300 g or measuring >60 mm
- Category II: commercial, tubers weighing 80-200 g or measuring 30-60 mm and
- Category III: non-commercial, tubers weighing < 80 g or measuring < 30 mm

Reporting internal defects at harvesting is critical for estimating processing quality. In this regard, a sample of 10 commercial tubers was cut transversally and checked for external defects such as cracking, secondary growth and warts, and internal problems such as hollow heart, black spots, heat necrosis, and rot (CIP, 2006). For each entry, the number of affected tubers was recorded on the tuber yield datasheet and the percentage of affected tubers was calculated.

3.2 Data Analysis:

Since the trial design is RCBD in a Multi-locational variety trials (MLVT) data collected from the trial was analyzed using combined Analysis of Variance (ANOVA). This was done after testing the homogeneity of experimental variance across the sites, where experiments with high coefficients of variation will be eliminated from the analysis. The sources of variability used in the statistical model are the site, the blocks within each site, the treatment (variety and planting method), the site-treatment interaction and the experimental error.

IV. RESULTS

Data collected over the study period included temperature, germination and plant habit (plant height and vigour). The average temperature in area over the period was 22^{o}C min and 28^{o}C max.

With regards to germination, the final data was collected at 45 days after planting and the germination calculated thereof. The germination percentage for the various treatments are shown in figures 4, 5, and 6 for Nebilyili, Yapalsi and Wulensi respectively. Considering the fact that the Irish potato plant is suited for temperate conditions, it can be said that the germination in these experiments was good, as we recorded a germination between 0 and 99% for the Nebilyili, 1 and 85% for Yapalsi and between 0 and 100% for Wulensi. Germination percentage of 0 and 1 as recorded in this trial on the surface may appear bad compared to T1 (Wumbei et al., 2020, unpublished) which had the lowest germination percentage around 35, but this could be attributed to a number of factors such as; varietal difference, number of seeds planted per treatment and the age of the seed planted. In terms of varietal performance, the Mayan Rose variety recorded better germination than Maris Peer and Nadine. The Nadine variety performed worst as far germination was concerned.

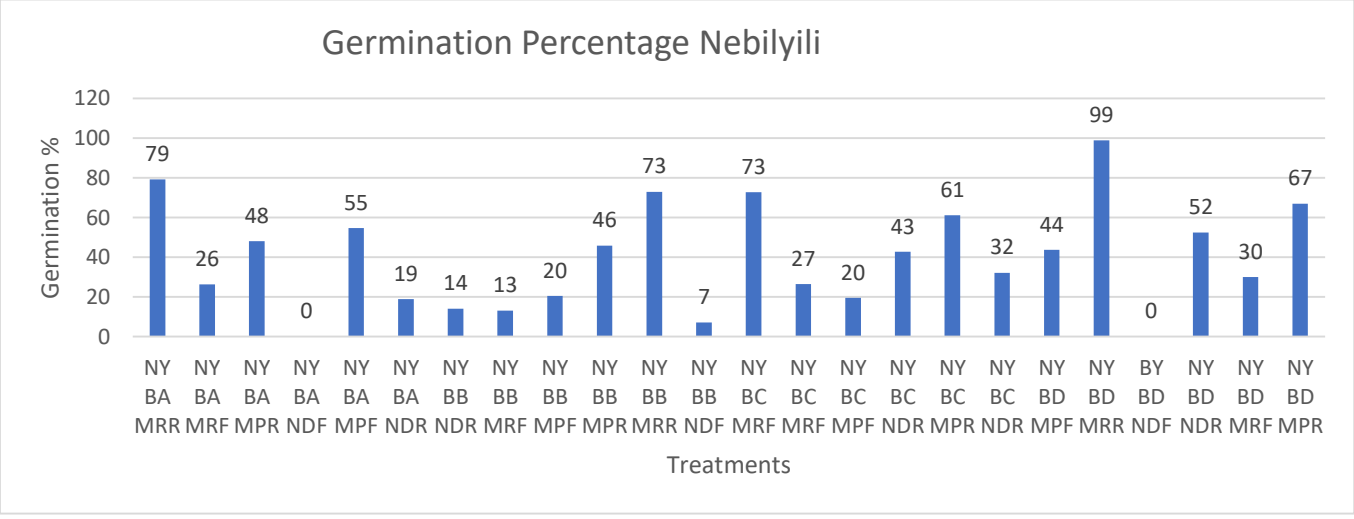

FIGURE 4: Germination Percentage at Nebilyili

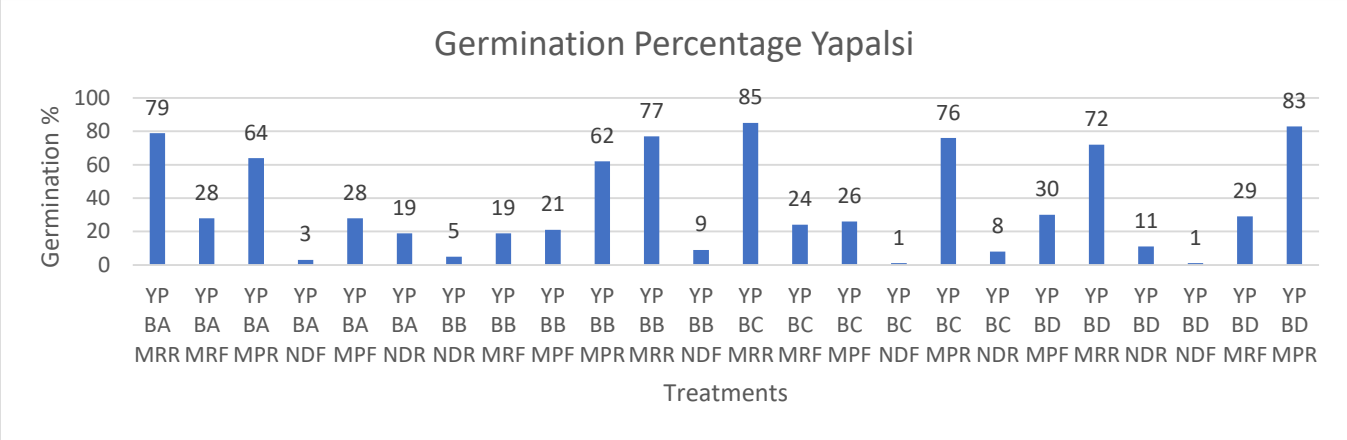

FIGURE 5: Germination Percentage at Yapalsi

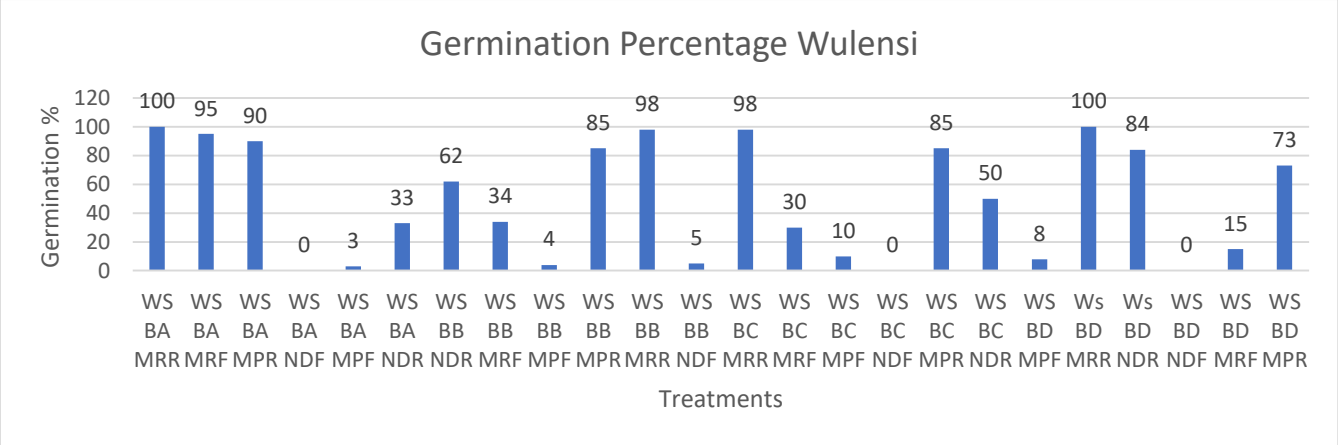

FIGURE 6: Germination Percentage at Wulensi

With regards to plant habit, the plants are looking vigourous compared to T1 which suffered a total die off at some point. Similar to the case of T1, the plants suffered some disease symptoms at 3wap and 6wap leading to the rotting of some of them, but the rotting was on a smaller scale compared to T1. The plant height from which the growth rate and the vigour were calculated was taken twice with one-week interval between the two measurements. In figure 7, 8 and 9 can be seen the plant growth rate for Nebilyili, Yapalsi and Wulensi respectively. The growth rate of the plants was not uniform among the varieties and across the sites. At the Nebilyili site, while BA MPR recorded a growth rate of almost 4, BB MRR recorded a negative growth rate of -2. Among the varieties, Maris Peer recorded the highest growth rate followed by Nadine and Mayan Rose respectively. The growth rate at the Yapalsi site, similar to the Nebilyili site was not also uniform and Maris Peer recorded the highest growth rate, but this time around followed by Mayan Rose with Nadine recording the lowest growth rate of -1.2. The growth rate at the Wulensi site was relatively uniform between 0.9 and 3.1 with Mayan Rose planted on flat land in block A recording the highest growth rate and Mayan Rose planted on ridges in block D recording the lowest growth rate.

