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Preface

We would like to present, with great pleasure, the inaugural volume-11, Issue-9, September 2025, 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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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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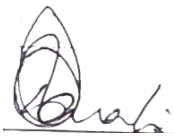

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IoT-Driven Smart Farming using Wireless Sensor Networks: Comprehensive Survey on Data Collection Techniques and Challenges

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Abstract— *Agriculture is a critical sector for global food security and economic stability, yet it faces unprecedented challenges due to rapid population growth, urban expansion, and the adverse impacts of climate change. Precision agriculture, enabled by the integration of the Internet of Things (IoT) and Wireless Sensor Networks (WSNs), offers a promising solution by enabling continuous monitoring and data-driven decision-making for optimized resource utilization and improved crop yields. WSNs, composed of spatially distributed sensor nodes, facilitate real-time collection of environmental parameters such as soil moisture, temperature, humidity, and nutrient levels, which are transmitted wirelessly to centralized systems for analysis. This paper presents a comprehensive survey of IoT–WSN technologies applied in smart farming, with a focus on wireless communication protocols including RF, Bluetooth, Zigbee, LoRa, GSM, and Wi-Fi. Each protocol is evaluated in terms of range, data throughput, energy efficiency, scalability, and reliability, highlighting their strengths, limitations, and suitability for different agricultural contexts. Comparative analysis reveals that while short-range, low-power protocols like Bluetooth and Zigbee excel in energy efficiency, they are constrained by limited coverage; GSM provides wide-area connectivity but incurs higher operational costs; and Wi-Fi offers high throughput and scalability at the expense of greater power consumption. The review identifies key challenges such as energy constraints, environmental interference, network scalability, and cost barriers, and outlines future research directions for developing low-cost, energy-efficient, and resilient IoT–WSN architectures tailored for large-scale precision agriculture.*

Keywords— IoT, WSN's, Zigbee, LoRa, Bluetooth, GSM, Wi-Fi.

I. INTRODUCTION

Agriculture remains a cornerstone of the global economy, providing food security and employment to a substantial portion of the population. In India alone, it contributes nearly 20% to the national Gross Domestic Product (GDP) and sustains the livelihoods of more than half of the workforce [1]. However, the sector faces mounting challenges arising from rapid population growth, urbanization, industrial expansion, and the escalating effects of climate change. Unpredictable rainfall patterns, prolonged droughts, rising temperatures, and extreme weather events have disrupted conventional agricultural cycles, leading to reduced yields and economic instability for farming communities [2]. The need for increased productivity, efficient resource utilization, and sustainable farming practices has driven the adoption of advanced information and communication technologies in agriculture. Among these, smart farming—powered by the convergence of the Internet of Things (IoT) and Wireless Sensor Networks (WSNs)—has emerged as a transformative paradigm capable of enhancing crop management, improving efficiency, and supporting precision agriculture.

WSNs consist of spatially distributed sensor nodes capable of autonomously collecting environmental data such as soil moisture, temperature, humidity, nutrient levels, and rainfall, and transmitting it wirelessly to a central processing unit or cloud platform for analysis. When integrated with IoT technologies, these networks enable real-time monitoring and decision-making, offering farmers unprecedented control over field conditions regardless of their physical proximity to the farm [3]. By leveraging cloud computing and big data analytics, IoT–WSN systems can optimize irrigation schedules, reduce water and fertilizer wastage, detect pest infestations and diseases at an early stage, and forecast crop yields with improved accuracy.

Studies indicate that precision agriculture solutions incorporating WSNs can reduce water usage by up to 30%, lower input costs, and increase productivity significantly [4].

Despite these advantages, deploying WSNs in agricultural environments presents several challenges. The physical scale of farmlands, often extending over several hectares, imposes limitations on communication range for short-range protocols such as Bluetooth and Zigbee. Energy efficiency is another critical factor, as sensor nodes are frequently located in remote areas where battery replacement or maintenance is logistically difficult. Environmental factors, including dense vegetation and variable weather conditions, can cause interference and packet loss, compromising data reliability. Furthermore, scalability and cost constraints must be addressed to make these systems viable for smallholder farmers as well as large-scale agricultural enterprises. No single wireless communication protocol currently meets all performance requirements in terms of range, throughput, energy efficiency, scalability, and cost-effectiveness, making comparative evaluation essential for informed decision-making.

This paper provides a comprehensive survey of IoT-driven smart farming systems utilizing WSNs for agricultural data collection. It reviews the underlying architecture of IoT–WSN integration in farming, examines major wireless communication protocols—including RF, Bluetooth, Zigbee, LoRa, GSM, and Wi-Fi—and analyzes their applicability in diverse agricultural contexts. The comparative analysis covers performance metrics such as communication range, data throughput, energy consumption, scalability, and reliability, highlighting the trade-offs associated with each technology. Additionally, the paper identifies existing technical challenges, including network maintenance, security vulnerabilities, and environmental resilience, and discusses research gaps that need to be addressed for large-scale deployment. The goal of this study is to guide researchers, practitioners, and policymakers in selecting and optimizing wireless communication solutions for smart farming applications, ultimately contributing to the advancement of precision agriculture and sustainable food production systems.

II. IoT-WSN

Wireless sensor network (WSN) is used in numerous applications satisfying essential convenience and is composed of spatially distributed sensor nodes. These nodes are able to collect data from the environment to transmit it wirelessly over the server. It has an ability to operate autonomously in distributed manner. It is an expandable network and broadly used in industrial automation, home automation, patient monitoring, environmental monitoring and agriculture. But the key aspect of connecting these sensor nodes of WSN globally intricate IoT as central monitoring infrastructure [6]. IOT based WSN enhances the network by providing capabilities for remote monitoring, cloud-based data storage, and integration with other smart systems. IoT enables sensors to not only gather data but also transmit it over the internet for real-time analysis, control, and decision-making [7].

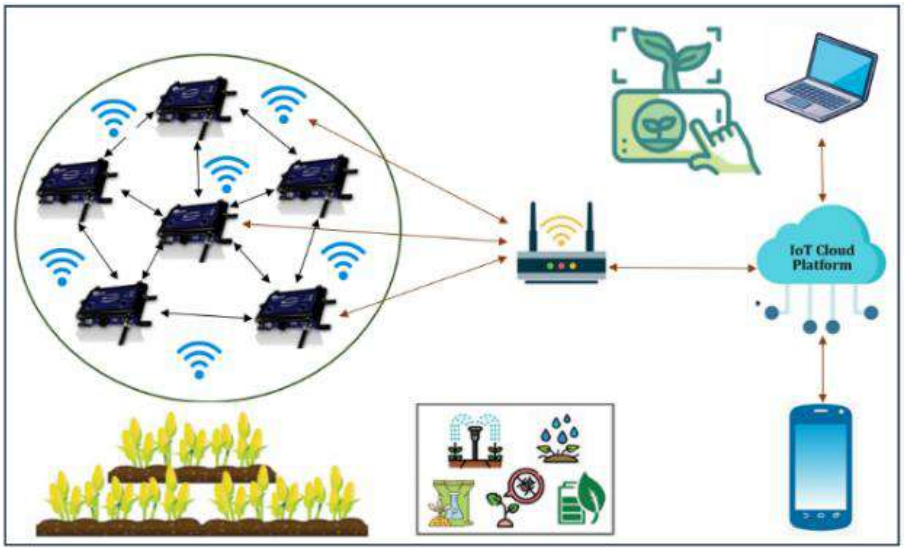

FIGURE 1: Architecture of an IoT-Based WSN

In smart farming applications, IOT based Wireless Sensor Networks provides irrigation management, crop disease and pest control, regularization and optimization of fertilizer, autonomous operation of machines for crop surveillance. Various technological approach in WSNs promotes agricultural automation to improve long term and sustained production. Through real-time field monitoring and efficient management of agricultural operations, wireless sensors and mobile networks enable

farmers to collect valuable data and generate precise yield maps, supporting precision farming practices [8]. This results in the production of high-quality crops at a reduced cost, facilitated by WSNs.

An architecture of IOT based Wireless Sensor Network depicts multiple sensor nodes connected in a mesh topology, transferring the collected sensor data to the master node. This master node communicates with the cloud and user applications for further computing and control actions. Thus, the master node acts as a mediator between the user and the sensor nodes, which are located far from the user [9].

Each sensor node is equipped with multiple modules of required sensors, such as humidity, temperature, soil moisture, water level, fertilizer, wind speed, and flow, among others. These sensor nodes must be connected to a controller unit to collect and store data for further computation [10]. For an IoT-based wireless sensor network, a wireless communication module is necessary to link the sensor nodes with the master node, where all the sampled data will be transmitted.

FIGURE 2: Sensor Node for Precision Agriculture in WSN

III. STATE OF ART TECHNOLOGIES IN IOT BASED WIRELESS SENSOR NETWORK

In Wireless Sensor Networks (WSNs), the core technologies are generally similar, but each research implementation often involves a customized network configuration with different wireless communication modules. In the context of IoT-based WSNs for smart farming, precise and extensive real-time field data is collected through various communication protocols, including RF based Bluetooth, Zigbee, GSM, WiFi, SigFox, and LoRaWAN. The primary goal of each protocol is to ensure efficient, sustainable, and accurate data transfer over long distances, while minimizing packet loss, power consumption, and optimizing connectivity. Sensors are strategically placed to monitor parameters such as temperature, humidity, soil moisture, wind speed, water levels, fertilizer requirements, location, and capture necessary camera images. The data collected by each sensor is transmitted to a master node, forming the IoT-WSN network. This large-scale data is then analysed and predicted to support informed decision-making for irrigation management, resource allocation, and timely interventions to enhance crop growth. The performance of the WSN is influenced by the varying characteristics of each communication module, including range, efficiency, and power consumption, which have a significant impact on the network's effectiveness in different applications [11][12].

3.1 RF Based Smart Irrigation:

In the Design of Wireless Sensor Network (WSN) with RF Module for Smart Irrigation System in Large Cultivated Areas by Radi et al., a model for smart irrigation is proposed. The model divides the cultivated area into smaller zones, each managed by its own WSN for automatic irrigation. The RF-based wireless communication system is employed to transmit sensor data to the cloud, operating at a frequency of 2.4 GHz. The system uses a star topology for data transmission, and the performance is tested over distances of 50m, 100m, and 150m [13]. This approach demonstrates the feasibility of using RF communication in large agricultural areas for efficient irrigation management.

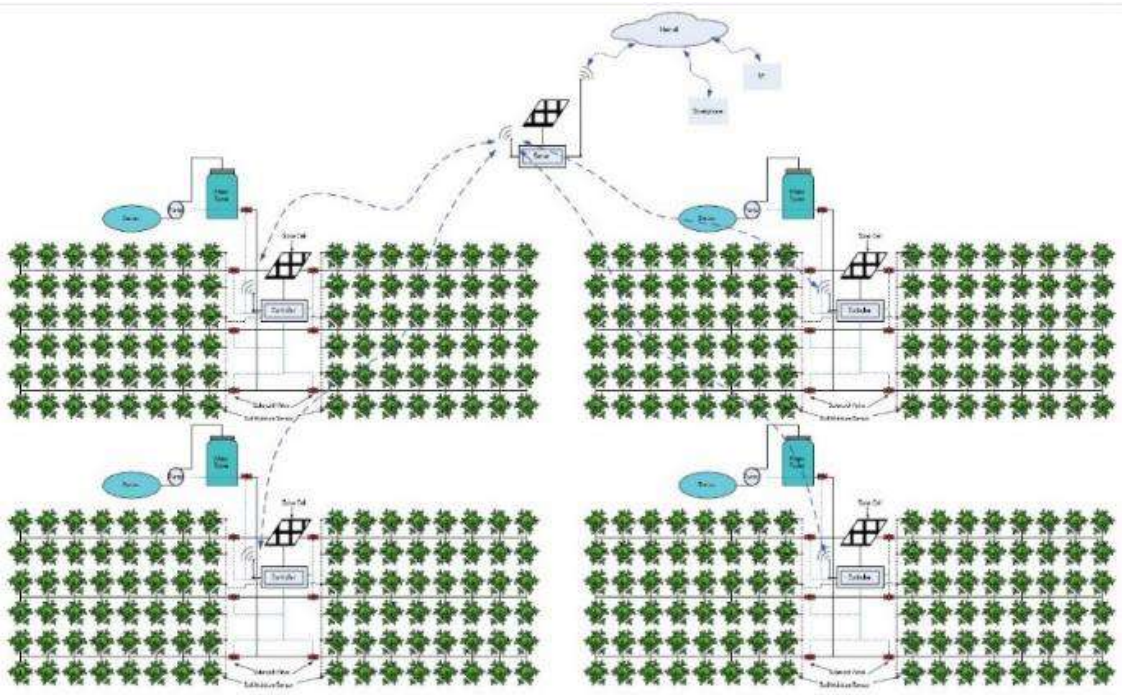

FIGURE 3: Smart Irrigation System using RF based WSN

3.2 Bluetooth Based WSN:

Bluetooth is most popular and globally used protocol for having low cost, short-range, low power consumption and reasonable throughput. The Bluetooth based WSNs uses Bluetooth technology for communication between various nodes. These networks enable the collection and transmission of data from multiple sensors to master hub for processing and analysis. This communication is completely transparent and indispensable for future oriented automation concepts. Bluetooth is a short-range wireless communication technology that enables devices to connect and exchange data over distances typically ranging from 1 meter to 100 meters, depending on the Bluetooth version and the environment [14].

TABLE 1
PERFORMANCE ANALYSIS WITH RESPECT TO DISTANCE

Slaves Node	Distance (m)	Time (h)	Period (s)	Data Packet		Data Loss (%)
				Potency	Actual	
1	50	72	5	51840	51862	-0.04%
2	100	72	5	51841	51862	0.00%
3	200	72	5	51841	22243	87.09%

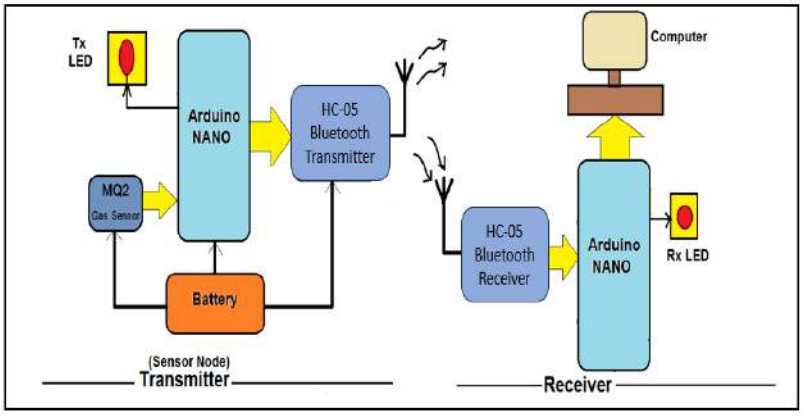

FIGURE 4: Bluetooth Based Wireless Sensor Network using Arduino controller

It is observed that this prototype has a good performance up to the distances less than 100 m. Hence it is concluded that vegetation affects data transmission and have data losses when distance increases.

3.2.1 Challenges of Bluetooth-Based WSNs:

Limited Range: Bluetooth has a relatively short range compared to other wireless communication technologies (e.g., Zigbee or LoRa). This can be a limitation in large agricultural fields unless mesh networks or multiple gateways are used to extend the coverage.

Interference: Bluetooth operates in the 2.4 GHz frequency band, which can be crowded and prone to interference from other devices (e.g., Wi-Fi networks, microwaves). This can affect data transmission reliability.

Security Concerns: Wireless communication networks are susceptible to cyber-attacks, and securing Bluetooth networks can be challenging, especially in large-scale deployments.

Battery Life: While Bluetooth Low Energy devices are power-efficient, the battery life of sensors can still be a concern in remote agricultural areas, requiring regular maintenance.

3.3 Zigbee based WSN:

Helmy Fitriawan etal in his research of ZigBee Based Wireless Sensor Networks and Performance Analysis in Various Environments achieved Zigbee based wireless sensor network for low data rate application. Here two nodes as stated in fig.1 have considered i.e. sensor node and master node. Sensor node collects all data reading from all kinds of sensor connected and sampled using the Atmega controller unit. Xbee S2 wireless module is used as communication channel for controller unit and master node with frequency 2.4 GHz band at 250 kbps RF data rate [14]. Both types of nodes are prepared in order to see performance of WSN in LOS and NLOS communications. The zigbee protocol supports network topology as peer to peer, star and mesh and Trans-receive data messages in the network [20].

TABLE 2
MAXIMUM THROUGHPUT WITH RESPECT TO BAUD RATE AND PACKET SIZE

Baud Rate	Data Size							
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**
9600	2	2.5	3	4	4.5	5	6	6.5
19200	3.5	4	5	6	7	8	9	10
38400	3.75	5	7	9	10	12	13	14
57600	4	6	8	10	12	14	15	17
115200	4	8	10	13	15	16	18	20

TABLE 3
MAXIMUM TRANSMISSION DELAY WITH RESPECT TO BAUD RATE AND PACKET SIZE

Baud Rate	Packet Size							
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**
9600	50	60	80	80	90	100	110	120
19200	30	38	42	50	55	60	65	70
38400	28	30	35	40	42	44	46	50
57600	22	24	26	28	30	34	36	40
115200	20	22	24	26	28	29	30	32

For the research, it has been concluded that the maximum throughput is increases as the baud rate increases with increasing packet size. It is also observed that the transmission delay reduces with higher baud rate and increases with packet size.

3.4 GSM based WSN:

Dedi Satria etal in his research of Implementation of wireless sensor network (WSN) on garbage transport warning information system using GSM module proposes a prototype of waste management using wireless sensor network and GSM as communication medium. Here the sensor information is transferred in the form of GSM based communication SMS [15].

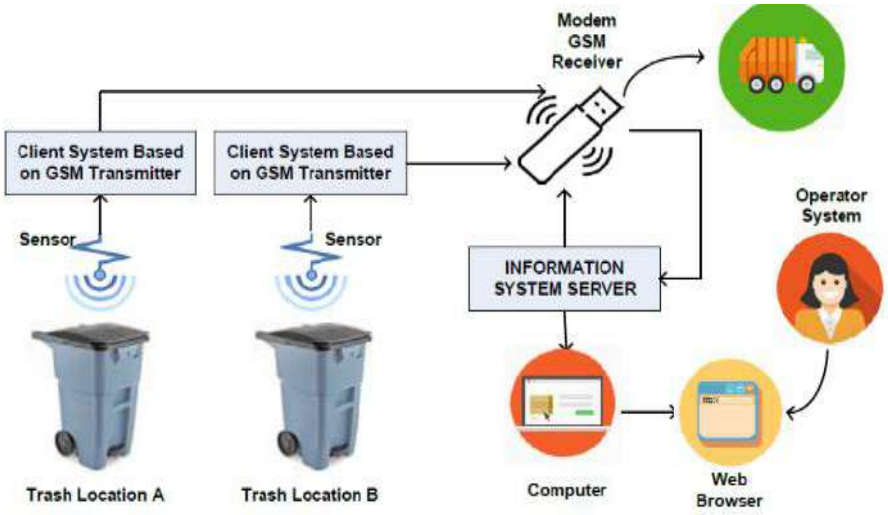

FIGURE 5: Waste Management using GSM based wireless sensor network

Above system is a concept of WSN to send data from client to server using messaging communication and the results are going to display on the web server. All the garbage data will be immediately transported to the officer for further actions.

The above prototype removes the limitation of range, distance, data loss using GSM. But, for each SMS, operator will need to pay cost. The GSM module will require a networking SIM with SMS recharge. So every time, operator need to check the recharge. Also the type of data communication is in the form of SMS where you can send limited sensor data. It is feasible only for few sensors. But when number of sensors increases, single SMS will not be able to send data due to character limitations.

3.5 Wifi Based WSN:

Gerard Rudolph Mendez etal in "A WiFi based Smart Wireless Sensor Network for an Agricultural Environment" monitored environmental parameters using sensor node where a controller unit is used WSN802G module. This prototype has inbuilt wifi module which can be used to transmit data wirelessly over the server [16].

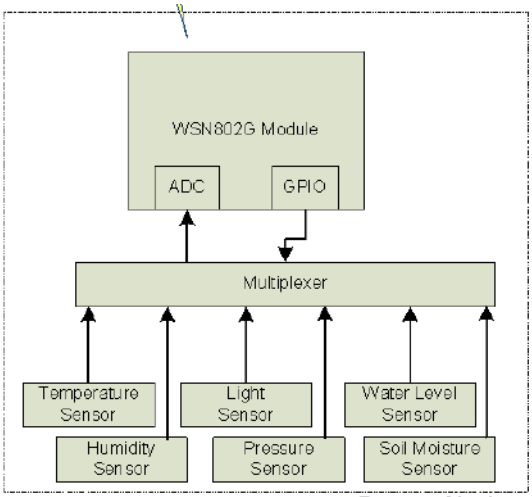

FIGURE 6: WSN802G based sensor node

This WSN802G module uses IEEE 802.11 standard to communicate sensor node with server for 2.4 GHz frequency. It requires operating voltage of 3.0V to 3.63V with two 10 bits analog to digital converter for sensor inputs. This protocol has three different modes of operations. In first mode sensor node can be sleep with timer, in farming, a comparative framework was developed based on key performance parameters reported in peer-reviewed literature and technical standards. The parameters include communication range, throughput, energy consumption, failure rate, security features, and scalability potential.

second mode serial data node can be sleep with timer and in third mode, both sensor and serial data node can be sleep with auto reporting. The module can sleep until the wake up call after the timer ends.

IV. COMPARATIVE ANALYSIS

To evaluate the suitability of wireless communication protocols for IoT-enabled smart

TABLE 4
COMPARATIVE PERFORMANCE OF WIRELESS PROTOCOLS FOR IOT-BASED WSNS IN SMART FARMING

Wireless Protocol	Typical Range (m)	Throughput (kbps/Mbps)	Energy Consumption (mW)	Failure Rate (%)*	Security Level	Scalability Potential
Bluetooth	10–100	1–3 Mbps	15–35	~5–8	Low	Low
Zigbee	10–100	20–250 kbps	25–40	~3–6	Moderate	Low–Moderate
GSM	1,000–35,000	~85–128 kbps	200–300	~2–5	Low	Moderate
WiFi	50–100	6–600 Mbps	500–1000	~1–3	High	High

The analysis demonstrates that **Bluetooth** offers low power consumption and reasonable throughput for short-range, localized applications, but its limited coverage severely constrains scalability. **Zigbee** provides slightly higher reliability and moderate energy efficiency; however, its range is still insufficient for large-scale deployments without extensive mesh networking. **GSM** offers extensive coverage, enabling deployment in remote areas without additional infrastructure, though its low throughput limits its suitability for high-data-rate applications such as real-time imaging. **Wi-Fi** excels in throughput and scalability, supporting data-intensive smart farming tasks, but its higher power requirements may limit use in battery-powered sensor nodes.

Given the diversity of agricultural environments, these results suggest that protocol selection should be application-driven, with hybrid or multi-tier architectures often providing the best balance between range, power efficiency, and data capacity.

V. CONCLUSION

The integration of Internet of Things (IoT) technologies with Wireless Sensor Networks (WSNs) is reshaping modern agriculture by enabling real-time monitoring, data-driven decision-making, and optimized resource utilization. This study reviewed the fundamental architecture of IoT–WSN systems in smart farming and presented a comparative evaluation of major wireless communication protocols—RF, Bluetooth, Zigbee, LoRa, GSM, and Wi-Fi—based on range, throughput, energy efficiency, scalability, and reliability. The findings reveal that no single protocol offers a universally optimal solution; instead, selection should be application-specific. Short-range, low-power protocols such as Bluetooth and Zigbee are energy-efficient and cost-effective for localized deployments, whereas LoRa achieves a balanced trade-off between long-range coverage and low energy consumption. GSM delivers wide-area connectivity but at higher operational and energy costs, while Wi-Fi supports high data rates and scalability but is less suited to remote areas without infrastructure.

Key challenges remain, including the need for improved energy management in off-grid deployments, enhanced resilience against environmental interference, cost-effective solutions for smallholder farmers, and robust cybersecurity measures to protect agricultural data. Future work should explore hybrid communication architectures that integrate multiple protocols, energy harvesting methods to prolong network lifetime, and adaptive topologies capable of self-healing under adverse conditions. Addressing these challenges will enable IoT–WSN solutions that are more accessible, efficient, and sustainable, accelerating the adoption of precision agriculture and strengthening global food security.

VI. FUTURE SCOPE

While Wi-Fi-based WSN deployments demonstrate high data throughput and scalability, their limitations in terms of power consumption, infrastructure dependency, and cost highlight the need for further innovation in wireless communication for smart farming. Future research should focus on developing hybrid communication models that combine the strengths of multiple protocols to achieve wide-area coverage, low energy consumption, and cost efficiency. Incorporating energy harvesting mechanisms, optimizing duty cycles, and leveraging low-power wide-area network (LPWAN) technologies such as LoRa or NB-IoT may address the shortcomings of current solutions. Additionally, exploring adaptive, self-healing network

topologies and cost-reduction strategies can make WSN solutions more viable for diverse agricultural environments, from smallholder farms to large-scale operations.

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Growth Response of Cucumber (*Cucumis sativus*) to Organic and Inorganic Fertilizers under Shade House Conditions

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Abstract**—** *The germination and growth of Cucumis sativus were studied by comparing the efficacy of selected organic (rabbit manure, goat manure, and fermented fruit tea) and inorganic Nitrogen Phosphorus Potassium (NPK) 11-22-22 fertilizers at a rate of 40g applied in 2 intervals. Cucumis sativum was grown for 3 months under shade house conditions in grow bags using a randomized complete block design (RCBD) with five treatments and four replications. Each block represented 40 plants with 8 plants per treatment. Although there was no statistical significance between the organic manures within the parameters tested, all organic manure was significantly different from the NPK in their effects. The fermented fruit tea treatment had the highest seedling growth rate as well as the highest germination percentage. The fruit tea also had the highest germination rate index after 5 days however the rabbit manure had the highest overall germination rate index as well as the highest number of plants flowering at the start of measurement. The NPK showed the lowest values overall. One-way analysis of variance was utilized for group comparison with significance noted at $P<0.05$ in germination rate and flowering. These comparisons were performed on essential germination rate and percent along with the time of flowering. This study shows that these organic treatments can have a positive effect on the germination percentage, germination rate, and plant growth of cucumbers. This research has provided valuable and statistically significant information to augment claims that organic fertilizers such as rabbit and goat manures along with fermented fruit tea, offer essential nutrients and can be used as a suitable alternative to inorganic fertilizers for those farmers wishing to move into organic farming of cucumbers.*

Keywords— Inorganic fertilizer, fruit tea, goat manure, rabbit manure.

I. INTRODUCTION

The importance of soil fertility to plant growth is widely studied and is one of the most important factors for crop production. Soil quality which is sometimes used interchangeably with soil fertility is defined as the capacity of the soil to function within the boundaries of ecosystems to sustain biological activity, maintain environmental quality and promote plant and animal health (Krishna, 2002). Where plant production is concerned, soil fertility is a combination of the chemical, physical, mechanical and biological aspects of the soil that contributes to agricultural yield (Krishna, 2002). According to Krishna (2002) Soil fertility and crop management are the two most important ingredients of modern agricultural activity, he defined soil as the medium for crop production where the texture, soil composition, and aggregation along with other factors such as aeration, are essential considerations. The inclusion of soil additives to support the cultivation of crops is often indispensable to farming and many farmers rely heavily on fertilizer or other enriched material to support the growth of their plants. Soil additives may be in the form of fertilizers or other soil-enhancing inputs that affect the various production aspects of plants. In addition to soil additives, microorganisms play an important role in crop production whether positively or negatively. Bacteria and fungi in the soil may act as great advantages or disadvantages to crop growth and yield.

Plants take up nutrients easily from fertile soils and where there is biological balance, productivity is high, this allows for healthy plants to grow in a healthy environment (Sari et al. 2007). Deficiency due to the scarcity of single or multiple nutrients occurs regularly in agricultural soils and is made worse by intensive cropping practices as soil fertility drives crop productivity and thus crop yields. The scarcity of essential nutrients limits crop yield if not replenished. Fertilizer utilization in agriculture has assisted in increased crop production and helped in spreading agricultural zones to once infertile lands (Krishna 2002).

Plants need more than just inorganic fertilizers, as the soil is a living system it needs to have a balance of organic, inorganic, and microorganisms as well as other important structural components.

Many countries around the world (IFOAM Organics Europe 2020) are focusing on sustainable agriculture and food safety (FAO, IFAD, UNICEF, WFP and WHO. 2019). A major focus for many sustainability-conscious farmers is to reduce the number of inorganic fertilizers used on the farm. Commercial farmers are therefore looking at different ways of improving yield and balancing the fertility of the soil. Some amendments studied (Minu Singh 2014), (Sari 2007), (N. Karagiannidisa 2011), (Tarraf W 2017), (Abay Ayalew 2012) and used effectively in other countries include a mixture of NPK and other fertilizers, compost, raw animal manure, microorganisms (IFOAM Organics Europe 2020).

The use of inorganic fertilizers has been the norm for a very long time and we see the effects of the depleted soil fertility from the use of inorganic fertilizers on our sugarcane (Chi L. 2017) and banana (Zake Y.K. 2000) production. Alternate ways of nourishing the soil are therefore necessary, these alternatives must also be available and adaptable to local conditions. These ways must be proven, economical, and can support the long-term fertility of the soil. There is a need for formal research and adequate testing of locally available soil nutrient sources.

As the world battles the unpredictable climatic variations it has become increasingly obvious that each nation needs to ensure its adequate food security. Global impacts such as the sudden decline in global trade and the uncertainty in the continuation of the crisis brought on by this pandemic, many countries are using more of their resources internally as opposed to exporting them (The World Bank 2020). The need for sustainable agriculture and food security ties in well with the United Nation's Sustainable Developments goals number 2, 6, 12, 13, and 15 (FAO, IFAD, UNICEF, WFP and WHO. 2019); Sustainable development goals: # 2: Zero Hunger, # 6: Cleaner Water and Sanitation, # 12: Responsible Consumption and Production, # 13: Climate Action, # 15: Life on Land. And therefore augments the need for such a local assessment as is being proposed.

In an FAO 2019 report on, the state of food security and nutrition in the world, safeguarding against economic slowdowns and downturns‘ the authors highlighted that there is a trend in severe food security in the world, this they say is an indication of increasing hunger (FAO, IFAD, UNICEF, WFP and WHO. 2019). This trend started before the current COVID19 pandemic and has thus been exacerbated. The report warned of; slowing and stalled economic growth in many countries, including emerging and developing economies; episodes of financial stress; elevated trade tensions, declining commodity prices, and tightening financial conditions. All these warnings are a reality in this current time, not only for Jamaica but for many countries of the world. To make recommendations, the FAO pointed to the need for individual countries to implement short-term measures such as strengthening savings capacity when the economy is growing, as well as implement longer-term measures to ‘invest wisely during periods of economic booms to reduce economic vulnerabilities and build capacity to withstand and quickly recover when economic turmoil erupts” (FAO, IFAD, UNICEF, WFP and WHO. 2019). The FAO called for the transformation of the agriculture and food systems to include the types and quality of food production. If this was necessary before December 2019, we are now in a serious state of urgency to consider our food systems.

We can no longer rely on food, fertilizers, and other recourses coming from the USA and China, these are restricted by the internal need of these countries, trade tensions, and poor purchasing power among other factors (The World Bank 2020). Besides, if the FAO's call for the transformation of the agriculture and food system to include the 'quality of the food' (FAO, IFAD, UNICEF, WFP and WHO. 2019) is to be considered at all, we must improve our food production to ensure food security. We are already constrained by our low storage capacity and must therefore find ways of producing food year-round. Locally grown foods when consumed also contribute to sustainability.

This research aims to test and identify sustainable methods of increasing the crop yield of *Cucumis sativus*, through the use of organic fertilizer treatments.

II. LITERATURE REVIEW

The benefit of fertile soil to plant growth and crop yield is unquestionable. The use of soil additives such as farmyard manure, poultry manure, and inorganic fertilizer among others is well documented and highlights the benefits e.g., (Adhikari A. 2020). It is also true that the intensive use of chemical fertilizers has a deleterious effect on the soil (Stoate C. 2001) among a host of other negative effects including eutrophication of water supplies (Vitousek PM. 1997), loss of biodiversity (Green RE. 2005). To alleviate the pressure on the environment farming systems are now being reviewed to implement more sustainable practices such as the use of organic amendments for the soil e.g. (Kong L. 2014), (Ambachew ZG. 2018), (Ram M. 2012).

The use of microorganisms such as bacteria and fungi is also widely studied and used as soil or seed inoculants to improve growth and yield (American Chemical Society 1991). The use of these microorganisms has been verified in studies such as (Tarraf W 2017) and (Umesha S. 2014).

TABLE 1
CONCEPTS DEFINITIONS

Concept	Definition
Compost/ Composting	Compost is a fertilizer produced from animal dung and other organic material. Composting is a method of obtaining a biological and chemically stable and rich product from the decomposition of plants and animal residues. Bacteria are usually active in breaking down the waste material in compost. The resulting product promotes the growth of beneficial bacteria, and earthworms build soil structure and support healthy plant growth when added to the soil (Yaqub 2018).
Raw animal manure	Raw animal manure is the dung from animals such as cattle, sheep, and goats (Yaqub 2018).

With a focus on soil composition, one of the major components and important soil factors is nitrogen. Nitrogen is a basic component of structural and functional proteins in plant cells and organs. Enzymes and co-enzymes which are important for biochemical reactions have nitrogen as their core constituent. DNA and RNA are also made up of nitrogen which is a basic component of structural and functional proteins in plant cells and organs. Besides, nitrogen is a key nutrient that influences soil fertility and crop production (Krishna 2002, Singh et al., 2014). It is the most widely studied essential nutrient element as it relates to its relevance to crop physiological activity and yield as well as its behaviour in the soil. It is required in comparatively greater proportions of plants than any other essential nutrient derived from the soil (Krishna et al., 2002). Thus, nitrogen is a very important factor to be considered in soil fertility. Nitrogen is a key source for plants to achieve their potential yield. Nitrogen fertilizers are generally expensive, leach easily from the soil, and cause environmental pollution with this in mind alternatives are desirable. Some alternatives include the use of soil microorganisms which can fix atmospheric nitrogen or solubilize phosphorus or stimulate plant growth through the synthesis of growth regulators (Krishna 2002).

Various organic soil additives such as raw animal manure, treated animal manure, compost, and inorganic material are used to enhance plant growth and other output. These additives may or may not contain a mixture of nutrients including nitrogen.

Poultry manure has been long used in Jamaica and other countries as a source of soil additive to improve crop growth and yield. Poultry manure is the excrement along with the dry matter used as bedding in intensively grown broiler chicken operations. This waste is generally removed from the coop and allowed to mature for some time before it is used in the field. Poultry manure proved to increase the yield and growth performance in Abelmoschus esculentus L. Monech more than nitrogen alone, farmyard manure, and goat manure (Adhikari A. 2020).

In a recent study to investigate organic amendments and microbial application on sodic soil properties and growth of basil plant, it was found that organic amendments help improve the Physico-chemical properties of sodic soil and increase crop production (Trivedi et al., 2017). The researchers used microbial inoculation of bacteria, vermicompost, and sludge. The study concludes that the treatments positively affected, soil pH, electrical conductivity (EC), exchangeable sodium (Na), soil microbial biomass carbon (SMBC), soil microbial biomass nitrogen (SMBN), soil respiration (SR), the microbial quotient (Cmic:Corg), and metabolic quotient (qCO2) as they were significantly higher in incubated soils than non-inoculated soils. Also, vermicompost, sludge, and microbial inoculants enhance the yield and oil quality of basil (Trivedi et al., 2017).

In a field study to look at the effects of organic and inorganic fertilizer on biomass, essential oil yield, essential oil content and compositions and antioxidant activity of denaian thyme, the researchers found that application of combined fertilizer significantly increased the biomass and essential oil yield. The treatments were: no fertilizer (control), chemical fertilizer (NPK) cow manure, vermicompost (VC) and combined fertilizers (chemical fertilizer+cow manure+vermicompost). The main essential oil was thymol. The highest amount of thymol was obtained under the application of combined fertilizers (Bistgania et al., 2018). This is in contrast to a study done by Hoseini-Mazinai et al., (2017) in which he found that the biofertilizer was the main influencer for the essential oil output. In Hoseini-Mazinai et al., (2017) study the authors found that a mixture of biofertilizers generally produced positive effects on biologically active substances. Treatments of beneficial soil bacteria (nitroxin and super nitro plus), mycorrhizae (Glomus intraradices), animal manure, chemical fertilizer (NPK) and control (no fertilizer) were added to the soil. The results showed that biofertilizer had significant effects on studied characteristics. 42

components were detected in the essential oil of *C. Officinalis* representing 94.3% of the total oil of these 29 constituents that were affected by the application of biofertilizer. The highest essential oil content and essential oil yield were obtained by using the biofertilizer (Hoseini-Mazinai 2017). The positive effects of biofertilizer over inorganic fertilizer correspond with Faramawy et al., (2014) study. This study investigated the response of *Prosopis Chilensis* to biofertilization under calcareous soil. The researchers used as treatments, active strains of *Azotobacter chroococcum* (as nitrogen-fixing bacteria), Bacillus megatherium (as phosphate dissolving bacteria), *Bradyrhizobium japonicum* (as symbiotic nitrogen fixer bacteria) and vesicular-arbuscular mycorrhizal fungi (as phosphate solubilizer symbiont) and control with no additive. The authors highlight that this quantitative variation of the flavonoids must be derived from induction by microbial inoculation (Faramawy et al., 2014).

Soil organic matter was highlighted as an important soil feature to increase active substances in the plant *Sinopodophyllum hexandru.* In a study to look at the "Influence of Ecological Factors on the Production of Active Substances in the Anti-Cancer Plant *Sinopodophyllum hexandrum*" the important active ingredients are quercetin and kaempferol. The researchers highlighted that primary ecological factors influencing the active substances included the annual average precipitation, July mean temperature, frost-free period, sunshine duration, soil pH, soil organic matter, and rapidly available potassium in the soil. They conclude that organic matter was the most important limiting factor and was significantly and positively correlated with the active substances (Liu et al., 2015). Organic amendments help to increase soil respiration and enzyme activity leading to better cycling of nutrients while making nutrients more available to the plant Khan et al., (2015). Carrots fertilized with pelleted chicken manure had 6–7% lower total soluble sugar content than carrots manured with 50 t ha−1 of composted or fresh manure. The falcarinol to total falcarinol-type polyacetylenes ratio was 15.4% in carrots manured with 50 t ha−1 of composted or fresh manure and 14.7% in carrots fertilized with pelleted chicken manure. The researchers also observed that seasonal fluctuations in falcarinol-type polyacetylenes were more pronounced in carrots manured with fresh or composted manure than in carrots fertilized with pelleted chicken manure. The authors conclude that manuring organic carrots with compost may be the most beneficial strategy in organic farming (Kjellenberg et al., 2015).

III. MATERIAL AND METHOD

3.1 Experimental site:

This pot experiment was carried out under shade house conditions at the Northern Caribbean University farm in Mandeville Manchester.

- The average daytime temperature at the research site: 27^{o} C
- Duration of study: August 2021 – October 2021

3.2 Experimental design*:*

Cucumis sativum was grown for 3 months under shade house growth bag conditions. Randomized Complete Block design (RCBD) with five treatments and four replications was employed. Each block represents 40 plants with 8 plants per treatment.

3.3 Plant material and Treatment:

Plant: cucumber

- Brand: semisis
- Specie: hybrid slicing
- Variety: Thunderbird 88%+CQ 12%
- Days to harvest:50
- Fruit description: straight fruit, 4lbs per vine

Grow bags were set 2 feet * 18 inches apart.

Treatment application was done at planting and then 4 weeks after planting as a top dressing.

Irrigation was done by manually watering on the requirement.

Treatments: mature goat manure, mature rabbit manure, fruit tea (8 weeks fermented mango and **Otaheite** apple.), NPK (11:22:22) and control.

Treatments were applied in two doses of top dressing at planting and one month after planting. Forty (40) grams of each treatment was used with the first application of 20g and the second application of 20g.