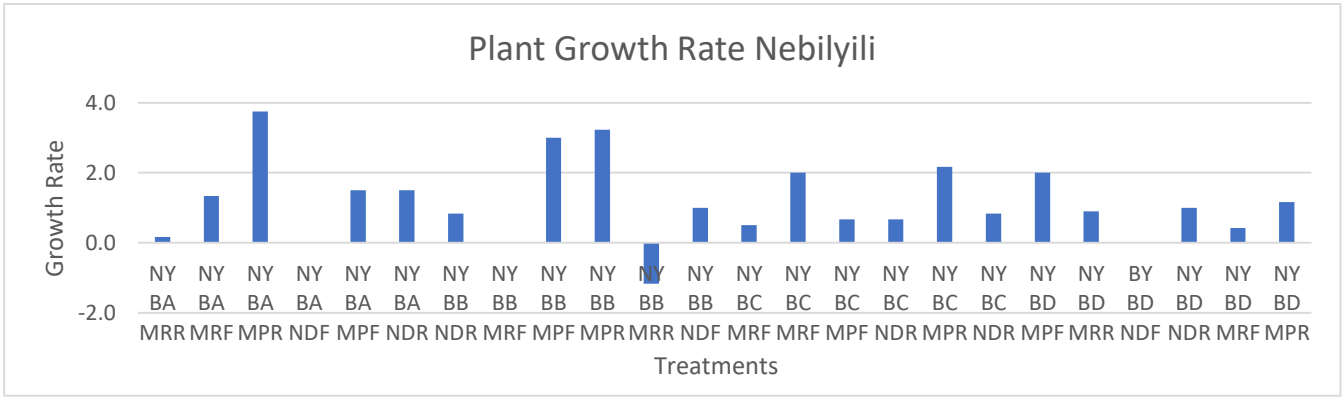

FIGURE 7: Plant Growth Rate at Nebilyili

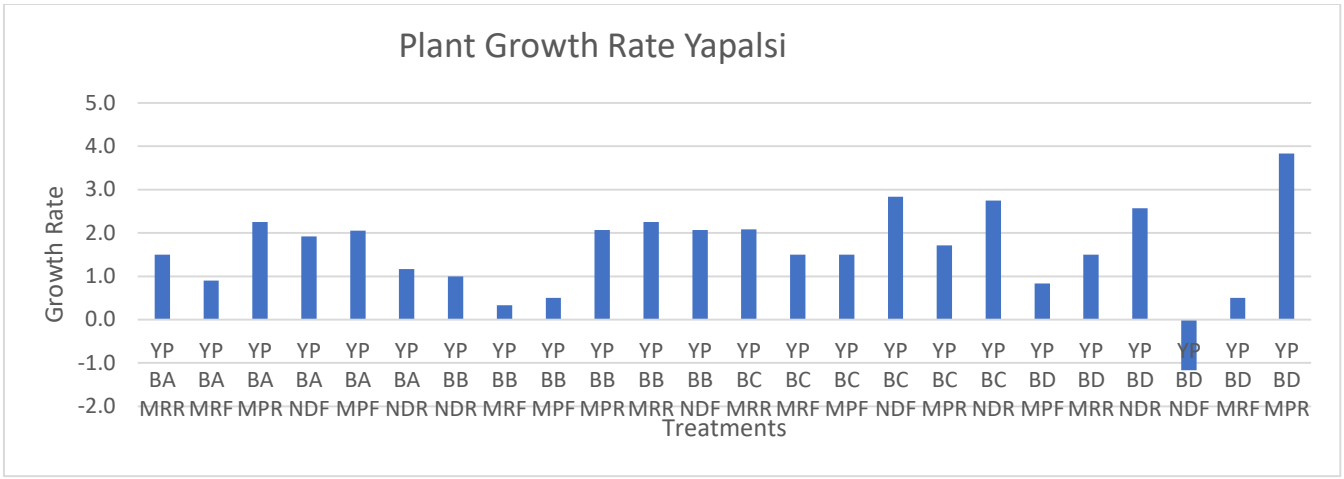

FIGURE 8: Plant Growth Rate at Yapalsi

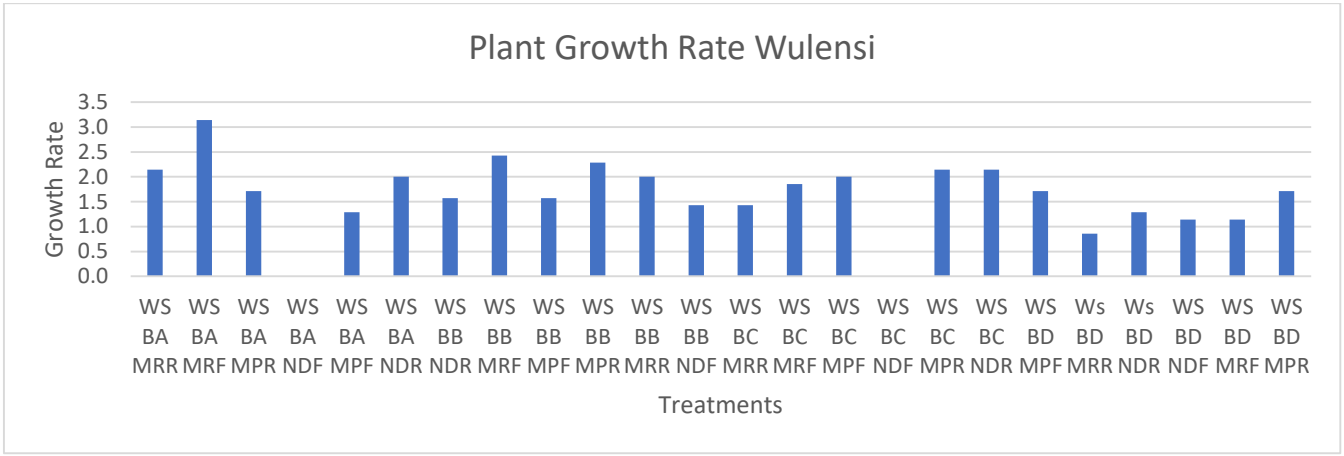

FIGURE 9: Plant Growth Rate at Wulensi

With regards to plant vigour, as stated earlier, this was calculated from plant height data picked at two times, with a week difference between the first and the second measurements. Vigour was calculated using the following formular: VI = S x (Gt/Dt), where S = Plant height, Gt = number of plants germinated in a treatment at the time of taking plant height, and Dt = number of days from first plant height measurement to the time of the second plant height measurement. The results are shown in figures 10, 11 and 12 for Nebilyili, Yapalsi and Wulensi respectively. On a scale of 1 to 10, where 1 is less vigorous and 10 is highly vigorous, the plants at the Wulensi site were observed to be more vigorous compared to those at Yapalsi and Nebilyili, since about 11 out the 24 treatments recorded moderate to high vigour while only 10 and 5 out of the 24 treatments, respectively in Yapalsi and Nebilyili recorded moderate to high vigour. In terms of varietal performance, Mayan rose appeared to be more vigorous than Maris Peer and Nadine.

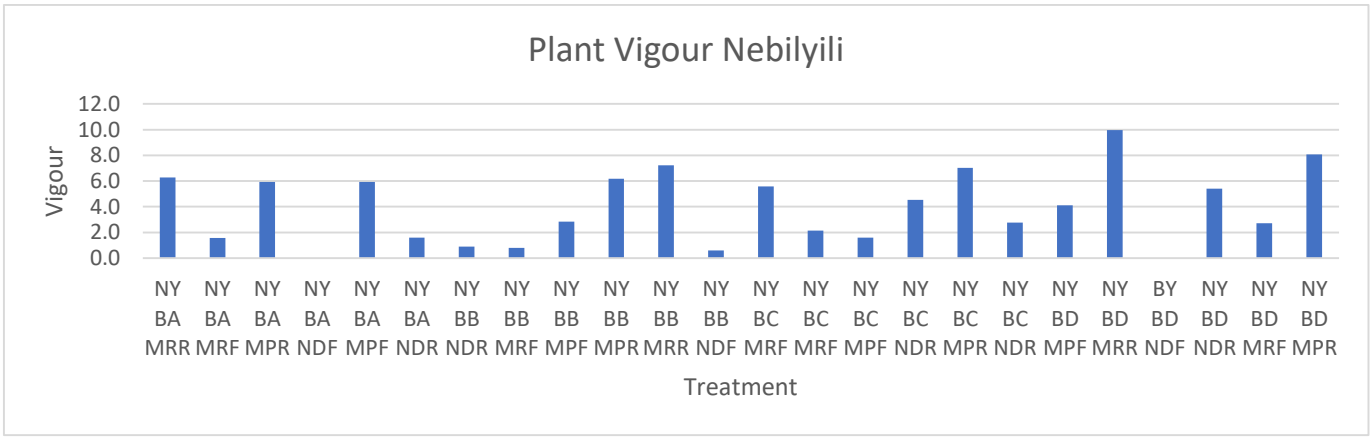

FIGURE 10: Plant Vigour at Nebilyil

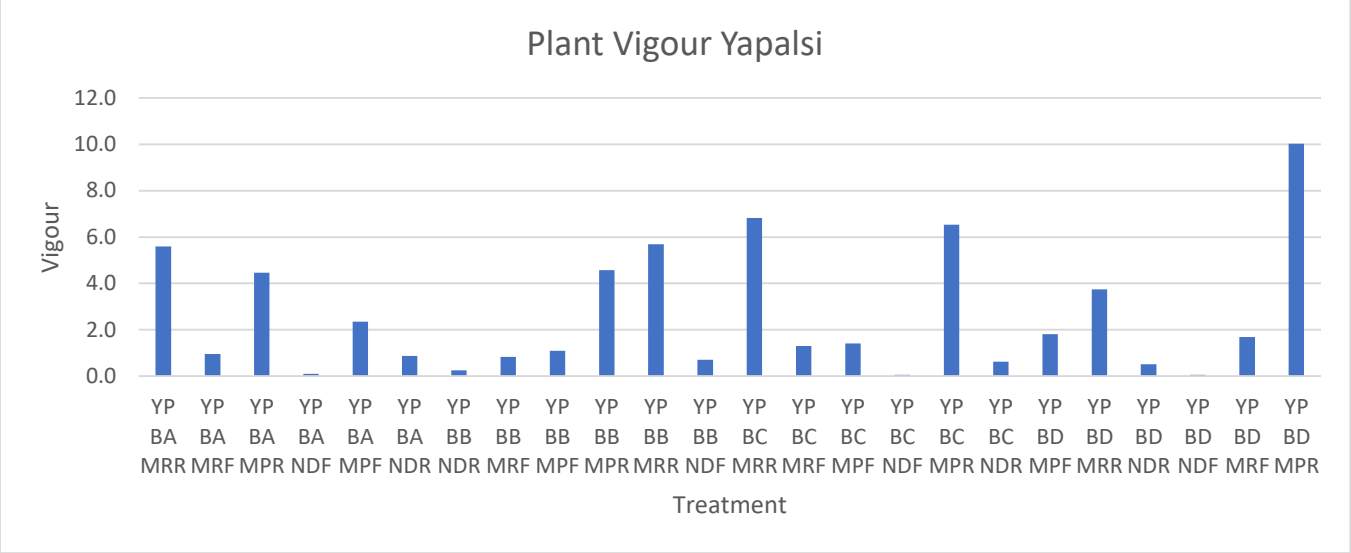

FIGURE 11: Plant Vigour at Yapalsi

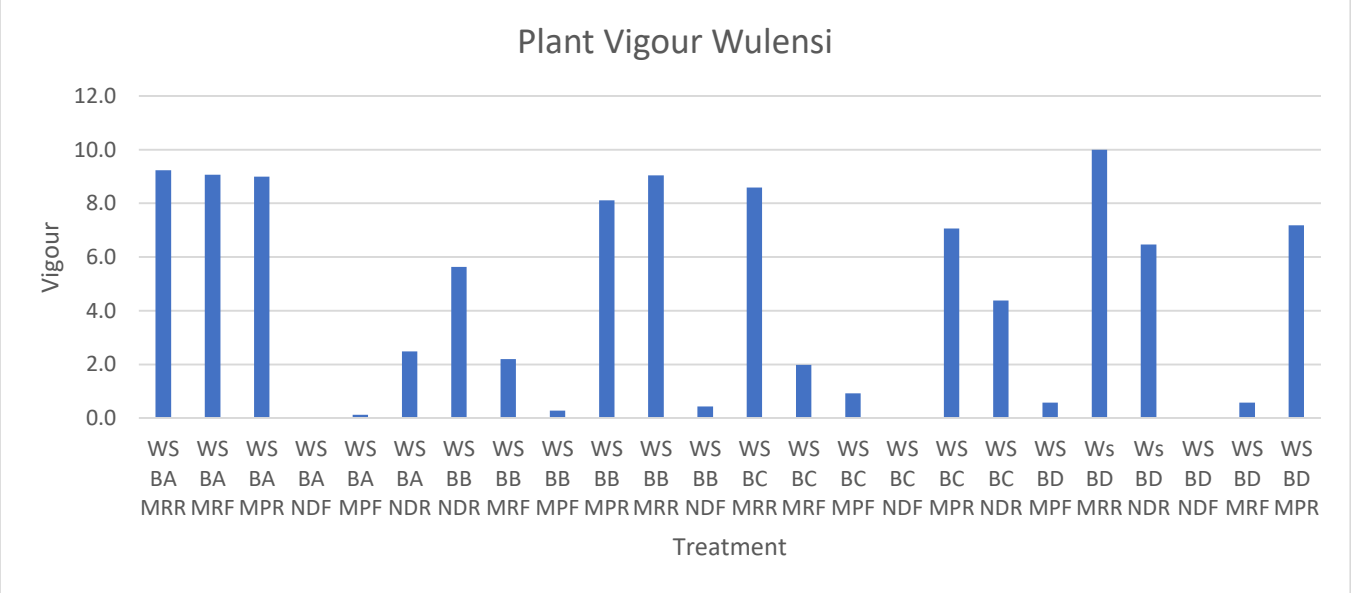

FIGURE 12: Plant Vigour at Wulensi

The crops were supposed to be monitored to the point of harvesting, where data on yield will be computed. Since the potato plants did not grow to full maturity (between 3 and 4 months) as a result a disease condition that set in, the yield was disappointingly low. As can be seen in figures 13, 14, and 15, generally, the yield was very poor, with a maximum of 3.1MT/ha compared to average local potato yield of 8MT/ha in Mozambique and as high as 50MT/ha in Europe and America (Belanger et al., 2000, Statista.com, accessed on 19th July, 2023). Among the varieties, Nadine performed better than the other two varieties (Mayan Rose and Maris Peer), although there was no significant difference ($P > 0.05$) between varieties. Among the three sites that were used for the trial, there was significant difference ($P < 0.05$) between Wulensi and the two other sites. The Wulensi site had improved yields over Nebilyili and Yapalsi. However, there was no significant difference between Nebilyili and Yapalsi. The potato seed were planted on both ridges and on flat land, but at harvest it was revealed that there was no significant difference ($P > 0.05$) between potato planted on ridges and those planted on flat land, even though, those planted on ridges produced more tubers than those on flat land. This difference can only be attributed to chance and a random occurrence.

At the Nebilyili site, out of the 24 plots planted, only 4 plots yielded crop. All of these four plots were of the Nadine variety and planted on ridges.

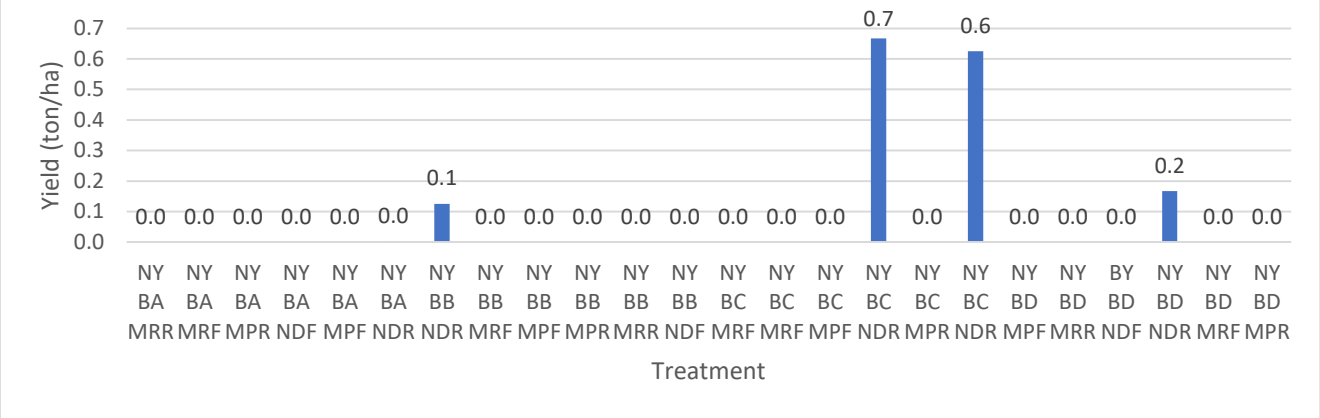

FIGURE 13: Yield (ton/ha) at Nebilyili

At the Yapalsi site, out of the 24 plots planted, only one plot produced some yield and that was also the Nadine variety planted on ridges similar to the Nebilyili site.

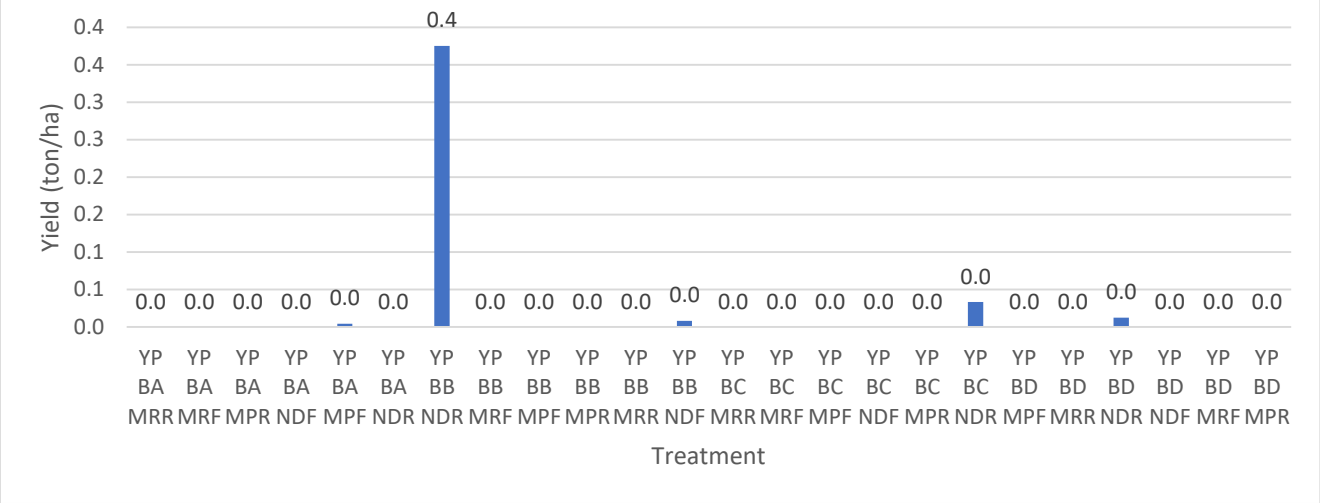

FIGURE 14: Yield (ton/ha) at Yapalsi

In contrast, to the Nebilyili and Yapalsi results, at the Wulensi site, out of the 24 plots planted, a total of 14 plots produced some yield. Out of the 14 plots from which yield was obtained, 5 were planted of the Nadine variety, 5 Mayan Rose and 4 Maris Peer. Of the 14 plots with yield, 12 were planted on ridges whilst 2 were on flat land. The ridged planting resulted in the higher yields.

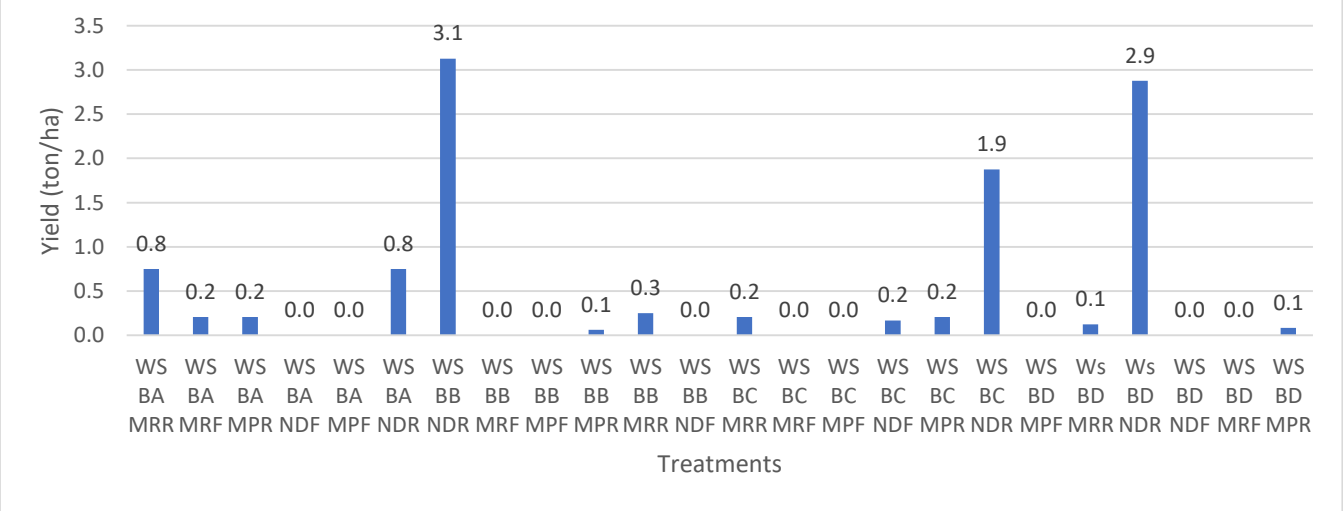

FIGURE 15: Yield (ton/ha) at Wulensi

4.1 Fungi isolates from healthy and rotten Irish potato tubers:

The fungal species *A. flavus, A. fumigatus, A.oryzae* and *F. oxysporum* were isolated from the healthy Irish potato tubers (Figure 16). *Aspergillus flavus* and *F. oxysporum* were recorded for Mayan Rose, Nadine and Maris Peer varieties of the Irish potato. *A. fumigatus* was only recorded for Mayan Rose, while Maris Peer only recorded occurrence for *A. oryzae*.

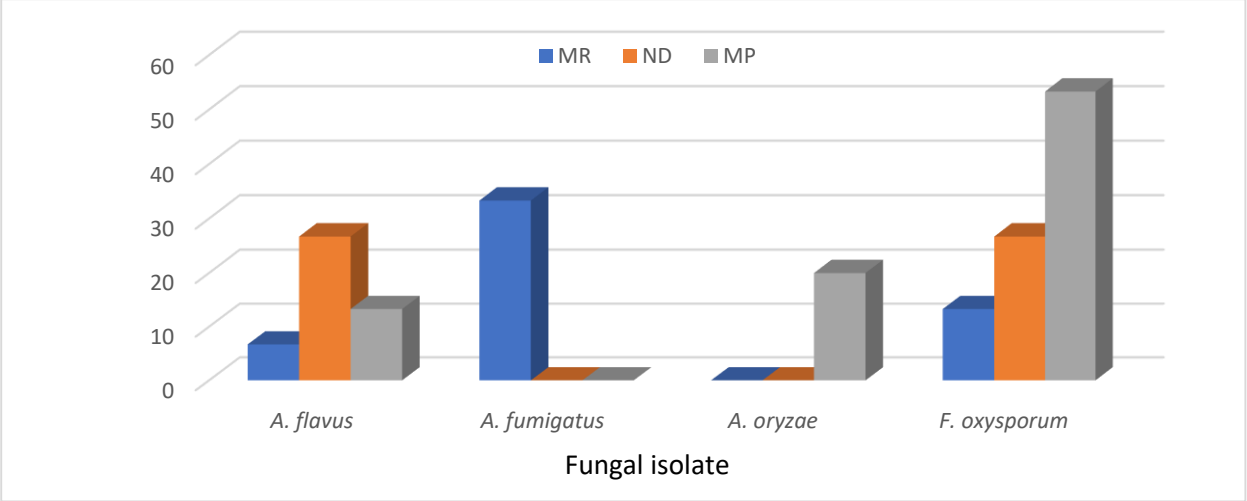

FIGURE 16: Fungal species isolated from healthy tubers of Mayan Rose, Nadine and Maris Peer varieties of the Irish potato

The fungal species recorded for the rotten Mayan Rose, Nadine and Maris Peer varieties of the Irish potato were *A. flavus, A. fumigatus, A. oryzae, A. tamaarii, F. oxysporum* and *Penicillium brvicompactum* (Figure 17). *Aspergillus flavus* and *F. oxysporum* were recorded for all the rotten tubers of the three varieties of the Irish potato varieties (Mayan Rose, Nadine and Maris Peer). *Aspergillus fumigatus* was recorded for Mayan Rose and Maris Peer but not Nadine. Only Nadine recorded occurrence for *A. oryzae*. Also, *P. brevicompactum* was only recorded for Mayan Rose.