3.4 Evaluation and measurements:

Plants were observed throughout the growing season.

3.4.1 Germination time:

The time is taken for germination of seeds under different treatments: observed and recorded for each plot (bi-weekly observation).

Germination rate: record made of the number of seeds germinated weekly from each plot.

(definition given consideration here is the emergence of green seedlings with one (mono) or two (di) cotyledons from the soil surface (Thomas B., Murray D. and Murphy D. 2017), Principal growth stage 0: Germination-Emergence: cotyledons break through soil surface ((BBCH working group 1997)

3.4.2 Seedling growth:

For the determination of seedling growth, the distance from the soil surface to the highest tip of the seedling was measured on all seedlings. This was done weekly starting 1 week after seed planting.

3.4.3 Time to flowering:

The time to flowering for each treatment was measured by counting the number of open flowers in each plot and treatment two times each week. Flowering was observed at principal growth stage 6: the first flower appears on the main stem (BBCH working group 1997).

3.5 Statistical Analysis:

One-Way Analysis of Variance was performed on all parametric measurements to determine significance within and between groups. Where there was significance the Turkey post hoc multiple comparison tests were used. The Spss version 28 was the software package used.

IV. RESULTS

4.1 Germination Percentage:

TABLE 2
ANOVA COMPARISON BETWEEN AND WITHIN GROUPS

ANOVA					
Germination %					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	21062.5	4	5265.625	39.186	<.001
Within Groups	2687.5	20	134.375		
Total	23750	24			

There was a statistically significant difference between the groups as determined by one-way ANOVA- F (4,20) =39.186, P<0.001. We can see from the table below that there is a statistically significant difference in germination % with the NPK fertilizer (20 +/- 20.9 %, p<0.001). Fruit tea had a germination percentage of 97.5+/-5.59%, P=0.997, Rabbit manure 95 +/- 6.85%, P=0.997, goat 87.5+/-8.83%, P=0.656 and the control group having mean germination % of 87.5 +/- 8.87, P=0.656. There were hence no statistically significant differences between the groups of organic treatments (p >0.05) when comparing germination percentage.

TABLE 3
TURKEY POST HOC OF GERMINATION % COMPARISON

Dependent Variable: Germination %						
Tukey HSD -POST HOC						
(I) Fertilizer type	**(J) Fertilizer type**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
Fruit Tea	NPK	77.50000*	7.33144	<.001	55.5616	99.4384
	Rabbit	2.5	7.33144	0.997	-19.4384	24.4384
	Goat	10	7.33144	0.656	-11.9384	31.9384
	Control	10	7.33144	0.656	-11.9384	31.9384
NPK	Fruit Tea	-77.50000*	7.33144	<.001	-99.4384	-55.5616
	Rabbit	-75.00000*	7.33144	<.001	-96.9384	-53.0616
	Goat	-67.50000*	7.33144	<.001	-89.4384	-45.5616
	Control	-67.50000*	7.33144	<.001	-89.4384	-45.5616
Rabbit	Fruit Tea	-2.5	7.33144	0.997	-24.4384	19.4384
	NPK	75.00000*	7.33144	<.001	53.0616	96.9384
	Goat	7.5	7.33144	0.842	-14.4384	29.4384
	Control	7.5	7.33144	0.842	-14.4384	29.4384
Goat	Fruit Tea	-10	7.33144	0.656	-31.9384	11.9384
	NPK	67.50000*	7.33144	<.001	45.5616	89.4384
	Rabbit	-7.5	7.33144	0.842	-29.4384	14.4384
	Control	0	7.33144	1	-21.9384	21.9384
Control	Fruit Tea	-10	7.33144	0.656	-31.9384	11.9384
	NPK	67.50000*	7.33144	<.001	45.5616	89.4384
	Rabbit	-7.5	7.33144	0.842	-29.4384	14.4384
	Goat	0	7.33144	1	-21.9384	21.9384

. The mean difference is significant at the 0.05 level

The average germination rate between the treatments was between 97% to 20% after 10 days. The NPK had the lowest germination rate out of the treatments applied at 20% (Figure 1). The highest germination percentage was observed in the fruit tea treatment at 97.5%. All treatments except the NPK had a germination rate above 87%. There was no overall significant difference in germination between the treatments (ANOVA- df = 4, p= .997).

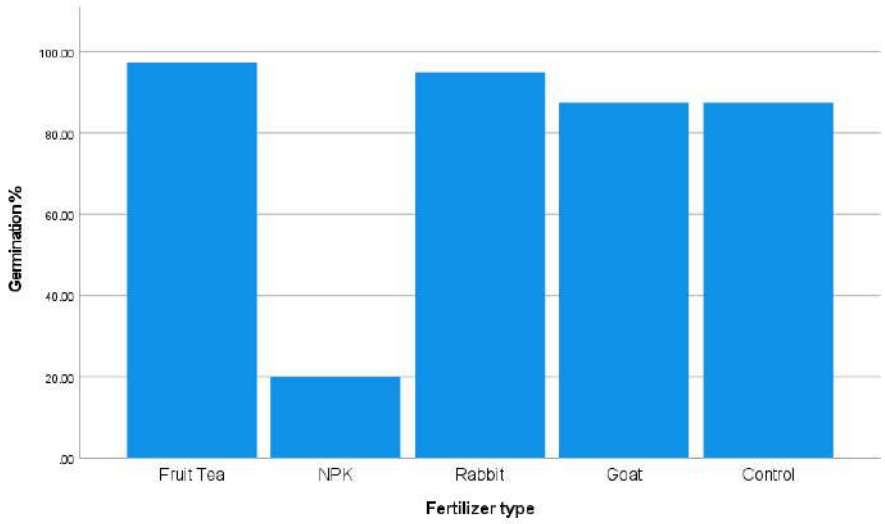

FIGURE 1: Germination percentage for treatments

It was revealing for the NPK to have such limited germination out of all the treatments, however, with further research, it was garnered that chemical fertilizers and especially its nitrogen component may harm germination. In a study done by Tange A., 2018, it was found that when chemical fertilizer was added at seed planting, it did not increase germination. It was pointed out by Kilmer J., et al, 1973, as early as the 1970s that biurets if placed near seeds in excess amount have the effect of inhibiting germination and injuring or killing seedlings. It has been found that some nitrification inhibitors may reduce seed germination (Bremner J. and Krogmeier M. 1989). These factors coupled with the close application of the NPK to the seeds may have affected their germination. It was also observed that some seedlings under the NPK treatment were burnt by the fertilizer at the second fertilizer application. These seedlings did not recover.

In a study looking at organic and inorganic manure on germination of beans, it was found that the highest germination percentage was observed in vermicompost application of the seedling (Vaithiyanathan T. and Sundaramoorthy P. 2016). This showed that organic treatments have the potential to contribute significantly to the germination of seeds.

4.2 Germination rate index:

GRI = Germination rate index (The GRI reflects the percentage of germination on each day of the germination period.)

Germination was measured at 5, 7, 10 and 13 days. The fruit tea had the lowest germination percentage at the beginning of the measurements but had the highest germination percentage after 13 days. Table 3 highlights the Germination rate Index (GRI) for the treatments at 5, 7, 10 and 13 days after planting.

The fruit tea treatment had the lowest germination at 5 days however it had the highest germination after 13 days. It had the highest increase in germination rate over 2 days (see Table 2). The control had the best germination rate index with 80% germination on day 5 after planting.

The ANOVA between-group effect showed a significant difference between the 5-, 7- and 10-day germination (ANOVA- df = 4, p.= <.001). Significant differences between treatments using Tukey's multiple comparisons test were observed as follows:

- On day 5, the rabbit, goat and control were significantly different from the fruit tea, p <.001, .006 and <.001 respectively. While at day 10, only the NPK remained significantly different from all the others (p <.001). This germination difference, in the end, may be attributed to a possible negative effect of the NPK on germination which may have been impacted by the proximity of the placement of the fertilizer to the seed when sown.

The positive germination rate index of the control is a strong indication that cucumber seeds can germinate without any assistance in the form of fertilizer application.

TABLE 3
GERMINATION RATE AT DAY AT 5, 7,10 AND 13

Day	FT	NPK	R	G	C
5	2	3	30	16	32
7	37	4	38	31	35
10	39	8	38	33	35
13	39	8	38	35	35
The TOTAL number of seedlings germinated	**117**	**23**	**144**	**115**	**137**

4.3 Seedling growth:

The ANOVA test of between group's effects showed that there was a significant difference (p=0.028) between the groups as it relates to seedling growth. Tukey's post hoc multiple comparison test did not reveal the difference observed between the groups. There was an overall difference which could not be identified in the multiple comparisons. The homogenous subsets moving together were NPK, Goat, Control and Rabbit.

The Fruit tea treatment was however observed to have the highest seedling length followed by the rabbit treatment (Figure 2). The favouring of seedling growth due to organic fertilizer treatment was consistent with Vaithiyanathan T. et al 2016 and Rajasekaran S., et al, 2015 who found that organic fertilizer had a higher growth rate in seedlings than NPK alone. Again

Jalaluddin M. and Hamid M. 2011 found that cow dung was comparable to triple phosphate when tested on seedling growth. In yet another study it was found that NPK harmed shoot length (Badar R., et al. 2015).

Though there was an overall difference in the change in plant height it could not be seen in the individual treatment comparison. No treatment could then be selected to indicate as favouring change in plant height/plant growth.

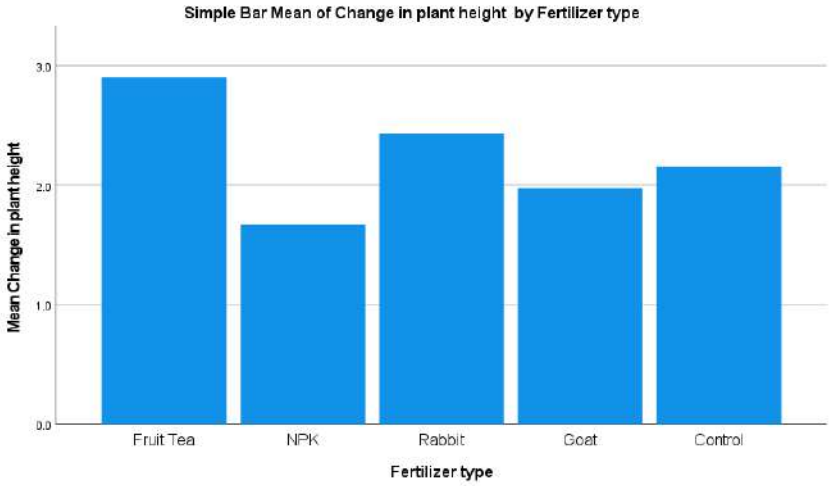

FIGURE 2: Chart showing mean change in plant height

4.4 Flowering:

Flowering in the NPK treatment was significantly different from the other treatments ($p < .001$) in both the between-group effect and the post hoc multiple comparison effect test. As it relates to homogenous subsets, the NPK was moving alone while the other treatments were grouped. This significant difference could be attributed to the low number of plants available at the time of measurement.

The treatment comprising the rabbit manure had the highest number of plants flowering at the time of measurement. This is noteworthy as it was not the treatment with the highest number of plants. The highest number of plants were in the fruit tea treatment.

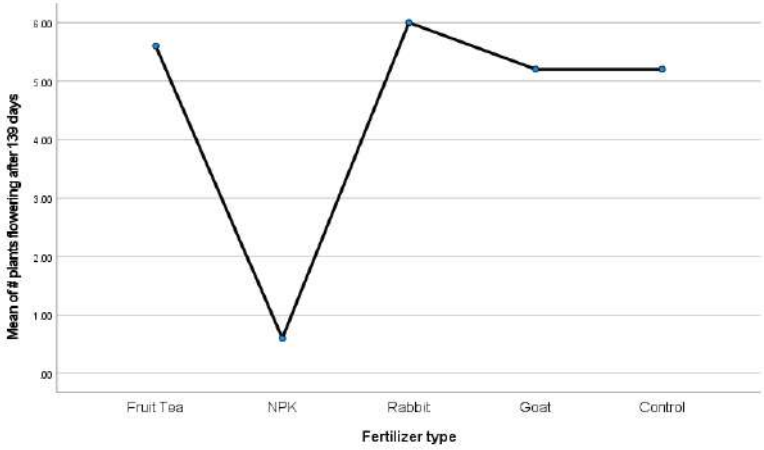

FIGURE 3: Line graph showing flowering after 139 days

V. DISCUSSION AND CONCLUSION

Germination is a critical phase in the lifecycle of a plant. This study shows that organic fertilizer treatments can have a positive effect on germination, plant growth and flowering. There is consistent evidence to show that organic manure can be highly competitive with inorganic fertilizers when used for germination, plant growth and plant yield (Jalaluddin M. and Hamid M. 2011, Vaithiyanathan T. and Sundaramoorthy P. 2016). Vaithiyananthan found that although triple phosphate had a greater germination rate than organic manure (cow dung), the cow dung gave a faster growth in the plants (Vaithiyanathan T. and

Sundaramoorthy P. 2016). Jalaluddin found that the highest germination (99%), root length, shoot length, fresh weight and dry weight were seen in combined biofertilizer application (Jalaluddin M. and Hamid M. 2011).

Organic sources such as the ones used in this research as well as green manure and compost not only increase soil fertility but also add organic matter to the soil (Ram M. 2012, Adhikari A. 2020). Organic manure provides organic acids that help dissolve soil nutrients and make them available for the plants (Obasi N., et al. 2013). Each type of organic fertiliser used has its benefits to the growth of the plant throughout its life cycle. Care needs to be taken in ensuring that plants are given the correct balance of macro and micronutrients that will aid in promoting optimal plant performance and increasing fruit yield. This research has provided valuable and statistically significant information to augment claims that organic fertilizers such as rabbit and goat manure along with fermented fruit tea offer essential nutrients and can be used as a suitable alternative to inorganic fertilizers for those farmers wishing to move into organic farming.

The shade in the greenhouse was a limitation to the normal development of the cucumber plants. Additional follow-up research is recommended in an area with sufficient light as well as recommendation to conduct yield measurements with these treatments.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Determining Heterotic Response, General Combining and specific Combining Ability for Yield and Yield Contributing Traits in Cowpea (*Vigna unguiculata* (L). Walp.)

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Abstract— *Gene action, General Combining and specific Combining Ability, Cowpea. Cowpea belongs to the genus Vigna and species unguiculata under the subfamily Faboideae (Papilionoideae) of the family fabaceae (Leguminosae) with a chromosome number of 2n=22. The present investigation was carried out during 2012-2013 at G.B. Pant University of agriculture and Technology, Pantnagar. First experiment was undertaken to estimate the relative importance of combining ability and heterosis for 11 quantitative characters including seed yield in cowpea (Vigina unguculata (L). Walp). Second experiment was conducted to understand the nature of gene effects involved in the inheritance of various quantitative characters. Pant Lobia-1, Pant Lobia-2, Pant Lobia-3, PGCP-12, PGCP-14, Bucksora Local and Pant Vegetable-3 along with their 21 F_1's were evaluated for genetic analysis. Six generations viz; - P1, P2, F1, F2, BC1 and BC2 of each three families, PGCP-12 x PGCP-14 (Family 1), Pant Lobia-1x PGCP-14 (Family 2), Pant Lobia-1x Pant Lobia-3 (Family 3), were evaluated. Analysis of variance revealed significant mean squares of general and specific combining abilities (GCA and SCA) for all the traits studied. Pant lobia-2 and Pant Lobia-3 had good GCA for seed yield per hectare. Pant Lobia-1 was best general combiner for 100-seed weight and number of pods per plant whereas, Pant Lobia-2 was found to be good general combining ability for number of pods per plant, seed yield per hectare and seed weight per plant. The hybrids PGCP-12 x PGCP-14 and PGCP-14 x PVCP-3 revealed highest SCA effects for seed yield per hectare. The magnitude of relative heterosis, heterobelteosis and economic heterosis for seed yield per hectare ranged from -18.24 to 63.34%, -18 .40 to 47.69% and -4.66 to 93.40% respectively. Pant Lobia-2 x Pant Lobia-3 was best cross combination for days to 1st flowering, Pant Lobia-2 x PVCP-3 for days to pod maturity. Cross PGCP-14 x PVCP-3 showed highest value for pod length. Cross PGCP-12 x PGCP-14 gave highest positive SCA effect for green pod weight per plant. For number of seeds per pod Pant Lobia-3 x PGCP-12 was the best cross combination, Cross PGCP-14 x PVCP-3 for seed weight per plant. Significant estimates of additive [d] and dominance [h] effects as well as all three epistasis were observed for most of the quantitative characters in all the three families. The opposite signs of [h] and [l] indicated that duplicate epistasis was important in inheritance for some of the traits in all the three families. The presence of additive gene action suggested that a part of the heterosis can be fixed in subsequent generations to take advantage in further selection. The preponderance of non-additive gene action, however brought out that heterosis component could be explained in hybrid development in cowpea.*

Keywords— Cowpea, Heterosis, General Combining Ability, Specific Combining Ability, Gene Action, Yield Traits, Hybrid Performance, Plant Breeding.

I. INTRODUCTION

Cowpea's high protein content, its adaptability to different types of soil and intercropping systems, its resistance to drought, and its ability to improve soil fertility and prevent erosion makes it an important economic crop in many developing regions. Cowpea belongs to the genus *Vigna* and species *unguiculata* under the subfamily *Faboideae* (*Papilionoideae*) of the family fabaceae (*Leguminosae*) with a chromosome number of 2n=22. *Vigna* is a pantropical genus with 22 species in India and Shoutheast Asia, 120 species in Africa and few in America and Australia. The speices *Vigna unguiculata* has one subspeices *unguiculata* which has three cultigroup, namely cv.gr. *Unguiculata,* cv.gr. *Biflora* and cv.gr. *Sesquipedalis.* Legumes represent the second largest family of higher plants, second only to grasses in agricultural importance **(Doyle and Luckow, 2003)**. Cowpea, (*Vigna unguiculata* (L.) Walp.), is an important food legume cultivated extensively in the tropics and sub-tropics of Africa, Asia, Brazil and some southern states of the United States of America **(Smart, 1976)**. An estimate of 14.5 million hectares of land is planted to cowpea each year worldwide. Global production of dried cowpeas in 2010 was 5.5 million metric tons; Africa was responsible for 94% of the total production **(CGIAR, 2010).** The experimental yields of the improved genotypes have been reported around 15 quintals per hectare. In India, cowpea is grown in almost all the states but the major cowpea growing states are Gujarat, West Bengal, Tamil Nadu, Andhra Pradesh, Kerala and Orissa.

The dominant world view is that the cowpea originated in West Africa, probably in the sub humid savanna grasslands of Nigeria, the area of its greatest diversity **(Faris, 1965, Rawal, 1975, Lush and Evans, 1981 Ng and Marechal, 1985).** It is, however agreed that the cowpea was domesticated about 4000 years ago from the wild progenitors *Vigna unguiculata* ssp. *Dekindtiana* var, *dekintiana* (in sub Sahelian West Africa) and *mensensis* (in the humid and sub humid zones) and distributed thereafter throughout sub Saharan Africa, reaching Middle East by 2000 B.C. and India by 1500 B.C. **(Lush and Evans, 1981 and Steele, 1976)**. The Indian cultigroups of *V. unguiculata* ssp. u*nguiculata* namely, Biflora (the catjang bean) and Sesquipedalis (the yard long or asparagus bean) arose probably by selection from the early cowpea domesticates **(Faris, 1965).**

According to **Bressani (1985**), the mature legume contains 23-25% protein and 50-67% carbohydrate, 1.9% fats, 6.35% fibre and small percentage of the B-vitamins such as folic acid, thiamine, riboflavin and niacin as well as some micronutrients such as iron and zinc. The richness in protein makes cowpea a source of cheap plant protein **(Anderson, 1985)** to people who hardly can afford animal protein derived from meat, fish, milk and eggs. According to **Yadav and Yadav (1986),** cowpea fix 563 kg of atmospheric nitrogen ha^{-1}.

Cowpea is a very diverse, usually glabrous, annual herb which is twinning to sub-erect and rarely erect. The first pair of leaves is simple and opposite. According to **Fery (1985)**, the inflorescence is axillary and formed of a peduncle 10 to 30 cm long, at the end of which there is a rachis with each node bearing a pair of flowers. The pod is green at early stage and when maturing it becomes usually yellow, light brown, pink or purple. The pod length may vary from less than 11 cm to more than 100 cm **(Rachie, 1976).**

Cowpea can withstand considerable drought and a moderate amount of shade. Cowpeas are short-day, warm-weather plants, sensitive to cold and damaged by frost **(Duke and James, 1990)**. According to **Duke and James (1990),** cowpeas can thrive on highly acid to neutral soils but they are less well adapted to alkaline soils. The crop is more tolerant of low fertility, due to its high rates of nitrogen fixation **(Elawad and Hall, 1987)** and effective symbiosis with mycorrhizae **(Kwapata and Hall, 1985). Singh (1987)** reported that the best cowpea yields are obtained in well-drained sandy loam to clay loam soils between pH 6 to 7.

The success of artificial pollination has been reported to be low ranging from 0.5 to 50% **(Rachie *et al.*, 1975)** and varies with genetic and physiological factors as well as the care taken in handling floral parts during the process of emasculation. In autogamous crop like cowpea, the objective of recombination breeding is to develop high yielding pure line varieties. Recombination breeding involves hybridization, the long process of selection and critical evaluation. Early generation testing and selection have gained momentum in self-pollinated crops, as additive genetic variance is more important. Genetic analysis in early generation helps the selection of desirable transgressive segregants and thereby reducing the population size in letter generations.

The basic objective of any breeding method is to increase yield per unit area, to meet the demand food for increasing populations. A distinct knowledge about type of gene effect, its magnitude and composition of genetic variance *i.e*., additive, dominance and epistatic help in formulating an effective and sound breeding programme.

The precise knowledge of nature and magnitude of gene action for characters related to productivity is helpful in the choice of effective breeding methods to accelerate the pace of genetic improvement of seed yield and other economically important characters. However, epistasis is important in the inheritance of quantitative traits besides additive and non-additive effects. Therefore, the present study was to study the nature and magnitude of heterosis and gene action for yield and yield components.

II. MATERIALS AND METHODS

The present investigation was carried out at the Breeder Seed Production Center of G. B. Pant University of Agriculture & Technology, Pantnagar (Uttarakhand). Geographically, Pantnagar is situated at 29^0N latitude and 79.30^0E longitude and at an altitude of 243.84 m above the mean sea level and falls in the humid subtropical zone. It is situated in the *Tarai* region of Shivalik range of the great Himalayas.

2.1 Development of breeding material:

Seven variety of cowpea viz. (Pant Lobia-1, Pant Lobia-2, Pant Lobia-3, PGCP-12, PGCP-14, Bucksoura Local and PVCP-3) were shown in crossing block and polyhouse during kharif 2012/summer 2013. Twenty-one (21) cross combinations were made among the parental lines in diallel mating design excluding reciprocals and three F_1s were selected and shown in polyhouse for making BC1P1, BC1P2 and F_2. In the early morning, emasculation was carried out.

During the kharif season 2013, the 21 F_1s' along with their seven parental lines were planted and evaluated for yield and yield attributing traits using RBD (Randomized Block Design) with three replications. In this study the available commercial variety Pant Lobi-1 was used as a parent as well as a check.

The experiment comprising six generations of each of three families viz. P_1, P_2, F_1, F_2, BC_1 and BC_2 were shown in family block design with three replications. The plot size consisted of variable number of rows of 4m length each for different generation P_1, P_2 (One row for each parent), whereas F_1 was raised in three row, BC_1 and BC_2 generations in two row each and F_2 was raised in seven rows. The rows were spaced 45cm apart between plants was maintained at 10 cm by thinning. Depending on the variability different numbers of plants in (P_1, P_2, F_1, BC_1 and BC_2 ten plant and in F_2 are 50 plant) were randomly selected from each plot in each replication.

Days to 1st flowering, Days to pod maturity, Number of pods per plant, Pod length (cm), Plant height (cm), Number of seeds per pods, Green pod weight per plant (g), Seed weight per plant (g) , 100-seed weight (g), Seed yield per hectare, Incidence of cowpea mosaic virus and other important Qualitative characters like Leaf type, Seed colour, Plant pigment, Flower pigment and Seed size

2.2 Photographs of Parents:

Pant Lobia-1

Pant Lobia-2

Pant Lobia-3

PGCP-12

PGCP-14

Buksoura Local

Pant Vegetable-3

2.3 Statistical Procedure:

For an in depth analysis of data recorded on various quantitative characters and estimation of certain genetic parameters, the following statistical procedure was followed.

2.4 Analysis of Variance:

Analysis of variance for all the parameters was carried out as procedure given

$$Y_{ij} = \mu + t_i + b_j + e_{ij} \quad (1)$$

where,

i = 1, 2, 3, 4,...…….t, number of genotypes i.e., treatments (t)

j = 1, 2, 3, 4,...…….r, number of replications (r)

Y_{ij}= performance of i^{th} genotype in j^{th} replication

μ = general mean of the population

t_i = effect of i^{th}genotype

b_j = effect of j^{th} replication

Heterosis expressed as the per cent increase or decrease in value of F_1s over mid-parent (heterosis), over better parent (heterobeltiosis) and over the check variety (standard heterosis) will be calculated as-

a. $\text{Heterosis } \% = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$

b. $\text{Heterobeltiosis } \% = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$

c. $\text{Standardheterosis } \% = \frac{\overline{F_1} - \overline{CP}}{\overline{CP}} \times 100$

2.5 Combining ability analysis:

Combining ability analysis was carried out following the Model II, method II (Parents and one set of crosses) of **Griffing (1956).** The mathematical model for the combining ability analysis is assumed to be:

$$X_{ijkl} = \mu + g_i + g_j + S_{ij} + \frac{1}{bc}\sum_k \sum_l e_{ijkl} \quad (2)$$

a) Estimation of gca effect

$$g_i = \frac{1}{n+2}\left[(Y_{i.} + Y_{ii}) - \frac{2}{n} y..\right] \quad (3)$$

b) Estimation of sca effect

$$S_{ij} = Y_{ij} - \frac{1}{n+2}\left(Y_{i.} + Y_{ii} + Y_{.j} + Y_{jj}\right) + \frac{2}{(n+1)(n+1)} Y.. \quad (4)$$

Calculated gi and sij effects were tested comparing with tabular t values of 5% and 1% multiplied by standard errors in which they were associated [$t_{5\%}$ X SE (gi) and $t_{1\%}$ X SE (sij)] at 5% and 1% probability levels, respectively. The estimated values of gi and sij greater then $t_{5\%}$ X SE (gi) and $t_{1\%}$ X SE (sij) the values of GCA and SCA effects regards as significant at 5% and 1% probability level.

2.6 Genetic Analysis:

The genetic analysis was done by using first degree statistics i.e. means of different generations. Adequacy of different models was tested using simple scaling test. A Gene effect was estimated following generation mean analysis.

III. RESULTS AND DISCUSSION

The experimental results obtained from present investigation have been presented under the following points like Analysis of variance, General and specific combining ability for yield and yield attributes, Heterosis and Gene action.

3.1 Analysis of Variance:

Analysis of variance for various characters is presented in table 1. There were significant differences among genotypes for all the characters studied.

3.1.1 Analysis of Variance for Combining Ability Effects:

The concept of combining ability is used in connection with testing procedures, in which it is desired to study and compare the performances of lines in hybrid combinations. The best lines identified could be used for variety development to accumulate desirable genes, or for hybridization to exploit heterosis. **Sprague and Tatum (1942)** developed original theory of combining ability and it has two components *i.e.,* general and specific combining abilities. The term general combining ability (GCA) is used to designate the average performance of a line in hybrid combinations. The term specific combining ability (SCA) is used to designate those cases in which certain combinations do relatively better or worse than would be expected on the basis of the average performance of the lines involved in that specific cross.

The mean squares due to general and specific combining ability variances for all the characters studied are presented in table 1. The variances due to general combining ability were found to be significant for all the characters. Variances due to specific combining ability were also significant for all the characters.

3.2 Estimates of General Combining Ability Effects:

The estimates of general combining ability effects of parents for all eleven characters are presented in table.2.

All the parents showed highly significant GCA effects. Pant Lobia-1, Pant Lobia-2 and PGCP-14 expressed GCA effect in positive direction, whereas, Pant Lobia-3, PGCP-12, Buksoura Local and PVCP-3 showed negative gca effects for Number of pods per plant. For Pod length (cm) all the parents exhibited highly significant GCA effects. Buksoura Local and PVCP-3 expressed GCA effect in positive direction, whereas, Pant Lobia-1, Pant Lobia-2, Pant Lobia-3, PGCP-12 and PGCP-14 showed negative GCA effects. Thus Buksoura Local and PVCP-3 were best combiners for improving pod length.

In grain cowpea dwarf bush type plant is desirable. The genotypes PGCP-12 and PVCP-3 were found best combiners for dwarfism.

TABLE 1
ANALYSIS OF VARIANCE FOR DIFFERENT CHARACTERS (RBD)

Source of variation	Mean square											
	d.f.	Days to 1st flowering	Days to pod maturity	Number of pods per plant	Pod length (cm)	Plant height (cm)	Green pod weight per plant (g)	Number of seeds per pod	Seed weight per plant (g)	100-Seed weight (g)	Seed yield per hectare	Incidence of cowpea mosaic virus
Replication	2	0.34	0.87	0.537	0.398	0.258	0.892	0.231	0.175	0.845	4.686	0.249
Treatment	27	30.382**	35.341**	88.281**	75.317**	73.196**	115.621**	14.644**	41.441**	40.202**	90.186**	1.474**
Error	54	1.441	1.248	0.604	0.734	0.491	0.423	0.931	0.122	0.218	2.948	0.895
CD at 1%		2.617	2.436	0.536	0.59	1.528	1.418	0.665	0.763	1.018	3.743	0.652
CD at 5%		1.965	1.829	0.402	0.443	1.147	1.065	0.499	0.573	0.764	2.81	0.489
CV (%)		2.953	1.707	1.91	1.329	1.688	1.603	1.988	2.095	2.651	6.899	23.269
SEM±		0.693	0.645	0.141	0.156	0.404	0.375	0.176	0.202	0.269	0.991	0.172

***** Significant at 1% probability level***
**** Significant at 5% probability level***

TABLE 2

GENERAL COMBINING ABILITY EFFECTS OF PARENTS

Name of parents	Mean square										
	Days to 1st flowering	Days to pod maturity	Number of pods per plant	Pod length (cm)	Plant height (cm)	Green pod weight per Plant (g)	Number of seeds per pod	Seed weight per plant (g)	100-Seed weight (g)	Seed yield per hectare	Incidence of cowpea mosaic virus
Pant Lobia-1	-0.448*	-0.382	0.954**	-2.720**	1.791**	-4.033**	-1.775**	-0.769**	2.175**	-1.302**	-0.106*
Pant Lobia-2	2.467**	1.796**	3.510**	-1.249**	1.269**	-1.115**	0.677**	0.990**	-0.084	1.328**	0.672**
Pant Lobia-3	-0.674**	-1.893**	-3.024**	-1.453**	0.387**	-1.678**	0.840**	1.516**	-0.858**	2.632**	-0.254**
PGCP-12	-0.837**	-1.701**	-0.676**	-0.868**	-3.428**	-1.233**	1.177**	1.994**	2.016**	2.802**	0.228**
PGCP-14	-2.577**	0.177**	0.680**	-2.320**	0.861**	-1.581**	-0.660**	-1.032**	0.812**	-1.687**	-0.069
Buksoura Local	1.749**	0.725**	-0.809**	2.343**	0.480**	4.037**	-0.253**	-2.006**	-2.732**	-3.131**	-0.217**
PVCP-3	0.319	1.277**	-0.635**	6.266**	-1.361**	5.604**	-0.005	-0.695**	-1.329**	-0.642*	-0.254**
SEM± (gi)	**0.214**	**0.199**	**0.044**	**0.048**	**0.125**	**0.116**	**0.054**	**0.062**	**0.083**	**0.306**	**0.053**

***** Significant at 1 % probability level***

**** Significant at 5 % probability level***

TABLE 3

SPECIFIC COMBINING ABILITY EFFECT FOR SEED YIELD PER HECTARE

Parents	Pant Lobia-1	Pant Lobia-2	Pant Lobia-3	PGCP-12	PGCP-14	Buksoura Local	PVCP-3
Pant Lobia-1		6.418**	4.447**	6.410**	-4.468**	-3.690**	1.121
Pant Lobia-2			3.751**	-2.353**	-0.531	0.647	4.758**
Pant Lobia-3				2.310*	2.599**	0.81	-0.479
PGCP-12					7.195**	2.106*	-1.016
PGCP-14						-3.705**	6.806**
Buksoura Local							0.818
PVCP-3							

	Sem±	CD at (1%)	CD at (5%)
Var (sij)	0.89	2.364	1.78

***** Significant at 1% probability level***

**** Significant at 5% probability level***

All the parents exhibited highly significant GCA effects except PVCP-3 for number of seeds per pod. Pant Lobia-2, Pant Lobia-3, and PGCP-12 expressed GCA effects in positive direction, whereas, Pant Lobia-1, PGCP-14 and Buksoura Local showed negative GCA effects. The results revealed that Pant Lobia-2, Pant Lobia-3 and PGCP-12 were good combiners for number of seeds per pod.

All the parents exhibited highly significant GCA effects. Pant Lobia-2, Pant Lobia-3 and PGCP-12 expressed GCA effects in positive direction, whereas, Pant Lobia-1, PGCP-14, Buksoura Local and PVCP-3 exhibited significant negative gca effects. The results indicated that Pant Lobia-2, Pant Lobia-3 and PGCP-12 were good combiners for seed weight per plant.

Pant Lobia-1, PGCP-12 and PGCP-14 expressed significant positive GCA effects, whereas, Pant Lobia-2, PVCP-3, Buksoura Local and Pant Lobia-3 exhibited significant negative GCA effects. Therefore, Pant Lobia-1, PGCP-12 and PGCP-14 were good combiners for 100-seed weight (g).

For Seed yield per hectare All the parents exhibited highly significant GCA effects. Significant positive effect was noticed for Pant Lobia-2, Pant Lobia-3 and PGCP-12, whereas, Pant Lobia-1, PGCP-14, Buksoura Local and PVCP-3 exhibited highly significant negative GCA effects. The results indicated that Pant Lobia-2, Pant Lobia-3, PGCP-12 were good combiner for seed yield per hectare and Pant Lobia-1, PGCP-14, Buksoura Local and PVCP-3 were poor combiners.

Genetically, GCA is a consequence of additive gene action while SCA is a consequence of non-additive (Dominance and Epitasis) gene action **(Henderson, 1952, and Falconer, 1989)**. A ratio of the two variances (GCA/SCA) could indicate which type of gene action is more important. When the ratio of GCA to SCA variances is more than unity, it indicates that additive gene action is more important than non additive gene actions in controlling the expression of the character and less than unity indicates the importance of non-additive gene action (Dominance and Epitasis) **(Gardner, 1963)**. If additive gene action is predominant in self-pollinated species, then the breeder can effectively select at various levels of inbreeding, because additive effects are readily transmissible from one generation to another. On the other hand, sufficient non-additive gene action may warrant the production of hybrids **(Gravois and Mcnew, 1993)**.

In the present study variances due to general combining ability were observed to be significant for all the characters studied. Variances due to specific combining ability were also significant for all the characters expect virus indicating the importance of additive as well as non-additive effects for these traits. Importance of both additive and non-additive effects for various characters was reported earlier by **Jatasara *et al.* (1980), Hazra *et al.* (1994), Bhushana *et al.* (1998), and Chaudhari *et al.* (2013).**

General combining ability study helps in making the choice of the parents and also helps in the isolation of suitable germplasm for further improvement. General combining ability is primarily a function of additive and additive x additive gene action. In present study significant and negative GCA effects were considered desirable for days to 1st flowering, days to pod maturity, plant height and cowpea mosaic virus, whereas, for other characters significant and positive GCA effects were considered desirable.

Pant Lobia-1 exhibited desirable GCA effect for days to 1st flowering, days to pod maturity, number of pods per plant, 100-seed weight. Pant Lobia-2 showed desirable GCA effect for number of pods per plant, number of seeds per pod, seed weight per plant, and seed yield per hectare. Pant Lobia-3 exhibited desirable GCA effect for days to 1st flowering, days to pod maturity, number of seeds per pod, seed weight per plant, seed yield per hectare. The variety PGCP-12 showed desirable GCA for days to 1st flowering, days to pod maturity, number of seeds per pod, seed weight per plant, 100-seed weight, seed yield per hectare. PGCP-14 and PVCP-3 exhibited desirable GCA effect for three characters *viz;* days to 1st flowering, number of pods per plant, 100-seed weight and pod length, plant height, green pod weight per plant. Buksoura Local showed exhibited desirable GCA effect for three characters *viz;* pod length, green pod weight per plant.

These results indicated that the parent deferred genetically in the manifestation of their GCA effects for different characters. These genotypes can successfully be utilized for improving seed yield of cowpea. Similar findings were also reported by **Patil and Bhapkar (1986), Mishra *et al.* (1987)**, **Hazra *et al.* (1994), Umaharan (1997), Manivannan and Kesar (2005), Pal *et al.* (2007), and Ayo-Vaughan *et al.* (2013)**.

3.3 Estimates of Specific Combining Ability Effects:

The SCA effects of all 21 crosses derived from 7 parents are presented for various characters. Results on character wise SCA effects are described here under:

Twelve crosses exhibited significant SCA effects. The estimate of SCA effect revealed highly significant negative values for Pant Lobia-2 x Pant Lobia-3 (-3.47) followed by Pant Lobia-2 x PGCP-14 (-2.569), PGCP-14 x Buksoura Local (-1.817), Pant Lobia-1 x PVCP-3 (-1.517) and Pant Lobia-3 x PVCP-3(-1.291). The cross Pant Lobia-2 x PVCP-3 (6.602) showed highly significant positive effect followed by Pant Lobia-1 x Buksoura Local (3.054), Pant Lobia-1 x Pant Lobia-3 (2.576), Pant Lobia -3 x PGCP-14 (1.606), PGCP-12 x Buksoura Local (1.409) and Pant Lobia-2 x Buksoura Local (1.139) showed significant positive SCA effect for days to 1st flowering.

Out of twenty-one crosses, nineteen crosses were found to have significant SCA effects. The cross Pant Lobia-1 x Pant Lobia-2 (11.997) had highest positive value. The number of pods per plant is one important yield component trait thus the likely to give better recombination in advanced generation.Out of twenty-one crosses, twenty crosses were found to have significant SCA effects. The cross PGCP-14 x PVCP-3 (2.228) had highest positive value and Pant Lobia-2 x PVCP-3 (-0.443). The crosses showing positive SCA effects for this trait are likely give long podded recombinants during the cause of selfing.

In case of 100-Seed weight (g) eighteen crosses exhibited significant SCA effects. The estimated SCA effect revealed significant positive value for Pant Lobia-1 x Pant Lobia-3 (6.301) followed by Buksoura Local x PVCP-3 (5.579), PGCP-14 x PVCP-3 (3.901) and PGCP-12 x PGCP-14 (0.590), whereas, highest negative value were found cross Pant Lobia-3 x PVCP-3 (-6.429) followed by Pant Lobia-1 x Buksoura Local (-2.092), Pant Lobia-1 x Pant Lobia-2 (-0.873), Pant Lobia-1 x PGCP-14 (-0.836) and Pant Lobia-1 x PVCP-3 (-0.062). The cross combinations showing positive SCA effects are likely to give bold seeded recombination upon selfing.

Best result for Seed yield per hectare out of twenty-one crosses, fourteen crosses were found to have highly significant SCA effects (Table 3). The cross PGCP-12 x PGCP-14 (7.195) had highest positive value followed by PGCP-14 x PVCP-3 (6.806), and PGCP-12 x Buksoura Local (2.106). Thus the crosses positive SCA effects emerged as better combinations which are likely to high yielding recombinants in advanced generation.