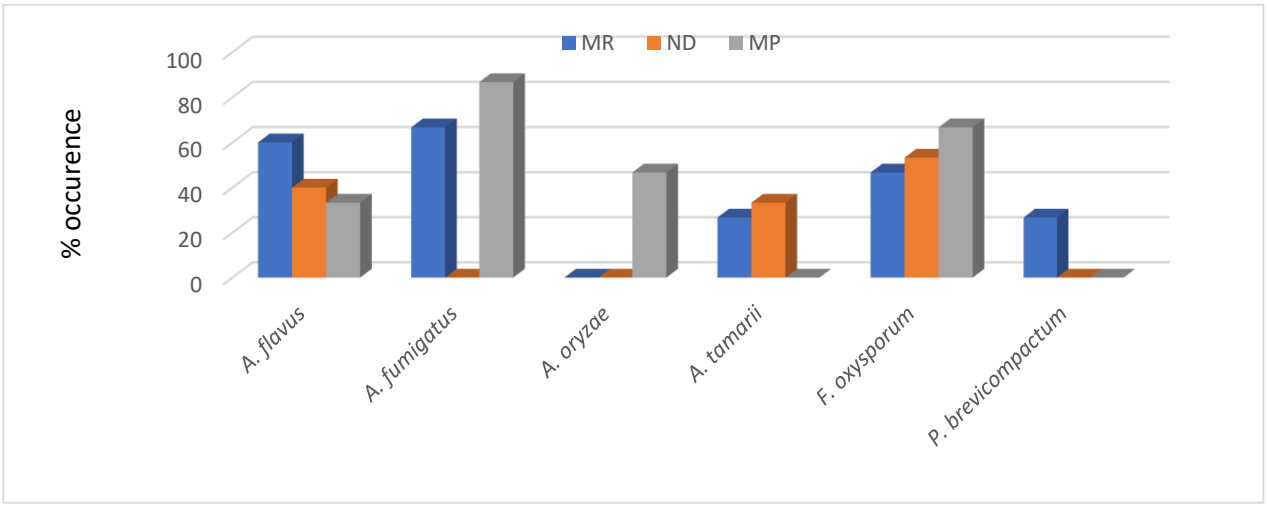

FIGURE 17: Fungal species isolated from rotten tubers of Mayan Rose, Nadine and Maris Peer varieties of the Irish potato

The pathogenicity test confirmed *A. flavus, A. fumigatus, A. oryzae, A. tamaarii, F. oxysporum* and *P. brvicompactum* as Irish potato tuber rot fungal pathogens. This agrees with the findings of Ibrahim et al. (2014) and Gashgari and Gherbawy (2013).

The fungi *A. flavus, A. fumigatus, A. oryzae* and *F. oxysporum* which were isolated from both the healthy and rotten Irish potato tubers could have been on the healthy potato tubers as normal mycoflora which became opportunistic pathogens under favourable environmental conditions for infection. Also *A. flavus, A. fumigatus, A. oryzae* and *F. oxysporum* could have induced a latent infection on the healthy Irish potato tubers which expressed rot symptoms as time progressed.

TABLE 5
FUNGI ISOLATED FROM IRISH POTATO PLANTS (ROOT SYSTEM)

No.	Code	Fungi							
		Fusarium oxysporum	*Penicillium citrinum*	*Alternaria alternata*	*Aspergillus flavus*	*Aspergillus niger*	*Aspergillus ochraceus*	*Trichoderma harzianum*	*Mucor hiemalis*
1	NY BAMRR	+	+	-	-	-	-	-	-
2	NY BAMRF	+	+	-	-	-	-	-	-
3	NY BAMPR	+	+	-	-	-	-	-	-
4	NY BA NDF	+	+	-	-	-	-	-	+
5	NY BA MPF	+	+	-	-	-	-	-	-
6	NY BB NDR	+	+	-	-	-	-	-	+
7	NY BB MRF	+	+	-	-	-	-	-	-
8	NY BB MPF	+	+	-	-	-	-	-	-
9	NY BB MPR	+	+	+	-	-	-	-	-
10	NY BB NDR	+	+	-	-	-	-	-	-
11	NY BC MRF	+	+	-	-	-	-	-	-
12	NY BC NDF	+	+	-	-	-	-	-	-
13	NY BC MPF	+	+	-	-	-	-	-	-
14	NY BC NDR	+	+	+	-	-	-	-	-
15	NY BC MPR	+	+	-	-	-	-	-	+
16	NY BDMPR	+	+	+	-	-	-	-	-
17	NY BDMRR	+	+	+	-	-	-	-	-
18	NY BD NDF	+	+	+	-	+	-	-	-
19	NY BDNDR	+	+	-	+	-	-	-	-
20	NY BD MPF	+	+	+	-	-	-	-	-
21	YP BA NDR	+	+	+	-	-	-	-	+
22	YP BA MPF	+	+	+	+	-	-	-	-
23	YP BA MPR	+	+	+	-	-	-	-	-
24	YP BA NDF	+	+	-	-	-	-	-	-
25	**YP BB NDR**	**+**	**+**	**+**	-	-	-	-	-
26	YP BB MRF	+	+	-	-	-	-	+	-
27	YP BB MPF	+	+	-	-	-	-	+	-
28	YP BB MPR	+	+	-	-	-	-	-	-
29	YP BC MRR	+	+	-	-	-	-	-	-
30	YP BC MRF	+	+	-	-	-	-	-	-
31	YP BC MPF	+	+	-	-	-	-	-	-
32	YP BC NDF	+	+	-	-	-	-	-	-
33	YP BD MPF	+	+	+	-	-	-	-	-
34	YP BD MPR	+	+	+	-	-	-	-	-
35	YP BD NDR	+	+	-	-	-	-	-	+
36	YP BD NDF	+	+	-	-	-	-	-	+
37	YP BD MRF	+	+	-	-	+	-	-	+
38	WS BA NDF	+	+	-	-	-	-	-	+
39	WS BA MPF	+	+	-	-	-	-	-	+
40	WS BA MPR	+	+	+	-	+	-	-	-
41	WS BB NDR	+	+	-	-	-	-	-	+
42	WS BB MRF	+	+	-	-	-	-	-	-
43	WS BB MPF	+	+	-	-	-	-	-	-
44	WS BC NDF	+	+	-	-	-	-	-	-
45	WS BC MRF	+	+	-	-	-	-	-	+
46	WS BC MPF	+	+	-	-	-	-	-	+
47	WS BD MPF	+	+	+	-	-	-	-	-
48	WS BD MPR	+	+	+	-	-	-	-	-

Key: *+ = fungi present; - = fungi absent = fungi absent, NY= Nebilyili, YP = Yapalsi, WS = Wulensi, BA = Block A, BB = Block B, BC = Block C, BD = Block D, MP = Maris Peer, MR = Mayan Rose, ND = Nadine, R = Ridge and F = Fatland*

The fungal species isolated from the root system of the Mayan Rose, Nadine and Maris Peer Irish potato varieties obtained from the fields of Nebilyili, Yapalsi and Wulensi were *Alternaria alternata, Aspergillus flavus A. niger, A. ochraceus, Fusarium oxysporum, Mucor hiemalis, Penicillium citrinum* and *Trichoderma harzianu* (Table 3). Although *Fusarium oxysporum* and *P. citrinum* were recorded among all the root systems examined, *Alternaria alternata, Aspergillus flavus A. niger, A. ochraceus, Mucor hiemalis* and *Trichoderma harzianum* were not recorded among all the root system examined. Among the various fungi isolated from the root system of the Irish potato crops, *F. oxysporum* is pathogenic to the Irish potato and causes Fusarium wilt in the crops. Symptoms of Fusarium wilt was expressed among some of the Mayan Rose, Nadine and Maris Peer varieties of Irish potato cultivated at the Nebilyili, Yapalsi and Wulensi locations; resulting in poor crop establishment on the field.

V. CONCLUSION AND RECOMMENDATION

Based of the study findings presented above, it can be concluded that there is the potential for Irish potato to be grown as another food crop in Ghana.

It is recommended that further studies should be conducted under irrigation, rain fed and green house conditions to determine the best conditions under which optimum yields can be obtained to feed the teaming Ghanaian consumers of the Irish potato.

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Effect of Coating Pelleted Animal Feed with Novel Edible Coating Mixture

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Abstract— *This current study was undertaken to evaluate the effect of combining Aloe vera gel and African star Apple (Chrysophyllum albidum) juice on the shelf life and physical appearance of pelleted animal feed. The extracts of these two plants were prepared using standard methods and applied by spray pyrolysis method on the feed. The two extracts were proportionally mixed using the optimal design of mixture method. The optimal proportion was 4:1 (Aloe vera gel to African star apple juice). The phytochemical analysis of both extracts was carried out and found to contain kaempferol, flavanone, tannin, phylate, and aphylidine which are very effective antimicrobial and antioxidant agents. The toxicity test (LD50) shows that the blend of both extracts was non-toxic. This result was buttressed by FTIR analysis which showed no harmful functional group. The resultant effect of coating feed pellets with this novel mixture was an extension of the shelf life of pellets by 14 days and improving the physical appearance of the feed.*

Keywords— Edible coating, Aloe vera, African star apple, shelf-life, Pelleted feed.

I. INTRODUCTION

Prolonging the shelf life of perishable food products is currently a major challenge. Food preservation technologies and edible film and coating seem to be the solution. The uses of edible films and coatings developed from food biopolymers have advanced significantly during the last few years. (Panchal et al., 2022).

The rising consumer concerns about food quality and health benefits compel researchers to find a way to enhance food quality while not disturbing the product's nutritional value. The demand for plant-based materials has been increased in the food industry as many of them contain essential elements and also found to be an eco-friendly material (Pham et al., 2023).

Applying a thin layer of edible coating made from protein and lipids can inhibit the product from decay and extend the shelf life. They serve as gas and moisture inhibitors which regulate the respiration rate, slowing down the ripening of vegetables. Antimicrobial agents, enzymes, minerals, and vitamins are also used in edible coatings, which boost practical properties. ("Edible Films and Coatings for Food Applications," 2009a). Edible coatings have become popular in the food industry because they produce less waste, are cost-effective, and offer protection after the package has been opened (Kundu et al., 2020).

The preservation of taste and extension of shelf-life of animals and other agro-products have been of major concern to many farmers (Agarwal & Saini, 2016).

Edible coating could be made from various substances both natural and synthetic, and their ability to serve in elongating the shelf life and retention of texture is of paramount importance. Yossef, M.A (2014) compared 4 different edible coating materials (pectin, gluten, starch, and protein) applied on the surface of fruits. Fruit quality was evaluated by weight loss, firmness retention, visible decay, surface color development, titratable acidity, total soluble solids, reducing sugars, and sensory attributes. The pectin-based coating had a significant effect on the retention of firmness, reduced weight loss, and showed better results from the Physico-chemical analysis compared to the other coatings and to the control fruit (O & Author, n.d.).

1.1 Aloe vera:

Aloe vera gel has recently drawn interest as a potential edible coating substance in the food industry. Aloe vera-based edible coatings prevent moisture loss and keep fruits firm, control respiration rate, delay oxidative browning, and reduce microorganism proliferation in sweet cherry, table grapes, and nectarines (Misir et al., 2014).

Polysaccharides, glycoproteins, phenolic compounds, salicylic acid, lignins, hormones, amino acids, vitamins, saponins, and enzymes are just a few of the complex ingredients that give aloe vera its wide range of beneficial properties. Gel made from aloe vera has antibacterial, antifungal, and anti-inflammatory properties. Aloe vera gel is primarily used in the cosmetics sector to treat burns, and scars, and to promote wound healing (Padmaja et al., 2015)(Singh et al., n.d.).

With the growing consciousness of the bad effects of various chemical techniques and environmental hazards emphasize a need to develop consumer-friendly and environment-friendly technology to increase the shelf life of mango fruits while maintaining their quality and general acceptability. The use of edible coating is becoming popular because it is hazard-free and environmentally ("Edible Films and Coatings for Food Applications," 2009b).

In a related study, (Suriati et al., 2018) reported the efficacy of Aloe vera gel as a source of cost-effective and eco-friendly packing material for tropical and subtropical fruits. It was found to extend the shelf life of figs by delaying decay and ripening as reflected in lower weight loss, lesser changes in physico-chemical parameters, greater firmness, better sensory quality, and marketability.

African Star Apple botanically called Chrysophllum Albidum and known in Igbo as Udara is a yellowish round tropical fruit. It is found mostly in Southeast and Southwest Nigeria. It is a seasonal fruit and is available in abundance from December to March annually. The fruit has four or five seeds and when ripe is sweet but tastes sour when unripe(Phytochemical Constituent of African Star Apple, n.d.).

Pelletization is the act of compressing and molding materials into pellets (Deb & Ahmed, 2016). Pellets could be produced in different sizes depending on the area of application. In recent years, pelletization has gained increasing interest among researchers due to its relative advantages over other similar industrial techniques. It is widely used in pharmaceutical, ore processing, animal feed, and fertilizer industries. Pellets are simple small free-flowing spherical particles formed by the agglomeration of fine powder of Phytochemical Constituent of African Star Apple (n.d.)granules. The mean diameter of pellets ranges from 3.0-9.0 mm.

With screw extrusion palletization, the pellets maintain all the active ingredients, and feed wastage is reduced to the barest minimum. Pelletization of animal feed facilitates the storage and transportation of the feed (Tashiwa et al., 2019). It also reduces selective Feeding.2.0mm.(Barkate et al., 2020) Among the various production methods of fish feed, screw extrusion. The edible films are differentiated from coatings by being a standalone material, whereas the coatings are directly applied to the food surface. The edible coatings hold the same properties as the films ("Edible Films and Coatings for Food Applications," 2009c) (Raghav et al., 2016).

II. MATERIALS AND METHOD

TABLE 1

S. No.	Material	Description
1	**P**elleted feed	Cylindrical-shaped brownish extrudate
2	**Aloe vera**	Shrubby or arborescent, perennial, xerophytic, succulent, pea-green colour plant
	(Aloe barbadensis)	
3	African star apple	Wild plant with sweet pleasantly acidic, fleshly fruit pulp
	(Chrysophyllum albidum)	

The pellets were produced using a single screw horizontal pelleting machine powered by a 5 hp electric motor.

Preparation of edible coating. The aloe vera and African star apple were thoroughly washed with chlorinated water and rinsed with distilled water. The back of the aloe vera leaf was peeled and the pulp was crushed and squeezed extracting the gel. While the African star apple seeds were extracted, the yellowish pulp was compressed and the juice was extracted. An optimal mixture design of the experiment was applied and the optimal mixture ratio was derived. 2.0g/L of Ascorbic acid and 4.5g/L OF citric acid were added to the mixture. Water served as the universal solvent.

Phytochemical analyses of both Aloe vera and African star apple were carried out to determine the active phytochemical composition of each plant. Also, a toxicology analysis using the LD_{50} method was equally carried out. Results were recorded accordingly.

Method of application of edible coating. A spray pyrolysis technique was adopted in coating the pellets.

III. RESULTS AND DISCUSSION

3.1 Optimal Mixture design:

The edible coating is composed of Aloe vera gel, African star apple juice, and water which are the major constituents. The appropriate quantities of Aloe vera gel, African star apple juice, and water used for compounding the edible coating were optimized using Optimal mixture design. The results were analyzed with Design Expert software. A ratio of 4:1 was derived and used in constituting the edible coating.

3.2 Graphical Optimization:

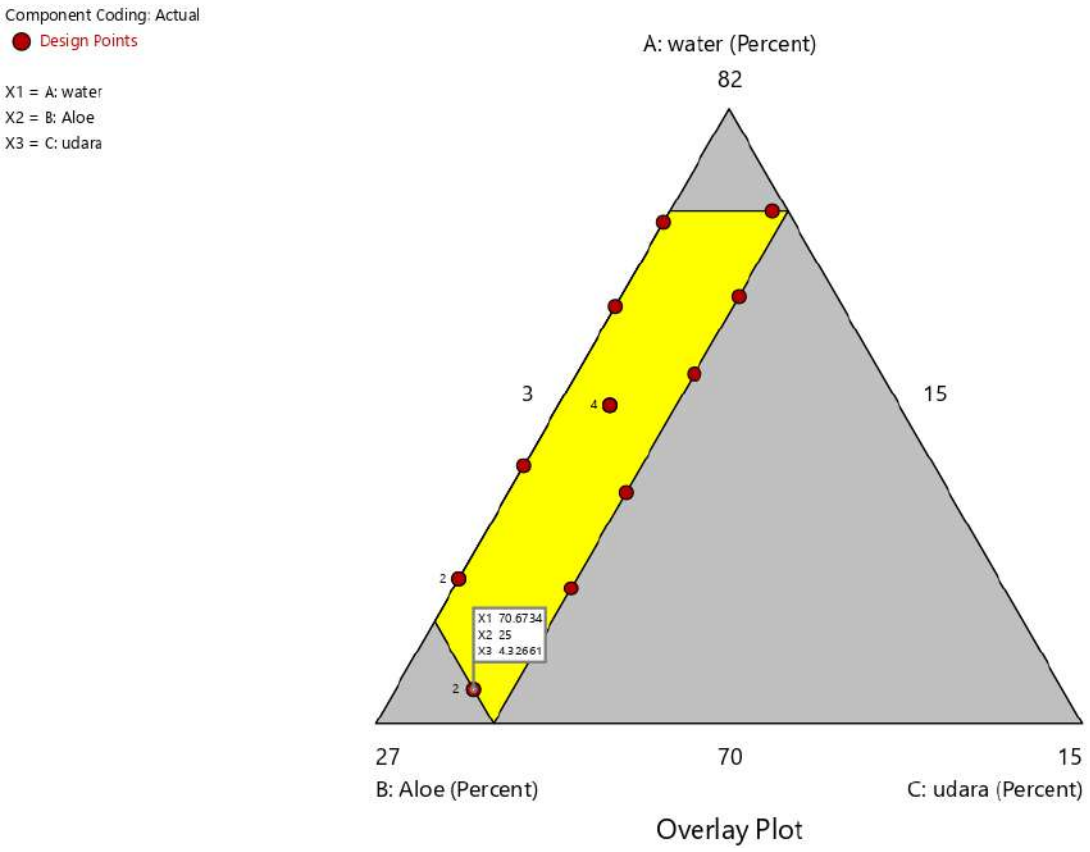

FIGURE 1: Graphical Optimization of Mixture Components.

The trapezium with the triangular defines the estimated values for the different combinations of the mixture components. The optimal values of the mixture components are the same as those generated by the numerical optimization plots. These values are still 70.7% water, 25% Aloe vera gel and 4.3% African star apple juice.

3.3 Phytochemical analysis:

Active phytochemicals in Aloe vera are of Aloe vera of African star apple.

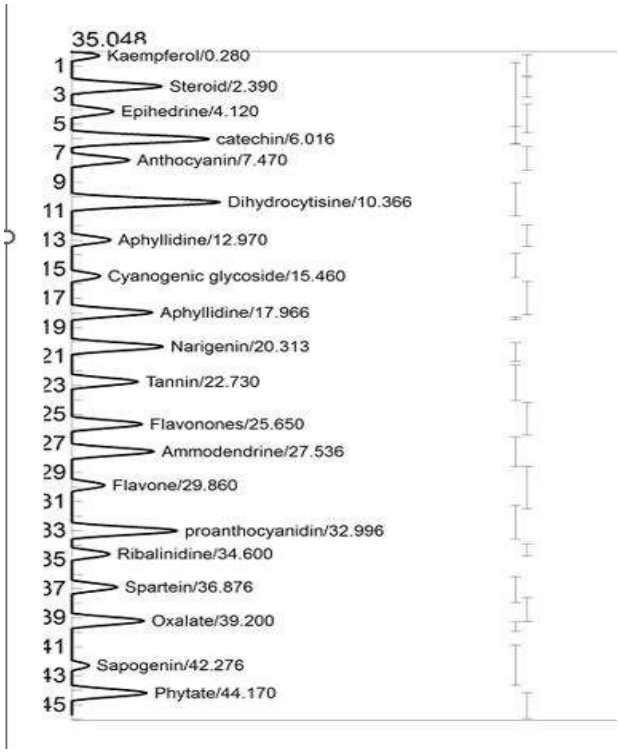

FIGURE 2: Spectral display of phytochemical of Aloe vera

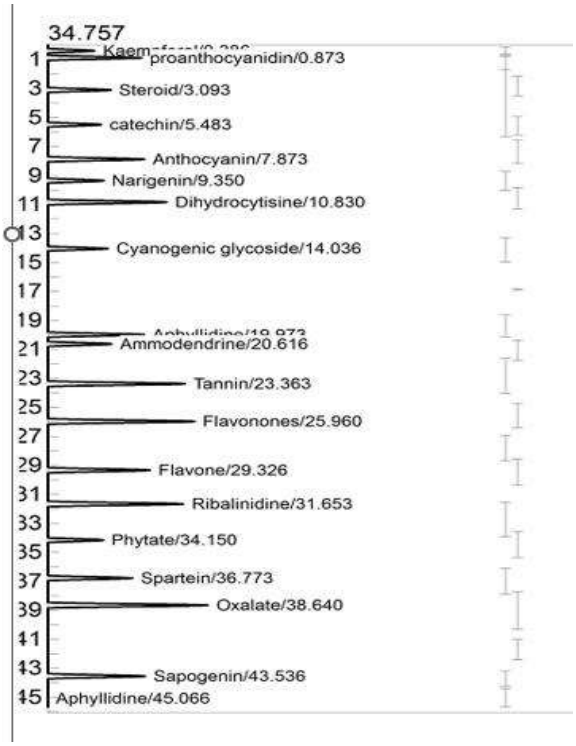

FIGURE 3: Spectra display of phytochemicals of African star apple

Figure 2 shows that aloe vera contains 44.170Ug/ml of phylate which is the most dominant phytochemical in aloe vera. Study results have shown that phylate has beneficial health effects such as antioxidant and anticancer potential and reduction in pathogenic disorders. Next in the order of abundance is sapogenin 42.276Ug/ml. Sapogenin is known for its antimicrobial effect. The phytochemicals of the African Star Apple were determined quantitatively by Springbod laboratory, Awka, Anambra state. As seen in Figure 3, Aphylidine has the highest retention value of 45.066 Ug/ml. Quantitative analysis of phytochemicals in African star apples shows the presence of kaempferol, steroid, catechin, tannin, flavanones, flavone, oxalate, and aphylidinein reasonable quantities. These are effective antimicrobial and antioxidant agents.

IV. CONCLUSION

The blend of Aloe vera gel and African star apple juice has proved to be a very effective edible coating mixture. The shelf life of pelleted feed was extended by 14 days as the novel mixture acted as an antimicrobial and antioxidant agent. A visible improvement in the physical appearance of the pellet was recorded. The outcome of this research work could be extended to the preservation of other perishable agro-products and subsequent reduction in post-harvest losses.

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Direct Seeding of Rice with Drum Seeder in Visakhapatnam District of North Coastal Zone of Andhra Pradesh

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Abstract— *Rice is the major predominant crop during Kharif in Visakhapatnam district of Andhra Pradesh, cultivated in an area of 1,10,008 ha with a productivity of 2624 kg/ha. Farmers traditionally grow rice using methods involving high seed rates, close spacing, and late transplanting with over-aged seedlings—practices exacerbated by erratic rainfall and climate change. Scarcity of labor, escalating wages, and reduced labor efficiency are leading to low net returns. In this context, the DAATTC, Visakhapatnam, in collaboration with the Department of Agriculture, introduced the 'Drum Seeder' technology—a simple, labor-efficient method for direct seeding. This technology saves time and money, enabling harvest 7-10 days earlier than conventional transplanted rice. On-Farm Demonstrations (OFDs) were organized during Kharif 2021 and Rabi 2021-22 across 8 locations. Results showed that drum seeder technology recorded an* ***11.39% higher average grain yield*** *(6245 kg/ha) compared to conventional transplanting (5604 kg/ha). The technology reduced the cost of cultivation by* ***9.35%*** *(Rs. 4,850/ha), primarily through savings on nursery management and transplanting labor. Combined with a* ***7-10 day earlier harvest****, this led to a* ***55.8% increase in net income*** *(Rs. 40,430/ha vs. Rs. 25,950/ha) and a superior cost-benefit ratio (2.03 vs. 1.59). The study concludes that drum seeder technology is a viable, profitable, and labor-saving innovation for rice cultivation in the region.*

Keywords— Direct Seeded Rice, Drum Seeder, Cono Weeder, On-Farm Demonstration, Yield, Economics, Labor Saving.