Summary of estimate of SCA effects of hybrid for yield and yield contributing traits are presented. Out of 21 F_1's evaluated, many crosses displayed significant SCA effects in the desired direction like 6 for days to 1st flowering, 6 for days to pod maturity, 11 for number of pods per plant, 13 for pod length, 11 for plant height, 16 for green pod weight per plant, 13 for number of seeds per pod, 13 for seed weight per plant, 13 for 100-seed weight, 10 for seed yield per hectare.

Significant positive SCA effects for seed yield per hectare in PGCP-12 x PGCP-14 was associated with significant and desirable SCA effects for number of pods per plant, green pod weight per plant, seed weight per plant and 100-seed weight. The desirable SCA effects for seed yield per hectare in Pant Lobia-1 x Pant Lobia-2, Pant Lobia-1 x PGCP-12 and Pant Lobia-2 x PVCP-3 accompanied by significant SCA effects in desired direction for four, three and five components' characters, respectively. Thus, these crosses could be judged as outstanding crosses for simultaneous improvement of seed yield and one or more component characters.

The ranking of high SCA crosses for seed yield showed the parents having high estimates of GCA did not necessarily record high estimates of SCA. Out of ten crosses only one cross namely PGCP-12 x PGCP-14 had both the good general combiner parents. This cross is therefore amenable for improvement through selection. Remaining nine crosses exhibiting significant positive SCA effects for seed yield per hectare combined either both or at least one poor/average general combiners. The results therefore, indicate the operation of dominant x dominant and or additive x dominant gene interactions for the genetic control of expression of yield in these crosses. Based on this heterosis breeding appears to be the best approached for the exploitation of available genetic variability. Similar results were reported by **Patil and Bhapkar (1986), Mishra *et al.* (1987), Manivannan and Kesar (2005) and Ushakumari (2010).**

Based on SCA effects the crosses Pant Lobia-2 x Pant Lobia-3 and Pant Lobia-2 x PGCP-14 appeared promising crosses for earliness of flowering. These observations suggest that maintenance of heterozygosity in the population could be necessary for desired expression of these characters. Similar results were reported by **Patil and Bhapkar (1986), Mishra *et al.* (1987), Pal *et al.*, (2007) and Mote *et al.* (2007)**.

3.4 Estimates of Heterosis:

Heterosis was explained as per cent increase (positive) or decrease (negative) in the average performance of hybrid over the mid parent (relative heterosis), better parent (heterobeltiosis) and check variety (economic and standard heterosis).

The Days to 1st flowering estimate of relative heterosis, heterobeltiosis and economic heterosis is presented. Out of the twenty-one crosses, fifteen crosses showed significant relative heterosis, which ranged from -10.00 to 22.15%. The cross Pant Lobia-

2 X Pant Lobia-3 (-10.00) followed by Pant Lobia-1 x PGCP-14 (-6.94), Pant Lobia-2 x PGCP-12 (-6.90), Pant Lobia-2 x PGCP-14 (-5.36), Pant Lobia-1 x PGCP-12 (-4.31) and PGCP-14 x Buksoura Local (-3.80) showed heterosis in negative value that is heterosis for flowering. The estimate of heterobeltiosis ranged from -2.50 to 28.20 %. The one cross showed significant heterobeltiosis in desired direction (negative heterobeltiosis) Pant Lobia-2 x Pant Lobia-3 (-2.50).

Number of pods per plant the estimate of relative heterosis, heterobeltiosis and economic heterosis is presented. Relative heterosis was found to be significant for all cross combination that ranged from 15.52 to 238.58 %. The combination PGCP-14 x Buksoura Local (238.58) showed highest relative heterosis by Pant Lobia-1 x Pant Lobia-2 (210.70) and Pant Lobia-3 x PVCP-3 (15.52). The range of economic heterosis was -11.95 to 223.70 %. nineteen crosses showed significant economic heterosis Pant Lobia-1 x Pant Lobia-2 (223.47) and Pant Lobia-3 x PGCP-14 (6.96).

The significant heterobeltiosis was showed by the entire cross which ranged from -46.15 to 24.66%, out of the eleven cross combinations showed heterosis in positive direction. The heterobeltiosis was noticed for Pant Lobia-2 x Pant Lobia-3 (24.66) by Pant Lobia-3 x PGCP-12 (21.25) and Pant Lobia-2 x PGCP-14 (1.28). The estimate of relative heterosis, heterobeltiosis and economic heterosis for seed weight per plant presented. Significant relative heterosis was showed by crosses which constitute a range of -18.09 to 63.07 %. Out of twenty-one, the eighteen-cross relative heterosis in positive direction. The highest value was notice of for Pant Lobia-1 x Pant Lobia-2 (63.07) followed by PGCP-12 x PGCP-14 (63.00), Pant Lobia-1 x PGCP-12 (59.24), and Pant Lobia-3 x PVCP-3 (5.21). All crosses exhibited significant heterobeltiosis. The range was -18.38 to 67.22%. Out of twenty-one, eighteen cross showed heterobeltiosis in desired direction.

For 100-seed weight (g) the estimate of relative heterosis, heterobeltiosis and economic heterosis is presented. The results of relative heterosis depicted that out of twenty-one, twenty crosses showed significant relative heterosis, which ranged from 38-28 to 72-70%. Heterobeltiosis ranged from-36.17 to 47.69%, twenty-one crosses should significant Heterobeltiosis, out of which twelve crosses expressed heterobeltiosis in positive Heterosis. The cross Buksoura Local x PVCP-3 (47.69) and Pant Lobia-3 x PGCP-14 (1.21), should positive heterosis. All the combinations except Pant Lobia-3 x PGCP-12 showed significant which ranged from -54.73 to 26.63%, six crosses combination should economic heterosis in desired direction.

For Seed yield per hectare **t**he estimates of all three types of heterosis are given all the crosses showed significant relative heterosis with the range of -18.24 to 63.34. The maximum value in positive direction was noticed for Pant Lobia-1 x Pant Lobia-2 (63.34) followed by PGCP-12 x PGCP-14 (63.01), PGCP-14 x PVCP-3 (-9.31) and Pant Lobia-1 x PGCP-12 (59.22). Twenty crosses exhibited significant heterobeltiosis for Seed yield per hectare the range was -18.40 to 47.69%. The best combination was Pant Lobia-1 x PGCP-12 (47.64) followed by PGCP-14 x PVCP-3 (46.26), Pant Lobia-2 x PGCP-14 (43.10), and Pant Lobia-3 x Buksoura Local (7.69) showed positive Heterosis.

Heterosis is usually described in terms of the superiority of F_1 hybrid performance over some measure of parental performance that means definition of heterosis differs depending on the basis of comparison used. Heterosis is defined as improvement of F_1 over the mean of both parents (mid parent heterosis or relative heterosis) **(Pickett, 1993 and Stuber, 1999),** over the mean of the better parent or heterobeltiosis **(Briggs and Knowles, 1967 and Jinks, 1983)**. These definitions coincide with that of **Hayes *et al.* (1955)**

In the present investigation heterosis has been measured over better parent, BP (heterobeltiosis), over mid parental value, MP (relative heterosis) and standard variety, Pant Lobia-1 (economic heterosis). For days to 1st flowering the negative heterosis is desired to develop early genotypes. The cross Pant Lobia-2 x Pant Lobia-3 (-2.50) was found to be best heterotic combination for relative heterosis (-10.00) and heterobeltiosis (-2.50). Seventeen crosses combination showed heterosis over check in the desired direction. All the crosses showed economic heterosis in positive value. Similar results were obtained by **Marangappanavar (1984), Shakarad (1989), Bhushana *et al.* (2000), Ushakumari *et al.* (2010) and Patel *et al.* (2013).**

For seed weight per plant, relative heterosis, heterobeltiosis and economic heterosis ranged from -18.09 to 63.07 %, -18.38 to 67.22 % and -4.13 to 93.46 %, respectively. Cross Pant Lobia-1 x Pant Lobia-2 emerged as best combination for relative heterosis (63.07) and PGCP-14 x PVCP-3 was best combination for heterobeltiosis (67.22). One cross PGCP-12 x PGCP-14 (93.46), combination showed highest economic heterosis in desired direction. The results of investigation matched with the findings of **Sangwan and Lodhi (1995), and Patel *et al.* (2013).**

The range of relative heterosis, heterobeltiosis and economic heterosis for seed yield per hectare was -18.24 to 63.34, -18 .40 to 47.69% and -4.66 to 93.40%, respectively. The best heterotic combination for relative heterosis was Pant Lobia-1 x Pant Lobia-2 (63.34). The cross Pant Lobia-1 x PGCP-12 (47.64) was found to be the best for heterobeltiosis and PGCP-12 x PGCP-14 (93.40) was found to be best for economic heterosis. Similar results were reported by **Marangappanavar (1984),**

Srikantaradhya (1984), Kabiraj-Neupane (1986), Sangwan and Lodhi (1995), Bennett-Lartey (1999) and Patel *et al.* (2009).

IV. CONCLUSION

Based on the finding of the present investigation Pant Lobia-1, Pant Lobia-2, Pant Lobia-3, PGCP-12 and PGCP-14 were good general combiners for number of seeds per pod, seed weight per plant, 100-seed weight and seed yield per hectare which can be used in hybridization programme to improve grain yield. Buksoura local and PVCP-3 were good general combiner for number of pods plant, pod length, green pod weight per plant thus can be exploited for developing vegetable type varieties.

Considering results of gene action, it is apparent that most of the characters in either of the family were found under the control of both fixable (additive, additive x additive) and non-fixable (dominance and epistatic) gene effects coupled with duplicate type of epistasis. Therefore, selection programme aiming to improve such traits in a population should accumulate the fixable additive genes first in early generations. Simultaneously breeding method like modified recurrent selection *i.e.,* alternating pedigree and recurrent selection cycle, diallel selective mating system may be tried for the effective and efficient exploitation non-fixable gene effects.

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Evaluation of Rangeland Grass Species Composition in Different Livestock Land use Systems in Marondera Zimbabwe

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Abstract— *This research work investigated that livestock land use systems influence grass species composition (Density and Biomass), and basal cover. A number of three livestock land use systems; communal livestock land use system, commercial livestock land use system and the resettlement livestock land use system each replicated thrice were assessed using the botanical sampling technique. Grass species density, species biomass and basal cover were measured using 50cm x 50cm quadrats. The collected data was analysed using Minitab version 17 at P≤0.05 significant level. The results revealed that grass species density, biomass and basal cover were lower in the communal livestock land use system than in resettlement and commercial systems. The prevailing grass species were dissimilar where more unpalatable grasses were found dominating in communal areas than in other systems. The invasive and increaser species were found in the communal livestock land use system than in the commercial and resettlement system. Furthermore, the basal cover was lower in the communal grazing lands than in the resettlement and commercial land use systems. Lack of knowledge, high stocking densities as well as poor grazing strategies were ascribed to these results. As a measure against rangeland degradation, there is a need to devise a monitoring scheme or strategy for early recognition of changes as some grass species maybe vanished. The basal cover changes require close attention and monitoring as very low percentages of basal cover might reduce the production potential of the rangeland.*

Keywords— Increaser species, Unpalatable, Invasive species, Stocking density, Species composition.

I. INTRODUCTION

Livestock production is one of the main essential enterprises in Zimbabwe. As of the year 2005 livestock industry contributed 15 to 25% of the total value of agricultural output (Sibanda, 2007). Cattle, goats and sheep are the chief important ruminant species kept, cattle being the most essential while donkeys, pigs and poultry are also reared. Natural grazing remains the principal source of animal feed (Gambiza and Nyama, 2000). Degradation and the unproductiveness of rangelands have been a major problem under this sector. This is relatively accompanied with some drastic losses of vegetation and decline in forage quality, reduced ground cover and above ground biomass production. The current shortage of forage is to some extend hinged to improper veld management practices and lack of knowledge. The ever increasing need for more cropping and settling land has led to the decrease of land left for grazing. Exceeding carrying capacities increased grazing pressure, grazing severity and overgrazing overall posing a great challenge in the livestock production sector. Veld condition can be defined as the state of the veld in relation to its position in plant succession as modified by some disturbance (Westoby *et al*., 1989). Measurement and interpretation of parameters like species composition, basal cover, litter cover, bush encroachment, plant vigour, and soil compaction and erosion compound to veld condition assessment (Westoby *et al*., 1989). Grass species diversity is a good indication of veld condition because different species react differently to grazing pressure. The increaser and decreaser grass species have been used as indicators to appraise veld condition. Categorising these species and monitoring their relative abundance is an essential step for sustainable veld management (Van Rooyen, 2002). The resettlement farming system established through the land reform program by the Zimbabwean government brought some changes to the already existing rangelands (Sibanda, 2007). The program came with the land fragmentation 2 following the handover takeover processes which brought about changes in land management systems. There could be changes in veld species composition due to change in the farming systems from commercial subsectors to the resettlement farming systems. Knowing the changes brought by the difference in management is of essence in making recommendations for monitoring and managing veld condition for maximum

production. The farming system influences species richness, species diversity, bush encroachment and biomass yield (Gusha and Mugabe 2013). From the previous research, species richness and diversity were lower in the communal farming system than in the small and large scale commercial farming system (Mugabe and Gusha 2013). According to Mugabe and Gusha (2013), there were notable differences in species composition among farming systems. Invasive, more wiry and weedy grasses were more dominant in the communal farming system than in the large and small scale farming sectors. Poor grazing strategies and high stocking densities were suggested to have attributed to these veld conditions. Considering the great influence of climate and some edaphic factors on the structure and state of vegetation within a veld, there is a need to study relatively similar concepts in a different climate. The veld degradation has been estimated to be 73% in dry land areas of Zimbabwe (Bai *et al*., 2008). This is, however, an attribute of management which is also a major factor under different farming systems. Quantification of species losses occurring in these rangelands needs to be done to mitigate the losses. Understanding the existing forage resources for stock production is an imperative to know type of supplementation for efficient stock production. This provides the basis for persistent monitoring into species alterations happening in communal, resettlement and commercial farming systems. It is as well important in generating information for government policy makers and formulating regulations helpful in preserving or mitigating veld degradation problems as well as monitoring veld for different farming systems. Through information generation, the research can also be helpful to some researchers for further studies under the same subject. Knowing the species composition within the veld is of great importance in calculating the carrying capacities of different rangelands. It allows the farmer to allocate the animals to grazing areas considering the quality and quantity available to the animal. Thus improving the animal condition as well as lowering the veld deterioration rate. This study therefore aimed at evaluating the effect of different management practices on grass species biomass, density and cover in different livestock land use systems.

II. MATERIALS AND METHODS

2.1 Study site:

The study was carried out in Marondera District in three different livestock land use systems. The area is in natural region 2b which receives about 700mm-1000mm rainfall per year. Marondera experiences wet and dry season. The wet season starts from late October to March whereas the dry season extends from April to October. Temperature ranges from 5, 5-28 degrees Celsius. The communal area is located in Magorimbo under Svosve communal lands. A common rangeland site was randomly selected from all the sites in this area. Rangelands which are being used for grazing were sampled. The resettlement area selected is located in Masomera area and is partitioned into villages as well as some individual farms. Machangara grazing land was randomly selected from all these to represent the resettlement livestock farming system. A list of a number of commercial farms in Svosve area was compiled and Gwaai Farm was randomly selected from this list to represent the commercial livestock farming system. The research sites are in close proximity interlinking with each other with resettlements in between them, their land use, management and management regime being different. The communal grazing is often a shared possession with no grazing management in place. Commercial and resettlement farming systems had some similar attributes and tenure conditions but differed in veld control, management systems, resource base and disturbance regimes.

2.2 Grass species sampling and measurements:

Only top land rangelands portions were used, vleis or swamps and arable lands were excluded in this study. This was to exclude the biased effect of topography and artificial manipulation of the rangelands of grasses. Within each division a diagonal transect line was established using a 100m tape measure. The quadrat sampling method was used to carry out the research on grass species composition of the three farming systems represented in the study area. Three homogeneous stands were chosen within a farming system. Sampling was done in 30m x 30m square plots situated on top land grazing sites being used as grazing lands. A diagonal transect was stretched in each plot marked by pegs. Along the transect chain a quadrat was dropped after every 8 mitres determining each sampling point. Five quadrates for each plot in respective subdivisions were worked on for grass species composition for every farm unit. A total of 15 quadrats were sampled representing each farm unit as well as the respected farming system. Species identification was done at the field and verified with the experts. Fresh biomass was cut at a height of around 5 cm above the ground and dry matter weights were then attained by weighing using a digital scale after drying the samples in oven at 70 ^{0}C to a constant weight (mostly 24 hours) in khaki pockets. The data was collected thrice with a one week interval. The basal cover was evaluated following the same sampling procedures to complement the species composition outcomes as well as giving a general view of the rangeland condition.

2.3 Statistical analysis:

Qualitative statistical analysis was done, where different herbaceous species were identified and taken note of. The data was transformed using the formula √×+0.5. The data was then subjected to ANOVA (analysis of variance) at 95 % significance level. Fisher's least significant difference test was used for separation of means. Both ANOVA and separation of means were done using Minitab 15. Summary statistics was done using Microsoft excel.

III. RESULTS

3.1 Species density:

Generally, species density was highest in commercial areas and lowest in communal areas. Table 1 shows summarises findings on species density.

TABLE 1
SPECIES density / m^2

	Commercial	Resettlement	Communal
Mean	30	26	20
Maximum	37	29	22
Minimum	25	21	17

3.2 Total species density:

The commercial livestock land use system had the highest total species density/m^2 with about 33 total grass plants/m^2 followed by the resettlement livestock land use system. The communal livestock land use system had the lowest total grass plant species/m^2 with an average of 23 grass plants/m^2 (Fig 1). However, there was no significant difference in the total species density/m^2 between the commercial and resettlement livestock land use system. Furthermore, there was also no significant difference in the total species density between the resettlement and communal systems. A significant difference in the total species density/m^2 existed between the commercial and communal livestock land use system (Fig 1).

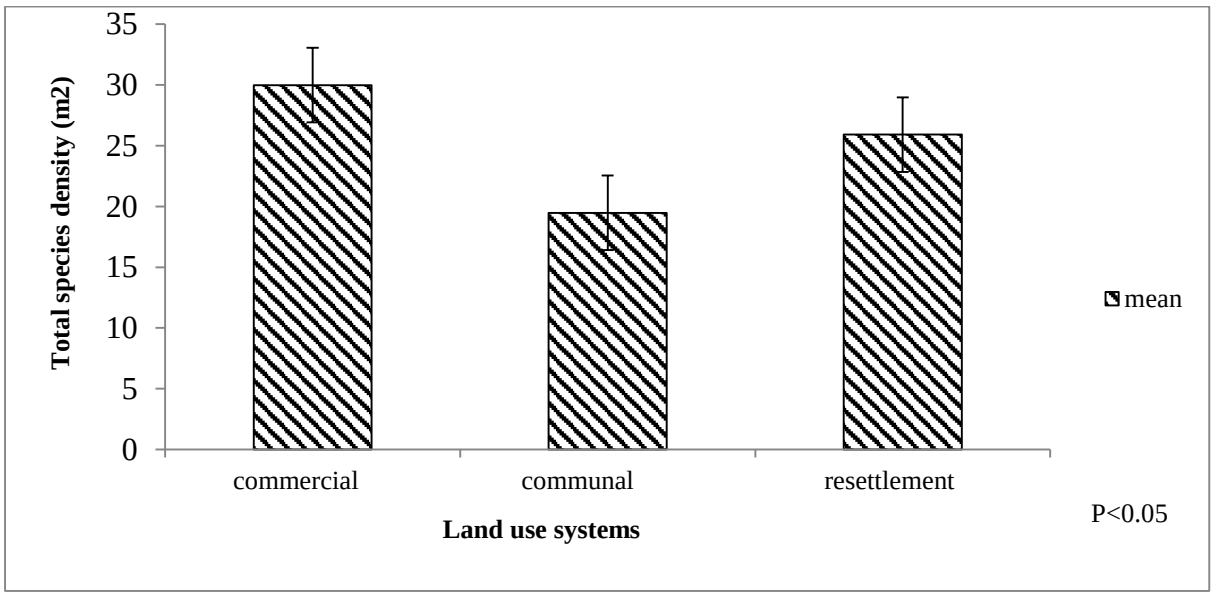

FIGURE 1: Total grass species density across land use systems

3.3 Categorised species density across farming systems:

The commercial livestock land use system had increasers with the highest species density/m^2 (around 14/m^2) followed by the invasive species and lastly the decreaser species which had the lowest species density of around 12 species/m^2 (Fig 2). However, there was no significant difference in species density between the relative categorised species within the system. The resettlement livestock land use system was found with the decreaser species having the highest density of above 14 grass plants/m^2 followed by the increasers which showed figures slightly above 12 grass plants/m^2. The invasive species had the

lowest species density in this system following an average of at 10 grass plants/m^2 (Fig 2). However, there was no significant difference in terms of species density between the increaser and the decreaser species category. A significant difference existed between the invasive and the decreaser species category. Furthermore, a significant difference was found existing between the invasive and increaser species category in terms of density/m^2. In the communal livestock land use system, the increaser species had the highest species density/m^2 (average of 13 plants/m^2) followed by the decreaser species category and lastly the invasive species with the lowest species density of around 8 species/m^2 .Nevertheless, there was no significant difference existing between the invasive species density and the decreaser species density. A significant difference existed between increaser species and the invasive species density. Furthermore, between the increaser species and the decreaser species density/m^2 exist a significant difference (Fig 2).

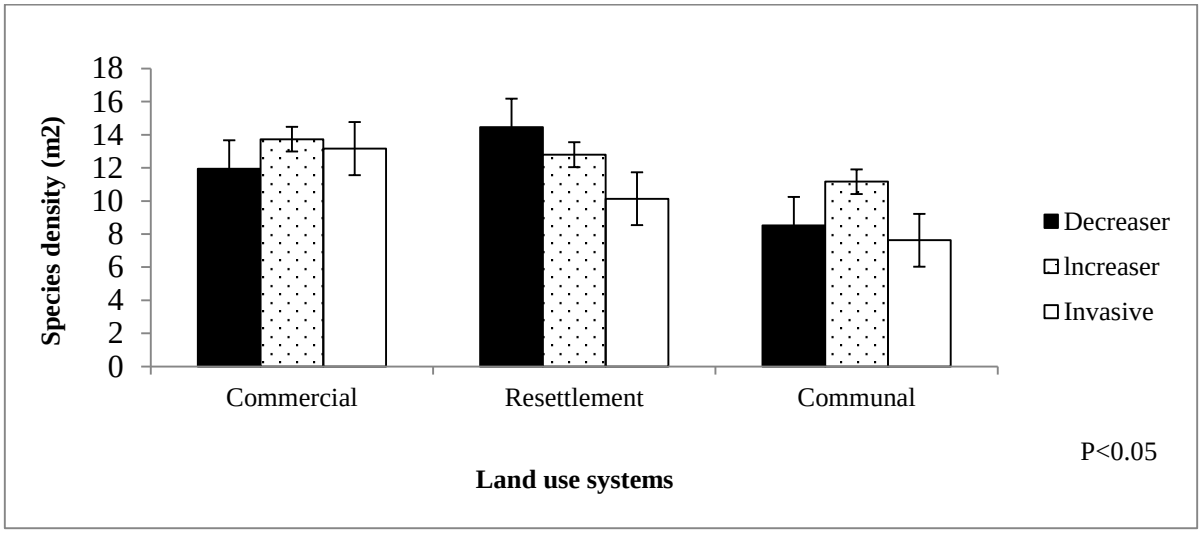

FIGURE 2: Relative density for the categorised species across land use systems.

3.4 Species dominance (density/m^2):

Decreaser species were more dominant in the resettlement system, followed by the commercial system in relation to increaser and decreaser species however more increaser species were found in the communal system as compared to all the systems. Table 2 shows summarises findings on relative species dominance.

TABLE 2
RELATIVE SPECIES DOMINANCE (density/m^2)

S.No.	Commercial	Resettlement	Communal
1	Egyptian crowfoot grass *(decreaser)*	*Hyparrhenia filipendula (decreaser)*	*Eragrostis curvula (increaser/invasive)*
2	*S. pyramidalis (increaser/invasive)*	*Panicum repens (decreaser/invasive)*	*Heteropogon contortus (increaser)*
3	*Eragrostis curvula (increaser/invasive)*	*S. pyramidalis (increaser/invasive)*	*Setaria sphacelata (decreaser)*
4	*Eragrostis aspera (increaser/invasive)*	*Panicum maximum (decreaser)*	*Melinis repens (increaser/invader)*
5	*Themeda triandra (decreaser)*	*Setaria sphacelata (decreaser)*	
6		*Melinis repens (increaser)*	

3.5 Species biomass:

Generally, species biomass was highest in commercial areas and lowest in communal areas. Table 3 shows summarises findings on species density.

TABLE 3
SPECIES BIOMASS (grammes/m^2)

Parameter	Commercial	Resettlement	Communal
Mean	342	179	85
Maximum	373	195	91
Minimum	231	106	30

3.6 Total species biomass across land use systems:

The commercial livestock land use system had the highest total species biomass (g/m^2), around 340g/m^2 followed by the resettlement land use system (250g/m^2). The communal livestock land use system had the lowest total biomass (g/m^2), having an average of 75g/m^2. Nevertheless, there was a significant difference between the commercial and resettlement livestock land use system in terms of total biomass g/m^2. A significant difference was also found to exist between the commercial and the communal system; however, there was no significant difference in biomass between the resettlement and the communal livestock land use system (Fig 3).

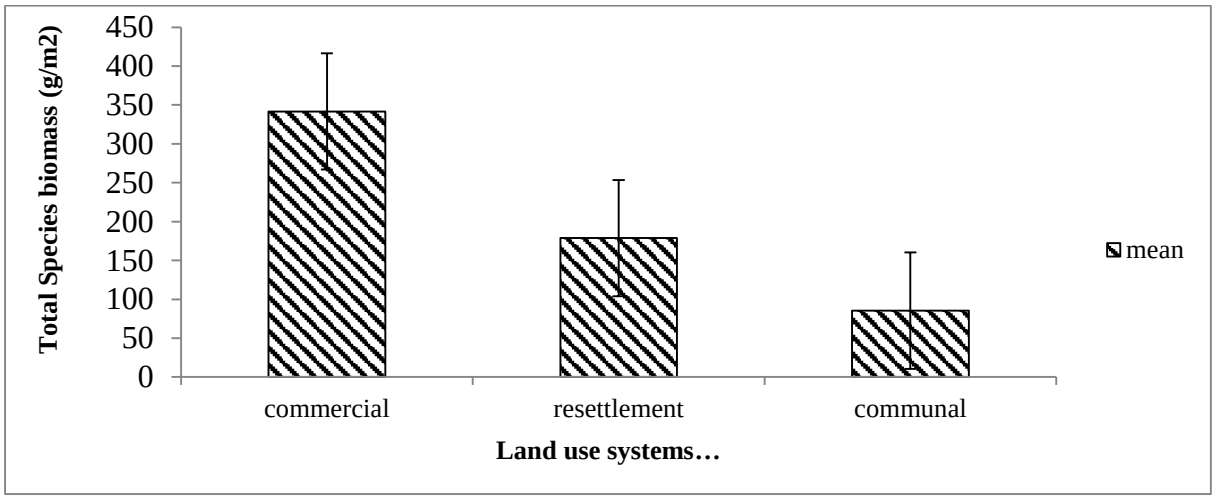

FIGURE 3: Total grass species biomass across land use systems

3.7 Categorised species biomass across land use systems:

The commercial livestock land use system had the decreaser species category having the highest biomass (g/m^2) of an average of 170g/m^2. This was followed by the increaser species having around 110g/m^2 and lastly the invasive species category had the lowest amount of biomass 100g/m^2 (Fig 4). A significant difference existed between the decreaser and the increaser species category as well as with the invasive species. However, there was no significant difference between the increaser and invasive species biomass (g/m^2). For the resettlement livestock land use system, the decreasers had the highest amount of biomass (130g/m^2). This was followed by the increaser species which has a biomass composition of around 100g/m^2. The invasive species category had lowest species biomass composition across all the categories in this system with biomass below 50g/m^2. A significant difference was found between the decreaser and invasive species. However, there was no significant difference between the decreaser and increaser species biomass composition in the resettlement system. A significant difference existed between increaser and invasive species in terms of biomass composition (g/m^2) in the resettlement system. In the communal livestock land use system, the invader species had the highest amount of biomass (Fig 4). The increaser category had the second highest species biomass composition slightly below the amount by the invader species. The lowest biomass composition was found with the decreaser species below 50g/m^2. Conversely there was no significant difference in species biomass composition across all the categories in this system.

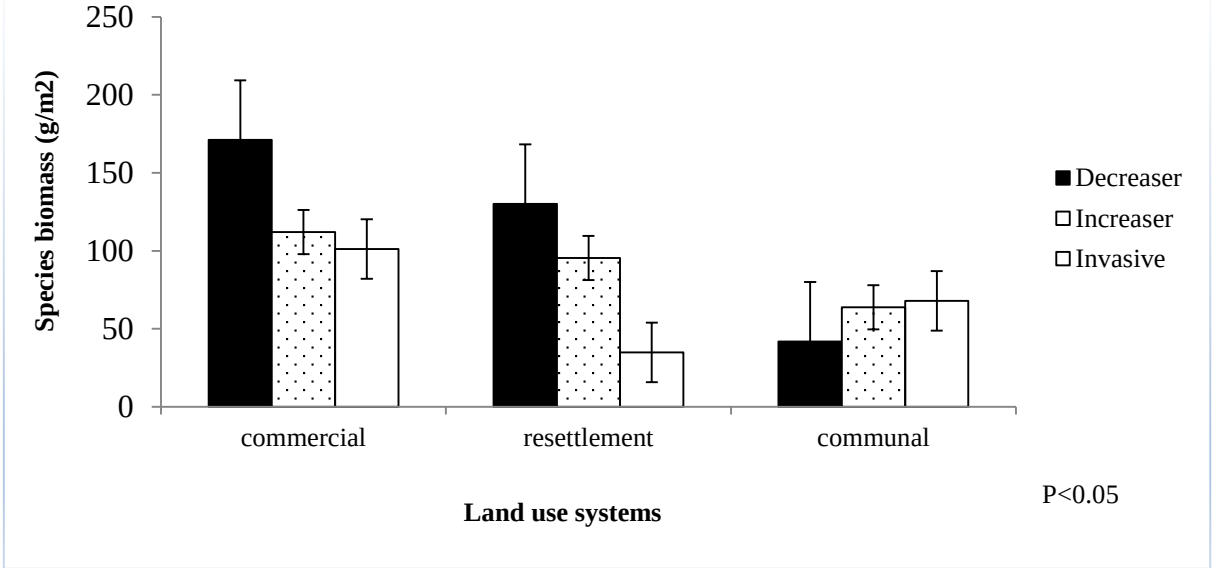

FIGURE 4: Species biomass for the categorised species across land use systems

3.8 Basal cover:

The commercial livestock land use system had the largest basal cover (92, 6%), followed by the resettlement (73%) and lastly the communal (46, 3%) system with the lowest basal cover.

3.8.1 Resettlement grazing land:

The basal cover was normally distributed statistically across the grazing land. The largest portion of the grazing land was 70% covered followed by areas which were 80% covered. It was the smallest proportion which was 60% or 90% and over covered (Fig 5). However, the results reveal that there was no significant difference between different portions of the resettlement grazing land in terms of basal cover.

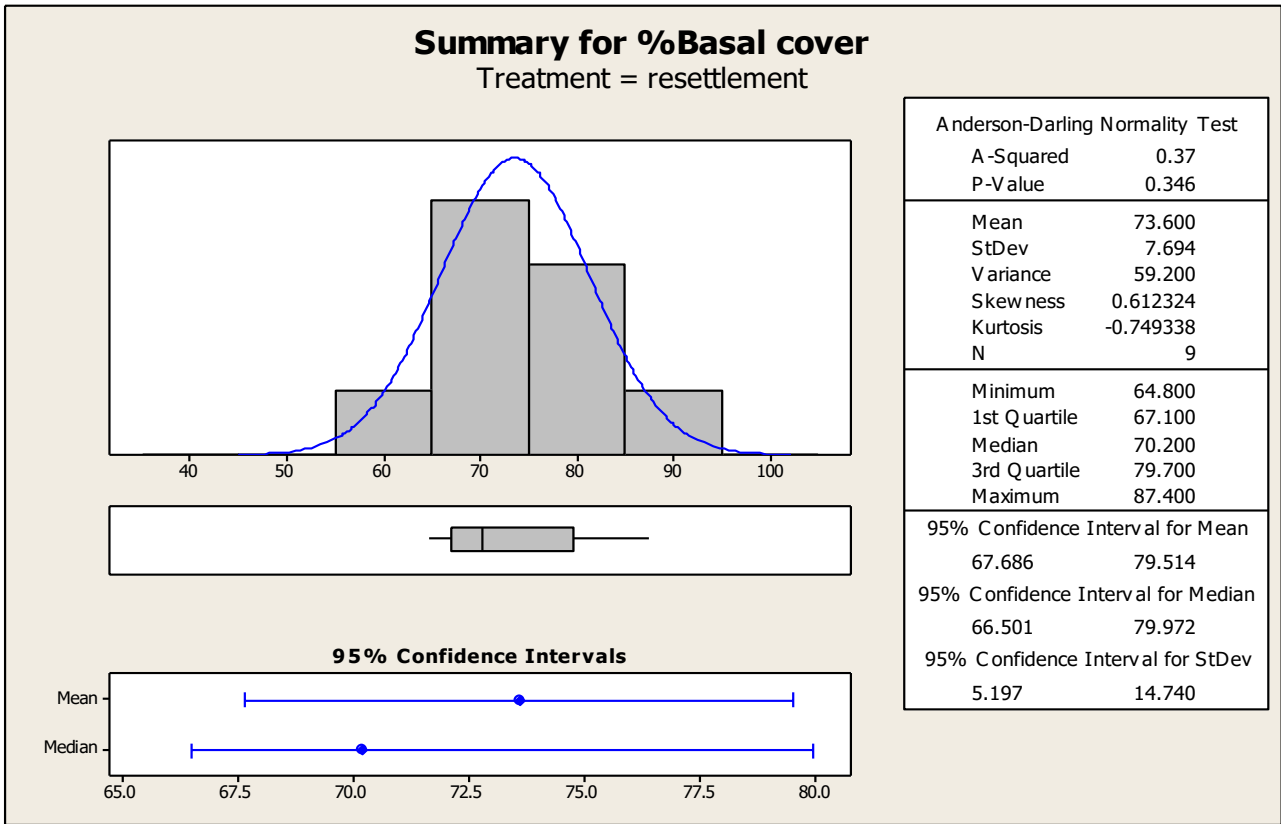

FIGURE 5: Basal cover distribution across the resettlement system grazing land

3.8.2 Commercial grazing land:

For the commercial grazing land, the largest portion of the land was 90% and above with very small portions below 90% cover. A considerable portion of the land even exhibited a cover of 100% (Fig 6). Nevertheless, the results showed no significant difference from this distribution across the commercial grazing land in terms of basal cover.

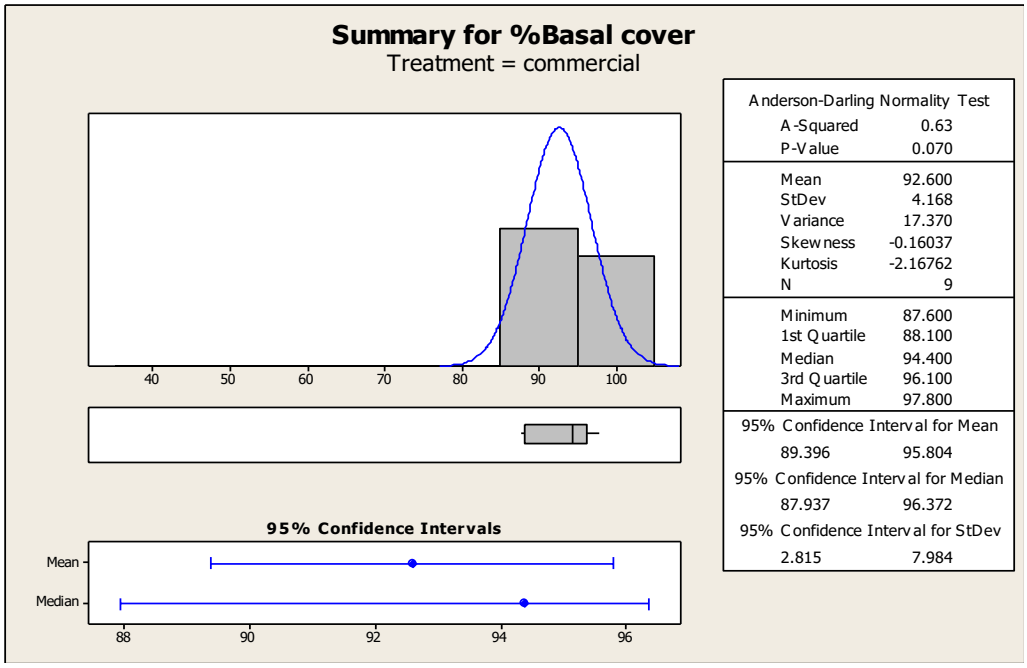

FIGURE 6: Basal cover distribution across the commercial system grazing land

3.8.3 Communal grazing land:

A considerable portion of the communal grazing land sites were below 50% cover averaging 40% followed by other portions of 50% percent cover. These percentage covers equally took up the greater portion of the communal grazing land followed by a relatively smaller portion which occurred with an average of 60% cover (Fig 7). Not even a considerable portion of the land existed with above 70% cover under this system (Fig 7). However, there was no significant difference in the cover distribution across the grazing land.

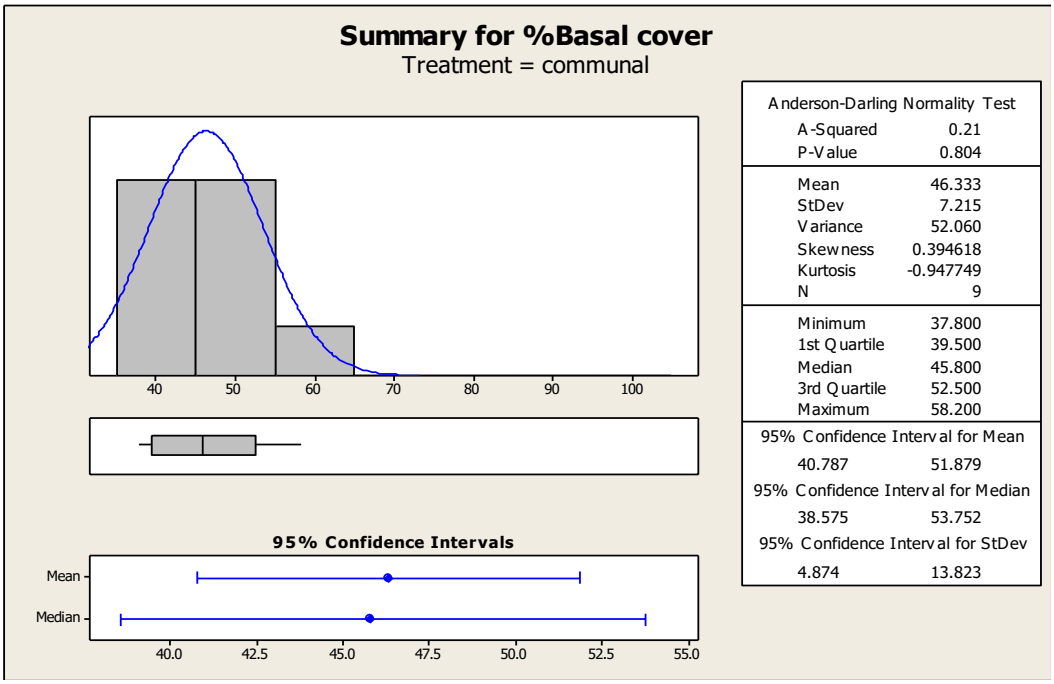

FIGURE 7: Basal cover distribution across the communal grazing lands

IV. DISCUSSION

4.1 Species density and biomass:

The outcomes point out that species density was low in communal than in commercial and resettlement systems in Marondera region 2b. This however might be a consequence of elevated stocking rates (Mavedzenge *et al*., 2005) as well as inappropriate supervision of the veld (Mugabe and Gusha. 2013). The general estimated stocking rate in the communal system was reported to be between 0.5 to 0.7LUs/ha units much higher than the proposed 0.3 to 0.34LUs/ha as reported by (Mavedzenge *et al*., 2005). Elevated stoking rates raise the intensity of grazing along with pressure on various palatable grasses. The transformation brought by this may possibly predict tragedy to communal producers who largely depend on livestock for draught power as well as dung. This is as a result of the declining capability intended for optimal production of herbage. The reduced forage production in communal rangelands has an effect on carrying capacity therefore the productivity per unit area. This as well reduces the amount of forage available to the foraging animals' hence poor livestock production (Mavengedze *et al*., 2005). The fraction of increaser/invasive species such as *Heteropogon contortus*, *Melinis repens* and unpalatable Eragrostis species was higher in the communal livestock land use system compared with other land use systems. This state could have been brought by preferential and selective foraging of more palatable grasses by the grazing livestock (Todd and Hoffman, 1999). These relative findings fell in the same line with the findings of Mugabe and Gusha (2013), Todd and Hoffman, (1999) and El-Keblawy (2003) backing that the grazing stoke reduce more palatable grass species for example decreaser species mostly recognised as perennials.

The increaser/invasive (unpalatable) grass species tend to increase density in relation to the palatable grasses dominating the grazing lands. This increase in less palatable grasses relate to the reduction in nutrient intake by the livestock as the animals are likely to be foraging on nutrients below the demands for maintenance (El-Keblawy ,2003). Therefore, the performance as well as the overall productivity of livestock reared under such rangelands deteriorates. Furthermore, the relative increase in abundance of unpalatable (increaser) grasses goes hand in hand with the weakly interactive model (MacDougall and Turkington, 2005). In the communal system the species dominant were rarely affected by the recruitment barrier together with the environmental stressors that are largely limiting when it comes to other grass species (Mugabe and Gusha, 2013). *Setaria sphacelata* with a good quality forage value was in limited amount and densities in the communal area showing a greater grazing severity. Following an uncontrolled grazing system in the communal livestock land use system where the livestock is left free to move around, decreaser (palatable) grasses are not given ample time to rejuvenate and replenish leading to overgrazing (Mugabe and Gusha,2013) and absolute elimination. Above optimal grazing intensity might shift the vegetation community stability paving way for the establishment of invasive and weed species. This however could be a reason for proportionally high biomass and densities of weedy and invasive grasses in the communal sector. Following the research by Gambiza *et al* (2009) in Zimbabwe wetter areas, there was no common trend viewed in relation to grass species density and biomass. Nevertheless, this was a different case with this study, the communal livestock land use system had the lowest species density and biomass that the resettlement and commercial farming system. The findings revealed a precise change in the dominant grass species adding up to the total biomass across all the livestock land use systems (communal, resettlement, 33 commercial). However, in this research study *Eragrostis curvula* was found occurring in both the commercial and communal livestock land use systems although it was considerably low in communal areas being insignificant to enhance livestock production. *Setaria sphacelata* and *Melenis repens* was also found in both the resettlement and communal systems but with relatively low densities and biomass in the communal areas. For the resettlement and commercial systems, the grasses of higher forage value (decreasers) were more dominant contrary to the situation found in communal areas. The fraction decreaser species were however insignificantly higher in the resettlement farming system than in the commercial farming system. However, this is in terms of grass density as the commercial areas conversely top in terms of biomass production (Mugabe and Gusha, 2013). This however could be more affiliated to the land use history over other factors such as overgrazing and stocking rates. The communal areas are very much associated with high population densities resulting in the overconsumption of the available resources. Higher level of bush infringement was observed in the communal livestock land use system more than in commercial and resettlement systems. This could be attributed to the lowered regularity as well as the fuel consignment of fire in the communal system. These results were therefore in agreement with the former findings by Trollope (1994) and Mugabe and Gusha (2013), stating that low biomass within a grazing land results in increased woody vegetation because of the reduced fuel load which reduces the intensity and frequency of fire. The grass biomass was higher in commercial than in the resettlement area which was also considerably higher than in communal grazing lands. This may be out of the factors such as the grazing pressure and the rate of grazing which was accountably elevated in the communal livestock land use system.

The fraction of decreaser grass species (good forage value grasses) was significantly higher in the resettlement areas in terms of density as well as biomass. This was also exceptionally higher in the commercial areas. These systems however revealed a significant difference in terms of grasses with better forage value in comparison with the communal systems. This could therefore be attributed to the level of management across these systems. Rotational grazing system practiced in the commercial system allows for the decreaser species to recover and re-establish after grazing by reducing the grazing severity, allowing forage to perpetuate with higher densities and biomass (Mugabe and Gusha, 2013). Lower stocking rates, slightly lower than the recommended carrying capacities in the resettlement grazing lands, by default, allow for maintenance of decreaser species vigour through reduced grazing severity (Todd and Hoffman, 1999). This however results in accumulation of the moribund stuff (top hamper) which is on the contrary regularly controlled by occasional/seasonal fires. The results showed the commercial system had the highest range distribution (difference between maximum and minimum) in terms of grass density and biomass across the grazing land as compared to all other farming systems. This however shows the high degree of heterogeneity in grass composition across the landscape. This could be because of increased selective and preferential grazing, where animals continuously graze particularly on their preferred sites and species neglecting some areas

4.2 Basal cover:

The findings of this study show that the communal areas had significantly lower basal cover (46, 3%) than all other systems. This could be attributed to higher stocking densities, exceeding carrying capacities leading to overgrazing in the communal areas. The grazing intensity and frequency was too high in the communal system, giving less time for the grasses to grow and cover the land. Higher population densities also increase compactions destroying 35 some grass species, leaving the soil prone to all the agents of erosion reducing the chances by some species to germinate and re-establish hence productivity is lowered in the process. Low levels of biomass in the communal areas mean low organic matter as well as decomposed organic matter (humus) rendering the soil infertile to support much vegetation to cover the grazing land. The basal cover below 50% is categorised poor (Hungwe, 2014) as this acts as an indicator of the potential productivity by the rangeland as well as its susceptibility to erosion and level of degradation. The basal cover is positively correlated to the grass species composition in terms of biomass and density (Hungwe, 2014).

V. CONCLUSION

There was a significant difference in species composition (density and biomass) and cover across all livestock land use systems. Grasses with good forage value (decreasers) were observed to be highly concentrated in the commercial system followed by resettlement and lastly the communal system. The increaser/invasive species were significantly more in the communal set up than in all other systems. In addition, the commercial system had the highest basal cover followed resettlement with the lowest basal cover in communal systems.

VI. RECOMMENDATIONS

Rangeland rehabilitation and maintenance takes a long and patient process, where in the mix are annual rainfall and dry spell uncertainties. However, in the face of a degraded rangeland it is important to initially restore the soil fertility. To bare soils with little cover rangeland thatch packing practices can be implemented to aid in water penetration reduce surface runoff; provide shading and aid to detritus build up. This remedial practice must therefore be practiced for several seasons necessary. As a soil remedial practice, it is also important to shape contours channelling water and prevent lateral erosion as well as tilling for aeration and seeding. Bush packing can also be done following the observation of new growth to avoid overutilization of such grasses during their early or establishing stages. To increase grass biomass as well as density, selective bush thinning can be useful as this will give support to grass competition. Decreaser (palatable) grass species losses could be solved by reinforcing the grazing land by planting relatively palatable grasses with some grazing resistance and quick establishment characteristics. Amongst these are *Panicum repens* and *Digitaria diagonalis* which under optimum conditions have high prolific rates, density, and biomass and are tolerant to grazing. This will in turn increase the carrying capacities of communal grazing lands. However, the major problem leading to low production potential and level by the communal grazing lands is management related. This is mainly due to lack of knowledge. Therefore, an increase in government extension services and educational campaign enriching people with communal grazing management knowledge can be a long-lasting solution. Government legislation and policies in control and monitoring of rangelands also need to be enforced with increased patrols and assessment. This encompasses the judicious burning legislations, where uncontrolled fires may lead to an accelerated species loss (decrease in biomass and density) as well as basal cover. Indicators and continuous monitoring should be set in place to scrutinize alterations much earlier. To minimize species loss, increasing grass biomass and density, holistic management practices ought to be promoted in the communal livestock land use system. The evaluation of species composition under this study was done over a

short period of time. A similar research over an extended period of a season or year might be more relevant in assessing seasonal species composition change.

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Effects of Agrarian Policies on Access to Agricultural Finance in Zimbabwe

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Abstract—

Introduction: *In Zimbabwe there is an agricultural finance gap for smallholder farmers. Formal financial institutions face policy barriers to fully participate in rural financial markets. The study is an analysis policy with a view to recommend measures to improve access to agricultural finance markets in Zimbabwe*.

Problem Statement: *Inappropriate policies and policy failures exacerbate poor access to finance by smallholder farmers in Zimbabwe. Poor access to finance results in low agricultural production and productivity, which in turn leads to perpetuation of poverty amongst smallholder farmers.*

Methodology: *The study is an evidence-based policy analysis. Qualitative data was collected from fifteen key Informant interviews. In addition, secondary data was collected from literature. Seventy-five (75) reference materials were utilised from Google Scholar and Scopus databases. The data was analysed using the framework for policy analysis.*

Results: *From the literature review, there has not been any independent policy analysis focusing on the negative impact of government agrarian policies on access to finance. Government agricultural support programs crowd out financial service providers, thereby reducing access to credit.*

Conclusion: *Government policies should be designed to incentivise private sector financing for agriculture*.

Keywords— Policy analysis, financial inclusion, collateral security, Land reform, Micro-finance.

I. INTRODUCTION

Zimbabwe is an agro-economy with agriculture contributing about 12% of the country's GDP in 2023 and more than 60% of inputs to the manufacturing sector [1]. In the premises, food security, employment creation and poverty alleviation are closely related with the development of agriculture [1]. Access to financial services particularly by smallholder farmers, however, remains a major bottleneck to agricultural performance in Zimbabwe [1].

According to the 2022 Finscope consumer survey [2] only 4% of farmers access credit from formal finance institutions, 53% do not borrow at all, 25% access credit from family and friends and the remaining 18% access credit through informal sources like savings and credit clubs and other formal non-bank sources like mobile money and micro finance institutions (see figure 3).

The demand for financial services critically depends on the provision of some of the most basic public goods and physical infrastructure: including roads, telephones, mail services, literacy and electricity [3]. On the clients' end, the most practical problem is the very low absorptive capacity of the majority poor in rural areas, greatly constraining the potential positive impacts of access to finance programmes [4]. The other barriers to accessing finance include fear of debts (58%), worry about ability to pay (32%). These barriers result from past experiences and unfavourable credit terms, including high interest rates [2].

Literature reveals that approaches to agricultural financing for poor smallholder farmers has evolved over time as a result of

the improved understanding of the underlying challenges. Beginning in the 1960s, subsidized agricultural credit programs were popularized as a way to correct the market failures thought to be the cause for the small amount of credit allocated to agriculture [4,5,6]. These programs usually imposed a rather naïve supply-leading approach of interest rate ceilings that undermined the health of the mostly government financial institutions delivering credit [7]. In most African countries it has been documented that governments, in the quest to address poverty and food insecurity as top priorities, have always intervened in agricultural markets, including in finance [8,9,10]. For the same purpose international development partners, such as the World Bank (WB), African Development Bank (AfDB), and International Fund for Agricultural Development (IFAD), provided credit lines to national central banks or ministries of finance, who in turn refinanced local banks at concessionary interest rates [10]. This approach was largely declared a failure, including by [11], in their work 'Undermining Rural Development with Cheap Credit', which is a widely cited critique of this credit led approach.

Governments, as policy makers, provide frameworks for processes that lead to the promotion of financial inclusion and these policy frameworks also articulate clear operational modalities to achieve national financial inclusion objectives [12]. The Reserve Bank of Zimbabwe (RBZ) is pushing for financial inclusion through National Inclusion Strategies I (2016-2020) and II (2022-2026). In addition to putting in place consumer protection regulations, governments can facilitate innovative models for financial inclusion, including promoting ease of entry of new entrepreneurs into the financial sector [13]. Instead of providing financial services directly, the role of government is to maintain macroeconomic stability and provide appropriate regulatory and supervisory frameworks [14].

II. PROBLEM ANALYSIS

2.1 What is the problem?

According to [15] 58% of Zimbabwean households are involved in farming of which 33% rely solely on agriculture for their livelihoods. Although [15] reported that 45% of farmers are banked and 31% use mobile money products bank and mobile money credit facilities have low uptake. In the agricultural sector 53% of farmers do not borrow at all, 25% access credit from friends and family and 18% from the informal sector. From these statistics, we conclude that access to credit by farmers is still very low. The constrained access has been confirmed by several studies of Zimbabwe's smallholder farmers. The studies found out that most smallholder farmers used owners' savings as the primary source of agricultural finance [16,17,18,19]. Own resources are however seldom enough to cover seasonal cash flows.

Commercial banks prefer to provide loans to established large businesses rather than small loans to numerous micro-entrepreneurs [20]. As a result, there is a yawning smallholder farmer financing gap that has kept Zimbabwe's economic potential untapped. This gap needs solutions and offer opportunity for transforming smallholder farming from subsistence to commercial. Micro finance institutions (MFI) have attempted to fill this gap. It is acknowledged by [21] that the financial needs of small agribusiness remain underserved. As observed by [20] their financial needs are too large for microfinance and too small for commercial banks.

2.2 Analysis of the problem context:

Zimbabwe has instituted agricultural policies during different phases of its Agricultural revolution, which can be divided into pre-colonial, post-independence and the multicurrency era. Despite these macro level interventions smallholder farmers still face constraints to access agricultural finance.

Barriers and constraints to financial inclusion in Zimbabwe can be classified as demand side, supply side and regulatory [22]. They [22] further elaborated that the constraints include: under demand side, low-income levels, failure to meet minimum account opening requirements, inadequate information on financial services and products, lack of confidence in the financial system and financial illiteracy. Under the supply side the barriers include absence of a robust credit information system, poor infrastructure in rural areas leading to financial institutions reluctance to establish branches and lack of skills to understand the dynamics of the projects of those at the bottom of the pyramid; regulatory constraints include absence of coordinated national policy and strategy on financial inclusion, weak consumer protection regulatory framework, weak institutional capacity and resource constraints.

Risks in agriculture are high (policy, market, production and environmental risks). Farmers lack formally recognised collateral, there are high costs in lending to smallholder farmers, MFIs lack sufficient funds for lending and repayment structures may not suit agriculture [23].

There was need to rope in the rural communities for inclusion into the formal financial system [24]. According to [24], the per

capita banking facility ratios in rural areas indicate unacceptable levels of financial exclusion of the rural populace. The situation on the ground however suggests that the demand for microfinance resources is very high [25].

In a historical overview of the Microfinance sector in Zimbabwe, [25] noted that microfinance resources are on demand because of their ability to meet the capital needs of the poor who are considered 'unbankable' by the formal finance sector. It is further pointed out by [25] that traditional banks are not willing to take the risk because they rate the sector 'credit unworthy' thereby creating a huge gap that gets filled by private moneylenders who usually charge usurious rates of interest, hence exploiting the vulnerable poor people. It is noted by [25] that traditional banks argue that it is problematic to provide financial services to the rural areas because of their remoteness, which brings very high transaction costs hence raising sustainability questions. Other challenges noted for Zimbabwe include adverse selection and information asymmetry leading to moral hazard.

III. LITERATURE REVIEW

3.1 1890- 1980: Political and Legal Constraints:

During this era the political and legal constraints from the colonial state constrained efforts by Africans to organise savings and credit institutions. Colonial legislation including the Land Apportionment Act (1930), the Native Urban Areas Registration and Accommodation Act (1946) restricted Africans owning and utilising land in rural and urban areas [26]. This constrained Africans to provide collateral for credit from the financial service providers.

The development of means of saving amongst the poor in Zimbabwe started with the concept of burial societies during the early years after colonial occupation in 1890 [27]. Members of a burial society paid a joining fee and monthly subscriptions. When an immediate family member died, the member of the burial society was paid a lump-sum payment [28].

African professionals established Friendly Societies to provide loans to finance household needs and bigger financial projects. The friendly societies included the Central African Mutual Association, the Bantu Trading Cooperative Society (1938), the First African Friendly Society (1960) and the United Consumer Cooperative Society (1964), all of which were short lived [27].

On 11 November 1965 the colonial Rhodesian government declared the Unilateral Declaration of Independence (UDI) from the British empire [28]. As a result of the UDI the country was put under international mandatory sanctions because of widespread human rights violation of the indigenous black population [29]. To burst sanctions, the Rhodesian government instituted economic controls. As a result, the economy was one of the most controlled economies in Sub Saharan Africa [30]. Rhodesia's economy was dichotomous, comprising a poor and colonially marginalised black majority and an economically empowered and dominant white sector [31]. Blacks earned about one tenth as much as whites [32].

Brother Francis Waddilove, a Catholic missionary established the first savings club in 1963 in Southern Rhodesia [27]. The objective of the savings club was that the members could accumulate enough money to purchase agricultural inputs in preparation for the rainy summer season. This model was scaled-up by the Catholic Mission at Silveira House in 1968. Members of the savings club were to contribute savings for a period of two years after which they would qualify to receive loans equivalent to not more than 10% of their accumulated savings for productive purposes. The number of clubs reached a high of 3000 in 1975, with 60 000 members [27]. Activities were however severely hampered by the war of liberation between 1976-80, [32].

3.2 Post Independence (1980):

At Independence in 1980, Government through statutory instruments directed Agricultural Finance Corporation (AFC) to extend loans to all farming sectors including communal farmers [33]. In the early 1980's the (AFC) played a central role in extending loans to small scale farmers. The World Bank, European Commission (EC), Danish International Development Agency (DANIDA), and the Japanese government among others, supported this policy. Credit by the AFC to both small farmers in the resettlement areas and mainly white commercial farmers, increased from US$10 million in 1983/84 to US$22 million in 1984/85 [34,26]. Smallholder indebtedness and levels of debt defaulting increased as a result [34]. Attempts to 'throw money at the problem' failed to deal with fundamental constraints such as unsustainable interest rates, and the inefficiencies of the controlled marketing system. In the 1990's the process of commercialising the AFC under a new bank, AGRIBANK, resulted in further limitations for the poor communal area farmers.

The Commercialisation of other Government institutions under the Economic Structural Adjustment Program (ESAP) such as the Small Enterprises Development Corporation (SEDCO) and the Zimbabwe Development Bank (ZDB) led to a greater emphasis on collateral-based lending [35]. In addition, many difficulties arose over the complex procedures for accessing credit.

Prior to 2009, agricultural finance was provided by the state through Agribank, the Reserve Bank of Zimbabwe (RBZ), Commercial Banks, Microfinance Institutions (MFIs), Commodity Brokers, Farmer Contracting Agencies and NGOs. The Ministry of Agriculture provided agricultural credit in the form of direct input support to farmers, under the administration of its parastatals and departments. In this regard, the Grain Marketing Board (GMB) administered a scheme that distributed seasonal inputs; the Livestock Development Trust (LDT) focused on Heifer Support; the District Development Fund (DDF) administered tillage support; Agriculture and Rural Development Authority (ARDA) administered the Irrigation Rehabilitation Support Facilities and the Ministry of Agriculture with the support of the Army, administered the *Maguta* (*Food Security*) and Champion Farmer Input Support Scheme Facilities. The Reserve Bank of Zimbabwe (RBZ) administered the Agricultural Sector Productivity Enhancement Facility (ASPEF) and the Farm Equipment and Mechanisation Support Programme. All these loans were provided at below market interest rates thus crowding out private banks' own lending capital/capacity [36].

Zimbabwe has, in the past, instituted several policy initiatives to broaden access to financial services. Notwithstanding the strides made in the pursuit of an inclusive financial sector, gaps still exist in the level of access to, usage and quality of financial products and services, as well as the impact on the lives of those consuming the products and services. The gaps are particularly pronounced among special groups such as Micro, Small and Medium Enterprises (MSMEs), women, youth, rural population and the small-scale agricultural sector [1].

In Zimbabwe, land is owned by the state and the current land tenure system for current holders or users does not permit transfer of ownership. It then becomes difficult for banks to extend credit securitised by land given the complexities in both ownership and transferability [37,38].

IV. METHODOLOGY

4.1 Conceptual Framework:

Policy is a process with distinctive (differentiated) stages, each with an activity that enables the next stage, the results of which feed back into the process [39]. These stages aim to address an issue (programme, problem) in a systematic way by defining it, developing solutions, implementing the solutions and evaluating the results [40,41,42]. Policy analysis is the process of systematic investigation of the implementation and impact of existing policy (ex-post analysis), and of options for new policy (ex-ante analysis) [43,44,45]. The purpose of policy analysis is to facilitate the choice of sound policy with a view to improvement [46].

4.2 Data Sources:

Qualitative methods were used to collect data. Data was collected from fifteen Key Informants including from the Ministry of Lands, Agriculture, Water and Rural resettlement, Department of Agricultural Technical Extension Services, Department of Mechanisation, Veterinary Services, Dairy Services, Economics, Farmers Organisations, Banks, MFIs, Ministry of Finance and Economic Development, and the Reserve Bank of Zimbabwe (RBZ). An extensive literature review provided the additional evidence that was used for the analysis. Only reliable sources of data sources were used to ascertain the data's validity. This necessitated the use of government and academic reports, policy documents and data from other sources.

V. RESULTS

5.1 Evidence of the agricultural finance gap in Zimbabwe:

Evidence can be presented in the form of descriptive information, such as case studies, observations, reports, or protocols from literature[47]. It is further explained by [48] that direct evidence is directly related to the issues under investigation and offers a direct answer to the specific questions of the analysis. This as opposed to indirect evidence that does not directly relate to the questions but to some aspect that is related to the questions. In this study both direct and indirect evidence were gathered, described and analysed under this section.

5.1.1 Agricultural Sector borrowing and Loan Performance:

Figure 1 shows that, in 2024 78.45% of formal banking loans went to the productive sector. Of the productive sector loans, 22.94% went to Agriculture. Most of the loans to agriculture are under the government guaranteed National Enhanced Agricultural Productivity Scheme. This scheme only gives loans to farmers who are putting above 30ha into maize and wheat production. This leaves most farmers out. That is why figure 2 is showing that in the same year 2022, 53% of farmers did not borrow from any source including from formal, mobile money, and informal financial services.

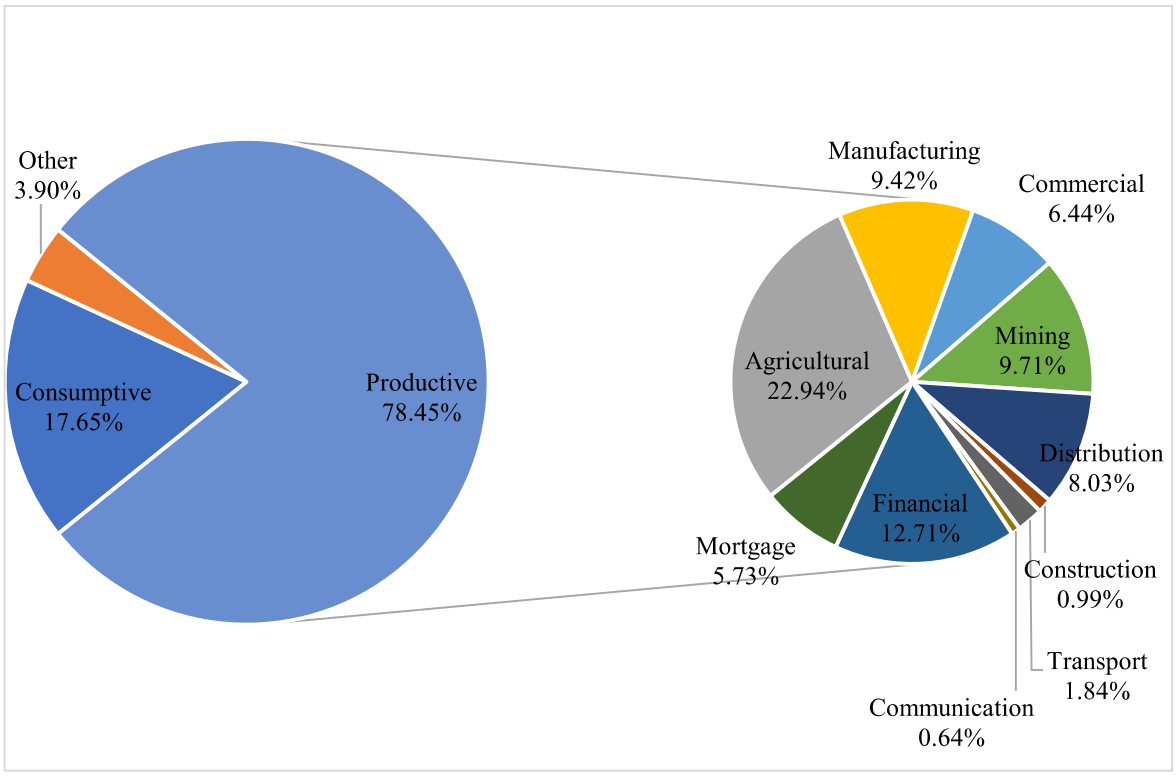

FIGURE 1: Sectoral Distribution of Loans as at 31 December 2022

Source: [49]

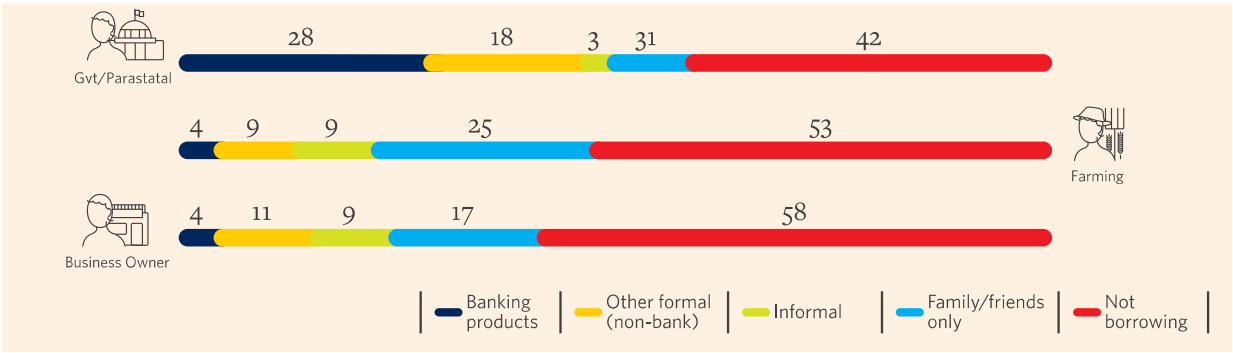

FIGURE 2: Comparing credit uptake among key livelihoods

Source: [2]

5.1.2 Non-Performing Loans:

When Zimbabwe dollarized in 2009, bank deposits and lending rapidly increased, and net credit to the economy rose to over 10% of GDP during 2011-14. Significant confidence appears to have softened due diligence standards when assessing borrower risk. This resulted in the share of Non-Performing Loans (NPLs) steadily increasing, reaching over 20% of the loan portfolio in September 2014 [36]. Most bank loans were not contingent on any collateral, hence the risk of default was very high. By 2014 the capital-to-asset ratio dipped below the 10% benchmark. To solve this challenge the government had to do something to capitalize the banks. The Zimbabwe Asset Management Corporation (ZAMCO) was created to address this challenge. In July 2014 banks were bailed out by ZAMCO which bought the NPLs using financial resources generated through the issuance of Treasury Bills (TBs) [36]. The bailout increased the capital adequacy ratio back to healthy levels.

The NPL experience resulted in commercial banks reducing lending generally but particularly to the agriculture sector. By 2018 lending to the agricultural sector had declined by 18%. Loan application rejections by banks included lack of collateral security. Lack of collateral security alone accounted for at least 60% of loan application rejections. Farmers with a poor credit history accounted for 20% of the rejections [36]. For quasi agriculture institutions like AGRIBANK, collateral security featured less as a means of screening farmers for agricultural credit.

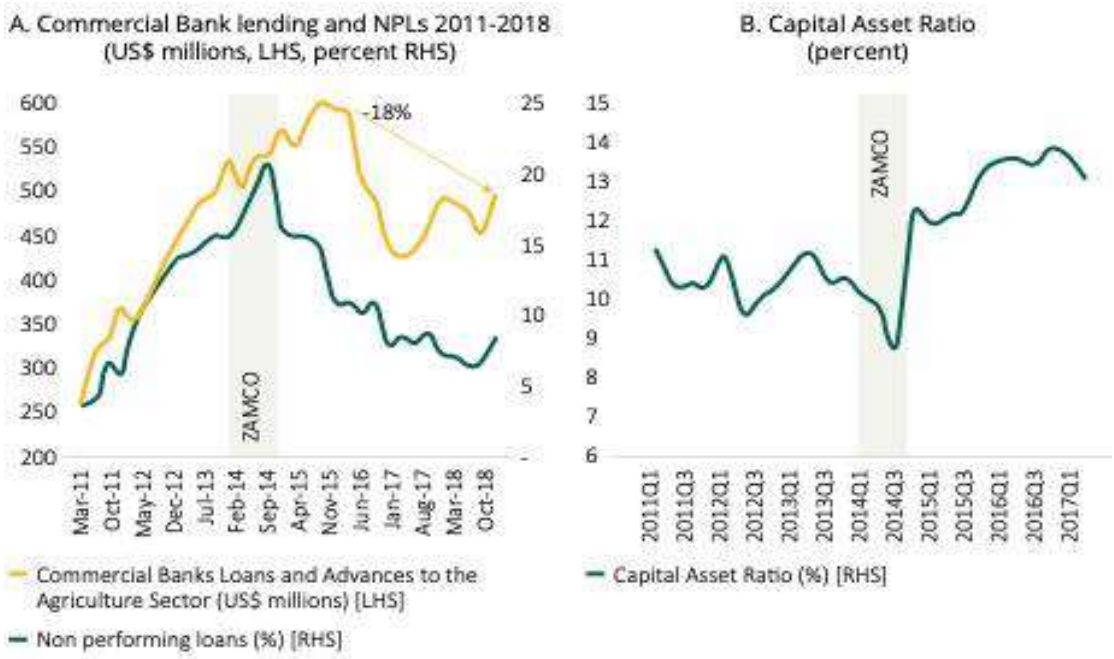

FIGURE 3: Commercial Bank lending and NPLs 2011-2018 (US$ millions, LHS, percent RHS)

Source: [50]

5.1.3 Reasons for Bank Loan Application Rejections:

A survey by [36] shows that among the reasons for bank loan rejection by farmers, were lack of collateral security accounting for at least 60% of the rejected loan applications followed by poor past farmer production performance, which accounted for 20% of the rejections, poor past loan performance, accounts for at least 37% of loan rejection, while lack of collateral accounts for 30% by the institutions. These reasons are shown graphically in figure 4.

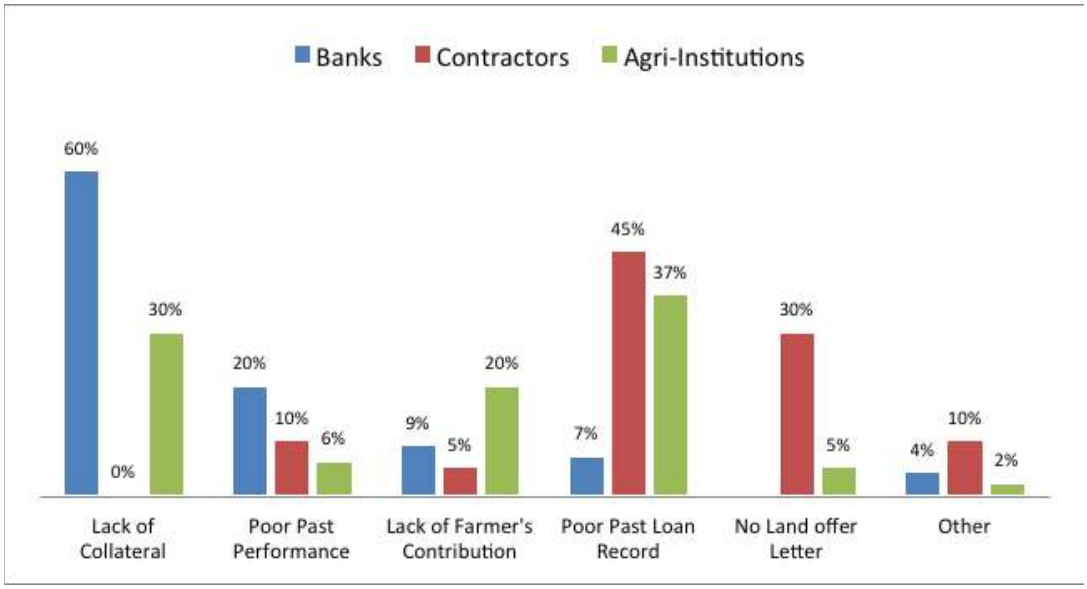

FIGURE 4: Factors Leading to Agricultural Loan Rejection

Source: [35]

5.1.4 Financial Inclusion Status:

The Reserve Bank of Zimbabwe (RBZ) has been implementing a financial Inclusion Strategy since 2016, the National Financial Inclusion I , NFIS I (2016-2020) and the NFIS II (2022-2026). NFIS I registered significant inroads in narrowing the financial inclusion. NFIS I registered significant progress on the access strand, with 83% of adults now formally served, up from 69% in 2014, and 95% of MSMEs formally served, up from 18% in 2012, despite the disruptive effects of the Covid-19 pandemic [37]. Women's financial inclusion increased from 68% in 2014 to 83% in 2022, while men that are formally served increased

from 70% to 85% on the back of increased access to banking products. The financial exclusion gap narrowed from 23% in 2014 to 12% in 2022 [37]

Despite these financial inclusion inroads in NFISI, NFIS II seeks to address various challenges including, lack of acceptable collateral by the majority of low-income groups hampered access to affordable funding, Low level of financial literacy among the targets segments; Lack of business skills which militate against effective utilisation of funding; Lack of historical credit data on some low income borrowing segments; High level of informality in the MSME sector; Weak infrastructure including poor connectivity, inconsistent power and water supplies, and poor road & communication infrastructure, adversely impacted on outreach; The centralisation of the financial inclusion activities in major urban areas, High cost of delivering financial services; Inadequate financial resources to implement planned initiatives; and Weak legal framework to support some innovations e.g. value chain financing

5.1.5 Agricultural Financial Access in the Multicurrency Era:

Zimbabwe experienced a decade of recession up to 2009 where the Zimbabwean Dollar lost value against major currencies. The United Nations Operational Rate of Exchange which was at Z$117:1US$ in May 2006 dropped to Z$35 X 10^{15}: 1USD in November 2008 [19]. This eventually led to dollarization informally during the last half of 2008 and eventually the Zimbabwean dollar was abandoned for a multicurrency monetary policy in January 2009. This ushered a new economic dispensation of relative price stability, improved business confidence and increased capacity utilisation (from 10% to around 40% by end of 2009) positive economic growth (5.7 per cent in 2009) [51,52].

Since the introduction of the multi-currency monetary policy in 2009, banks in Zimbabwe maintained between 10% and 25% of their loan portfolio in agriculture [35]. With total financial sector deposits of approximately US$2.5 billion in 2010, for example, this translates to more than US$250 million being outstanding bank loans to farmers. They also note that factors that are considered by banks in appraising farmers' loan applications include availability of collateral security, past farmer production performance, farmer's own financial contribution and past loan performance.

5.1.6 Land reform:

Lack of title deeds has been identified as contributing to poor access to finance because farmers cannot use the land as collateral security to apply for agricultural credit. The government of Zimbabwe is issuing 99 year leases to newly resettled A2 farmers and most of these farmers are ignorant of the various policy provisions, conditions and entitlement associated with these leases [53]. The estimated issuance rate is 1000 per year. This is a very low rate considering that there is a total of over 16000 resettled A2 farmers [54].

The current legal framework forbids the buying and selling of the 99 year lease. The leases are not transferable, registrable and executable. As a result commercial banks, micro finance institutions and private creditors are all reluctant to lend to the farmers as a result of lack of security.

5.1.7 Agricultural Support Programmes:

The Presidential Input Program (PIP) was designed to benefit vulnerable farming households [55,56]. In 2017, 1.4 million small-scale rural farms received free inputs for grain and soya bean production under this scheme. Grain production inputs accounted for about US$53 million of costs with US$38 million going to oilseed crops (mainly soya) input costs. For cotton, each farmer receives free fertilizers, seed and chemicals for a hectare. The Cotton Company (Cottco) is responsible for administering the scheme, which benefited 385,000 farmers in 2017/2018. In 2016/17 and 2017/18, US$125 million and US$263 million was spent respectively [57]. A2, Small Scale Commercial and Large Scale Commercial Farmers, are supported through the Command Agriculture Scheme [58,59,60,61].

In the Command Agriculture Scheme, farmers are financed through a state-led contract farming model to grow prescribed crops. Over the years of its implementation most farmers failed to pay back for the support received – which was the same case under previous input support facilities in 2004-2007 and 2009-2014 [57]. In 2018 Government availed financing to the tune of US$105 million in 2016, US$439 million in 2017, and US$238.3 million in 2018. Yet recovery in 2017 was only US$47 million, while US$81.3 million was recovered in 2018. This implies very high and increasing non-payment rates from 54% in 2017 to 81% in 2018 [62].

A Key informant gave the reasons for poor loan performance as follows:

The contract requires farmers to pay back the loan in kind or the money equivalent of 5 tonnes per hectare. However, productivity is very low due to other factors besides adequacy of inputs from the contract. Productivity is also affected by, inter alia, quality of season, agro-ecological region, farmers' expertise, level of mechanisation and timeliness of receiving inputs. As a result most farmers are not able to meet their contractual obligation.

This observation was a common immerging theme with 90% of the respondents.

5.2 Findings from the available evidence:

5.2.1 Land tenure:

It was noted by [38] that most farmers in Zimbabwe do not have title to their land, particularly in Communal, Old Resettlement, A1 and A2 Fast Track Land Reform Programme (FTLRP) settlement schemes. In [63], 18 percent of the beneficiaries cite their lack of title and fear of eviction as factors limiting their farm investments. A proportion of resettled farmers believe that freehold land tenure (title deeds) will secure their land rights and unlock the value in land. [64] estimated the proportion of such land beneficiaries at 5%, [65] at 20%, [66] at 40%, and [67] at 20%. The [68] Land Tenure Commission also recommended formalisation of resettlement tenure for farmers to use land as collateral.

Some commercial banks are reluctant to extend loans to farmers because they lack adequate and acceptable forms of collateral. Those banks that have advanced limited loans to the A2 Model resettlement beneficiaries have instead preferred urban properties and movables for collateral. Other banks prefer to lend to contractors, e.g. in cotton, tobacco and horticulture who in turn finance farmers through contract farming arrangements.

The communal tenure system gives an individual a secure and normally inheritable right to property, the land however belongs to the state, which may reduce investment incentives. Due to perceived and severe moral hazard problems, private sector institutions have been reluctant to service rural financial markets in the absence of acceptable collateral and a legal and regulatory framework [39].

In 2024 the Government of Zimbabwe issued a policy statement that Agricultural land held by farmers under 99-year leases, offer letters and permits will be held under bankable, registrable and transferable documents of tenure. These title deeds were launched by the President in the same year. This policy shift was cited as addressing challenges faced by farmers under the current land tenure system. The challenges included face difficulties faced by resettled farmers in accessing finance for their farming activities, lack of security of tenure resulting in farmers not fully developing their land holdings, problems related to succession and inheritance and failure to repay loans given or guaranteed by the Government. For a farmer to get the title deeds , they are required to buy the land from government either through cash payments or mortgage with selected banks. Most farmers are still warming up to this requirement since poor access to agricultural financing will not guarantee productivity and enough returns to service the mortgages.

5.2.2 Agricultural Support Programmes:

Over the years the Government of Zimbabwe has implemented agricultural support programs including the 2000 Government Input Scheme, the 2004 Productive Sector Facility introduced through the RBZ, and the Agricultural Sector Productivity Enhancement Facility (introduced in 2005 through the RBZ).