I. INTRODUCTION

Rice is a staple food crop crucial for India's food security. Although productivity has increased in states like Andhra Pradesh, the compound growth rate at the national level is declining (Krishnaiah, 1999). With limited scope for area expansion and plateauing yields in irrigated ecosystems, increasing production per unit area and time is imperative. India must produce 135-145 million tonnes by 2020 to feed its growing population, requiring a productivity increase to 3.2 t/ha from the current 2.05 t/ha (The Hindu Survey of Indian Agriculture, 2006).

In Visakhapatnam district, rice is cultivated on 1,10,008 ha during Kharif and 2,000 ha during Rabi. Rising cultivation costs—driven by labor scarcity, escalating wages, and increased input prices—threaten profitability. The labor-intensive transplanting operation is a major bottleneck. Direct seeding of rice using a drum seeder offers a promising solution. This technology reduces labor dependency by 30-50% and can increase productivity by 20-30% (Directorate of Rice Research, 2003). It eliminates the need for nursery raising, pulling, and transplanting, allowing earlier crop establishment and maturity. However, successful adoption requires appropriate field selection, irrigation management, suitable varieties, and effective weed control.

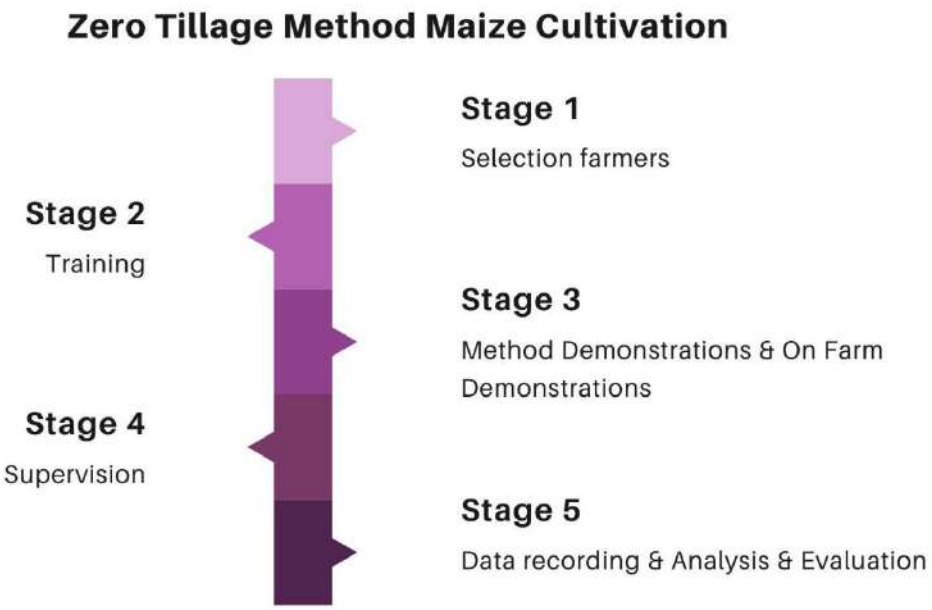
To address these challenges and promote sustainable intensification, the DAATTC, Visakhapatnam, conducted on-farm demonstrations with the following objectives:

Objectives:

1. To evaluate the feasibility and agronomic performance of drum seeder technology in Visakhapatnam district through On-Farm Demonstrations (OFDs).
2. To compare the grain yield and yield attributes of drum-seeded rice with conventionally transplanted rice.
3. To analyze the economics of drum seeder technology, including labor savings and profitability.

II. MATERIALS AND METHODS

The study was conducted by scientists from DAATTC, Visakhapatnam, in collaboration with the District Department of Agriculture. On-Farm Demonstrations (OFDs) were established in 8 locations during Kharif 2021 (3 locations) and Rabi 2021-22 (5 locations).



2.1 Technology Description: The Drum Seeder and Cono Weeder:

The drum seeder (Fig. 1) is a manually operated implement made of plastic, designed to sow pre-germinated paddy seeds directly in puddled fields. It sows 8 rows simultaneously with a row spacing of 20 cm. The cono weeder (Fig. 2) is used for inter-row weed control, incorporating weeds into the soil.

FIGURE 1: The eight-row drum seeder used for direct seeding.

FIGURE 2: The cono weeder used for intercultivation and weed management.

2.2 Salient Features of Drum Seeder Technology:

- Eliminates costs associated with nursery raising, pulling, and transplanting.
- Reduces seed requirement (12-18 kg/acre vs. 30 kg/acre in transplanting).
- Ensures uniform plant population and spacing.
- Enables earlier crop maturity by 7-10 days.

- Lightweight, easy to operate; can cover 1 hectare per day.

2.3 Agronomic Management:

Paired demonstrations were set up on each farm, comparing drum-seeded plots with adjacent farmer-managed transplanted plots (check). Popular varieties MTU-1001 (Kharif) and MTU-1010 (Rabi) were used. In drum-seeded plots, pre-germinated seeds were sown directly into well-puddled fields. Recommended fertilizer doses were applied. Weed management combined the use of the cono weeder (twice at 20 and 40 days after sowing) with need-based herbicide applications. The crop was maintained using recommended package of practices.

2.4 Data Collection and Analysis:

Observations on yield attributes (productive tillers/m², grains/panicle) and grain yield (kg/ha) were recorded from both treatments. A detailed account of labor utilization (men/women days) and cost of cultivation was maintained. Simple mean comparisons were used to analyze the data across locations. Percentage changes and cost-benefit ratios were calculated to assess economic performance.

III. RESULTS AND DISCUSSION

3.1 Crop Duration and Yield Attributes:

The performance of drum-seeded rice compared to conventional transplanting is summarized in Table 1.

TABLE 1
YIELD AND YIELD ATTRIBUTES OF DRUM-SEEDED VS. TRANSPLANTED RICE (AVERAGE OF KHARIF 2021 & RABI 2021-22)

Season & Locations	Parameter	Drum Seeder (Demo)	Conventional (Check)	% Change
Kharif 2021 (n=3)	Crop Duration (days)	124	134	-7.50%
	Productive Tillers / m²	227	190	19.50%
	Grains / Panicle	213	198	7.60%
	Grain Yield (kg/ha)	6580	5680	**15.80%**
Rabi 2021-22 (n=5)	Crop Duration (days)	113	121	-6.60%
	Productive Tillers / m²	230	212	8.50%
	Grains / Panicle	171	153	11.80%
	Grain Yield (kg/ha)	5910	5528	6.90%
Average (n=8)	Crop Duration (days)	119	128	-7.00%
	Productive Tillers / m²	229	201	13.90%
	Grains / Panicle	192	176	9.10%
	Grain Yield (kg/ha)	6245	5604	11.40%

Drum-seeded rice matured **7-10 days earlier** (average 9 days) than transplanted rice, reducing exposure to terminal stresses and enabling earlier harvest. This earlier establishment likely contributed to better tiller production, with drum-seeded plots showing **13.9% more productive tillers per m²** and **9.1% more grains per panicle**. These superior yield components resulted in an **average yield advantage of 11.4%** (6245 vs. 5604 kg/ha). The results corroborate findings by Chandrasekhara Rao et al. (2013), who reported that direct seeding facilitates better root development and tiller production.

3.2 Labor Utilization and Cost of Cultivation:

A detailed comparative cost analysis is presented in Table 2. The drum seeder technology significantly altered the labor and cost structure.

TABLE 2

COMPARATIVE ANALYSIS OF LABOR AND COST OF CULTIVATION (Rs./ha) FOR DRUM-SEEDED vs. TRANSPLANTED RICE

Cost Component	Drum Seeder Technology	Conventional Transplantation
1. Nursery Management	Rs. 0	Rs. 1,100 (2 M Labor + FYM)
2. Seed & Treatment	Rs. 1,200 (40 kg seed)	Rs. 2,250 (75 kg seed)
3. Land Preparation	Rs. 6,600 (10 M Labor)	Rs. 5,600 (8 M Labor)
4. Transplanting/Sowing	Rs. 2,000 (5 M, 3 W Labor)	Rs. 8,700 (15M+3W Pulling + 25W Transplant)
5. Weeding	Rs. 6,500 (3M,20W Labor + Herbicide)	Rs. 4,300 (1M,20W Labor + Herbicide)
6. Fertilizer Application	Rs. 10,400 (8 M Labor + Fertilizers)	Rs. 10,400 (8 M Labor + Fertilizers)
7. Plant Protection	Rs. 4,500 (2M,2W Labor + Chemicals)	Rs. 6,300 (4M,4W Labor + Chemicals)
8. Irrigation	Rs. 2,400 (8 M Labor)	Rs. 3,000 (10 M Labor)
9. Harvest & Post-Harvest	Rs. 13,400 (16M,16W Labor)	Rs. 13,000 (16M,16W Labor)
TOTAL LABOR (Men/Women)	52 M / 68 W	64 M / 93 W
TOTAL COST (Rs./ha)	Rs. 47,000	Rs. 51,850

The drum seeder technology reduced total labor by **12 man-days and 25 woman-days per hectare**. The most significant savings came from eliminating nursery operations and reducing transplanting labor. This resulted in a **9.35% reduction in the total cost of cultivation** (Rs. 4,850/ha).

3.3 Economic Profitability:

The economic advantage of drum seeder technology is clear from Table 3. Calculations are based on average yields and costs, with grain valued at Rs. 14/kg for both treatments for a fair comparison.

TABLE 3

ECONOMICS OF DRUM SEEDER TECHNOLOGY VS. CONVENTIONAL TRANSPLANTING (AVERAGE OF KHARIF & RABI)

Sl. No.	Particulars	Drum Seeder Technology	Conventional Method	Difference (Rs./ha)
1	Grain Yield (kg/ha)	6245	5604	641
2	Gross Returns (Rs./ha)*	87,430	78,456	8,974
3	Cost of Cultivation (Rs./ha)	47,000	51,850	-4,850
4	Net Income (Rs./ha)	40,430	26,606	13,824
5	Cost : Benefit Ratio	2	2	0

Grain price: Rs. 14/kg for both (assuming same market for produce).

The synergy of **higher yield (11.4%) and lower cost (9.35%)** resulted in a **51.9% higher net income** for drum-seeded rice. The cost-benefit ratio was also more favorable (2.03 vs. 1.59). If the earlier harvest from drum seeding commands a premium price, the economic advantage would be even greater.

IV. CONCLUSION

The on-farm demonstrations conclusively demonstrate that direct seeding of rice using a drum seeder is a highly feasible and profitable technology for Visakhapatnam district. It offers a triple advantage: **significant yield increase (11.4%), substantial cost reduction (9.35%), and earlier crop maturity (7-10 days).** The technology directly addresses critical constraints of labor scarcity and high wage rates by saving 37 labor-days per hectare. This translates into a dramatic **51.9% increase in net income** and a better return on investment. For sustainable intensification of rice systems in the region, large-scale promotion of drum seeder technology, coupled with training on proper weed and water management, is strongly recommended.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Evaluation of New Herbicides on the Physiological Response and Control of Chrozophora (*Chrozophora rottleri*)

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Abstract— *Chrozophora rottleri is an aggressive, competitive broadleaf weed commonly found in rainfed and irrigated cropping systems. Its rapid growth and high resource consumption significantly reduce the growth and productivity of main crops. Effective management requires a thorough understanding of how different herbicides affect its physiological processes. A field experiment was conducted during the Rabi season of 2014-15 at the Regional Agricultural Research Station (RARS), Lam Farm, Guntur. The study employed a Randomized Block Design (RBD) with ten herbicidal treatments: atrazine, alachlor, pendimethalin, 2,4-D Na salt, bispyribac, pyrithiobac, topramezone, Iris (a.i. mesosulfuron-methyl + iodosulfuron-methyl), ethoxysulfuron, and an untreated control. Herbicides were applied at their recommended field doses, and physiological observations were recorded at 14 and 21 Days After Sowing (DAS). Parameters assessed included plant height, leaf area, total chlorophyll content, photosynthetic rate, stomatal conductance, transpiration rate, and phytotoxicity symptoms. Results revealed significant variation among treatments for all measured traits. The untreated control showed the highest plant height (24.53 cm) and substantial leaf area (1141.0 cm²), indicating vigorous growth in the absence of herbicide stress. These values were statistically on par with those observed in plots treated with pendimethalin and pyrithiobac, suggesting minimal growth suppression by these herbicides. Chlorophyll content was highest in the control (1.375 mg g^{-1} fresh weight), followed closely by pendimethalin (1.352 mg g^{-1}) and bispyribac (1.348 mg g^{-1}). In stark contrast, topramezone (0.642 mg g^{-1}) and ethoxysulfuron (0.0 mg g^{-1}) caused severe chlorophyll degradation. Interestingly, photosynthetic rate was highest under alachlor (51.93 µmol m^{-2} s^{-1}) and bispyribac (50.91 µmol m^{-2} s^{-1}), while ethoxysulfuron completely inhibited photosynthesis. Phytotoxicity was most severe with ethoxysulfuron (score 10) and topramezone (score 9), causing plant mortality, whereas pendimethalin and pyrithiobac showed minimal visible injury (score 0). The study concludes that pendimethalin and pyrithiobac exert limited suppressive effects on the physiology of C. rottleri, while ethoxysulfuron and topramezone are highly effective and phytotoxic, causing complete physiological shutdown and plant death. These findings provide critical physiological insights for designing integrated and targeted weed management strategies against this problematic weed under field conditions.*

Keywords— Chrozophora rottleri, Herbicides, Physiological Parameters, Phytotoxicity, Photosynthesis, Weed Control, Integrated Weed Management.