Since January 2009, the Ministry of Finance directed the Reserve Bank to stop operating its quasi-fiscal activities in providing financial support to the agriculture sector. The Reserve Bank was tasked to put in place measures to restore and enhance the level of participation by commercial banks and other financial institutions in lending to farmers [69]. The intention was to see commercial banks and MFIs become the main source of agricultural finance, drawing from the deposits by the general public. The Government would still fund schemes targeting input support to smallholder farmers in communal and resettlement areas. These current schemes under this arrangement are the Command Agriculture targeting medium to large-scale resettlement farmers and the Presidential Input Scheme targeting 1.6 million communal smallholder vulnerable farmers [70]. However, a history of low rates of farmer repayment and the perceived high risk of lending to the agricultural sector, have limited the involvement of commercial banks and MFIs in agricultural financing [50]. Government support programs that are ill targeted and operationally leave out key financial institutions crowds out the private sector including supply chain actors like agro dealers [71].

5.3 Discussion and Policy Recommendations:

5.3.1 Security of land tenure:

Probable solutions to the lack of security of tenure for resettled farmers include titling and registering land; reforming the law of secured transactions, such as legally acceptable forms of collateral; establishing legal registries and expanding the scope for private operation; lowering the cost of registration and foreclosure; drafting specific, clear and limiting homestead provisions; and removing interest rate ceilings [72]. Promoting secure forms of land tenure can be beneficial to stimulate productive farm-level investment and to allow producers to pledge land as collateral for obtaining finance. In the absence of long-term land-use rights, farmers lack incentives to invest in the land, Farmers are not motivated to engage in productivity enhancements as well as sustainable and environmentally friendly land use.

5.3.2 Government Support programmes:

Perhaps the biggest failure of the present rural financial system was its founding assumption that poor people were too poor to save and required free inputs [73]. This assumption seriously undermined the ownership and sustainability of the institutions serving the rural community. The reliance on public funding not only exposed such institutions to political manipulation but also subjects them to severe budgetary constraints in the event of macro-economic decline as Zimbabwe has experienced in the post land reform period [73].

The government's involvement should be to create a supportive legal environment. Massive government participation in input distribution programmes is not sustainable due to limited government budgets, the disruption of the growth of the private sector as well as inherent inefficiencies that lead to input distribution delays, limited choice of inputs, lack of quality assurance and the misallocation of scarce resources due to poor targeting and leakages. Heavy government subsidies that are not properly targeted crowd out the private sector actors from the rural financial markets and create dependency amongst the target groups.

Government support should be directed towards public goods and investments in financial and physical infrastructure with industry-wide, systemic benefits. Utilization of "smart" subsidies that minimize market distortions and elimination of regressive measures help encourage private sector investment, leading to sustainable agricultural development and finance.

Policymakers should avoid historically ineffective and sometimes damaging measures such as interest rate caps, debt forgiveness, and directed or mandatory lending targets, which impede the functioning of financial markets. Governments can actively support growth of agricultural insurance through investments in weather stations and data collection, such as weather and area yield data, necessary for commercial products to be developed, which may also require suitably designed insurance premium support.

VI. CONCLUSION

There have been documented policy failures in attempts to address rural poverty through subsidised credit. Poor land tenure security has emerged to be a challenge dating back from the colonial era and has remained so to this date. Government support programmes and the distribution of free inputs should be designed to crowd in the private sector as opposed to crowding them out. Government policies should be consultative, and evidence based to build ownership by stakeholders. In this way policy failures will be minimised. With sound policies the rural finance gap will be narrowed.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was conducted in accordance with ethical research standards. Since the research involved policy analysis and key informant interviews, ethical approval was not required from a formal institutional review board. However, informed consent was obtained verbally from all participants prior to interviews, and confidentiality of responses was strictly maintained.

HUMAN AND ANIMAL RIGHTS

No human clinical trials or animal experiments were conducted in this study. The research was limited to interviews with consenting individuals and the use of publicly available secondary data.

CONSENT FOR PUBLICATION

All authors have read and approved the final manuscript. Participants provided consent for the use of anonymized data for academic publication purposes.

CONFLICT OF INTEREST

The authors Prince J T Kuipa, PhD and Douglas Ncube PhD certify that they have no affiliations with or involvement in any organisation or entity with any financial interest (such as honoraria; educational grants; participation in speaker's bureaus; membership; employment; consultancies; stock ownership, or other equity interests; and expert testimony or patent-licensing arrangement), or non-financial interests (such as personal of professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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Mushroom Production: A Synthesis of Socio-economic and Economic Aspects of Review Studies

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Abstract— *A review of literature on socio-economic, economic and marketing aspects of mushroom production are crucial in research because they directly impact the livelihood of farmers, contribute to the rural development by creating employment opportunities, influence market demand and price stability and ultimately determine the overall profitability and sustainability, especially for small scale producers in developing region. Literature review on socio-economic profile of mushroom production reveals that it has significant potential to improve livelihoods, particularly for marginalized communities, by providing a reliable income source, utilizing readily available agricultural waste, and offering a relatively low-cost entry point for small-scale farming, thereby contributing to enhanced nutritional security and promoting sustainable agricultural practices through its ability to generate income while simultaneously recycling waste materials; however, successful implementation requires access to proper training, market linkages, and awareness campaigns to maximize its socio-economic impact. Secondly, a review of the economic aspects of mushroom production reveals that it presents a promising opportunity for income generation, particularly for small-scale farmers, due to its high yield per unit area, ability to utilize agricultural waste as a substrate, and relatively low production costs; however, challenges like market volatility, technical requirements, and limited access to quality spawn can hinder its full economic potential, requiring targeted support and infrastructure development to maximize its benefits for rural communities and economies. Lastly but not the least, the identification of marketing channels, costs, and price spreads in mushroom production literature reveals that direct-to-consumer channels offer the highest marketing efficiency and producer share, while channels with intermediaries like wholesalers and retailers lead to higher costs and lower efficiency. This means that while direct sales provide higher profits for the grower and potentially lower prices for the consumer, they also limit market reach compared to the broader access offered by intermediaries.*

Highlights

a) Literature review on Socio-economic Status of different mushroom growers.
b) Literature review on economics of different types of mushrooms.
c) Literature review on various marketing channels, marketing costs and margins.

Keywords— mushroom production, socio-economic, age, education, income, profit, economics, costs and return, variable cost, fixed cost, marketing channels, price spread, , wholesaler, retailer, producer share, marketing efficiency.

I. INTRODUCTION

By reviewing previous research, one can gain a deep understanding of what is already known about your topic, providing a starting point for one's own investigation. Analyzing existing literature helps in pinpoint areas where knowledge is lacking, allowing one to focus in his research on addressing these gaps and contributing new insights. Reviewing previous studies ensures you are not repeating research that has already been done, saving time and resources. By understanding the current state of knowledge, you can develop focus and relevant research questions that build upon existing research. Studying previous research can guide your choice of research methods, data collection techniques, and analysis strategies. A literature review can help you identify relevant theories and concepts that can guide your research and interpretation of results. A well-conducted literature review shows that you are familiar with the existing body of knowledge in your field. By comparing your results to previous research, you can effectively interpret and discuss the implications of your study.

In this backdrop, the brief resume of relevant research work by various scholars on various aspects of mushroom cultivation in India and abroad has been evident as in the ever proliferating literature. In these contexts, a vast range of literature review has been studied by consulting various books, journals and internet sites for the topic of research on production and marketing of mushroom cultivation in Kangra valley of Himachal Pradesh and the same has been categorized into following main headings:

1) Literature review on Socio-economic Status of different mushroom growers
2) Literature review on economics of different types of mushrooms
3) Literature review on various marketing channels, marketing costs and margin

II. LITERATURE REVIEW

2.1 Socio-economic Status of different mushroom growers:

Single and Goel (2016) investigated 25 women producer of mushroom to analyze the socio-economic situations and challenges experienced by them in Patiala district of Punjab. According to the research, 72 per cent of mushroom growers have improved their occupation with improvements in social status (24%), knowledge and attitude (52%), saving more money (60%), and standard of living (64%). The women faced the maximum limitation with regard to value-added products, lack of information regarding mushroom growing and higher cost of cultivation.

Shirur et al. (2017) studied the impact of the identified variables on the entrepreneurial behaviour of the Karnataka farmers. Four extension variables, six socio-psychological trait features, and five characteristics of farmers and their units were examined to see how they affected the respondents' entrepreneurial activity. Regression analysis model was used in the study. The results of the regression analysis revealed that the respondents' entrepreneurial activity was substantially influenced by their academic background, cosmopolitanism, self-reliance, engagement in mass media, extension activity, and training.

Bashir et al. (2018) analyzed that over 33 types of mushrooms are cultivated commercially around the globe, with three of them being widely grown in India: white button, oyster, and paddy straw mushrooms. White button mushrooms account for 90–92 per cent of India's total mushroom production; the remaining portion is supplied by paddy straw mushrooms and oyster mushrooms. The study was organized in three districts of Kashmir and it was found that 90 per cent of women in the district of Anantnag and 1 per cent of women in Kulgam and Pulwama felt that the increased money from mushroom farming had improved their level of living. The majority of women in the districts of Anantnag, Kulgam, and Pulwama have achieved financial independence as a result of mushroom farming. 99.00 per cent of women in district Pulwama and 100.00 per cent of women in districts Anantnag and Kulgam were able to fully support their family and were able to give their children a healthy diet and a good education because of improved revenue from mushroom cultivation.

Boin and Nunes (2018) conducted a study in Portugal where data was collected on basis of the rate of consumption, consumption by form (fresh, canned, frozen and dried) and consumption by species (five farmed and four wild mushrooms). Regression model was used to determine the results. The results indicated that there was a higher (81.9%) consumption of canned than fresh and dried/frozen mushrooms. The characteristics that had the greatest impact on consumption were gender, degree of education, and size of the household.

Shipra et al. (2018) conducted a study on 75 rural women of Samastipur district of Bihar to investigate the effects of mushroom farming on rural women's economic position through skill development. The results of the study indicate that as a result of training, rural farm women's knowledge of all the subcomponents of mushroom production had improved which empowered women to raise the standard of life for themselves and their families. It was concluded from the study that the development of entrepreneurship was the best option for rural farm women to achieve economic independence.

Koirala (2019) studied how beneficiaries' socioeconomic circumstances were affected by the growing of mushrooms and explained the respondents' socio-demographic traits. The study was conducted on 50 households of Padampur. It was found that 38 per cent of the 50 households were found to be in the age group of 40–50. The results of the field survey indicated that 46 per cent of the respondents had only completed elementary school but now data interpretation reveals that 46 per cent of households send their kids to private schools in order to provide them with a quality education. With reference to social structure of the mushroom growers, 32 per centwere janjati, 4per cent are dalit, and 20 per cent are brahaman and kshetri. The results revealed that 90 per cent grow oyster mushrooms while 4 per cent row both oyster and white button mushroom since they were quick to produce and profitable. Eighty per cent of the fifty households agreed that they were receiving better medical care than they had in the past. The study concluded that those engaged in mushroom cultivation had greater social and financial status than they had previously.

Kala and Hans (2020) conducted a study in Samastipur district of Bihar where 60 respondents in all, or fifteen from each of the listed villages, were chosen for the "Impact assessment on socioeconomic profile of women mushroom growers". The study revealed that 56.67 per cent of the respondents were fewer than 35, 91.67 per cent were married, 65per cent belonged to the lower social classes, and 71.66 per cent had a combined family. Most respondents (60%) reported that their family's annual income ranged from Rs. 50,000 to Rs. 80,000.

Pandey et al. (2020) conducted the study on the substrate of the mushroom. The study examined how commercial mushrooms are supplied with bio-waste, including wood chips, straw, and sawdust. Spent mushroom substrate (SMS) was regarded as a waste product. The study concluded that encouraging research and development was necessary to provide significant advancements that enable the efficient utilisation of mushroom bio-resources.

Koodagi et al. (2021) studied that ICAR KVK, Mandya conducted mushroom-related skill-development workshop with the aim of fostering employment and microenterprise. The study found that the trainees varied in their socioeconomic status. The study's findings showed that participants' pre- and post-training understanding of mushroom production technology ranged from 2.12 to 34.62 per cent and 42.04 to 85.87 percent, respectively and the percentage change in knowledge ranged from 26.14 to 74.91 per cent. The study concluded that right training and direction will enable interested producers to survive and make a living.

Sharma et al. (2021) in his study considered 60 mushroom growers that were chosen through a simple random sampling method.The mushroom producers were categorized into three groups according to the quantity of bags they produced: Small Group (600 or less), Medium Group (601–1200), and Large Group (more than 1200).The literacy rate of all houses showed 2.69, and 88.25 per cent of their members were literate as a whole.The acquired results revealed that mushroom yielded the highest value share of overall farm income (43.44 %) in the medium and large categories (72.18%), respectively. It is evident from the conducted studies that mushroom was the most contributing crop among the all other farm crops accounting for 49.42 per cent of the total amount.

Ashiegbu et al. (2022) studied the involvement of young people from rural areas at the Agricultural Zone of Umuahia in Nigeria in the activity of cultivating mushrooms. There was provision of 60 young people from the Umuahia Agricultural Zone to undertake a training program on mushroom production technology. The finding of this study shows that 58.3per cent of the respondents were male, 65.0 per cent had education beyond secondary level while 63.3 per cent had worked in mushroom sector for a period of one year or longer. It is therefore argued that education level, family size, years of experience and income of the respondents had significant influence level of mushroom production technology in the study area this is based on the regression analysis model that was used to analyze the data. Despite all the studied reasons for the lack of young people's involvement in mushroom farming, the government should promote younger generations to engage in mushroom production using technologies information that they could understand and apply effectively.

Kumari and Mazhar (2023) conducted a study in Dhanbad district of Jharkand to assess the adoption level of knowledge towards mushroom cultivation. The study was done on 120 growers and the respondents' knowledge of mushroom growers was divided into three categories: low, medium, and high. The results revealed that 19.17per cent 59.17 per cent and 21.66 per cent were having low, Medium and high level of knowledge respectively whereas the majority (52.20%) belonged to the medium level adoption group, whereas 29.17 per cent had a high level of adoption group for mushroom farming, while the remaining 18.33per cent of the respondents were observed in the low level of adoption group. It was found that the socioeconomic standing of mushroom farmers has significantly improved as a result of the various entrepreneurial skills that have been developed through mushroom cultivation.

To sum up, A socio-economic profile of review of mushroom production reveals that it has significant potential to improve livelihoods, particularly for marginalized communities, by providing a reliable income source, utilizing readily available agricultural waste, and offering a relatively low-cost entry point for small-scale farming, thereby contributing to enhanced nutritional security and promoting sustainable agricultural practices through its ability to generate income while simultaneously recycling waste materials; however, successful implementation requires access to proper training, market linkages, and awareness campaigns to maximize its socio-economic impact.

2.2 Economics of different types of mushrooms:

Chrishti et al. (2000) investigated the financial position of mushroom producers in the Rawalpindi and Islamabad region of Pakistan. The findings indicated that there were statistically significant differences in the variable costs between small and medium farms as well as between small and large farms.The larger farm holding which comprised of medium and large, had the powers to lower cost by bargaining on the purchase of bulk and by reinvesting money which could have been otherwise

used on handling and shipping. Net profits per unit area of large farm (3000 sq. ft.) were higher than small farms. The study suggested that mushroom farming cannot be carried out successfully as a viable business unless the private sector builds large farms instead of small ones.

Thakare et al. (2006) carried out a study on sixty-four growers who were chosen from three districts in the plain of Chhatisgarh: Raipur, Durg, and Bilaspur. The results indicated that the proportion of fixed costs to overall production costs was relatively low (33.58%), with variable costs accounting for 66.42 per cent of the total and the net return per kilogramme was, on average, Rs. 24.04. Large farms were found to have the highest input-output ratio, indicating that they benefit more than other growers. Lack of spawn and other acceptable mushroom species, as well as lower productivity resulting from a lack of technical know-how, were reported to be the main obstacles to mushroom cultivation.

Ram and Ram (2007) carried out the study in the Gurgaon and Sonepat District of Haryana in order to calculate the cost-benefit ratio of mushroom farming. The study found that the fixed capital investment was more than double when comparing large and medium farms to small farms. The study also revealed that the compost usage and the farm size had positive relationship. Large farmers produced mushrooms at the lowest cost when compared to small and medium farmers because they made the best use of their fixed farm resources. The study suggested that mushroom farming requires a lot of capital and grows as farms get bigger in size.

Ahmed and Rahman (2008) carried out their research in Bangladesh and reported that 49.8 per cent of the population lives below poverty line. He found that increased population, reduced income are some of the causes of poverty which can be reclaimed through mushroom cultivation. By taking this enterprise, the average net profit calculated was tk. 29300.00 which was more than the rice and wheat cultivation. He concluded that farmers have cultivated mushrooms on a modest scale and reaped direct benefits in various parts of Bangladesh. They've succeeded in adopting the technology in a more straightforward manner that allows them to make small-scale investments. They were mostly using agricultural waste, primarily straw from paddy fields and wheat fields.

Celik and Peker (2009) examined the advantages, disadvantages, and SWOT of mushroom growing as a means of diversifying rural income in a study carried out in Konya. The average production area was 1135.1m2 and the average yearly income was 45.4kg/m2 and compost output was 256.6kg/ton. The study showed that the average cost of 1 kg mushroom was USD 1.36 and average sales price was 1.54.The study came to the conclusion that boosting mushroom production was crucial to maintaining the health and growth of the rural economy, expanding and diversifying business and employment opportunities in rural areas, and supplying small family farms and underprivileged groups with income opportunities.

Barmon et al. (2012) determined mushroom profit, BCR and household income as a benefit while developing some problems associated with mushroom production in Bangladesh. The results would show that as average production cost of a mushroom per farm were Taka 41,948 and the revenue were Taka 64,826. The mean BCR per mushroom unit was approximately 1.55. It was being analyzed that marketing costs and profit margins are fairly higher than the ones that it would be in case of any other agricultural product. Following the study there were coupled by a wide range of production related problems that the producers faced which include high cost of the spawn, infestation of the fly and cockroaches as well as the high-temperature marketing, technical and awareness challenges.

Karma and Bhatt (2013) conducted a study on *Ganodermalucidum* species of mushroom to create an organic farming method using polypropylene bags in a subtropical environment. The study showed that the spawn run took 51 days to complete and after that spawn sacks were exposed to 90–95 per cent relative humidity and 30°C. It took 67 days to complete the vegetative phase and 92 days to finish the fruiting phase. The crop was planted for a total of 224 days, with a 65-day interval between each flush. The results indicated the total yield which was 570gm and no pest attack was seen during cultivation. The study recommended growing *Ganodermalucidum* species under subtropical climate.

Tahir and Hassan (2013) conducted a study on the profitability of button mushroom production on a small scale at the National Agricultural Research Centre in Islamabad, Pakistan in 2010. For this analysis, cost of production methodology was applied. Estimates for the mushroom output and gross returns were 155.6 kg ha^{-1} and Rs 77,800 ha^{-1}, respectively. The findings showed that mushroom production is highly profitable for its growers since it may maximise net return by lowering production costs because the crop's growth depends on inexpensive agricultural raw materials.

Kangotra and Chauhan (2014) revealed in their research that the majority of the sampled mushroom farmers, who were largely middle-aged and typically between the ages of 40 to 60, had 6-7 years of experience, with the rest 5 years of experience. The results of the financial test ratios indicated that growing mushrooms on big scales was more economically feasible and profitable due to larger investment and improved marketing connections with suppliers, which guaranteed a sufficient and

consistent supply of produce. The major limitation reported were scarcity of spawned compost bags, poor quality spawned compost material, absence of remunerative prices, and the prevalence of diseases. The study proposed growing at least two crops annually with timely delivery of high quality spawned compost bags at reasonable prices to their doorsteps so as to increase the output.

Thakur (2014) studied the characteristics of the mushroom and analysed that enzymes secreted by mushroom mycelia degrade substances including cellulose and lignin, which were subsequently taken up by the hyphae. The study indicated that India and several other developing nations have a lot of potential for mushroom production because the necessary raw materials were readily available at low cost. Mushroom cultivation function as a vehicle for creating jobs, especially for young people and women from remote areas to improve their social standing. Tropical mushrooms, such as oyster (Pleurotus spp.), paddy straw (Volvariellavolvacea), and milky mushroom (Calocybeindica), were produced using agricultural wastes as they were readily available in the area, such as paddy straw, wheat, soybean, chickpea, mustard, lathyrus, cotton wastes, and lignocellulosic wastes. An estimated 15–20,000 metric tonnes of oyster mushrooms were produced in India. However, only about 10,000 tonnes of milky mushrooms and paddy straw were produced each year. It was found from the study that on a small to medium scale, oyster mushroom farming was mostly carried out by the women in self-help groups which was a significant source of revenue for them.

Sharma et al. (2016) conducted an investigation in Himachal Pradesh district of Mandi where it was found that 80 per cent of the mushroom growers grow button mushroom only. The results showed that for every 100 bags, the fixed cost of production ranged from 44.47 per cent to 22.42 per cent on small farms to large farms respectively whereas on large farms, the variable cost ranged from 77.58 per cent to 55.53 per cent on small farms. The BC ratio calculated was 1.87:1. It was estimated that both small and large farmers had different break-even outputs, ranging from 279 kg to 147 kg. The study concluded that mushroom growers faced many problems but production problems were more severe than other problems.

Singh and Singh (2018) did a study in Amritsar and Gurdaspur district of Punjab to determine the cost and return structure of white button mushroom by taking 80 samples. The study revealed that with increase in the farm size of mushroom the recurring and non-recurring expenditures per square metre of bed area spawned declined due to economics of scale. The mushroom farms were categorized on the basis of input-output ratio in which large farms (1.81) were more productive followed by medium-sized (1.47) and small-sized (1.35) mushroom farms. The results indicated that due to the greater average price realization, medium-sized mushroom farms had better gross returns, but large mushroom farms had higher net returns because of reduced costs. The study recommended farmer's training for canning and refrigerated facilities, mechanised compost preparation plants, and mushroom growing shed disinfection.

Raut (2019) did a study in Nepal to examine the current situation and various problems faced by mushroom growers. He pointed out that lack of improved technology, poor quality of the raw material, pest and disease attack, insufficient investments, lack of well organised marketing channels and high prices of the raw material are some of the main problems which the mushroom grower faces. The study also showed the increasing trend of output of mushroom cultivation which was only 30 kg in 1974 which has reached 9300 tonnes in 2016.

Acharya and Tiwari (2021) noted the current state of mushroom cultivation and related businesses in the land areas of Kalika Municipality and Bharatpur Metropolitan City. Different analytical tool were used to analyze the data. The study found that Spawn costs the highest percentage of investment, followed by straw cost and depreciation of equipment. The average production of oyster mushrooms in the Chitwan district was determined to be 4,307.71 kg per Kattha. The oyster mushrooms yielded a gross return of Rs. 808,966.61, with a total cost of production of Rs. 318,089.61. In the Chitwan district, mushroom cultivation was regarded as a lucrative agricultural endeavour with a BC ratio of 2.54. It was discovered that the majority of farmers sell their mushrooms to neighbourhood whole vendors and collectors. According to the survey, farmers don't employ any value adding strategies that would increase their profit.

Bringye et al. (2021) conducted its research to investigate the various aspects of mushroom-related consumer behaviour in Hungary. Total 1768 samples were collected and groups of connecting variables describing mushroom consumption were found using exploratory factor analysis. Four aspects of Hungarian customer behaviour were discovered by the authors: (1) medicinal and functional qualities; (2) enjoyment-based consumption; (3) additional food source; and (4) unfavourable evaluation of the product line. Three categories of consumers were distinguished through the use of cluster analysis: typical consumers, indifferent consumers, and health-conscious consumers. The result of the study showed that the socio-demographic attributes of consumers, such as age, educational attainment, marital status, and place of residence, have a noteworthy influence on their consumption behaviour of mushrooms.

Radhakrishnan et al. (2021) conducted the study in the krishi Vighan Kendra laboratory, Wayanand and gathered the information from the farmers who participated in the mushroom cultivation training course. The study revealed how mushroom experiment were conducted as front line demonstrations and on farm testing. *Pleurotuscystidiosus* species of mushroom was preferred after conducting experimental trials because of its higher yield and less day's requirement for bud initiation. The result of the study showed that banana pseudostem waste was considered as a suitable substratum for mushroom cultivation in the study area, and unorganized market structure was the biggest challenge that the farmers faced.

Mulazimogullari and Ceylan (2023) conducted a study in Turkey where the production reported was 55455 tonnes in 2020. The average producer profit per unit was estimated to be Rs24.98, whereas the average profit inefficiency was identified as 44 per cent. The stochastic profit frontier method was used to estimate the inefficiency score. The results highlights the factors which reduces the profit inefficiency which include producer's gender, degree of education, and level of contentment whereas factors contributing to inefficiency were identified as the farmer's age, the usage of composted manure in the garden, and the sale of mushrooms through middlemen.

Saikia and Bora (2023) in their study revealed that mushrooms provide significant nutritional and functional worth, medicinal attributes, nutraceutical significance, and organoleptic potential. The study mainly focused on various challenges faced by mushroom growers in Jorhat district of Assam. The snowball sampling approach was used to choose 60 samples. Nineteen problem statements were formulated to investigate the issues encountered by the participants in the cultivation of mushrooms. Respondents were classified as having a low, medium, or high level of problem based on the mean scores from the respondents and the standard deviation. The results showed that around 60.00 per cent of the participants experienced medium level of problem.

In brief, A review of the economic aspects of mushroom production reveals that it presents a promising opportunity for income generation, particularly for small-scale farmers, due to its high yield per unit area, ability to utilize agricultural waste as a substrate, and relatively low production costs; however, challenges like market volatility, technical requirements, and limited access to quality spawn can hinder its full economic potential, requiring targeted support and infrastructure development to maximize its benefits for rural communities and economies.

2.3 Review of literature on various marketing channels, marketing costs and margins:

Carrera et al. (2005) conducted a study to investigate the distribution networks of wild and farmed mushrooms in central Mexico between 1999 and 2004 using an institutional approach. It was found that the majority of cultivated and wild mushrooms were sold in that area. Three representative locations were chosen for the study: a rural village (Cuetzalan), two medium-sized cities (Puebla, Toluca), and a big city (Mexico). There were several marketing channels discovered and detailed, including public markets, retail food stores, wholesalers, retailers, middlemen, "tianguis," and food services. It was analyzed that the current method for marketing mushrooms developed from a modest, centralised operation to a mix of decentralised and centralised marketing procedures with a restricted number of activities. Large private companies assumed control of a number of marketing responsibilities during this wave of reforms, assisting the decentralisation process while impeding the growth of new businesses specialising in the marketing and processing of mushrooms. It was concluded from the study that Changes resulted in the market concentration of open-market sales in sizable private companies and useful wholesalers at the same time.

Zamil and Cadilhon (2009) carried out a study under the FAO portion of the UNDP-funded Local Partnerships for Urban Poverty Alleviation Project in Bangladesh. The project connects the underprivileged urban residents of Mymensingh city with the oyster mushroom specialty market. This small business endeavour seemed to be sustainable since it increased agricultural production to meet a particular need of an already-existing small marketing business. The merchant had incentive to work with the project beneficiaries who supplied the produce as long as he found market for his mushroom. This model demonstrated how a development project's catalytic effect could benefit both a merchant and incredibly tiny landholders.

Ganie and Yousuf (2010) revealed that India produced 1, 00,000 MT of mushrooms in 2006–07, which rises from 5,000 Mt in 1990. Study was conducted in Jammu and Kashmir where the mushroom cultivation was of recent origin so the majority of producers were concerned about large-scale production in such a young industry, with issues such as inadequate infrastructure, uninformed consumers, lack of technical support and required institutional support. Growers often sell the majority of their produce directly to consumers (40.37%) or to retailers (47.19%). The results analyzed that the entire cost of marketing, including profit margins, ranged from 2.50 to 10.65 rupees per kg in three most popular channels and producer's share was maximum in channel where mushroom grower sells directly to consumer. It was observed that net margins were also correlated with the expenses incurred during the marketing process.

Adinya et al. (2012) in their study in three villages in Central Cross River State, Nigeria analyzed that women and children controlled the edible mushroom market, with monthly profit margins being N60,000.00, N56,000.00, and N52,000.00 for Alesi, Ekukunela, and Ochon marketplaces per year. Regression analysis examined that the transportation had the most effect on sellers' profits. Therefore the study suggested that growers should establish a cooperative called Mushroom Grower and Marketing in order to apply for bank loans who offers less interest rate and government should implement Action-research programmes through export processing zones or cooperatives. The study concluded by recommending that significant effort be put into making market to perfect market.

Banga et al. (2013) studied that promotional materials were not being used by any of the mushroom farmers in Punjab to market their products. The finding clearly indicated that produce of every mushroom farmer was being sold packaged, but without a brand name. The study also highlights the main issues that mushroom growers deal with which were the product's high perishability and lack of popularity, low demand brought on by high costs, the absence of nearby processing facilities, and insufficient farm-to-market transportation.

Mohd et al. (2013) carried out a study in Malaysia to examine the problems and difficulties faced by growers that could slow down its development. Focus group discussions were conducted to learn about participants' perceptions, expectations, and experiences with fresh mushroom cultivation and commercialization in Malaysia. The result of the study showed that government policies, marketing, and production were the three primary areas of concern for this industry. The problems with production included controlling the hot water, getting low-quality seeds, and raising production costs. Demand exceeded supply as oyster mushroom growers could not meet the increased demand which conversely leads to increase in the prices in the Klang valley area. The study recommended some government initiatives in the form of training, subsidies for the production house, and research and development on the production system to address environmental issues.

Singh (2014) carried out a study by selecting equal number of wholesalers and retailers from Amritsar and Gurdaspur district of Punjab to ascertain the marketing structure of mushroom. Cumulative cube root frequency technique was used to divide the mushroom growers into different categories. Marketed surplus was about 99 per cent. The marketing pattern showed that the producer-consumer channel had the greatest net price paid to growers, although the marketing agency that handled the majority of the produced goods was the wholesaler. The study focused on the necessity of refrigeration and canning facilities for mushroom growers in the event of increased production to prevent distressed sales and raising public awareness of the nutritional value of mushrooms to promote their use.

Sabyasachi (2016) highlights the importance of mushroom cultivation as it doesn’t require access to land making it attractive activity for both rural farmers and pre-urban dwellers for sustainable development in North Bengal. The present study focused on analyzing the market potential for mushroom producers by taking into account the factors that affect consumer awareness and competitiveness. SWOT analysis and hypothesis testing was done to generate the information and for mathematical reasoning respectively. The study recommended that the government must provide much-needed financial and technical support on a high priority basis.

Shirur and Shivalingegowda (2016) conducted a research on consumer behavior among people. The study examined the degree of fluctuation in the average selling price across all mushroom kinds, ranging from Rs. 27 to Rs. 40, when sold to consumers, merchants, and wholesalers. No skilled workers, processing facilities, and the high rate of perishability were the main drivers of the surge in prices. The study revealed that the majority of consumers preferred button mushroom even though they have similar nutritional and therapeutic qualities to other mushroom because they were inexpensive to grow.

Singh et al. (2016) indicated that in the study area, Jammu province four marketing channels were used by the mushroom growers. The study showed that marketing efficiency was highest in case of fourth channel (mushroom grower- consumer) followed by third channel (mushroom grower- wholesaler – consumer), second channel (mushroom grower – retailer-consumer) and first channel (mushroom grower –wholesaler –retailer-consumer) with the estimated figures of 1.75, 1.25, 1.16 and 1.06 respectively. It was concluded that with enough infrastructure and supportive government policies, marketing could have been done more effectively.

Shirur and Chandregowde (2017) analyzed the constraints in mushroom entrepreneurship in the Karnataka state. 60 mushroom growers were selected and SWOT analysis was done. It was concluded from the case study and SWOT analysis that mushroom entrepreneurs require unique characteristics of entrepreneurial activity and for the success in mushroom entrepreneurship it requires the understanding of the nuances of mushroom biology, calculating profitability based on scale of economy, coming up with creative packaging and marketing ideas, figuring out ways to cut down on energy costs for temperature modulation during cropping, and being personally involved in the business.

Chattopadhyay and John (2019) highlighted the importance of mushrooms that mushrooms were nutrient-dense food that can be used in place of dairy, eggs, meat, etc despite being coming from lingo-cellulosic waste. The study analyzed that 280 of the approximately 2000 edible mushroom species were grown in India and Guchhi, the most significant mushroom, was supplied to western nations. The report showed that mushrooms were not used extensively in India even though they have a high nutritional value because of lack of awareness among people and insufficient marketing.

Sachan et al. (2019) analyzed the breakeven point, various costs and their returns, marketing system and Marketing efficiency in Haryana. The study observed that the fixed cost and its investment was twice for large and medium-sized farms when compared to small farms due to absence of availability of money to mushroom growers. The size of the farm was closely correlated with the cost of spawn and compost. The largest producer share in the consumer price was found in Channel I (consumer – mushroom grower) whereas most produce went through channel IV Mushroom Grower-Wholesaler-Retailer-Consumer). The study suggested upgrading the infrastructure to extend the crop's shelf-life.

Lidyana et al. (2021) carried out a study in Probolinggo where the census approach was used to pick oyster mushroom farmers. The study finding's indicated that Probolinggo oyster mushroom growers employed logs as a tool, which generated them high revenue. Oyster mushrooms use two distinct patterns in their marketing channel and second pattern (mushroom farmer-reseller- consumer) was considered more profitable than first pattern (mushroom farmers- resellers-retailers- consumers).

Dey et al. (2022) conducted a study in Dehradun district of Uttrakhand which is the second largest producer of mushroom after Punjab. In his study he observed that the channel I (producer- consumer)showed the greatest levels of marketing efficiency (36.70%) and producer share (97.28%) in consumer rupee followed by channel II (producer-retailer-consumer) and channel III (producer-wholesaler-retailer-consumer).Channel III had the highest marketing cost, marketing margin, and price spread, followed by Channel II, I.

Farooz et al. (2022) examined the particular issues and constraints that the Hardoi District of Uttar Pradesh experienced when marketing mushrooms. He pointed out that the absence of marketing structure prevents farmers from receiving a fair price and were often obliged to sell their goods at an unprofitable minimum market price after reaching crop thresholds and in need of cash.The study underlined the need for fair and appropriate mushroom marketing mechanism in the district to engage in profitable transactions. Marketing through cooperative and farmer-producer organisations needs to be promoted in order to raise the share of producers in the consumer rupee and simultaneously efforts need to be made to improve the quantity and quality terms in order to increase export of mushrooms.

Sikander et al. (2022) curtained that recycling agricultural waste, including agro-industrial waste, is one of the main ways to help achieve the goals of resource conservation and higher productivity. Multi stage random sampling technique was used to select the mushroom growers in Patiala. Button mushroom cultivators were divided into three size groups based on the quantity of bags they produce: small (<4000 bags), medium (4000-6000 bags) and large (>6000 bags). The result of the study showed that out of the three marketing channels, Channel I: Producer-Consumer Channel II: Producer-Retailers-Consumer Channel III: Producer-Wholesaler Retailer-Consumer the total marketing cost was same in channel II and III i.e. Rs.15/kg, marketing margin and price spread was maximum in channel III i.e. Rs.32/kg and Rs.42/kg respectively whereas the producer share in consumer rupee was maximum in channel I i.e. 88.75 per cent.

Andrew (2023) conducted a study in Kenya whereby the purpose was to measure the effect of farmers' marketing strategies. The results showed that 43.3 per cent of the farmers gave their goods to hotels and restaurants, while 56.7 per cent of them sold mushrooms in rural open markets. In addition, 53.3 per cent of farmers sold directly to customers, while 46.7 per cent relied on suppliers for distribution. 3.3 per cent of the packaging was done in bottles, compared to 96.7 per cent that used polythene bags. The study concluded that existing marketing strategies had a limited impact on the performance of Oyster mushroom cultivation and suggested creating cooperatives for mushrooms, cold storage facilities, creating incentive programmes, and providing extensive training.

Kumar et al. (2023) studied the marketing cost, marketing margin, price spread, marketing efficiency and marketing channels of oyster mushroom in the Kaithar district in Bihar. 120 mushroom growers were selected randomly and were grouped into three categories large, medium and small on the basis of their production and the mushroom yield for small, medium, and large farms was 0–50 kg, 50–100 kg, and 100 kg and above respectively. The two marketing channels, channel I. producer-consumer, channel II. producer-retailer-consumer were used in the study area with greater marketing efficiency in channel I (36.7%) compared to channel II (17.23%) and greater marketing cost per kg of mushroom in channel II (Rs 4.54/kg) compared to channel I (Rs 3.25/kg).

In short, the identification of marketing channels, costs, and price spreads in mushroom production literature reveals that direct-to-consumer channels offer the highest marketing efficiency and producer share, while channels with intermediaries like wholesalers and retailers lead to higher costs and lower efficiency. This means that while direct sales provide higher profits for the grower and potentially lower prices for the consumer, they also limit market reach compared to the broader access offered by intermediaries.

III. CONCLUSION

It is evident from the above reviewed studies that most of the studies on mushroom production and marketing pertained to its cost in different parts of the country with few exception across the globe, but no study were found during the recent two decades pertaining to the different components of costs that are involved in the mushroom production and its marketing. Additionally, no study was conducted on mushroom production and its economics and marketing recently in Kangra district of Himachal Pradesh to provide input on costs and return structure which suggested that there is ample scope to conduct such an empirical case study. This literature review can be used by the planners, extension workers and policy makers to create a new plans and regulations for the welfare of mushroom producers. The review can also provide further insight into the cost of mushroom cultivation and its marketing effectiveness. Researchers will find this review study very helpful in understanding the approach on how to start mushroom cultivation as a profitable venture. The review study has further outlined the issues and offered suggestions which will be highly beneficial to the mushroom producers.

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Colony Growth of Local Honey Bee (*Apis cerana*) in Teak and Eucalypt Stands

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Abstract— *There are various species of plants that potentially become a food source of local honey bee (A. cerana) in Wanagama Education Forest. Therefore it is necessary to do research on the development of local honey bee colonies in Wanagama Education Forest. This study was aimed to determine: the development of local honey bee colonies kept in teak and eucalyptus stands, The research was conducted in teak and eucalypt stands of compartment 14, Wanagama Education Forest in September to December 2016. The research was done by measuring the weight of the bee colony, the width of the honeycomb, the length and weight of the individual worker bees once a month. The results showed that the weight increase of bee colony kept in eucalypt stand (102,3%) was higher than that in teak stand (62,6%) in four months. The width of honeycomb increase in eucalypt stand (122.6 %) tended to be higher than that in the teak stand (99.7%). The highest body length (1.20 cm -1.23 cm) and body weight (0.052 g -0.055 g) of worker bee was observed in November. Local honey bee colony in Eucalypt stand developed better than that in teak stand. Eucalypt stand in Wanagama Education Forest seems to have a good carrying capacity for keeping local honey bees.*

Keywords—Apis cerana, colony growth, local honey bee, teak stand, eucalypt stand.

I. INTRODUCTION

Honey is one of the bee products that have high economic value. Bee keeping has not developed well in Indonesia. Production of honey in Indonesia is around 4000 tons per year and most of this honey production is produced from hunting wild in the forest (Kuntadi, 2016). The results of honey in Indonesia is not sufficient for the community because the need for honey is estimated to increase by 7000 tons / year. Indonesia still imports many honey from other countries such as Australia, New Zaeland, Thailand etc. Therefore honey bee keeping needs to get serious attention so that we do not depend on imports of honey from abroad.

In Indonesia there are several species of honey bees cultivated such as local honey bee (*Apis cerana*) and honey bees from Europe (*Apis mellifera*). *A. mellifera* is widely developed and cultivated intensively in Indonesia because it has great honey results. But these bees have the disadvantage of not being able to withstand parasitic attacks of mites that can damage and kill colony *A. mellifera* quickly. Besides that the bees are not easy to adjust to the environment. These bees also need to be transferred to other places following the flowering plant species. However, the transfer of colonies required considerable cost and manpower.

Local honey bees (*A. cerana*) produce less honey than *A. mellifera* but this bee has the advantage of high resistance to the attack of mite parasites known to greatly damage in apiculture. In addition *A.cerana* has a good ability in adaptation to the environment. *A. cerana* also has a greater genetic diversity compared to *A. mellifera.* Therefore, this local honey bee needs to be developed intensively to produce honey with high quality and quantity (Koetz,2013).

During this time *A. cerana* has not been intensively cultivated. Honey bee *A. cerana* usually is obtained from nature or cultivated traditionally without good care. For example in Wanagama Forest the average production of honey bee *A.cerana* is

still low around 1-3 kg / colony / year. Besides the bee *A.cerana* also easily move to another place. With the innovation of honey bee cultivation technique, it is expected to increase the production of honey.

Forest is one of the potential places in the supply of bee feed. The diversity of flowering vegetation in the forest allows the bees to get enough feed each season. One of the forests that the surrounding community serve as the location of honeybee cultivation is Wanagama I Forest Forest, Gunungkidul, Yogyakarta (Adityawan, 2015). The honey bees forage for collecting nectar, pollen and water (Seeley,1989; Abou-Shaara, 2014). Pollen collection increase in the larval stage (Hellmich and Rothenbuhler, 1986). An increase in the uncapped brood in the colonies cause a decrease nectar foraging (Hoopinger and Taber, 1997). The decrease of the pollen in the hive can decrease the brood rearing activity (Barker and Jay, 1974; Antonsenko and Ermoleava, 1979). Changes in the internal environment of the honey bee colony influence its foraging response (Calderone, 1993; Dreller et al.1999). The stronger colony produce more honey than weaker colony (Bhusal et al., 2011; El-Kazafy and Al-Kahtani,2013)

Wanagama Forest is a reforestation forest by converting an area that was once a barren hill that has not been overgrown by vegetation (Al-Mubarrok, 2016). The carrying capacity of Wanagama Forest in providing food sources plays an important role in the development of local honey bee colony (*A. cerana*) which is stationery beekeeping within the forest area. The objectives of the research was to know the development of local honey bee colony kept in teak stand and eucalypt stand.

II. MATERIALS AND METHODS

The research was done in Wanagama Education Forest, Gunung Kidul, Yogyakarta Indonesia. This area is located at an altitude of 150 to 400 meters above sea level, covering an area of 600 ha. Teak stand and eucalypt stands are located on plot 14. Ten local honey bee hives were put in eucalypt stand and teak stand respectively. The development of local honey bee colonies was observed by measuring colony weight, honeycomb size, body length and body weight of worker bee. Colony weight was measured by weighing bee colony on each hive using electrical balance. Honeycomb area was measured by drawing a honey comb on a plastic sheet. Then the image of the the honeycomb on plastic sheet was scanned using a scanner to obtain a honeycomb softcopy in jpeg format. Furthermore, the honeycomb area measurement was done by using Autocad 2010 software. The weight and length of the worker's bees were done by taking 3 individual worker bee samples from each hive. The weight measurement was done using an electrical balance.

III. RESULTS AND DISCUSSION

The colony development of honey bee in Wanagama Forest was showed in Figure 1. At the beginning of observation the weight of honey bee colony in teak stand was 196 g and eucalyptus 229.8 g; while at the end of the observation, the weight of the bee colony was 318.7 g in teak stand and 464,85 g in eucalypt stand. The weight increase of bee colony kept in eucalypt stand (102,3%) tended to be higher than that in teak stand (62,6%) in four months (Figure 3).

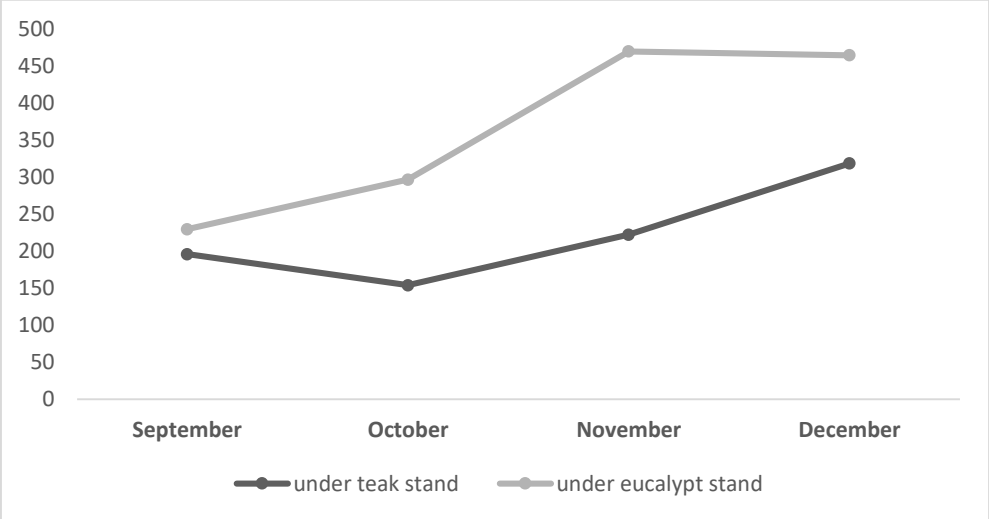

FIGURE 1: Weight of local honey bee colony (g) kept under teak stand and eucalypt stand

Although in September the weight bee colony kept in eucalypt stand was higher than that in teak stand, but statistically this was not significantly different (P> 0.05). The development of honey bee colony kept in eucalypt stand was better than in teak stand. The food source for honey bee in eucalypt stand seemed to be better than in teak stand. According Sihombing (1997), pollen eaten by honeybees primarily as a source of protein and fat, little carbohydrates and minerals. Protein is a major determinant of the growth and proliferation of honeybees, as well as in general insect. The development of bee colonies is strongly influenced by dietary factors. Honeybees require various nutrients for growth, development, reproduction, and production (Sihombing, 1997).

Significant increase of honey bee colony in November may be due to the abundance of *Acacia auriculiformis* pollen in nature so that pollen deposits in nest cells are also abundant. Djam'an., et al. (2016) in the study of flowering patterns of *Acacia auriculiformis* in Banyumas, West Java, suggested that *Acacia auriculiformis* experienced flowering peaks in April-May and ready-to-harvest fruits in July-August. The abundance of *Acacia auriculiformis* pollen in November in Wanagama is the late flowering phase

Development of honeycomb area becomes one of the indications of whether the number of bees in a colony increases or not. Honeycomb development was affected by the availability of the nectar and pollen. According to Pratt (1999) bees build new nests during flowering seasons where nectar sources are abundant, so the colonies need new cell to store honey. Bee colonies in the educational forest of Wanagama obtain the supply of nectar from the shoots and buds of mangium leaves (extrafloral nectar).

The increase of honeycomb area was observed in teak stand and eucalypt stand (figure 2). Honey comb area in the bee colony in teak stand increased from 541.18 cm2 in September to 1080.65 cm2 in December.. The honeycomb area in eucalypt stand increased from 680.69 cm2 in September to 1515.17 cm2 in December. The width of honeycomb increase in eucalypt stand (122.6 %) tended to be higher than that in the teak stand (99.7%). A more rapid increase of honeycomb area of the local honey bee colony kept under eucalypt stand indicated that eucalypt stand is more favorable for beekeeping than teak stand. Food factors certainly provide a significant influence in spurring the development of the colony. The species of pollen obtained by bee colonies kept under the eucalyptus stand may be greater than the colony under the teak stands.

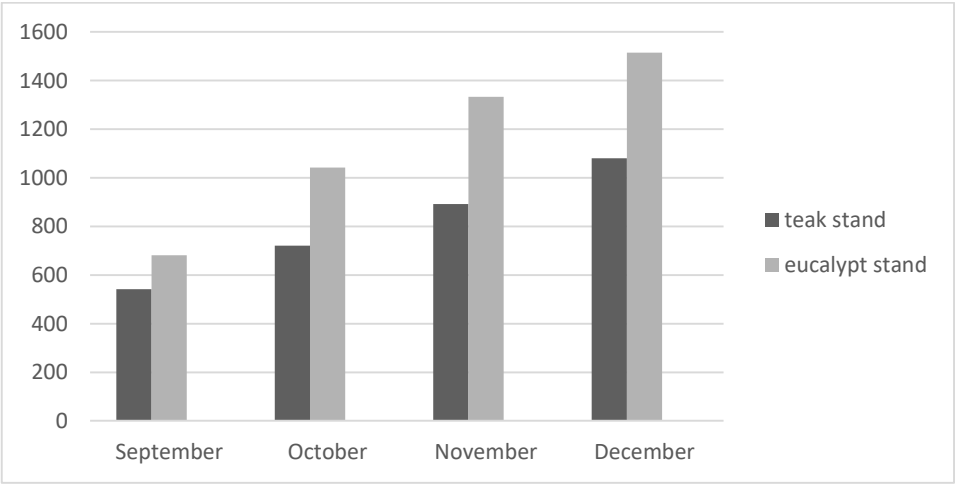

FIGURE 2: Honeycomb area (cm^2) of honeybee colony kept under teak and eucalypt stand

The body length of worker bee ranged 1.11 to 1.15 cm in teak stand and 1.14 -1.23 cm in eucalypt stand (Figure 3). The weight of worker bee was 0.049 – 0.054 g in teak stand and 0.049-0.052 g in eucalypt stand (Figure 4). The length and the weight of worker bee in eucalypt stand and teak stand was similar. The length and the weight of worker bee either in teak stand and eucalypt stand in November was higher than in other month. It may due to the fact that in November the availability of the food was higher than that in the other month.

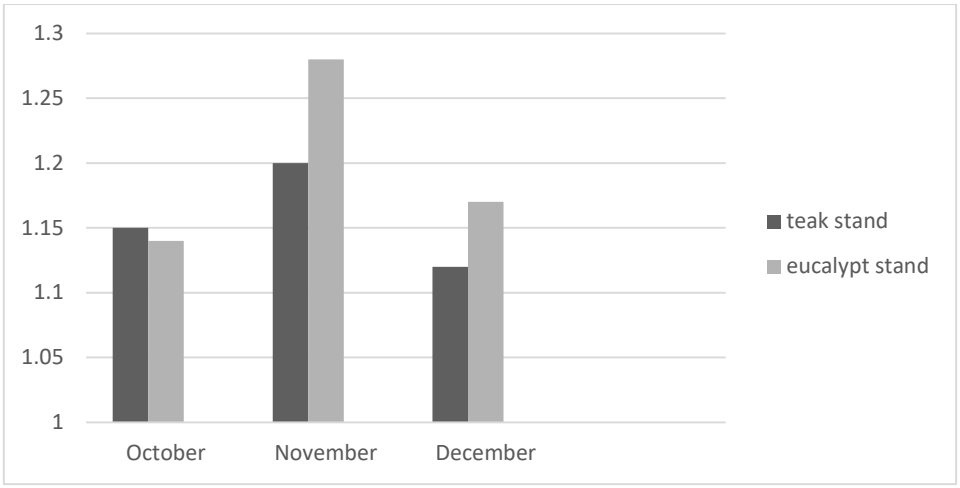

FIGURE 3: Body length of worker (cm) bee kept under teak stand and eucalypt stand

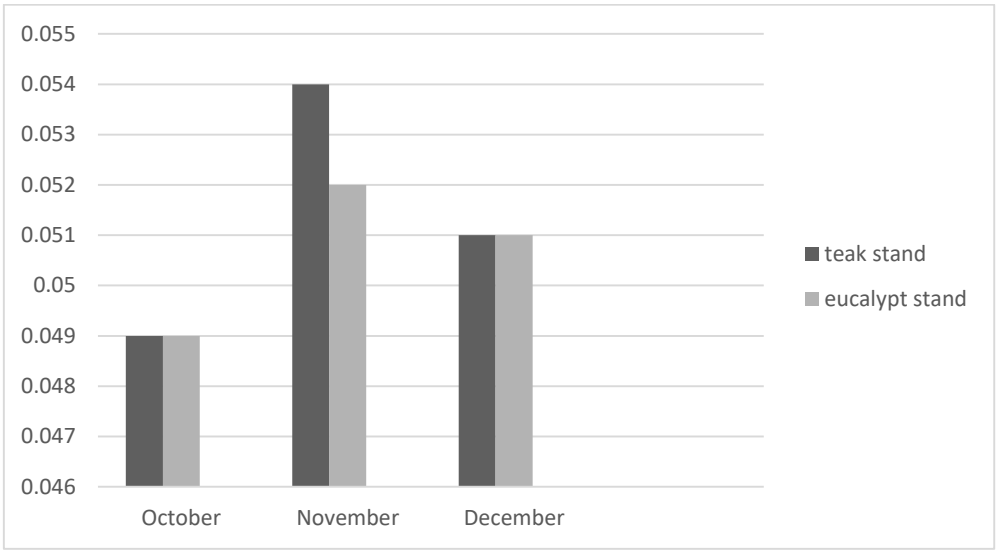

FIGURE 4: Body weight of worker bee (g) kept under teak stand and eucalypt stand

IV. CONCLUSION

Honey bee colony growth in eucalypt stand is better than in teak stand. It may due to the availability of nectar and pollen in eucalypt stand is better than in teak stand.

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Integrated Farming System to Mitigate Climate Change Impact on Horticulture in India

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Abstract— *This research examines the function of Integrated Farming Systems (IFS) in the sustainable agricultural approach which address the ill effects of changing climatic conditions on horticulture crops in India. It analyses the various elements of IFS across different agro-climatic regions and assesses its potential to strengthen farmers' resilience against unpredictable weather events like droughts and floods. The study utilizes secondary data from governmental reports, international organizations, academic research, and case studies, employing a descriptive methodology to evaluate environmental and socio-economic advantages, significant obstacles to implementation, and strategies for successful execution. The results indicate that IFS enhances resource efficiency, improves soil health, and promotes biodiversity, while also diversifying income streams, boosting food security, and creating job opportunities. However, widespread adoption is hindered by factors such as lack of awareness, financial constraints, inadequate infrastructure, and limited access to institutional support. The study concludes that a region-specific, policy-driven, and technologically enabled approach—supported by training, financial aid, and market linkages—is vital for scaling up IFS practices across India. This transformation is essential to achieving long-term agricultural sustainability, climate resilience, and rural development.*

Keywords— Farmers, climatic conditions, Integrated Farming, sustainability, livelihood.

I. INTRODUCTION

In India fruits, vegetables, ornamental plants, aromatic and medicinal plants come under the head of horticulture crops. There is major contribution of these crops in increasing agriculture prosperity of the nation. India ranked First in whole world in terms of production, consumption and exports of spices and also ranked Second in production of fruits and vegetables in the whole world. With reference to the Second Advance Estimates for the year 2023-24 by the Department of Agriculture and Farmers Welfare, India's total horticulture production is estimated to be 352.23 million tonnes, which is slightly lower than the 355.48 million tonnes recorded in 2022-23, marking a decline of 0.91%. However, the area under horticulture cultivation has slightly increased from 28.44 million hectares to 28.63 million hectares, showing a growth of 0.66%. (Datta et al., 2022)The total fruit output is projected at 112.63 million tonnes, compared to 110.21 million tonnes in the previous year—an increase of 2.19%. Fruits like banana, mango, guava, lemon, and grapes have shown growth in production but there is a decline in the production of apple and pomegranate. Vegetable production has declined. The estimated vegetable output for 2023-24 stands at 204.96 million tonnes, down from 212.55 million tonnes in 2022-23, reflecting a 3.55% decrease. Increase in production can be seen in bottle gourd, bitter gourd, cabbage, cauliflower, pumpkin, tapioca, carrot, and tomato, while major crops like onion, potato, and brinjal have shown a drop. (Muchie & Assefa, 2021)

Climate change or we can say unpredictable and uneven weather conditions in a nation directly affects its agriculture sector. It causes biotic and abiotic stress while adversely affecting the horticulture crops of the country. Changing climatic conditions are as follows: -

- Global warming
- Rise in temperatures

- Uneven monsoon rains
- Unexpected cold & heat waves,
- Droughts
- Floods
- Rise in Sea Level
- Extreme & Unpredictable Weather Events
- Glaciers and Ice Melting
- Ocean Acidification
- Loss of Biodiversity
- Stronger Tropical Storms
- Thawing Permafrost
- Desertification

The damages faced by farmers due to these adverse and unpredictable effects of climate change on different horticulture crops are stated below: -

- Change in time taken for production of crops, because of rise in temperature crops develop very fast and mature early especially citrus fruits like lemon, oranges, melon and grapes.
- Reduction in crop yield and production
- Poor quality of crops due to drastic temperature variants.
- Increased risk of pest and other sudden weather change diseases.
- Flooding & Waterlogging
- Soil Degradation
- Reduction in Pollination
- Nutrient Imbalance

The above stated problems, causes huge losses to the livelihood of farmers across the nation. To overcome these losses the adoption of sustainable agriculture farming techniques is required. Sustainable agriculture practices are conservative agriculture methods used for the optimization of natural resources. Integrated Farming System is one of the many methods of sustainable agriculture used in the nation. Integrated Farming System (IFS) is the best remedy to deal with all sorts of problems faced by the farmers of Horticulture crops in India. IFS is a holistic approach that helps in a year-round income generation and ensure food and nutritional security to farmers, especially small and marginal farmers, Overall, IFS promotes economic stability, resource conservation, and environmentally friendly farming. (Bhagat et al., 2024)

The IFS has following Goals:

- To Enhance the productivity of per unit area in production of the crops.
- To improve the Soil heath and fertility
- To Maximize the reduction of chemical fertilizers usage while encouraging the use of organic fertilizers.
- Maximum yield & continuous income throughout the year.
- Proper Waste Management System
- Pest management.
- Economic Stability to farmers
- Conservation of natural resources

- Protection of Environment and Biodiversity as a whole.

The Various Components in Integrated Farming System (IFS) are as follows:

TABLE 1

VARIOUS COMPONENTS IN INTEGRATED FARMING SYSTEM (IFS)

Crop Husbandry	Growing and managing of crops for food, fodder and other purposes.
Aquaculture	Farming of different species of fish and other water animals or water plants.
Apiculture	Keeping bees for production of honey and also to help pollinate plants.
Sericulture	Growing silkworms to make silk.
Poultry	Raising birds like geese, chicken and emu for eggs and meat.
Livestock Husbandry	Raising of cows, buffaloes' goats, sheep, camels, horses and pigs for milk, wool, meat & transport.
Agro-forestry	Growing trees, shrubs & herbs together with crops or animals on the same land to increase soil fertility & additional income generation
Biogas Plants	Turning organic waste into gas for energy and compost.
Mushroom Cultivation	Growing mushrooms for food or medicinal use.
Duckery *(corrected)*	Raising ducks for their meat, eggs, or feathers.
Horticulture	Growing fruits, vegetables, flowers, and ornamental plants.

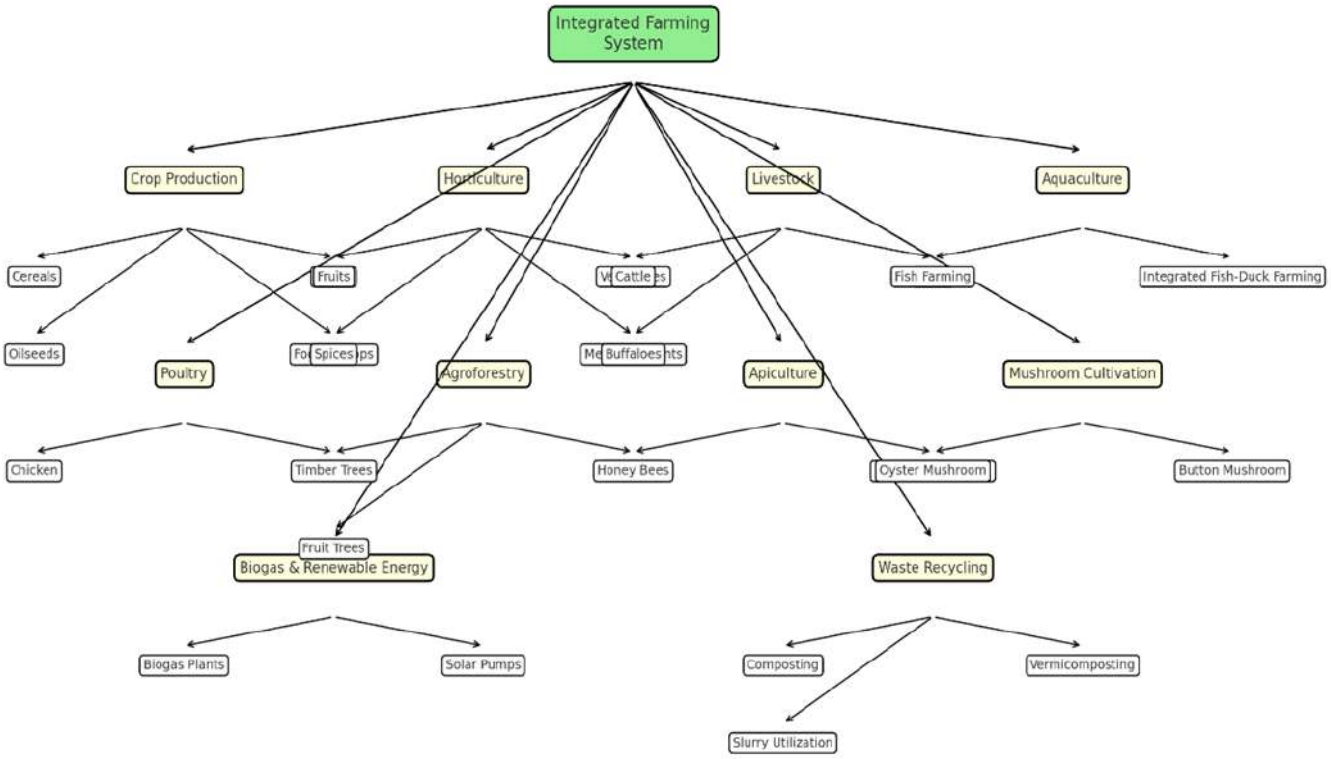

FIGURE 1: Various Components in Integrated Farming System (IFS)

Source: Self-Created

Research Gap:

Despite various national and international studies highlighting the impact of climate change on horticultural crops, there remains a lack of comprehensive, region-specific evidence on the effectiveness of Integrated Farming Systems (IFS) in enhancing climate resilience among Indian farmers. Furthermore, most existing literature does not focus on the unique challenges faced by small and marginal farmers in adopting such systems. Therefore, this study is crucial in bridging this

research gap by examining IFS applications, benefits, barriers, and policy needs, thereby underlining the significance of adopting IFS as a sustainable model to mitigate climate-related risks in horticulture.

II. LITERATURE REVIEW

Climate Change refers to the notable changes in mean state of climate or its variability or in any one of them which persistent in large period of time (10 years or more). These changes effects agriculture, horticulture fish and livestock production impacting the food supply., Main problems arising from the climate change are extreme unpredictable events, more erratic rainfall and unexpected high temperatures. Due to large burning of fossil fuels there is an increase in concentration of greenhouse gasses like CO2, nitrous oxide, and methane which is called greenhouse effect and it is a projected warning to the earth. (Kaur & Singh, 2021). To deal with changing climatic conditions and maintaining long term sustainability in agriculture agroforestry is one of the most adaptive methods to be used in India. Agroforestry can be used to improve soil fertility, increase water holding capacity and reduction in greenhouse gas emissions. It also provides additional livelihoods to farmers and helps in biodiversity conservation by minimizing risk of climate change conditions. Investment in research & development, awareness programs to increase farmers involvement and good government policies can lead to full potential utilization of the agroforestry which will ensure climate resilience for future generations**.** (Vaishnav et al., 2025).

To fight with the climate change adversities like rise in temperature, erratic & decrease in rainfall, the perceptions & adaptation of the farmers plays a pivotal role. Majority of famers in India are able to perceived these adversities with accordant to the metrological department. Farmers are doing necessary changes land use ,labour allocation .occupational pattern, and cropping system to adapt these unexpected changes due to climate change .But the factors like income, farm size ,gender, resource endowment, lack of information and lack of sufficient credit at right time are becoming hindrance to the farmers .There is need of large scale investment in agriculture sector which will lead farmers towards prosperity and long term sustainability as a whole. (Datta et al., 2022) To save horticulture from the negative effects of changing climate scenario & to sustain productivity, horticulturists need to play a significant role by implementing effective methods and strategies such as: More use of greenhouse technology, use of renewable energy, forest and water conservation, reforestation developing new cultivars which are immune of pest & diseases and also produce good yield in short duration. Wise use of natural resources will as play important role to face this challenge. (Kumar, 2024)

The main cause of biotic and abiotic stress in horticulture crops is climate change. Thers is a need to adopt certain strategies to minimize this stress. Use of renewable energy, developing new crops which are tolerant to high temperature, intercropping crop diversification, use of sustainably customized fertilizers, tillage practices, improving irrigation system, modifying date of planting, adjusting cropping seasons, improving pest control methods, adapting new farm techniques, mulching are some of these strategies. Accurate weather forecast, enabling GIS & insurance of crops scheme can also help in stress reduction in horticulture crops. (Thakre & Bisen, 2023)

A study conducted on variability of annual rainfall pattern during the growing season of crops across the nation for past 5 years highlights adverse effect like fluctuating monsoon onset, increase in number of dry spells & heavy rainfalls. It also reveals that farmers in India only protects their crops against these ill effects of rainfall only when they believe in climate change. Therefore, it is required that climate change adaptation should focus on farmers perception & weather records history befitted for each climatic zone. To improve farmers knowledge about weather change conditions and efficient land management, continuous integration of site- specific knowledge as well as practical experience can play an important role in future. (Paramesh et al., 2022) Protecting the environment by ensuring farmers' food, nutrition and livelihood needs and to encourage green revolution IFS is the most important tool. If implemented systematically IFS farms are more profitable and productive in comparison to the simple farms. IFS farms provide income generation and food diversification to meet the needs of farmers, these farms also help in conservation of biodiversity, reduction in greenhouse gas emissions, meet food demands in long run and ensure that farms are climate-resilient in this current climate change scenario. To achieve these benefits of IFS government should provide good capital investments, infrastructure and on-field demonstration to farmers specially the one with small and marginal land holdings. (Bhagat et al., 2024)

Integrated Farming Systems (IFS) have emerged as a promising approach to address the increasing challenges in the field of food security, income instability, and environmental degradation in Indian agriculture. Several studies across the country highlight that crop cultivation alone is insufficient to meet the nutritional and economic needs of small and marginal farmers. IFS, which integrates multiple farm enterprises such as livestock, poultry, fishery, and agroforestry with crop production, has proven effective in improving resource use efficiency and ensuring better livelihood outcomes. It facilitates nutrient recycling,

enhances soil fertility, and supports sustainable agricultural practices while preserving ecological balance. Overall, IFS is increasingly recognized as a viable and sustainable model for holistic rural development. (S. Kumar et al., 2018).

The research is conducted on the trends in mean annual precipitation & temperature for 115 years in the 15 districts of Madhya Pradesh. Case study of four main agriculture crops was also done for better understanding of production process and forecasting future growth trend. With the implementation of Man-Kendall test it was found that there is rise in temperature due to climate change. the aim of the research was to reduce loss of production in horticulture crops by providing detail understanding present as well as future of changing climatic conditions. (Sharma et al., 2022). Adaptation towards environment friendly and sustainable methods is becoming more and more important in gardening due to various ill effects of traditional horticulture methods such as soil erosion, water pollution & greenhouse emissions. The study examines the efficacy of different techniques which includes organic farming, integrated pest control, water conservation, soil health management and biodiversity improvement. It is revealed that environmentally friendly gardening methods results in lower input costs and more ecosystem benefits. But the broad use of these methods also has some hinderance and problems which needs to be resolved with help of providing proper guidance, financial support and training for the persons involved in gardening industry. (M. Kumar et al., 2023).

Research on sustainable resource management for the climate-smart 0.4-hectare Integrated Farming System (IFS) model was conducted at the College of Agriculture, Rewa, as part of an all-India initiative during 2021-2023. IFS model yielded a rice equivalent of 131.24 quintals, generating a gross return of Rs. 271,531, a net profit of Rs. 130,090, & a benefit-cost ratio i.e. 1.91. Dairy component, featuring two cows, produced a net profit of Rs. 86,933 and a benefit-cost ratio of 1.92. Among cropping systems, the okra and garlic combination achieved a benefit-cost ratio of 2.23, yielding a net profit of Rs. 8,066 from 0.02 hectares. Employment generation varied from 36 man-days in June to 51 in October, totalling 513 man-days annually. Monthly income ranged from Rs. 2,501 in June to Rs. 29,913 in April. The IFS model's self-reliance status was 89%, with green fodder at 27.39%, dry fodder at 41.87%, and concentrates for cattle. Additionally, vermicompost and compost units provided 36.1% of total nitrogen, 46.26% of total phosphorus, and met 95% of total potassium needs. (Mourya et al., 2024) Due to changes in climate, the growth and development of good quality fruits is severely affected because it increases pest evasions, altered flowering and also effects the geographic distribution, phenology & local abundance of plants and pollinators. One such example of weather change is low winter chills. To deal with this situation there is a need to develop heat & drought resistant crops by the researchers with the help of modern genetic & Production methods. (Lal et al., 2018)

Projected climate data (2071–2100) downscaled via the PRECIS model for seven stations in Gujarat indicate a 15–101% increase in annual rainfall compared to the 1961–1990 baseline. Maximum and minimum temperatures are expected to rise by 2.8–7.7°C and 3.8–5.2°C, respectively. Crop simulations using Info Crop and DSSAT models suggest significant yield reductions under future climate scenarios. Wheat shows the highest projected decline (up to 61%), while pearl millet is least affected (–8% to –14%). Maize is more vulnerable in the kharif season (–47%) than in rabi (–10%). (Patel et al., 2015) Adverse & ill effects of global warming such as uneven climate and accelerated warming can be seen across the India nowadays, especially in North Western India. The productivity & quality of horticulture crops is affected due to these. For minimizing losses in the horticulture sector there is need to focus on adoption of conservative agriculture, use of renewable energy, natural resources conservation, modification of present horticulture practices and by developing pest and variations resistant crops. (Bhati et al., 2018).

To counterattack the negative consequences of changing climatic conditions horticultural crops, have better advantage over other agriculture crops by providing better carbon trade &carbon silk. Smart horticulture, keeping a watch on carbon silk potential and crop-based strategies will help to provide a pathway to reduce climate change issues. (MALHOTRA et al., 2017) At both local and global scales, farmers decision-making process in response to climate change has gained a significant attention within the broader discourse of human-environment interactions. A study was conducted to explore the human dimension of adaptation decisions among farmers in rural India. Specifically, farmers' perceptions on climate change and the socio-economic determinants that influence both their decision to adapt and their choice of adaptation strategies. In a micro-level assessment involving 700 farmers across seven districts of Bihar, India. The data were analysed using descriptive statistics and logistic regression methods. Findings indicate that approximately 80% of the surveyed farmers perceive changes in climate and respond by adopting various adaptation measures. Key socio-economic factors—such as age, gender, household size, education level, farm income, and farm size—were found to significantly influence adaptation decisions. The insights from the study were highlighting critical household characteristics that should be considered to design and implement effective and inclusive climate adaptation strategies. (Jha & Gupta, 2021).

Majority of fruit crops are grown in open fields condition which makes them highly vulnerable to the impacts of climate change. Rise in temperatures adversely affect the establishment, growth, and yield of fruit crops. Physiological disorders such as spongy tissue in mangoes, fruit cracking in litchis, and flower/fruit abscission are likely to become more pronounced. Additionally, air pollution exacerbates certain disorders, including black tip in mangoes, while low winter temperatures can cause chilling injury in tropical fruits like bananas. To ensure the sustainability of these crops, it is crucial to adapt horticultural practices such as, increasing the use of greenhouse technologies, and developing hybrids or cultivars resistant to abiotic and biotic stresses. Adopting high-tech horticulture and optimizing resource management will be key strategies in mitigating the adversity of climate change in the production of fruit crop. (Reddy et al., 2016)

Production factors such as use of fertilizers and cultivated area deeply effect the horticulture crops, vegetables are one of them. To mitigate climate change and to improve vegetables supply in the market, there is a need of proper advisory services by government and policy makers and establishment of agriculture credit channels with the help of banks. By implementing these farmers will be able to get financial support to cope up with changing weather which can lead to increase in food production and food security in the nation. (Chandio et al., 2025) Changing climate or we can say environmental stress leads to decrease in irrigation water, rise in temperatures, flooding, salinity, reduction in soil moisture & increase in heat stress which causes negative effects like shortened growth period, reduction in yield & decline in quality of fruits and vegetables across the world. Due to these unpredictable climatic variations for example melting of ice caps in Himalayas, cultivation of horticulture crops has become unreliable and inconsistence in both quantity & quality. These challenges can be overcome by adopting improved management practices, increase use of greenhouse, modified cultivation techniques and developing crops which are heat resistant, pest resistant as well as provide high yields in short period of time. (Hirpo, 2019)

Being perishable and highly sensitive to the variations in climate horticulture crops are facing decrease in quantity and quality across the globe. This ill effect is also called as Abiotic Stress. Cracks & sun burns in apples, drying of cashew flower and hindrance in growth of roots in potatoes are adverse effects of temperature change. Not only this but due to recent climatic disasters across the globe has caused hug loss of yield in horticulture crops. For example, 1) 47.5% yield loss of vegetables & 40% of onions yield lost due to flooding in China .2) In Indian state of Kerala flooding caused huge loss of 25,138 tonnes of species, 80% tomato yield lost to TLM. bugs in banana and high amount of CO2 in coffee lead to quality degradation. (Muchie & Assefa, 2021).

III. RESEARCH QUESTIONS

- In what ways do Integrated Farming Systems enhance climate resilience in horticulture throughout India?
- What are the primary socio-economic and ecological advantages gained from IFS?
- What are the main obstacles to the adoption of IFS, and how can policy and practice address these challenges?

IV. OBJECTIVES

The objectives of the study are: -

1. To examine how Integrated Farming Systems (IFS) contribute to improving climate resilience in horticultural practices.
2. To evaluate the socio-economic and environmental advantages of IFS for smallholder and marginal farmers.
3. To recognize the obstacles to adoption and propose strategies for the successful implementation of IFS in India.

V. RESEARCH METHODOLOGY

The study is a phenomenal and descriptive research in nature which aims to describe a population, situation, or phenomenon in a very systematically accurate manner. The main focus of this research is on "what" of a subject rather than the "why" or "how." It is mainly used to gather information about current conditions without altering the environment or making any assumptions for the same.

In this study secondary data is used which is derived from reputable and credible sources only. The details of various sources are mentioned below:

1. Government Reports and Publications:

- Data from the Ministry of Agriculture and Farmers Welfare, GOI

- Reports of the Department of Horticulture, National Horticulture Board (NHB), and the Indian Council of Agricultural Research (ICAR).

2. Research Studies:

- Academic papers, theses, and dissertations related to Integrated Farming Systems (IFS) and horticulture crop productivity for past 10 years.

3. International Organizations:

- Data from organizations such as the FAO (Food and Agriculture Organization) and the World Bank on farming systems, climate change, and agricultural sustainability in India.

4. Industry Reports:

- Reports from market research firms, agricultural industry bodies, and non-governmental organizations (NGOs) focused on sustainable farming and rural development.

5. Statistical Databases:

- National Sample Survey Office (NSSO) data, National Agricultural Survey (NAS), and other relevant databases.

6. Climate Data:

- Data from meteorological agencies and climate prediction centres.

VI. DISCUSSION

To minimize the adverse effects of the present unpredictable weather and variations in climatic conditions on horticulture crops Integrated Farming Systems (IFS) provides a reliable and strategic remedy.

Key contributions of IFS include:

- Economic Resilience by enabling multiple income streams, IFS cushions farmers against the failure of only crop which leads to failure of only source of income.
- Resource Optimization by promoting organic waste recycle and converting it into productive resources which reduces environmental contamination.
- Increase in Soil Health by adopting organic practices like vermicomposting & green manuring to restore soil structure & improve microbial activity.
- Climate Adaptation through practices like agroforestry which offer shade and windbreaks, and rainwater harvesting to supports irrigation during dry spells.
- Pest and Disease Control by promoting natural pest control and maintaining ecological balance.
- Environmental Protection through reduction in chemical inputs which helps in biodiversity conservation, and improved carbon sequestration contribute to ecological stability.

The successful adoption of Integrated Farming System (IFS) models by farmers requires careful planning, resource management, technical know-how, and strong support systems. This can be achieved by implementing proper strategic planning which has the following components:

1. Training and Capacity Building:

This provides technical knowledge and practical skills to farmers to manage various components of IFS with help of

- Farmers' Training Programs
- Workshops and Demonstrations
- Farmer Field Schools (FFS)

2. Financial and Policy Support:

This help farmers to reduce their financial burden by providing the required finance assistance as per the needs of the farmers, which will also help in increasing productivity in long run. Below are the ways thorough which farmers can be provided support.

- Subsidies and Grants by the Government or private agencies.
- Micro-Credit for Farmers for small-scale farmers to buy inputs like seeds, equipment, and livestock.
- Insurance Schemes for crops and livestock
- Subsidized Inputs such as organic fertilizers, pest management tools, and other critical resources.

3. Resource Optimization and Sustainable Practices:

This will help the farmers to reduce the use of chemical inputs which will lead to natural resource conservation. Some methods which can be used are as follows:

- Adoption of Water Conservation Techniques such as rainwater harvesting systems, using drip irrigation or sprinkler systems and aquaculture ponds.
- Soil Health Management by using crop rotation, green manuring, and vermicomposting, bio-fertilizers, and crop residues as natural nutrients for the soil.
- Waste Recycling through using animal manure for biogas production or as organic fertilizer for crops and crop residues as fodder for livestock
- Implement multi-layer agroforestry systems, such as integrating fruit trees and timber species with crops and livestock.

4. Diversification and Risk Management:

Reduction in risk of losses due to market fluctuations or weather-induced crop failure can be done through diversified sources of income which will help farmers, especially small farmers to improve economic resilience. Some most used methods are:

- Crop and Livestock Diversification:
- Integration of Aquaculture and Livestock:
- Risk Mitigation through Agroforestry:

5. Infrastructure Development to ensure smooth IFS operations. This can be done by the following ways:

- Establishment of efficient irrigation systems such as drip, sprinkler, or rainwater harvesting to ensure water supply.
- By providing farmers with low-cost yet effective housing for poultry, dairy cattle, and goats.
- Development of fish ponds or tanks integrated with crop fields. Farmers can use pond water for irrigation and grow crops on raised beds around the pond.
- Establishment of biogas plants to convert organic waste into energy for cooking and heating, and the slurry can be used as organic fertilizer.

6. Technological Interventions and Innovation:

With the help of data driven and technology-enabled practices farmers can increase productivity and profitability. Some ways are as follows:

- To encourage farmers for adopting digital tools and mobile applications to gather information about weather forecasting, market price information, and crop management guidance.
- To increase the use of smart sensors to monitor soil health, water levels, and plant growth.
- Implementation of precision farming technologies, such as drones, GPS mapping, and remote sensing, to enhance productivity and efficient use of resources.

- Use of Integrated Pest Management (IPM) and eco-friendly pest management practices, to reduce reliance on chemical pesticides.

7. Market Linkages and Value Addition:

To gain better prices for farmers, increase value of their produce and to Improve farmers' access to markets in rural areas following ways can be adopted: -

- Encouraging farmers to form cooperatives or farmer producer organizations (FPOs) to collectively market and sell their produce, which will improve their bargaining power.
- Promotion of more processing units for crops such as fruits (e.g., making jams, juices), dairy (e.g., making cheese), and mushrooms (e.g., drying or canning).
- To provide cold storage facilities for perishable products, especially in horticulture and dairy.
- Establishment of direct sales channels, such as farmer markets, online platforms, or community-supported agriculture (CSA) models, to bypass middlemen.

Few Case Studies that showcase the successful implementation of Integrated Farming Systems (IFS) in India are stated below:

1. Chhindwara, Madhya Pradesh – Organic Cotton and Diversified Farming:

With WWF's assistance, the SRIJAN organisation in Chhindwara helped 6,000 farmers switch from traditional GMO cotton production to organic methods. Cotton, orange trees, millet, wheat, corn, millet, vegetables and cattle were all part of the integrated system. Even though the production was initially lower, this method enhanced soil health, decreased input costs, and raised profitability. In order to facilitate irrigation during dry spells, water retention facilities were also put in place. This allowed for several harvests and decreased labour migration.