I. INTRODUCTION

Chrozophora rottleri is a troublesome broadleaf weed prevalent in both rainfed and irrigated agricultural ecosystems across India. Its competitive ability for essential resources—light, nutrients, and water—poses a significant threat to crop yields. Effective and timely weed management is therefore paramount for sustainable crop production and resource use efficiency. Among various control methods, chemical weed control via herbicides remains a cornerstone due to its efficacy, timeliness, and economic feasibility. However, herbicide effectiveness is highly variable, depending on factors such as the weed species, its growth stage, the herbicide's mode of action, application rate, and environmental conditions. Furthermore, non-target effects and the potential for developing herbicide resistance necessitate a judicious and science-based selection of herbicides (Chauhan & Abugho, 2013).

Traditional herbicides like atrazine, alachlor, pendimethalin, 2,4-D, and newer molecules like bispyribac and pyrithiobac have been widely used for broad-spectrum weed control. Concurrently, newer herbicides such as topramezone (an HPPD inhibitor), ethoxysulfuron (an ALS inhibitor), and pre-mixes like Iris (mesosulfuron-methyl + iodosulfuron-methyl) are being introduced. However, their specific physiological impact and efficacy on *Chrozophora rottleri* are not well-documented, particularly under field conditions in the Indian context. A detailed understanding of how these herbicides affect key physiological processes—photosynthesis, pigment synthesis, and transpiration—is crucial for predicting their efficacy and understanding the basis of weed susceptibility or tolerance (Grossmann & Ehrhardt, 2007; Heap, 2022).

This investigation was undertaken with the objective of evaluating the effect of a range of pre- and post-emergence herbicides on the growth and physiological performance of *Chrozophora rottleri*. The specific aim was to identify herbicides that effectively disrupt its physiology, leading to control, while also assessing their degree of phytotoxicity to understand their potential fit within integrated weed management (IWM) programs.

II. MATERIALS AND METHODS

2.1 Experimental Site and Design:

A field experiment was conducted during the Rabi season of 2014-15 at the Regional Agricultural Research Station (Lam Farm), Guntur, Andhra Pradesh. The experiment was laid out in a Randomized Block Design (RBD) with three replications. The soil of the experimental site was a sandy loam with good drainage.

2.2 Weed Establishment and Treatments:

A pure stand of *Chrozophora rottleri* was raised by sowing its seeds in well-prepared field plots. Ten herbicidal treatments were imposed, including an untreated control. The herbicides, their active ingredients, and doses are listed below:

1. **T1:** Atrazine @ 1.0 kg a.i./ha
2. **T2:** Alachlor @ 1.0 kg a.i./ha
3. **T3:** Pendimethalin @ 1.0 kg a.i./ha
4. **T4:** 2,4-D Na salt @ 1.0 kg a.i./ha
5. **T5:** Untreated Control
6. **T6:** Bispyribac-sodium @ 25 g a.i./ha
7. **T7:** Pyrithiobac-sodium @ 100 g a.i./ha
8. **T8:** Topramezone @ 30 g a.i./ha
9. **T9:** Iris (Mesosulfuron-methyl 3% + Iodosulfuron-methyl 0.6%) @ 14.4 g a.i./ha
10. **T10:** Ethoxysulfuron @ 18.75 g a.i./ha

Herbicides were applied as post-emergence sprays using a knapsack sprayer when the weeds were at the 3-4 leaf stage.

2.3 Observations Recorded:

Data on growth and physiological parameters were recorded at 14 and 21 Days After Sowing (DAS) from five randomly tagged plants per plot.

- **Plant Height (cm):** Measured from the base to the apex of the main stem.
- **Leaf Area (cm^2):** Measured using a leaf area meter (Model: LI-3100C, LI-COR, USA).
- **Total Chlorophyll Content (mg g^{-1} fresh weight):** Estimated spectrophotometrically using the method of Arnon (1949).
- **Gas Exchange Parameters:** Measured between 10:00 AM and 12:00 PM on clear, sunny days using a portable photosynthesis system (LI-6400XT, LI-COR, USA).
    - Photosynthetic Rate (Pn; µmol CO_2 m^{-2} s^{-1})
    - Stomatal Conductance (gs; mmol H_2O m^{-2} s^{-1})

- Transpiration Rate (E; mmol H_2O m^{-2} s^{-1})

- **Phytotoxicity Score:** Visual injury symptoms were scored on a scale of 0 to 10, where 0 = no injury, 5 = 50% plant mortality or injury, and 10 = complete plant death.

2.4 Statistical Analysis:

The collected data were subjected to Analysis of Variance (ANOVA) appropriate for a Randomized Block Design using the statistical software SPSS (Version 16.0). The treatment means were compared at a 5% level of significance using the Least Significant Difference (LSD) test.

III. RESULTS AND DISCUSSION

The application of different herbicides had a profound and statistically significant ($p<0.05$) influence on all measured growth and physiological parameters of *Chrozophora rottleri* (Table 1).

TABLE 1
EFFECT OF DIFFERENT HERBICIDES ON GROWTH AND PHYSIOLOGICAL PARAMETERS OF *CHROZOPHORA ROTTLERI* (MEAN OF 14 AND 21 DAS)

Treatments	Plant Height (cm)	Leaf Area (cm^2)	Total Chlorophyll (mg g^{-1} f.w.)	Photosynthetic Rate (µmol m^{-2} s^{-1})	Stomatal Conductance (mmol m^{-2} s^{-1})	Transpiration Rate (mmol m^{-2} s^{-1})	Phytotoxicity Score (0-10)
T1: Atrazine @ 1 kg a.i./ha	20.46	585.56	0.927	43.35	0.44	7.19	0
T2: Alachlor @ 1 kg a.i./ha	17.46	412.82	1.109	51.93	0.56	8.51	0
T3: Pendimethalin @ 1 kg a.i./ha	24.4	1652.66	1.352	49.85	0.56	8.3	0
T4: 2,4-D Na salt @ 1 kg a.i./ha	21.66	715.96	1.358	46.15	0.5	7.89	0
T5: Control (Untreated)	24.53	1141	1.375	48.5	0.48	7.49	0
T6: Bispyribac @ 25 g a.i./ha	17.4	398.53	1.348	50.91	0.54	8.41	0
T7: Pyrithiobac @ 100 g a.i./ha	22.93	1187.51	1.346	47.67	0.47	7.33	0
T8: Topramezone @ 30 g a.i./ha	5.46	0	0.642	0	0	0	9
T9: Iris @ 14.4 g a.i./ha	8.66	457.06	0.829	47.66	0.5	8.03	4
T10: Ethoxysulfuron @ 18.75 g a.i./ha	0	0	0	0	0	0	10
SEm±	0.95	24.35	0.04	0.59	0.008	0.14	-
LSD (p=0.05)	2.83	72.15	0.119	1.74	0.024	0.41	-
Coefficient of Variation (CV %)	9.1	22.3	5.9	2.5	3.2	3.5	-

Note: Phytotoxicity Score: 0 = No injury, 10 = Complete plant death.

3.1 Growth Parameters:

Plant height and leaf area are primary indicators of vegetative growth and competitive ability. The untreated control (T5) produced the tallest plants (24.53 cm), which was statistically on par with treatments receiving pendimethalin (T3; 24.40 cm) and pyrithiobac (T7; 22.93 cm). This indicates that these herbicides had minimal inhibitory effect on the vertical growth of *C. rottleri*. In contrast, ethoxysulfuron (T10) caused complete plant mortality (0 cm), followed by severe stunting in topramezone (T8; 5.46 cm) and Iris (T9; 8.66 cm) treatments. Similarly, the maximum leaf area was recorded under pendimethalin (1652.66 cm^2), significantly higher than the control (1141.00 cm^2), suggesting a possible hormetic or non-inhibitory effect. Pyrithiobac

(1187.51 cm²) also allowed considerable leaf expansion. Ethoxysulfuron and topramezone completely suppressed leaf development (0 cm²). These results align with the known mode of action; pendimethalin, a microtubule assembly inhibitor, primarily affects root growth and may have less immediate impact on established seedling shoot growth, while ALS and HPPD inhibitors like ethoxysulfuron and topramezone rapidly halt new growth (Senseman, 2007).

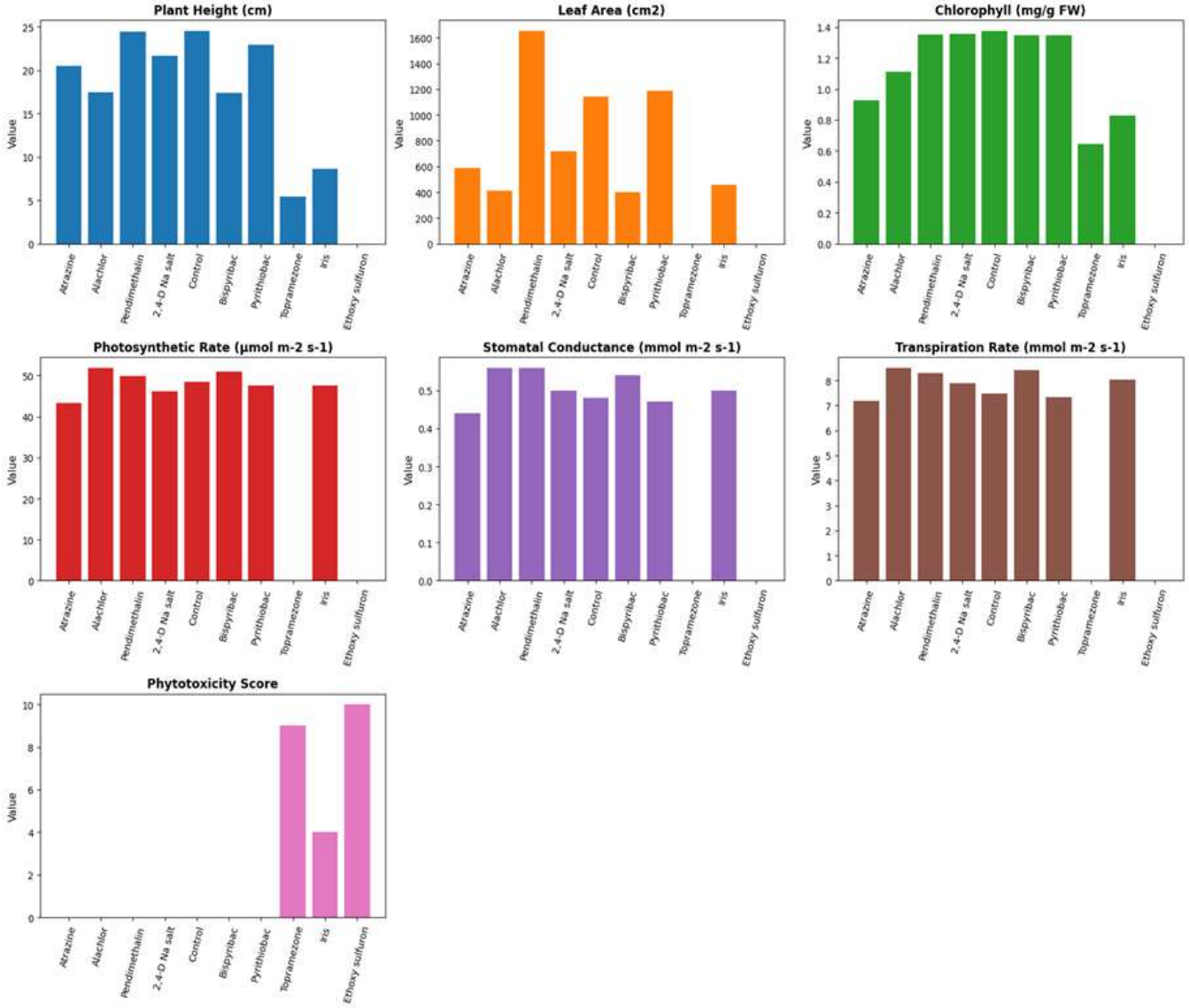

FIGURE 1: Effect of different growth parameters on the different growth parameters