2. Champawat District, Uttarakhand – Multi-Component IFS Model:

A farmer in the Champawat area used an IFS model on a 1-hectare plot of land, combining the production of fish, dairy, poultry, vegetables, orchards, bees, and mushrooms. A benefit-cost ratio of 3.08 and a gross revenue of ₹6,94,000 were the outcomes of this diversified strategy. Additionally, for eight months per year, the system guaranteed the household's food and nutritional security.

3. Muzaffarnagar, Uttar Pradesh – Crop-Livestock Integration:

Compared to monoculture, integrating crops with dairy, horticultural, and goat husbandry increased system yields by 58.89% to 86.17%, according to four-year research conducted in the Muzaffarnagar area with 1,036 families. Improved fodder supply and the introduction of exotic crops raised net returns per hectare from ₹60,000 to ₹2,20,000. Furthermore, a season's worth of household costs were cut by $20 to $27 thanks to healthy kitchen gardening.

4. Modipuram, Uttar Pradesh – Diversified IFS Model:

An IFS model combining crops, dairy, horticulture, aquaculture, mushroom production, and border plants on 1.38 hectares at the Indian Institute of Farming Systems Research (ICAR) at Modipuram produced net yearly returns of ₹5,50,090 with a benefit-cost ratio of 3.42. Through excess production of grains, fruits, milk, fish, and mushrooms, this approach also improved food and nutritional security and produced 34% more man-days of annual employment.

5. Koraput, Odisha – Rice-Fish-Poultry System:

An IFS model integrating rice, fish, ducks, veggies, and fruit trees was put into practice by a tribal farmer in Koraput. When compared to traditional ways, this integrated approach tripled income. Additionally, the approach improved sustainability and output by using ducks to aerate and eliminate pests in fish ponds.

6. Kuttanad, Kerala – Rice-Fish and Coconut-Based IFS:

With benefit-cost ratios of 2.63 and 2.86, respectively, the rice-fish and coconut-banana-dairy-poultry-goat systems were determined to be extremely lucrative in Kuttanad. Increased net returns from resource allocation optimisation in these systems showed how integrated techniques could result in higher income.

7. Bidar, Karnataka – Horticulture-Based IFS:

In Bidar, the adoption of IFS resulted in a change from conventional crops to horticultural varieties. Farmers growing plants such as papaya, marigold, watermelon, onion, chili, and brinjal experienced increased net earnings per acre, with papaya achieving the highest profit at ₹1,10,988 per acre. This change also enhanced soil fertility and lowered input expenses.

8. Karaikal, Puducherry – Livestock and Crop Integration:

In Karaikal, an Integrated Farming System (IFS) that combines livestock, crops, and waste management showed a benefit-cost ratio of 1.75. This approach boosted productivity, optimized resource use, and increased food production, aiding small and marginal farmers in achieving income stability and nutritional security.

9. Gariyaband, Chhattisgarh – Rainfed vs. Irrigated IFS Models:

A research project conducted in Gariyaband analyzed Integrated Farming System (IFS) models in both rainfed and irrigated environments. The irrigated model over 1.5 acres demonstrated greater profitability, yielding higher net returns and enhanced employment generation potential when compared to the rainfed model occupying 3.5 acres, underlining the significance of water access in the success of IFS.

10. Integrated Farming System (IFS) in Andhra Pradesh – Sree Sairam Integrated Farming System Model:

In the Andhra Pradesh area, smallholder farmers have historically relied on monoculture cropping practices. The Sree Sairam Integrated Farming System (IFS) model was implemented, which incorporates Crop cultivation, Livestock, Aquaculture, Agroforestry, and Agro-processing. The IFS model resulted in enhanced farm income, offering year-round profits from its diverse components.

VII. FINDINGS

This research reveals that due to some constraints the Indian farmers are still hesitant to adopt IFS and they need more knowledge and awareness to overcome this resistance. Some major challenges are:

- Climate change causes extreme weather, erratic rainfall, and rising temperatures.
- Global climate stress reduces water availability, yield, and crop quality.
- Integrated Farming Systems (IFS) enhance sustainability and profitability.
- IFS models show high resource efficiency and employment generation.
- Farmers in India are slowly adopting IFS methods.
- Lack of knowledge and awareness among the farmers about the different IFS methods and ways to use them.
- Lack of ease in loan taking and credit facilities for farmers
- Lack of proper transport and storage facilities especially for perishable commodities.
- Small land holdings by majority of farmers which leads to financial incapability to adopt something new.
- Dependence on Traditional agriculture practices by the farmers
- Lack of knowledge about different government policies, schemes and programmes to promote sustainable agriculture development in India.
- Lack of timely availability of various inputs required.
- Major loss of crops is also seen worldwide due to unpredictable weather events.

VIII. SUGGESTIONS

On the basis of the study, here are few suggestions which can help to better implementation of Integrated Farming System in India: -

- Promotion of climate-resilient horticulture methods, through awareness campaigns, farmer training, and field demonstrations should be held by the central and state government in villages as well as taluka levels with the help of NGO and other cooperative societies to educate the Indian farmers.

- Expand adoption of IFS by showcasing success stories and offering region-specific models for small and marginal farmers.
- A contingent planning is required to be prepared to deal wisely with changing climate/weather threats by Developing early warning systems and crop insurance schemes to protect farmers from losses due to unpredictable weather.
- The government should provide more financial aids to the farmers for adopting IFS and other Sustainable farming practicing. They should also improve access to institutional credit and subsidies with simplified loan procedures and financial literacy programs.
- Increase awareness about government schemes through local extension services, farmer help desks, and digital platforms.
- More emphasis should be laid on new research to find to more economical and feasible methods in modern sustainable farming practices by introducing farmers to innovative tools, techniques, and climate-smart technologies.
- Ensure timely supply of all necessary inputs required farmers in implementation of IFS methods.
- Tailored IFS Models or Region-specific models should be adopted by considering agro-climatic conditions, dominant crops, and socio-economic contexts of the area.
- Strengthening local and export markets for diversified IFS products.
- To increase the usage of ICT tools, mobile advisory services, and climate data for improvement in decision-making and resource planning at the farm level.

Above stated suggestions will help to increase number of farmers adopting Integrated Farming System India as well as will help to attain the futuristic goal of our nation, which is: Sustainability as a whole.

IX. CONCLUSION

The study highlights that climate change effects like rise in temperature, erratic rainfall, significantly and extreme weather events significantly affects horticulture crops which leads to loss of farmers livelihood. Integrated Farming methods have full potential in improving resilience to climate change and farmers are also slowly adopting different methods of IFS but are facing challenges of limited resources, lack of proper training and lack of credit facility. Therefore, to unlock the full potential of IFS, a collaborative approach involving government, scientists, and communities is essential. The goal of a climate-resilient agricultural system for long-term sustainability and food security will also be achieved through this.

X. LIMITATIONS

Although the study provides a brief idea about the effects of changing climatic conditions on horticulture crops of the nation and how the implementation of integrated Farming System techniques is helping the farmers to minimizes their losses, but this study also has its certain limitation, which is: It is mainly based on the secondary data and therefore it lacks the data about the current situation, so more primary data will be required for further studies in this field to find out real time solution.

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Evaluation of Root Traits for Water Stress Tolerance in Rabi Sorghum Genotypes

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Abstract— *The experiment was conducted for evaluation of nineteen sorghum genotypes for their varying degree of drought tolerance by studying their root system architecture. The genotypes were grown in 'Phule Root Box' structure one of which maintained with drought stress and other received regular irrigation considered as control. Root system architecture changes were recorded at post anthesis stage by studying the root profile. The responses under drought stress found increase in root length, root shoot ratio, decreased in root length density, root volume, root diameter, fresh root weight and root number. The genotypes RSV 2408, RSV 2371 and Phule Anuradha showed better performance in root traits such as increased root length, root shoot ratio, better root length density, fresh root weight and decreased root diameter. Considering the overall performance of root traits, the genotype RSV 2408, RSV2371 and Phule Anuradha could be selected as drought tolerant genotypes for their further utilization in crop improvement program.*

Keywords— Sorghum, Rabi sorghum, Drought tolerance, Water stress, Root traits, Root length, Root-shoot ratio, Root volume, Root diameter, Root biomass, Crop improvement, Stress adaptation.

I. INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the most important multipurpose cereal crops cultivated in tropical and subtropical regions of the world. Being a C_4 crop plant, it plays an essential role in feed, food, and fodder security in dry land agriculture (Chapke and Tonapi, 2019). India is the fifth largest producer of sorghum in the world with total production of 4.7 MT from its 4.8 million hectares of area (USDA, 2020). However the average yields of 1050 kg ha^{-1} is very low among the major sorghum producing countries. Among the sorghum producing state, Maharashtra is the leading state in sorghum production with the production of 2.15 MT from the area of 2.28 million hectares and the productivity of 941kg ha^{-1} during 2021-22 (ESM, 2022-23). Drought stress causes major losses in agricultural productivity every year (Ahluwalia *et al.*, 2021). The early vegetative stage and reproductive stage (pre and post flowering) of sorghum are vulnerable to the effects of water deficit (Wani *et al.*, 2013). In response to drought stress, plants undergo several physiological and morphological modifications like reduced transpiration and photosynthesis rate, osmotic adjustments, repressed root and shoot growth, overproduction of reactive oxygen species (ROS), modified stress signaling pathways, and senescence. These modifications can cause

permanent injury to the plants (Ahluwalia et al., 2021). In order to acclimate to water shortage, plants adjust their growth and development to promote water absorption and reduce water loss (Zheng *et al*. 2016; Kim *et al*. 2020). Root response is of prime importance to crop productivity under drought stress. This is because the root size, architecture and distribution determine the ability of plants to access and uptake the water for proper physiological functioning of shoots (Taiwo *et al.,* 2020; Henry 2013; Comas *et al.,* 2013). Drought stress adapted plants are often characterized by deep and vigorous root systems. Water uptake capacity of roots can be estimated by root parameters including root biomass, root volume, primary root length, lateral root number, root depth, and root length distribution (Meng, 2018). Generally, under drought conditions, plants trigger several phenomena to generate more developed root systems and a higher root to shoot ratio. This is evidenced by a more pronounced restriction of shoot production than root production in plants under water deficit (Zheng *et al*. 2016; Du *et al*. 2020). Sorghum grown in arid and semiarid parts of the tropics and subtropics are frequently prone to drought accompanied with water stress and high temperature stress in plants affecting various growth stages (Reddy et al., 2012). Therefore, the better water stress tolerant genotypes are desired in such a region to reduce the crop failure due to water deficit problem. The most drought tolerant and susceptible genotypes could be used in hybridization programmes to increase genetic variability and the selection criteria used under water stress for drought tolerance in sorghum could be higher root length, shoot length with lower leaf water potential, osmotic potential, and turgor pressure (Bibi *et al*., 2012). Keeping in consideration the above facts, an attempt has been made on different sorghum genotypes for water stress tolerance by studying and investigating the root architecture system of the sorghum genotypes.

II. MATERIAL AND METHODS

Plant material and growth condition

The seeds of nineteen *rabi* sorghum genotypes were obtained from the All India Coordinated Sorghum Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri. A field experiment was carried out at All India Coordinated Sorghum Improvement project, MPKV, Rahuri during *rabi* season 2021-22 to study physiological root traits in "Phule Root Box" structure under limiting water condition. Two replications of the experiment were carried out using a randomized block design. Nineteen genotypes of rabi sorghum were planted with a 45 x 15 cm spacing and optimal soil moisture levels. Every recommended cultural and agronomic practice was followed. One plot was treated as an unstressed control and was irrigated 17, 27, 49, and 63 days after seeding, whereas another plot that did not give irrigation was treated as a stressed plot. In order to maintain the water stress condition during unseasonal rain the root boxes were protected under rainout shelter. At post flowering stage, five plants were randomly selected from each genotypes and physiological study of roots were conducted for measurements of root length, root volume, root length density, fresh root weight, number of roots, root shoot ratio, and root diameter.

III. RESULTS AND DISCUSSION

The sorghum genotypes grown under water stress condition resulted in the considerable variation in overall growth as compared to that of unstressed condition (Table 1).

TABLE 1

ANALYSIS OF VARIANCE OF NINETEEN SORGHUM GENOTYPES FOR SEVEN ROOT PARAMETERS UNDER DROUGHT AND NORMAL CONDITION

Genotypes	Root Length (cm)		Root volume (ml)		Root Length Density (cm cm^{-1})		Root Diameter (mm)		Fresh Root Weight (g)		Root Count		Root Shoot Ratio	
	Control	stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress
RSV 2408	53.33	72.33	96	73.33	0.164	0.121	3.12	2.63	128.33	86.67	46.33	37.67	0.26	0.31
RSV 1850	53.67	71	161	88.33	0.174	0.11	3.68	3.5	147.67	101.33	52.33	37.33	0.28	0.33
RSV 1876	56.67	62	138.33	76	0.159	0.11	3.79	2.99	125.67	78.67	52.33	35.67	0.25	0.29
RSV1945	60.33	71.33	165	63.33	0.171	0.104	3.6	2.69	178.33	76.67	51.33	32.67	0.29	0.31
RSV 2371	56.67	63.33	113.33	80.33	0.153	0.121	3.3	2.35	133.33	97.67	46.67	39.33	0.2	0.3
CRS 89	67	73.33	126	71	0.184	0.116	2.66	2.61	140.67	68.67	51.67	35.33	0.27	0.37
CRS 93	59.33	65	103.33	64.33	0.181	0.123	2.42	2.2	143.33	76.33	54.67	34.67	0.23	0.31
CRS 95	48	55.33	98.33	63.33	0.153	0.119	2.8	2.38	135.67	103.67	49	41.67	0.21	0.23
CRS 98	55.33	66	141	68.33	0.169	0.111	3.54	2.75	165.67	89	47.67	36.33	0.26	0.29
CRS 99	55.67	68.33	136	53.33	0.162	0.097	3.25	2.48	143.33	97	45.67	33.33	0.27	0.29
VJP 2704	62.67	68.67	123.33	53.33	0.145	0.11	3.22	2.36	119	90.67	41.33	33.67	0.24	0.3
VJP 2705	56.67	63.33	113.33	73.33	0.133	0.104	3.6	3.14	166.67	91.33	39.67	31.67	0.23	0.28
RNTN 13-39	56	64	138.33	68.33	0.163	0.132	3.38	2.5	158.33	96.67	48.67	41.67	0.25	0.29
RNTN 141	48.67	53.33	125.67	52.33	0.171	0.099	3.11	2.38	145.67	69.33	52.33	33.67	0.22	0.26
RNTN 142	49.67	55	110.67	58.33	0.167	0.107	2.84	2.45	103.33	76.33	52.33	35.67	0.2	0.25
RNTN 143	56.33	67.67	93.33	65.67	0.173	0.125	2.33	2.25	98.33	79	50.33	39	0.26	0.3
M-35-1 (C)	44.33	53.67	108.33	61.67	0.152	0.098	3.18	2.42	113.33	85.67	47	37.67	0.22	0.25
Phule Suchitra (C)	46.67	53.33	116	78.33	0.161	0.103	3.2	3.04	128.33	84.33	50.67	34.67	0.21	0.28
Phule Anuradha(C)	50.67	71.67	83.33	58.33	0.144	0.102	3.07	2.32	108.33	88.33	42.67	35.67	0.23	0.31
Mean	54.61	64.14	120.56	66.91	0.162	0.111	3.16	2.6	133.33	85.93	48.56	36.18	0.24	0.29
SEm (±)	1.34	1.42	3.39	1.71	0.005	0.005	0.03	0.11	2.54	3.13	0.98	1.17	0.002	0.006
CD at 5%	3.83	4.06	9.74	4.89	0.015	0.015	0.08	0.31	7.27	8.58	2.82	3.34	0.007	0.018

It was observed that the root architecture were significantly altered which is the important attributes for drought avoidance mechanism in plants. The sorghum genotypes Phule Anuradha and RSV 2408 recorded maximum increase in root length by 41.44 percent and 35.63 percent respectively under water stress over control. The genotypes RSV 2408 (72.33 cm) and CRS 89 (73.33 cm) recorded higher root length than the standard check Phule Anuradha (71.67 cm). The similar result was reported in sorghum with higher root length in CRS 67(56 cm) over the standard check M 35-1 (40.67 cm) under water stress condition (Kiran *et al*. 2022). Shinde *et al*. (2017) observed the positive correlation between root length and grain yield of sorghum genotypes under moisture stress. The genotypes RSV 1850 recorded the highest volume of 88.33 ml plant^{-1} under water stress condition. However, the genotypes RSV 2408 showed the lowest percent decline in root volume by 23.6 percent followed by RSV 2371, RNTN 143 and Phule Anuradha. The results were in accordance with the findings by Vinodhana and Ganeshmurthy (2010). Gadakh *et al*. (2021) observed the positive correlation between root volume and dry fodder yield concluding that fresh root mass and root volume at maturity plays an important role for higher dry fodder yield in *rabi* sorghum genotypes under rainfed condition. The genotypes RNTN 1339 and RSV 2371 found the minimum percent decline in root length density with 19.02 and 20.92 percent respectively. The genotypes RNTN 141 recorded the highest 42.11 percent decline in root length density. The better root length density in the active root zone area up to 30 cm depth improved the uptake of water as well as nutrients which ultimately resulted in higher yield in chickpea grown under water deficit condition (Varshney *et al*., 2011). The mean root diameter for control and stressed condition was 3.16 mm and 2.60 mm respectively which indicate that there was mean reduction of 17.22 percent in water stress condition. The highest decline of 28.79 percent in root diameter was observed in RSV 2371 followed by VJP 2704 and RNTN 1339. The reduction in root diameter has been previously recorded as a trait for increasing plants acquisition for water and productivity under drought stress (Wasson *et al*., 2012). Dorbnitch *et al*. (2021) observed the association of greater root pressure with greater proportional investment in fine root length. The genotypes Phule Anuradha, RNTN 143 showed lowest decline in fresh root weight under drought stress by 18.46 percent and 19.66 per cent respectively. The genotypes RSV 1945, RNTN 141 and CRS 89 showed the significant decline in root weight by 57.01 per cent, 52.41 per cent, and 51.18 per cent respectively. Silva *et al*. (2016) observed the positive correlation of 0.457 between fresh root matters with grain yield. Goche et *al*. (2020). There was 24.77 percent reduction in mean root count in stress condition. The root number was significantly decreased by 36.58 percent and 36.53 percent in CRS 93 and RSV 1945 respectively. However, RNTN 1339 and CRS 95 showed the lowest decline of 14.38 percent and 14.96 percent respectively under water stress condition. Similar result was recorded by Gano *et al*. (2021) with reduction in number of root from mean 44.03 in well watered condition to 26.83 in drought stress condition in ten elite sorghum varieties. Shinde *et al*. 2017 observed a positive correlation between mean number of roots and grain yield in *rabi* sorghum genotypes under receding soil moisture condition. The genotype RSV 2371 showed the highest increase in root shoot ratio by 50 percent followed by CRS 95 and CRS 98. Fadoul *et al*. (2018) recorded shorter root and shoot length of drought sensitive sorghum cultivar than the drought tolerant cultivars. Ali *et al*. (2009) found that root to shoot ratio based on length was ranged from 0.119 to 0.375 at post anthesis stage in sorghum.

IV. CONCLUSION

The sorghum genotypes grown under water stress condition resulted in the considerable variation in overall root architecture under water stress which is the important attributes for drought avoidance mechanism in plants. Most of the sorghum genotypes under water stress modified their root system in order to combat the negative impact of drought stress. Longer the roots deeper it goes for more water extraction. The strongly hold water by soil particles can be better absorbed by this finer roots with smaller diameter would show the better drought tolerance. Considering the overall performance of root traits, the genotype

RSV 2408, RSV2371 and Phule Anuradha could be selected as drought tolerant one for their further utilization in crop improvement program.

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Nutrient Uptake and Quality of Finger Millet as Influenced by Organic Nutrient Management

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Abstract— *A field experiment was conducted during rabi2023-24 at Agricultural College Farm, Naira, Acharya N.G. Ranga Agricultural University, Andhra Pradesh. The experiment was laid out in a split-plot design and replicated thrice. The finger millet variety Indravathi (CFMV 1) was tested in the present experiment. Application of 100% RDF (60:30:30 NPK kg ha^{-1}) recorded significantly higher nutrient uptake by plant, straw and grain over the rest of the nutrient treatments. Among the organic nutrient foliar sprays, foliar application of Panchagavya spraying twice @ 3% at tillering and flowering stages was found to be the best over other three organic foliar sprays tried under organic finger millet cultivation. Application of 100% RDN through Poultry manure (M_3) recorded significantly higher soil microbial population i.e., total count of bacteria, fungi and actinomycetes, which was however comparable with application of 50% RDF (NPK kg ha^{-1}) + 50% RDN through Poultry manure (M_2). Among the foliar sprays, application of Liquid Azospirillum+ PSB+ KRB+ ZnSB@1.25L ha^{-1}biofertilizer consortium by root dipping at transplanting (S_1) recorded. Significantly the highest protein content in grain was recorded with the application of 100% RDF (60:30:30 NPK kg ha^{-1})(M_1), which was superior over the rest of treatments applied and the lowest protein content was recorded with application of 100% RDN through Poultry manure (M_3).*

Keywords— Recommended dose of nitrogen, Poultry manure, Finger millet, Vermiwash and Panchagavya, Dry matter production.

I. INTRODUCTION

Millet crops are indigenous to India and are often referred to as "Nutri-Cereals" because they provide essential nutrients vital for proper bodily function. India, particularly the semi-arid regions including Andhra Pradesh, has long been a hub for millet production. Finger millet, also known as ragi, holds particular importance as a staple food and a dryland crop. It has been part of the diet in India for thousands of years, and its cultivation continues to support agricultural systems, especially in areas where other crops may struggle due to water scarcity and poor soil conditions (Tripathi *et al.,* 2023).

Finger millet is a key small millet crop, predominantly cultivated in regions with erratic rainfall and marginal soils. In India, Finger milletis the third most important millet, next to sorghum and pearl millet, grown over an area of 10.37 lakh hectares with an annual production of 13.86 lakh tonnes and productivity of 1336 kg ha^{-1}. Karnataka is the leading Finger millet producer in India followed by Tamilnadu and Maharashtra states. In Andhra Pradesh, it is cultivated in an area of 27,000 hectares with a production of 33,000 tonnes having productivity of 1222 kg ha^{-1} (Directorate of Agriculture and Farmers' Welfare, 2023-24).

Organic farming, which prohibits the use of synthetic fertilizers and chemicals, offers an alternative approach. In organic systems, crop nutrient requirements are met through organic inputs and biological processes. This method prioritizes the restoration and maintenance of soil fertility and health, promoting sustainability over the long term. Farmers are increasingly recognizing the benefits of organic farming in terms of improved soil quality, enhanced sustainability and long-term productivity. By diversifying and making better use of these resources, farmers can improve soil fertility, reduce dependence on external inputs and move towards more sustainable farming systems.

To address the slow release of nutrients from bulky organic manures, foliar nutrition offers an effective solution by providing nutrients directly to the site of metabolism. This allows for the translocation of nutrients during peak periods of crop growth, promoting more efficient absorption through the leaves, where plants are often able to absorb nutrients more effectively than through their roots. As a result, organic foliar supplementation is considered safe for crops (Sujatha*et al.,* 2016). Various types of foliar sprays, such as vermiwash, panchagavya and jeevamrutham have proven to be excellent means of addressing micronutrient deficiencies in organic farming. Additionally, they contain a diverse range of micro-organisms that not only support plant growth but also help restore soil fertility by activating biological reactions. This microbial diversity in the foliar sprays acts as a plant growth stimulant, enhancing crop productivity and resilience (Swaminathan, 2005 & Sreenivasa *et al.,* 2011).

II. MATERIALS AND METHODS

A field experiment was conducted during *rabi*2023-24 at Agricultural College Farm, Naira, Acharya N.G. Ranga Agricultural University, Andhra Pradesh. The soils of the experimental site were sandy clay loam in texture, neutral in reaction, low in organic carbon (0.49%) and available nitrogen (221 kg ha^{-1}), medium in phosphorus (22.7 kg ha^{-1}) and potassium (245 kg ha^{-1}) having 7.2soil pH with EC 0.25 dSm^{-1}.

The experiment was laid out in a split-plot design and replicated thrice. The treatments consisted of three (inorganic and organic) nutrient sources *viz*M_1: 100% RDF (60:30:30 NPK kgha^{-1}), M_2: 50% RDF (NPK kg ha^{-1}) + 50% RDN through Poultry manure and M_3: 100% RDN through Poultry manure assigned to main plots, four foliar sprays *viz.,* S_1: Liquid *Azospirillum*+PSB+KRB+ZnSB@1.25 L ha^{-1}biofertilizer consortium by root dipping at transplanting, S_2: Vermiwash spraying twice @ 5% at tillering and flowering stages, S_3: Panchagavya spraying twice @ 3% at tillering and flowering stages andS_4: Jeevamrutham spraying twice @ 10% at tillering and PI stages were allotted to sub plots. The finger millet variety Indravathi (CFMV 1) was tested in the present experiment. The total cost of cultivation of finger millet (Rsha^{-1}) was calculated for treatment on the basis of inputs used. Gross returns (Rsha^{-1}) were computed by considering the prevailing market price of the output. Net returns (Rsha^{-1}) were arrived at by deducting the cost of cultivation of respective treatments from gross returns for the corresponding treatments.

The data recorded on various parameters of finger millet was analyzed statistically by following the analysis of variance for split-plot design as suggested by Panse and Sukhatme (1985). Statistical significance was tested with 'F' test at 5 per cent level of probability and whenever the 'F' value was found significant, critical difference (CD) was worked out at 5 per cent level of probability the treatment means were compared with critical difference.

III. RESULTS AND DISCUSSION

Nutrient uptake of finger millet recorded at 60 DAT and at harvest was significantly influenced by various organic, inorganic sources and foliar sprays. Nutrient uptake of finger millet inclined to increase steadily with advance in the age of the crop up to harvest. The trend of nutrient uptake in response to organic nutrient management practices was similar at all the stages of observations. During the study, among the organic and inorganic sources, significantly the highest nutrient (nitrogen,

phosphorus and potassium) uptake by plant was observed with application of 100% RDF (60:30:30 NPK kg ha^{-1}) (M_1). Application of 50% RDF (NPK kg ha^{-1}) + 50% RDN through Poultry manure (M_2) is the next best nutrient uptake treatment and was comparable with each other. The lowest nutrient uptake was recorded with application of100% RDN- Poultry manure (M_3). The higher nutrient uptake in inorganic treated plots is due to the higher availability when compared to the organic plot. The uptake of nitrogen and zinc were found significantly high in conventional plot when compared to organic plot. This could be primarily due to increased availability of the nutrients in the crop root zone resulted in increased absorption of the elements by the plants as well as higher dry matter production.

Among the foliar sprays, significantly the highest nutrient uptake was observed with Panchagavya spraying twice @ 3% at tillering and flowering stages (S_3) followed by Vermiwash spraying twice @ 5% at tillering and flowering stages(S_2), which was however comparable with Jeevamrutham spraying twice @ 10% at tillering and PI stages (S_4). Significantly the lowest nutrient uptake was noticed with Liquid *Azospirillum*+PSB+KRB+ZnSB@1.25 L ha^{-1}biofertilizer consortium by root dipping at transplanting (S_1). The increase in uptake of nutrients with inorganic fertilizers might be due to better availability of nutrient which leads to increase nutrient uptake. This could be ascribed primarily due to increased availability of the nutrients in the crop root zone that resulted in increased absorption of the elements by the plants as well as higher dry matter production. These results are in line with the Singh *et al. (*2009) and Vajantha *et al*. (2017).

The N uptake by grain was significantly higher with inorganic treated plot than organic plot. The P, K and Zn uptake by grain and protein content were significantly affected by organic and inorganic treatments. The higher nutrient uptake with inorganic fertilizers may be due to high nutrient in grain coupled with higher grain yield (Somasundarm *et al*. 2020 and Vajantha *et al*. 2017). The elevated uptake of N, P and K may be due to enhanced biological efficiency in crop plants with foliar spray of panchagavya, and jeevamrut creating a more significant source and sink in the plant system, that leads to better nutrient uptake. Above findings are in conformity with Sonawane *et al*. (2024).

Significantly the higher Zn uptake was observed with 50% RDF (NPK kg ha^{-1}) + 50% RDN through Poultry manure and is at par with the application of 100% RDF (60:30:30 NPK kg ha^{-1}). The lowest Zn uptake was noticed with 100% RDN through Poultry manure at 60 DAT and harvest. Among foliar sprays highest Zn uptake was recorded with the application of Panchagavya spraying twice @ 3% at tillering and flowering stages and it was on par with Vermi wash spraying twice @ 5% at tillering and flowering stages and Jeevamrutham spraying twice @ 10% at tillering and PI stages at both 60 DAT and harvest.

The highest nutrient (nitrogen, phosphorus, potassium and Zn) uptake by grain and straw was significantly observed with application of 100% RDF (60:30:30 NPK kg ha^{-1}) (M_1). Application of 50% RDF (NPK kg ha^{-1}) + 50% RDN through Poultry manure (M_2) is the next best nutrient uptake treatment and was comparable with each other. Among the foliar sprays, significantly the highest nutrient uptake (NPK and Zn) was observed with Panchagavya spraying twice @ 3% at tillering and flowering stages (S_3) followed by Vermiwash spraying twice @ 5% at tillering and flowering stages(S_2), which was however comparable with Jeevamrutham spraying twice @ 10% at tillering and PI stages(S4). Significantly the lowest nutrient uptake was noticed with Liquid *Azospirillum*+PSB+KRB+ZnSB@1.2 L ha^{-1}biofertilizer consortium by root dipping at transplanting (S_1). The yield obtained could be attributed to the combined impact of growth attributes and favorable yield characteristics when provided with sufficient nutrients by organic and inorganic nutrient sources. This encourages the photosynthesis and eventually better partitioning to the sink. These findings are in accordance with Sonewane *et al*. (2024). The possible reasons for increase in nutrient content and uptake by finger millet may be due to ready assimilation of plant nutrients by crop, these plant liquid organics also contain different plant growth promoting substances which results in good crop growth. These findings are in close agreement with those reported by Dholariya *et al.* (2022).

TABLE 1

N PK Zn uptake (Kg ha^{-1}) by plant at maturity and N P K Zn uptake (Kg ha^{-1}) by grain and straw by finger millet as influenced by different organic, inorganic sources and foliar sprays

Treatments	Uptake by plant at maturity				Uptake by grain and straw							
	N	P	K	Zn	N		P		K		Zn	
Fertilizer levels (RDF:60:30:30 kg ha^{-1})					Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
M_1: 100% RDF (60:30:30 NPK kg ha^{-1})	105.5	32.9	109.6	156.6	52.1	48.2	14.3	11.4	40.7	65.6	67.2	94.3
M_2: 50% RDF (NPK kg ha^{-1}) + 50% RDN through Poultry manure	104.4	30	106.6	178.1	49.7	45.5	13.7	10.2	38.4	60.8	62.2	93.1
M_3: 100% RDN through Poultry manure	76	28.9	95.8	148.9	37.6	37.5	11.4	9.1	36.6	50.7	61.2	84.9
SEm (±)	2.4	0.79	2.65	4.71	1.1	1.18	0.33	0.2	0.7	1.1	1.1	1.7
CD *(p=0.05)*	9.5	3.1	10.4	18.4	4.5	4.6	1.2	1.1	2.7	4.5	4.4	6.7
CV (%)	8.8	8.9	8.8	10.1	8.6	9.3	8.6	9.5	6.3	6.8	6.2	6.5
Four liquid organic manures												
S_1:Liquid*Azospirillum*+PSB+KRB+ZnSB@1.25 L ha^{-1} biofertilizer consortium by root dipping at transplanting	88.2	28.5	101	143.3	43.2	40.2	12.2	9.3	37.2	56.1	59.4	87
S_2: Vermiwash spraying twice @ 5% at tillering and flowering stages	97.6	31.2	100.5	173.4	48	44.78	13.67	10.29	38.44	60.78	64.67	92
S_3: Panchagavyaspraying twice @ 3% at tillering and flowering stages	101.5	32.7	111.6	169	49.89	47.78	14.44	11.57	41.11	62.33	68.56	95.89
S_4: Jeevamruthamspraying twice @ 10% at tillering and PI stages	93.8	30.1	102.7	159.2	45	42.22	12.33	9.89	37.67	57.11	61.67	88.33
SEm (±)	2.42	0.87	2.91	5.01	0.98	0.96	0.59	0.39	0.94	1.54	2.12	2.08
CD *(p=0.05)*	7.19	2.55	8.64	14.88	2.9	2.86	1.75	1.17	2.78	4.57	6.29	6.18
CV (%)	7.62	8.54	8.39	9.31	6.3	6.61	13.44	11.51	7.27	7.81	9.98	6.87
Interaction												
S at M												
SEm (±)	4.19	1.51	5.04	8.67	1.69	1.67	1.02	0.68	1.62	2.66	3.66	3.6
CD *(p=0.05)*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
M at S												
SEm (±)	4.37	1.53	5.11	8.86	1.87	1.86	1.33	0.65	0.57	2.58	3.37	3.56
CD *(p=0.05)*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

TABLE 2
Microbial population and protein content (%) as influenced by different doses of RDF and liquid organic manures

Treatments	Soil microbial counts			Protein content (%)
	Bacteria (No. x 10^6 CFU g^{-1})	Fungi (No. x 10^4 CFU g^{-1})	Actinomycetes (No. x 10^3 CFU g^{-1})	
Fertilizer levels (RDF:60:30:30 kg ha^{-1})				
M_1: 100% RDF (60:30:30 NPK kg ha^{-1})	28.42	14.56	13.47	11.13
M_2: 50% RDF (NPK kg ha^{-1}) + 50% RDN through Poultry manure	29.74	15.43	15.19	11.49
M_3: 100% RDN through Poultry manure	32.7	17.08	15.72	10.71
SEm (±)	0.66	0.37	0.26	0.36
CD *(p=0.05)*	2.6	1.46	1.03	1.43
CV (%)	7.58	8.23	6.15	11.34
Four liquid organic manures				
S_1: Liquid *Azospirillum*+PSB+KRB+ZnSB@1.25 L ha^{-1}biofertilizer consortium by root dipping at transplanting	32.09	16.67	15.54	10.04
S_2: Vermiwash spraying twice @ 5% at tillering and flowering stages	29.35	15.35	14.49	11.33
S_3: Panchagavyaspraying twice @ 3% at tillering and flowering stages	30.68	15.72	15.16	12.49
S_4: Jeevamruthamspraying twice @ 10% at tillering and PI stages	29.04	15.02	13.98	10.59
SEm (±)	0.71	0.37	0.37	0.31
CD *(p=0.05)*	2.12	1.11	1.09	0.91
CV (%)	7.05	7.13	7.42	8.26
Interaction				
S at M				
SEm (±)	1.23	0.65	0.63	0.53
CD *(p=0.05)*	NS	NS	NS	NS
M at S				
SEm (±)	1.26	0.67	0.61	0.59
CD *(p=0.05)*	NS	NS	NS	NS

Application of 100% RDN through Poultry manure (M_3) recorded significantly higher soil microbial population *i.e.*, total count of bacteria, fungi and actinomycetes, which was however comparable with application of 50% RDF (NPK kg ha^{-1}) + 50% RDN through Poultry manure (M_2). Among the foliar sprays, application of Liquid *Azospirillum*+PSB+ KRB+ ZnSB@1.25L ha^{-1}biofertilizer consortium by root dipping at transplanting(S_1) recorded significantly higher soil microbial count followed by Panchagavya spraying twice @ 3% at tillering and flowering stages (S_3) and vermiwash spraying twice @ 5%at tillering and flowering stages(S_2). The lowest soil microbial count was noticed under Jeevamrutham spraying twice @ 10% at tillering and PI stages (S_4). Organic manures not only help to supply the nutrients but also act as a food for microorganisms and encourage the multiplication of their population which in turn improve the mineralization of nutrients in soil and thus fertility and productivity of soil will be improved. Also Basavarajappa *et.al*. (2002) reported similar observations, indicating the use of organics in increasing the yield and soil health as well. In general, organic manures, beside causing overall improvement in the soil health, increased activity and number of soil microorganism by feeding them.

Increase in protein content may be due to increase in carbohydrate production during photosynthesis. In the present investigation significantly the highest protein content in grain was recorded with the application of 100% RDF (60:30:30 NPK kg ha^{-1})(M_1), which was superior over the rest of treatments applied and the lowest protein content was recorded with application of 100% RDN through Poultry manure(M_3). The higher protein content in finger millet grain was mainly due to increased concentration of nutrient in the soil solution thereby uptake of nitrogen and phosphorus with application of 100% RDF compared to other sources. The protein content in grain is in fact a manifestation of nitrogen concentration in grain. Since phosphorus improves quality parameter by regulating the photosynthesis, respiration, root enlargement and carbohydrate metabolism, thus increased the protein content.

Among various foliar sprays studied, Panchagavya spraying twice @ 3% at tillering and flowering stages(S_3) recorded significantly the highest protein content (10.04 %) followed by Vermiwash spraying twice @ 5% at tillering and flowering stages (S_2). This might be because of well- known fact that nitrogen is the precursor of protein. Higher protein content under mixed application of liquid manures might be due to greater availability and uptake of nitrogen and translocation in finger millet seeds. The results are in accordance with Biswas and Das (2024).

IV. CONCLUSIONS

Application of 100% RDF (60:30:30 NPK kg ha^{-1}) recorded significantly higher nutrient uptake by plant, straw and grain over the rest of the nutrient treatments. Among the organic nutrient foliar sprays, foliar application of Panchagavya spraying twice @ 3% at tillering and flowering stages was found to be the best over other three organic foliar sprays tried under organic finger millet cultivation.

Application of 100% RDN through Poultry manure (M_3) recorded significantly higher soil microbial population *i.e.*, total count of bacteria, fungi and actinomycetes, which was however comparable with application of 50% RDF (NPK kg ha^{-1}) + 50% RDN through Poultry manure (M_2). Among the foliar sprays, application of Liquid *Azospirillum*+PSB+ KRB+ ZnSB@1.25L ha^{-1}biofertilizer consortium by root dipping at transplanting(S_1) recorded.

Significantly highest protein content in grain was recorded with the application of 100% RDF (60:30:30 NPK kg ha^{-1}) (M_1) and the lowest protein content was recorded with application of 100% RDN through Poultry manure (M_3).

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Assessing the Quality of Lye-Peeled Garlic: A Concentration-Dependent Approach with Artificial Neural Networks and Multivariate Analysis

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Abstract— *The effectiveness of lye-peeled garlic was evaluated based on its chemical characteristics: allicin content, pyruvic acid, total phenolic content (TPC), total flavonoid content (TFC), antioxidant activity (AA), and anti-nutritional properties. The garlic cloves were peeled using the lye solutions (2–16%) in a ratio of 1:5 at 40±2 °C exposed for 7 min. The principal component analysis (PCA) was used to develop to assess the effectiveness of lye-peeling on the quality parameters. In addition, a two-layered feed-forward artificial neural network (ANN) was applied to develop a model to assess the quality parameters of peeled garlic. The found regression correlations 1.00000, 0.99572, and 0.99054 found for training, validation, and testing of artificial neural networks reflected the applicability of the developed model in quality assessment as regression performance was found to be 0.99005. It is concluded that 12% lye solution for peeling garlic cloves provides better quality, having less unpeeled garlic surface area. Therefore, this research highlights the application of lye concentration along with suitable temperature for garlic peeling with affecting the phytochemicals and nutritional quality of garlic*.

Keywords— Allium sativum, Artificial neural network, Lye peeling, Allicin, Antioxidant activity, Anti-nutritional property.