3.2 Physiological Parameters:

Chlorophyll content is a direct indicator of photosynthetic potential. The control plants maintained the highest chlorophyll content (1.375 mg g^{-1}). Pendimethalin (1.352 mg g^{-1}), bispyribac (1.348 mg g^{-1}), and pyrithiobac (1.346 mg g^{-1}) were statistically comparable to the control, showing no significant bleaching or chlorophyll degradation. Conversely, topramezone, an HPPD inhibitor that disrupts carotenoid synthesis leading to photobleaching, significantly reduced chlorophyll (0.642 mg g^{-1}). Ethoxysulfuron resulted in complete chlorophyll loss (0.0 mg g^{-1}), consistent with its lethal effect. The pattern for photosynthetic rate (Pn) was intriguing. The highest Pn was recorded in alachlor-treated plants (51.93 µmol m^{-2} s^{-1}), followed by bispyribac (50.91 µmol m^{-2} s^{-1}) and pendimethalin (49.85 µmol m^{-2} s^{-1}), all surpassing the control (48.50 µmol m^{-2} s^{-1}). This transient increase could be a stress response or related to altered stomatal behavior before the onset of severe injury. As expected, photosynthesis was completely arrested (0 µmol m^{-2} s^{-1}) by ethoxysulfuron and topramezone. Stomatal conductance and transpiration rate followed a similar trend, being highest in alachlor and bispyribac treatments and completely inhibited by the most effective herbicides.

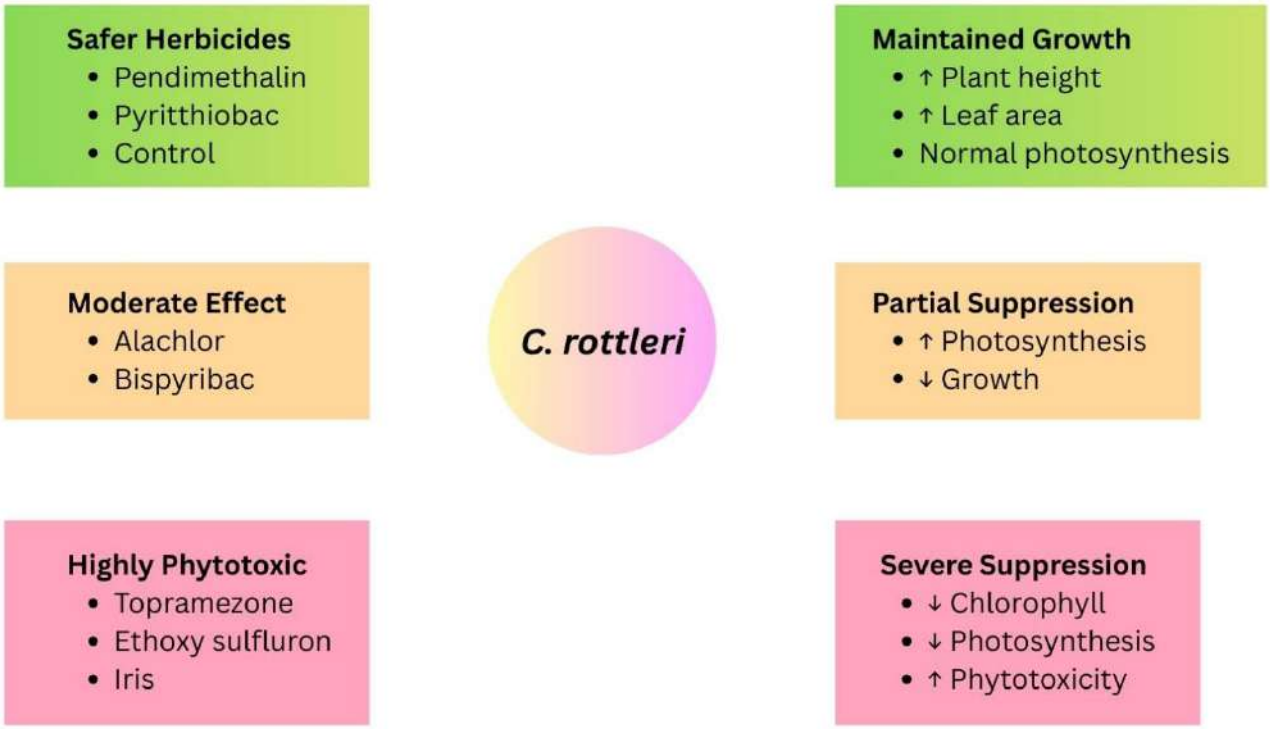

FIGURE 2: Graphical Abstract: Herbicide Effects on Crozophora rottlerin

FIGURE 3: Field view of the experiment

3.3 Phytotoxicity:

Visual phytotoxicity scoring provided a clear efficacy ranking. Ethoxysulfuron (score 10) and topramezone (score 9) exhibited extreme phytotoxicity, leading to severe chlorosis, necrosis, and plant death. Iris showed moderate injury (score 4). All other herbicides, including pendimethalin, pyrithiobac, atrazine, and 2,4-D, showed no visible phytotoxicity symptoms (score 0) on *C. rottleri*, indicating either tolerance or insufficient absorption/translocation at the applied dose for this species.

FIGURE 4: Effect of different chemicals on growth

3.4 Coefficient of Variation (CV):

The CV ranged from 9.1% for photosynthetic rate to 32.7% for plant height, indicating acceptable to moderate experimental precision. The LSD values confirmed that the observed differences among treatments for all parameters were statistically significant.

The findings are consistent with previous reports. Grossmann and Ehrhardt (2007) documented that HPPD inhibitors like topramezone cause rapid bleaching and growth arrest. The complete control by ethoxysulfuron aligns with the high sensitivity of many broadleaf weeds to ALS inhibitors (Heap, 2022). The minimal effect of pendimethalin on established seedlings of *C. rottleri* underscores the importance of application timing (pre-emergence) for this herbicide to be effective.

IV. CONCLUSION

The study conclusively demonstrates that herbicides have a differential and significant impact on the physiology of *Chrozophora rottleri*. Pendimethalin and pyrithiobac had minimal suppressive effects on growth and physiological functions, indicating that *C. rottleri* may possess tolerance or that these herbicides are not optimal for its post-emergence control. In contrast, ethoxysulfuron and topramezone were highly effective, causing severe physiological disruption—complete inhibition of chlorophyll synthesis, photosynthesis, and transpiration—leading to high phytotoxicity and plant mortality. Alachlor and bispyribac, while not severely inhibiting growth, showed interesting effects on gas exchange parameters that warrant further investigation. For effective integrated management of *Chrozophora rottleri* in field crops, post-emergence application of ethoxysulfuron or topramezone can be highly effective. However, their potential crop phytotoxicity must be carefully considered. Pendimethalin, if used, must be applied as a pre-emergence herbicide for effective control. These physiological insights provide a scientific basis for selecting and rotating herbicides in IWM strategies to manage this competitive weed sustainably.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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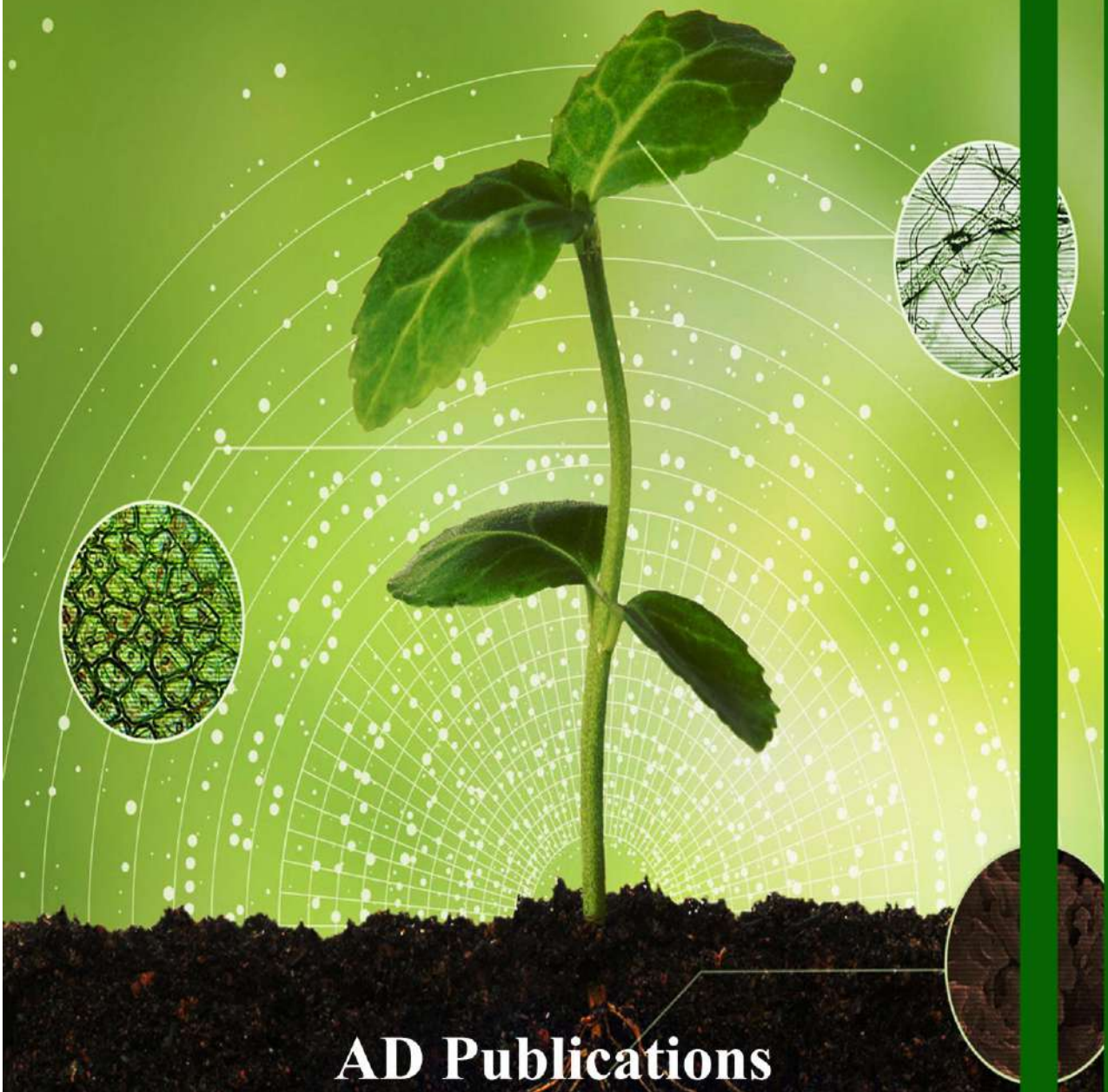

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