I. INTRODUCTION

Garlic (*Allium sativum* L.) is a bulb crop containing 2-4 layers of concentric semi-thick curvy masses known as cloves. The centre of garlic has a woody stem. It is grown worldwide, and 90% of garlic production is restricted to the Asian subcontinent, particularly in China and India (FAO, 2021). Garlic is mainly used for culinary purposes as a thickening agent in food preparation. It is also used to produce various processed products, namely pickles, paste, flakes, grits, powder, and so on. Garlic has a specific aroma, so it is also used to prepare mayonnaise, sausages, ketchup, and stews (Prasad *et al*., 2002). Its demand has increased several-fold because of its potential roles, i.e., as a flavouring agent, thickening agent, antimicrobial, therapeutic and medicinal properties. Recently, various researchers have proven that it reduces arterial pressure, controls platelet aggregation, inhibits cancer cells, and controls the cholesterol level in the blood (Pardo *et al*., 2007; Rekowska and Skupień. 2009; Shekhar *et al*., 2023).Since antiquity, raw garlic paste was traditionally combined with turmeric and/or onion to help relieve pain and sprains. These health benefits may be due to the occurrence of various types of volatile and non-volatile compounds. S-alk(en)yl-L-cysteine sulfoxide (alliin), which is present in the cytoplasmic vesicles at approximately 1%, is one of the significant compounds associated with raw garlic (Amagase *et al*., 2001). When raw garlic is crushed, the alliin reacts with the alliinase enzyme and forms allicin, an active unstable compound containing 60-80% of total thiosulfinates (Block, 1992). Other compounds, such as ammonia and pyruvic acid, are also formed during hydrolysis. Pyruvic acid, a stable compound, is correlated with the pungency of garlic. Although garlic contains a high concentration of bioactive compounds, it also contains a small quantity of anti-nutritional compounds, particularly tannins, saponins, phytic acid, flavonoids, and steroids (Yusuf *et al*., 2018).

Garlic is generally peeled before its use and mainly hand-peeled with the help of a knife. This method is laborious, time-consuming, expensive, and questionable regarding the uniformity of quality parameters. At the same time, with the change in lifestyles, there is an increase in the demand for either minimally processed products or semi-processed products for time-saving and ease of use for intended purposes. Due to this, peeled garlic demand on an industrial and home scale increased massively.

Lye peeling is one of the unit operations used for peeling of fruits and vegetables (Ramaswamy and Marcotte 2006). Garlic peel is rich in pectin, lignin, cellulose, and hemicellulose. Pectin acts as a binding agent, and lignin, an aromatic biopolymer, tightly binds cellulosic and hemicellulosic compounds. NaOH (10%)solution reduces the pectin and lignin content by breaking down or dissolving these compounds (Kumar *et al.*, 2022). It also dissolves the inner epicuticular wax by penetrating the epidermis layer, digests the cell walls and middle lamella, and loosens the thin membrane skin (Gould, 2013). Lye peeling may assist in removing potato skin and can hinder the enzymatic browning reaction by decreasing the reducing sugar concentration (Hidayat and Setyadjit 2019).

Dynamic model behaviour in the processing of some specific agricultural commodities using artificial neural networks (ANN) has gained momentum due to the ability to learn the neural networks. It is suitable for identifying complex agricultural product quality responses that mathematical approaches do not solve quickly. The ANN model was tried to dry sliced potatoes and fresh green peas to predict moisture content and residual vitamin C (Kamiński *et al.*, 1998). At the same time, the PCA technique was used for the optimization of microwave roasting of black rice based on a developed correlation between the resultant parameters, namely physical-functional properties, thermal properties, antioxidant and anthocyanin content (Arora *et al.*, 2021).

The present research was planned to study the effects of lye concentrations on garlic peeling without affecting the quality attributes, namely chemical parameters, pungency factors, antioxidants, and anti-nutritional properties. A quality parameters prediction model was developed to assess the effectiveness of lye peeling behaviour using ANN. PCA was applied to position the lye-peeled and manually peeled garlic based on a developed correlation between the measured parameters and applied lye concentrations.

II. MATERIALS AND METHODS

2.1 Materials:

Freshly harvested garlic bulbs (Haryana garlic-17) were brought from CCS-HAU, Hisar, Haryana. Manually, garlic cloves were separated from the whole bulbs. Mature garlic cloves of similar size were used for all the experimental work. L-cysteine,5,5'-dithio-bis-(2-nitrobenzoic acid) (DTNB),(4-(2-hydroxyethyl)-1-piperazineethanesulfonic acid (HEPS), 2,4 dinitrophenylhydrazine (DNPH), and sodium pyruvate were purchased from Nice Chemicals Pvt. Ltd., (India). Other chemicals utilized in the current research work were of analytical grade.

2.2 Lye peeling of garlic:

The garlic cloves were divided into 27 groups to conduct independent experiments in triplicate. Each group contained approximately 30 g of samples for manual or lye peeling. The garlic cloves were immersed in lye solution having concentrations of 2% (LP2), 4% (LP4), 6% (LP4), 8% (LP8), 10% (LP10), 12% (LP12), 14% (LP14), and 16% (LP16) for the lye peeling considering manual peeling as control. The tangible unpeeled garlic surface area was estimated with the help of transparent paper and converted into percentages (Oladejo *et al.*, 2014). The lye solutions were freshly prepared for each treatment. The temperature was maintained 40±2°C throughout the lye peeling process, i.e., 7 min. Immediately after the lye solution treatment, the left garlic peel was removed by rubbing the cloves under tap water. The surface moisture was removed using tissue paper. The phenolphthalein indicator test was performed for the presence of lye solution. The peeled garlic cloves were further used for different analyses.

2.3 Juice extraction process:

Around 17 g of peeled garlic clove was taken for juice extraction. It was crushed using the pestle and mortar without adding water. The juice was collected by pressing the garlic paste using a nylon cloth. The obtained juice was immediately used for the estimation of chemical properties.

2.4 Chemical properties analysis:

The pH of garlic juice was estimated using a previously calibrated electrical pH meter (model: LMPH-10, make: Labman Scientific Instruments Pvt. Ltd., India) at 20°C. Total acidity was estimated by the titration method (AOAC, 2006). Total soluble solids (TSS) of the garlic juice sample (20°C) were measured directly with a digital refractometer (model: 3810 PAL-1 digital, make: Atago Co. Ltd., Japan). The amount of reducing sugar in the garlic sample was estimated (Ahmad, 1996). The absorbance was taken at a 440 nm wavelength with the help of a UV-Vis spectrophotometer (model: DR6000, make: HACH company, USA). It was calculated using a standard glucose solution as a reference curve and expressed in g/kg. Ascorbic acid (AS.A) in the garlic samples was estimated using the 2,6-dichlorophenol indophenol reagent titration method with slight modification (Manas, 2014). Approximately 1 g of garlic was taken to prepare the extract using 25 ml of 4% oxalic acid. It was centrifuged at 8000 rpm for 18 min. Then, 10 ml of aliquot and 10 ml of 4% oxalic acid were titrated against 2,6-dichlorophenol indophenol reagent up to the appearance of a faint pink colour. Further, 5 ml of 0.1 mg/ml standard L-ascorbic acid solution and 10 ml of 4% oxalic acid were taken and titrated against 2,6-dichlorophenol indophenol reagent. The ascorbic acid (mg/g) concentration was calculated by the following equation.

$$Ascorbic\ acid\ = \frac{\text{Concentration}_{\text{standard solution}} \times \text{Titre volume}_{sample} \times \text{Volume taken for titration}}{Titre\ volume_{\text{standard solution}} \times Total\ volume\ made \times Wt\ of\ sample} \quad (1)$$

2.5 Allicin and Pyruvic acid content analysis:

The allicin and pyruvic content of the manual and lye-peeled garlic samples were measured by the spectrophotometric method at the wavelength of 412nm, and 420 nm, respectively (Prakash and Prasad, 2023a).

2.6 Total phenolic content (TPC), Total flavonoid content (TFC), Antioxidant activity (AA) analysis:

A solvent extraction technique was used to extract the garlic extracts (Prakash and Prasad, 2023a). TPC in the garlic extract samples was measured using a UV-spectrophotometer at 765 nm wavelength with minor modification (Prakash and Prasad, 2023a). The colourimetric technique was used to estimate the TFC (510 nm) in the garlic extract sample with slight modification (Bhandari and Rajbhandari, 2015). The DPPH antioxidant activity of the garlic sample was estimated by the method reported (Kinalski and Noreña, 2014).

2.7 Anti-nutritional properties:

Tannin, saponin, and phytic acid content in the garlic samples were estimated by the method followed by Prakash and Prasad (2023b).

2.8 Artificial neural network (ANN):

ANN is one of the malleable computational architects drawn by the inspiration from the human brain. It is capable enough for the modelling of any system or process before they are trained with the supply of sufficient numeric data obtained from the experiments. ANN tools can be implemented in a complicated model with numerous inputs and outputs data with a little experimental work. This type of model may be applied in the prediction of experimental data. The conditions chosen for garlic peeling were well-suitable for ANN model because of its non-linear attributes. In the present study, Matlab R2021 was applied for the ANN modelling. Manual peeling (MP) and different concentrations of lye peeling of garlic cloves were modelled with two-layer feed-forward neural networks. Neural network mapping was developed between numeric input data (peeling conditions) and numeric target data (quality parameters). The manual peeling of numerical input data was noted by the notation 0 (zero). The lye concentration of 16% solution was kept separate for the performance test of the developed model. The input and target data were statically represented in the [1×8] and [13×8] matrices, respectively. In the matrix, the first number represents the parameters, and the second represents the samples. The samples were randomly divided into 3 data sets, which were further used in training (50%), validation (25%), and testing (25%) functions. The training data set was used in the neural network training, and accordingly, its network error was adjusted. A validation data set was employed to assess the network's generalization, and when generalization reached a certain point, stop the training. Training did not affect the testing data set and offered a reliable network performance indicator before and after training.

The neural network contained one input layer, one hidden layer having ten neurons and thirteen output layers (Figure 1). Here, ten neurons were selected for the best prediction of results (outcomes) since a lower integer of neurons may not adequately cover the entire required network in the training step, while larger integers might memorize the network training patterns. Multiple hidden layers were used for a complex and particular application, but one hidden layer was sufficient for continuous non-linear functions (Mitra *et al*., 2011). The network was trained with the Levenberg-Marquardtback-propagation algorithm

(Fabani *et al.*, 2021). The training ceased automatically when generalization stopped improving the validated data set's mean square error (MSE). The training was performed until the mean square error (MSE) value was minimized to near zero, and the regression correlation (R) value maximized near one. Then, the performance check executed a sensitivity analysis against the developed model. The final ANN outcomes data were correlated with experimental data.

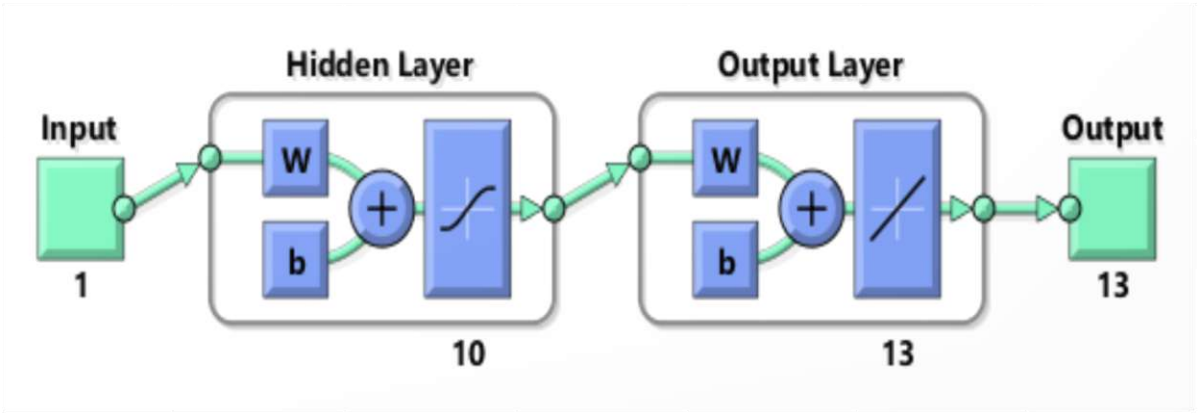

FIGURE 1: An ANN diagram of garlic lye peeling in different concentrations

2.9 Statistical analysis:

All the experimental parameters were performed in triplicate. The mean value was calculated using Microsoft Excel version 2007. Principal Component Analysis (PCA) was executed on mean data to explain the correlation between the variability of estimated parameters of the manual and different concentrations of lye-peeled garlic.

III. RESULTS AND DISCUSSIONS

3.1 Effect of lye concentration on garlic peeling:

The tangible unpeeled garlic surface area was reduced as the concentration of lye solution increased (Figure 2). At LP12, the garlic peeling rate was found to be maximum. It might be because the penetration power and diffusion process reach maximum at the exposed concentration and temperature (40°C). It reduces the amount of pectin (76.00%) and lignin (25.91%) content by diffusion of these compounds in 12% lye solution. The remaining peel content was mainly cellulose and hemicelluloses, which were easily removed by the cloves with gentle rubbing in water. The lye peeling efficiency process was influenced by the concentration of the lye solution, temperature, and immersion time (Caceres *et al.*, 2012).

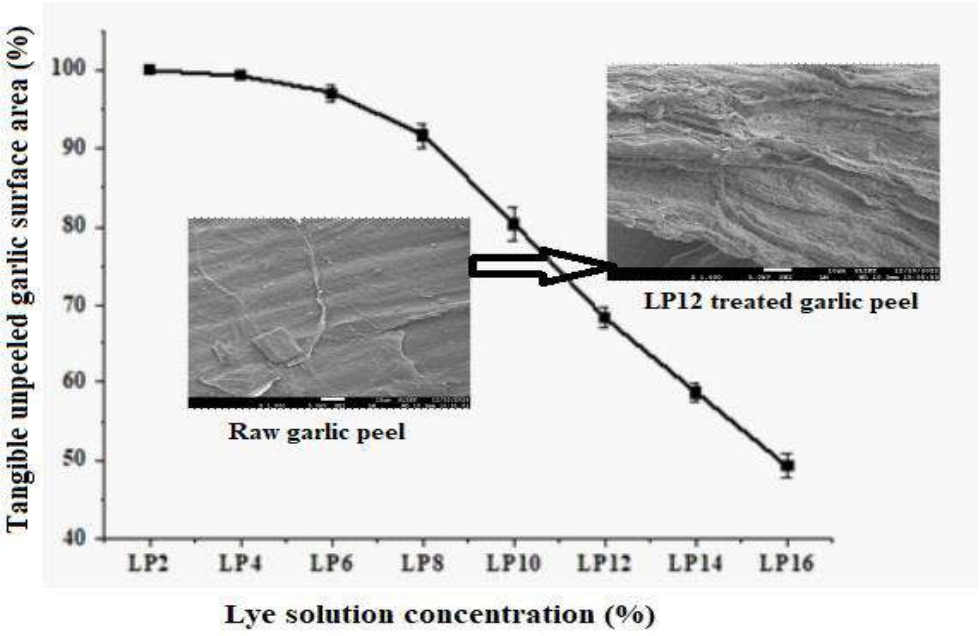

FIGURE 2: Effect of lye concentrations on tangible unpeeled garlic surface area

3.2 ANN model and its performance evaluation:

Training and validation phases are essential for developing the best ANN model. In the training phase, repeated iteration was used to achieve a regression coefficient near or equal to one. The best ANN model was found after 17th iteration, where regression coefficients for training, validation, and testing were 1.00000, 0.99572, and 0.99054, respectively (Figure 3A). Most errors were found in the testing stage because these datasets were not utilized in the training for the development of ANN network.

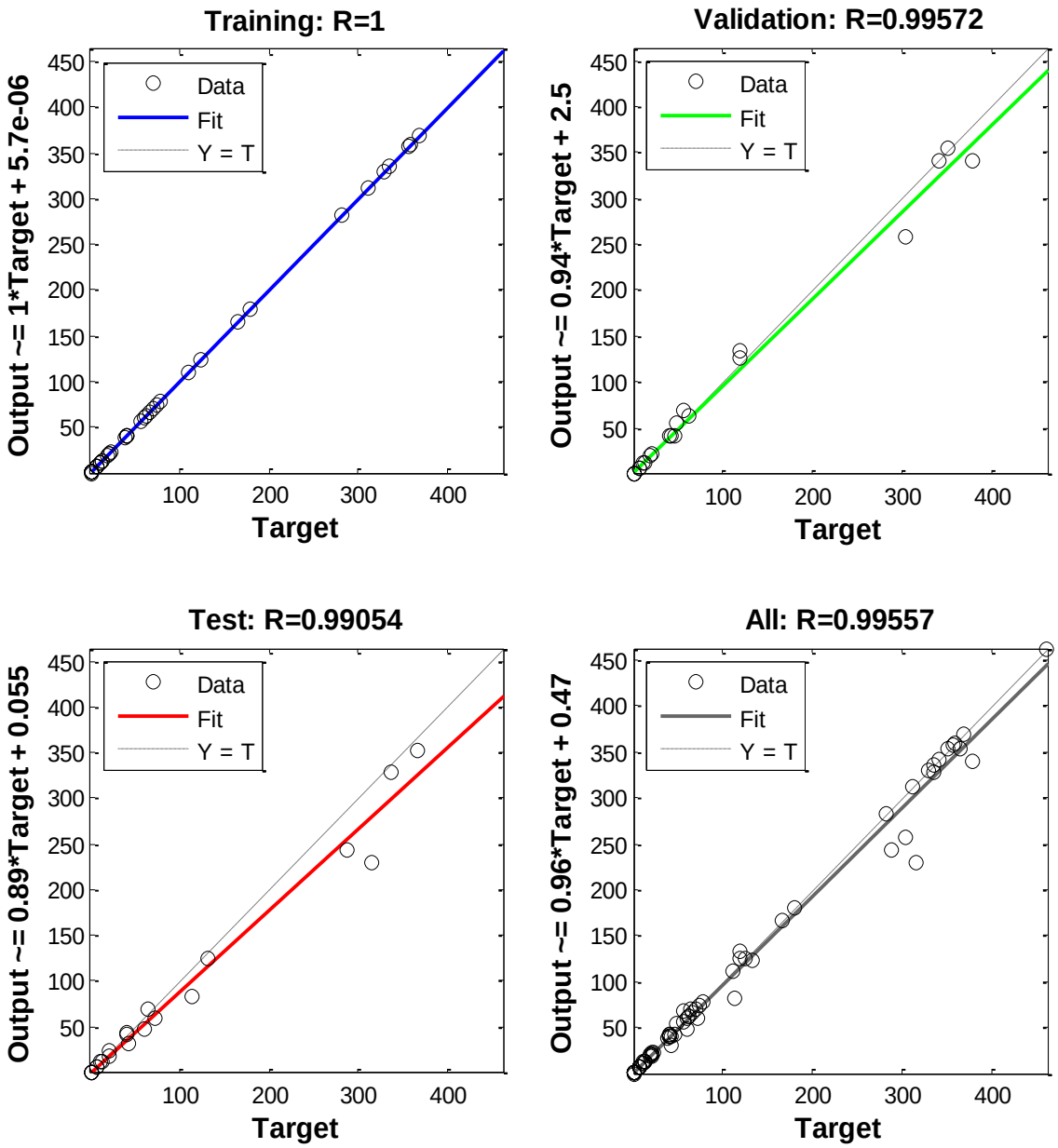

FIGURE 3A: Regressions plot in ANN trained model (Matlab R2013a software)

Once the ANN model was developed, its performance test was conducted with separate experimental data for practical application. The performance test data showed a regression coefficient of 0.99005, like the test data regression coefficient (Figure 3B). The developed model may thus be applicable in effectively predicting garlic peeling at different concentrations of lye peeling.

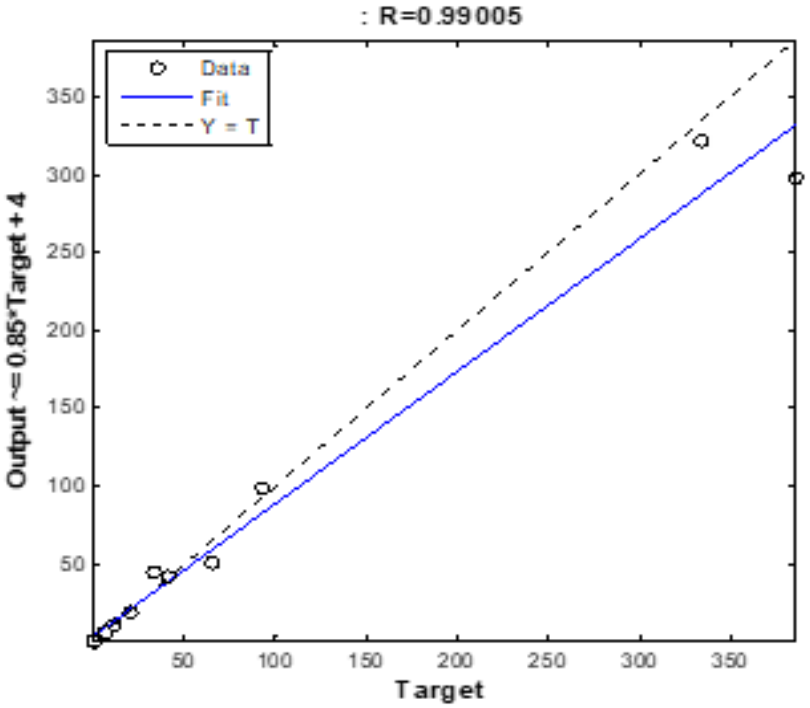

FIGURE 3B: Regression performance test of the developed neural network model (Matlab R2013a software)

3.3 Comparison of quality attributes of experimental and predicted ANN model outcomes:

The patterns of the experimental quality attributes and prediction by ANN model data set for chemical properties, bioactive compounds, i.e., allicin and pyruvic acid, TPC, TFC, AA, and anti-nutritional properties of lye-peeled garlic, are shown in Figures. 4 to 7, respectively. The remarkable point in the graphs is the pattern of the experimental and ANN model predicted results at different concentrations of peeled garlic. It indicates that ANN data outcomes are appropriately fitted and not under or over-fitted. Besides, it also noticed that the highest differences (errors) occurred at 4% and/or 10% of lye-peeled garlic in all the measured parameters. It might be because these concentrations of lye-peeled garlic were not involved in the training of the ANN model, and these data points were used to test the results. It means that the ANN model's outcome errors may be improved by training with the same experimental data sets or by minimizing the experimental errors at the same experimental points.

3.4 Chemical properties analysis:

The pH (6.10–6.23) and TSS (40.17–41.83°Brix) were varied as the concentration of lye solution increased from 2 to 14% for the lye peeling of garlic. The MP method had a pH similar to the lye-peeled garlic at 2, and 4% lye solutions, and other solutions had a slightly higher pH. Peeled garlic obtained from the MP method had less TSS content than all the lye-peeled garlic concentrations. Total acidity varied from 0.757 to 0.509% as the concentration increased from 2 to 14% (Figure 4). These changes might be due to the penetration power differences at different concentrations. At lower lye solutions, penetration power was almost negligible, and later, it was increased (Figure 2). Ascorbic acid content was decreased in all the concentrations of lye-peeled garlic (0.126–0.089mg/g) compared to MP garlic (0.142mg/g). Similar results were found in kiwi fruits, peeled with the concentrations of caustic solutions, i.e., 13, 18, and 23%, respectively (Guldas, 2003). Its ascorbic acid content decreased from 89 to 84.5% as there was an increase in caustic solution concentration. Manually peeled garlic had the highest amount of reducing sugar, and the lowest amount was found in a 2% lye solution. As the concentration of lye solution increased (2 to 14%), reducing sugar also increased but remained substantially less than the MP garlic (Figure 4). Pomelo peel was treated with various concentrations of alkaline (NaOH) solutions, and it was found that the reducing sugar increased from 52.81 to 91.01 g/100g (Chatkaew *et al*., 2021).

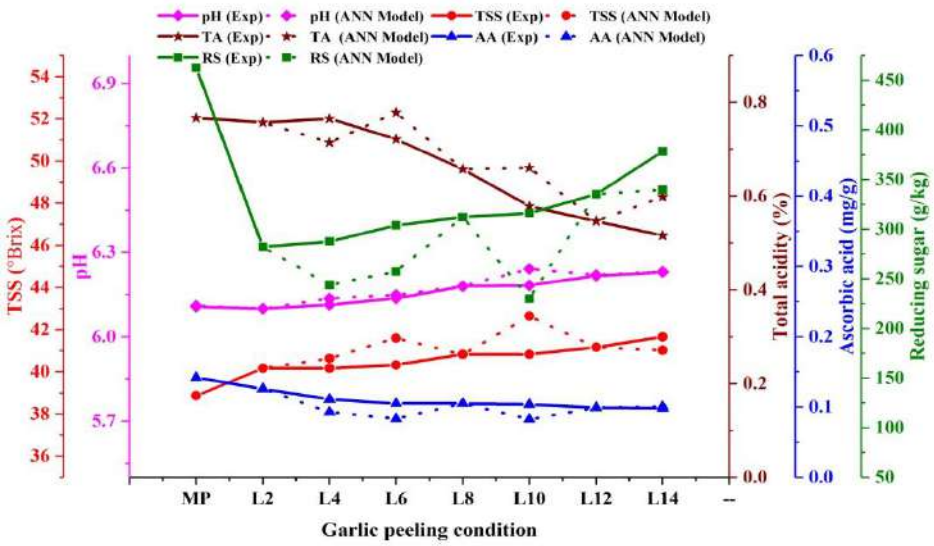

FIGURE 4: Experimental and ANN model predicated data of chemical parameters (manual peeled and lye-peeled garlic)

3.5 Allicin and pyruvic acid content analysis:

The allicin and pyruvic acid content in MP garlic and the different concentrations of lye-peeled garlic are shown in Figure 5. The manually peeled garlic contained 369.84 mg/100g of allicin and 69.40 µmol/ml of juice of pyruvic acid. Allicin content is relatively unstable at higher pH (Lee *et al*., 2014) or retard the chemical process; it may be the significant reduction of allicin and pyruvic acid content in lye solution peeled garlic. The lye-peeled garlic contained 330.13 to 366.19 mg/100g of allicin and59.77 to 66.51 µmol/ml of juice of pyruvic acid. The maximum amounts of allicin and pyruvic acid were present in peeled garlic with a 12% lye solution. Pyruvic acid content was lower (30.28µg/ml) in garlic pulp when garlic pulp was heated under ohmic conditions (Poojitha and Athmaselvi, 2020).

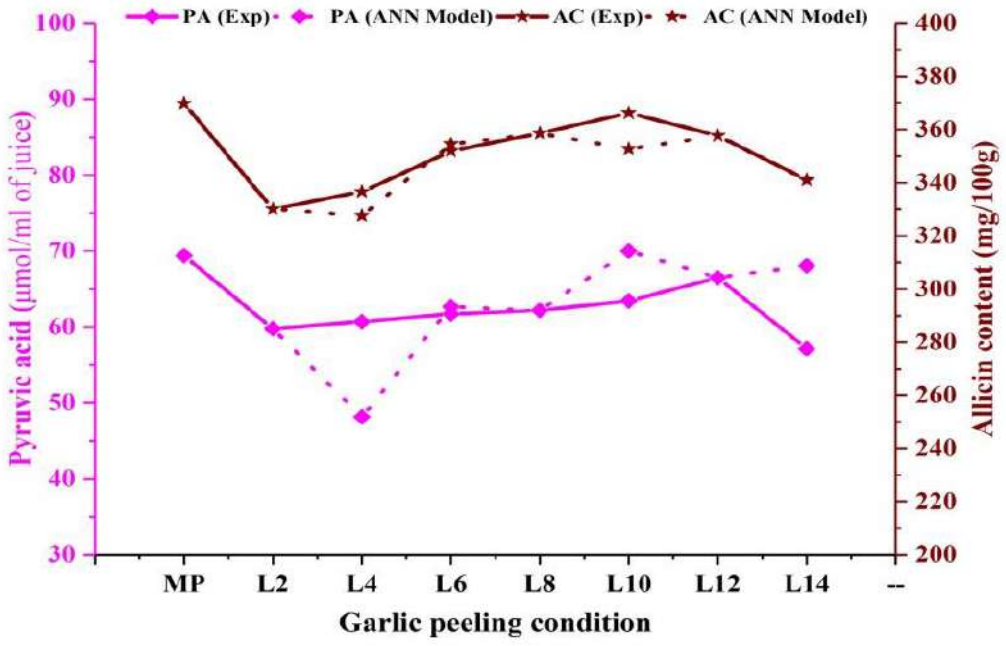

FIGURE 5: Experimental and ANN model predicated data of pyruvic acid and allicin content (manual peeled and lye-peeled garlic)

3.6 TPC, TFC, and AA properties analysis:

The TPC, TFC, and AA of different concentrations of lye-peeled garlic are presented in Figure 6. The TPC and TFC of lye-peeled garlic ranged from 136.56–248.01 mg/100g and 314.56–471.79 mg/100g at 2–14% concentration of lye-peeled garlic, respectively. The maximum amount of TPC (260.00 mg/100g) and TFC (511.08mg/100g) of garlic was found in manually peeled garlic, followed by 12% lye-peeled garlic. These significant changes may be due to the alteration in the structure of garlic and the destruction of the peel and outer waxy layer during lye peeling (Carranza-Concha *et al*., 2012). DDPH radical scavenging activities ranged between 19.20 and 21.15%, while manually peeled garlic was 22.53%. However, in DDPH radical scavenging activities, some changes occurred to the TPC and TFC. It might be due to less correlation with other compounds, particularly TPC, TFC, and ascorbic acid. Several researchers stated that there was no correlation between these compounds (Carranza-Concha *et al*., 2012; Kuskoski *et al*., 2005).

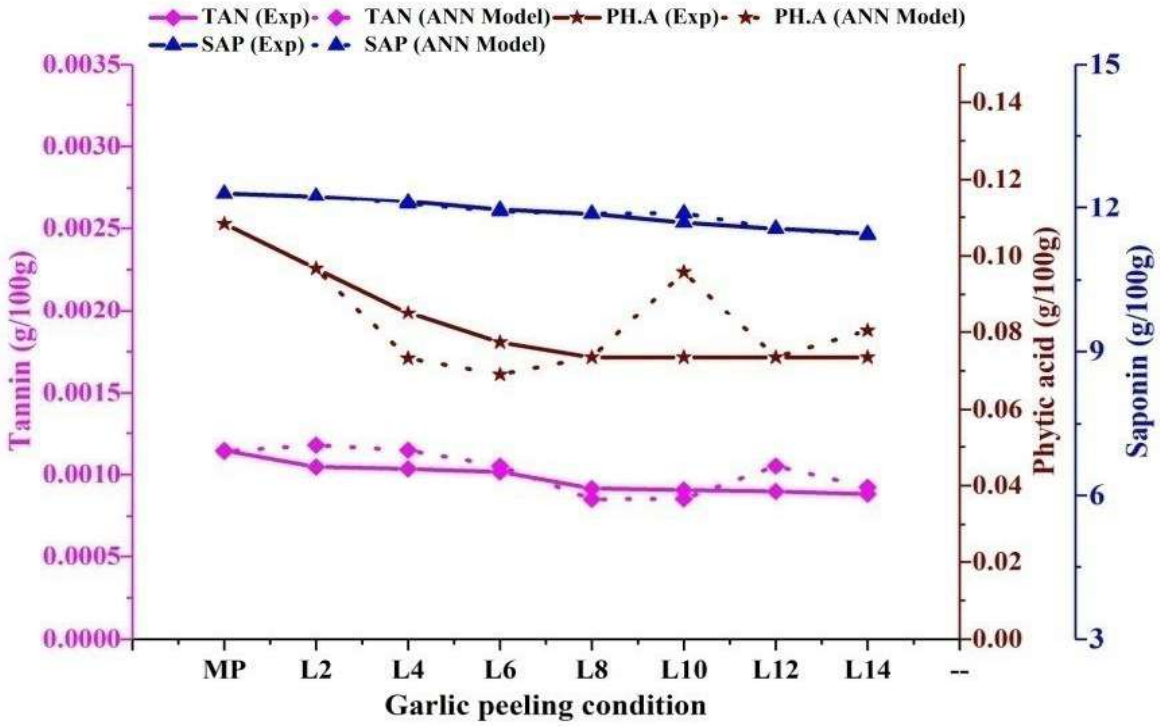

FIGURE 6: Experimental and ANN model predicated data of TPC, TFC and AA (manual peeled and lye-peeled garlic)

3.7 Anti-nutritional properties:

Tannins, astringent compounds belonging to polyphenols, combine with protein and other organic compounds to form a complex precipitate. Due to the formation of complex compounds, they block the nutritional content (Gemede and Ratta, 2014). Figure 7 shows that the tannins decreased by up to 15.65% when the concentration of lye solution increased from 2 to 14%. The tannins were reduced to 22.95% compared with the MP garlic over 14% lye-peeled garlic. Similar results were reported (Jyothi and Sumathi, 1995) on treating a low sodium hydroxide solution on common beans at room temperature for 24 hrs.

Phytic acid, an anti-nutritional compound, reduces the bioavailability of minerals to humans, primarily zinc, iron, calcium, magnesium, manganese, and copper (Gemede and Ratta, 2014). Phytic acid was found to be 0.1083g/100g in raw garlic (Figure 7). Its concentration decreased from 10.71 to 35.71% when the lye solution concentration increased from 2 to 14% for garlic peeling. The rate of phytic acid concentration drastically decreased in the initial stage of lye-peeled garlic; later, it decreased in the steady state. A similar phytic acid result was found in common beans when soaking in sodium hydroxide solution (14.6% in 24 hrs) at room temperature (Jyothi and Sumathi,1995).

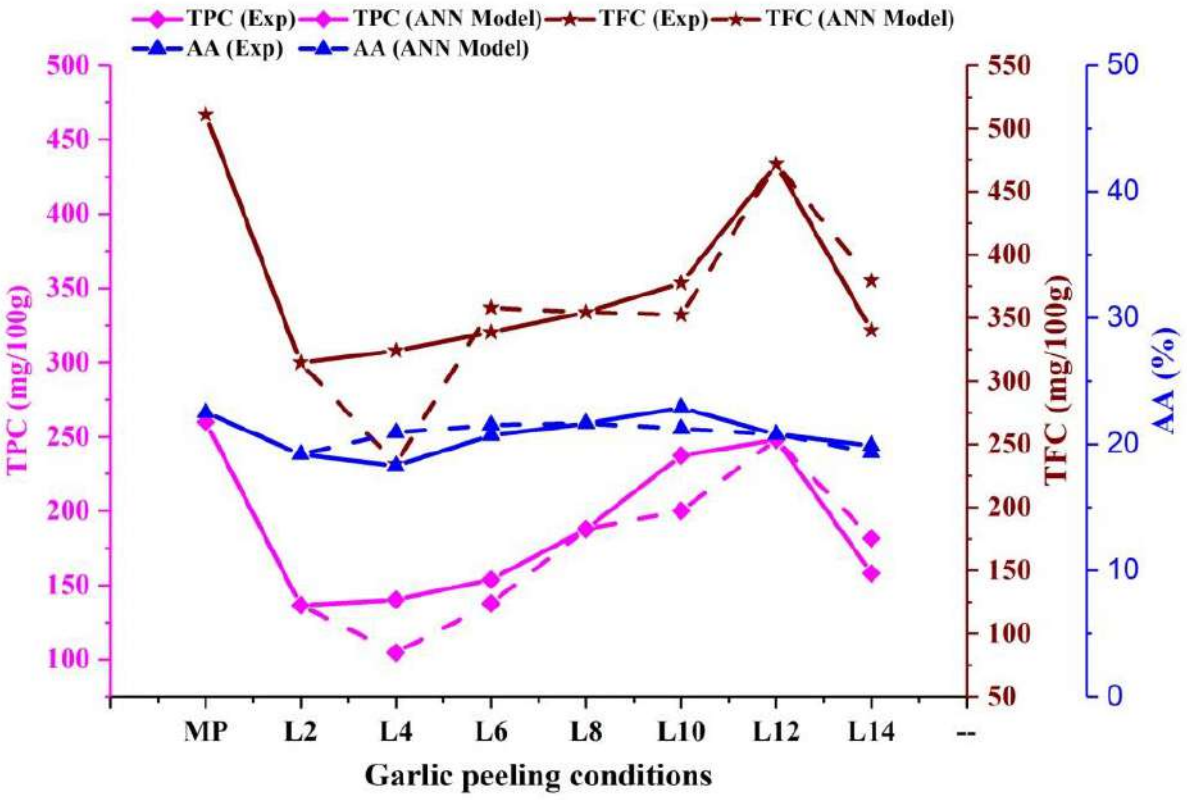

FIGURE 7: Experimental and ANN model predicated data of anti-nutritional properties (manual peeled and lye-peeled garlic)

Anti-nutritional compounds, namely saponins, can retard the absorption of some non-polar vitamins, minerals, and proteins due to the formation of insoluble complexes (Francis *et al.*, 2002). The saponin concentration was reduced due to garlic peeling, with a 2–14% concentration over MP garlic (Figure 7). The saponins that were present in the raw garlic were 12.31 g/100g. At 14% NaOH concentration, garlic saponin content decreased by up to 6.92% when peeled with NaOH solution. The saponins were gradually reduced, like that of tannin.

3.8 Principal component analysis (PCA) and optimization of lye-peeled garlic:

PCA was used to develop the correlation between the lye peeling concentration and chemical parameters (pH, TSS, titratable acidity, ascorbic acid, and reducing sugar), pungency parameters (allicin content and pyruvic acid), TPC, TFC, AA, and Anti-nutritional properties (tannins, phytic acid, and saponins). Figure 8 shows that the PC1 and PC2 showed61.55% and 26.81% variations, respectively. It was also observed that TPC, TFC, AA, AC, PA, and RS are positively correlated with MP, LP8, LP10, and LP12. It may be due to a minor effect on native measured parameters. However, LP2, PP4, and LP6 formed separate clusters having the properties of AS.A, PH.A, TAN, SAP, and TA parameters. It may be because lye peeling concentration did not affect these parameters, particularly anti-nutritional properties.

The lye peeling concentration of garlic was optimized using the ANN model and PCA with minimum unpeeled garlic surface area. The rate of unpeeled garlic surface area was found to be lower at a 12% lye concentration. From the ANN model, it was found that the estimated parameters of lye-peeled garlic had a lower error at 12% lye concentration. PCA also showed less effect on quality parameters and more on anti-nutritional properties. Overall, it was observed that LP12 has lesser effects on measured quality parameters, particularly TPC, TFC, AA, AC, PA, and RS, and a more significant impact on anti-nutritional properties.

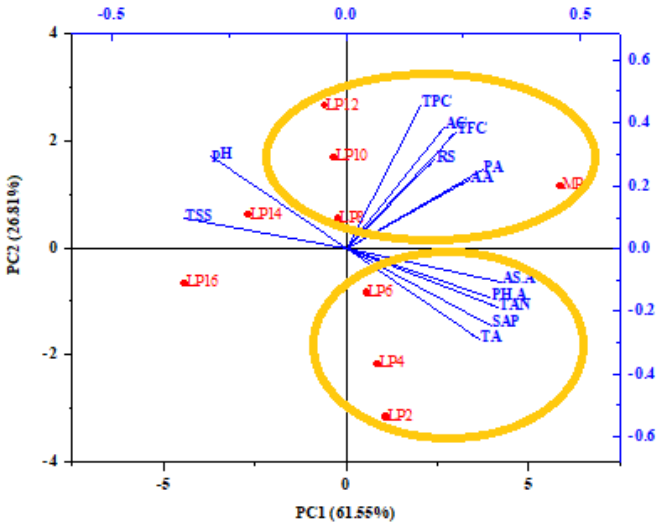

FIGURE 8: Biplot of PCA at different concentrations of lye peeling and manual peeling. Abbreviations: TS: total soluble solids; TA: titratable acidity; AS: ascorbic acid; RS: reducing sugar; AC: allicin content; PA: pyruvic acid; TPC: total phenolic content; TFC: total flavonoid content; AA: antioxidant activity (% reduction in 2,2-diphenyl-1-picrylhydrazyl hydrate); TAN: tannin; SAP: saponin; PH.A: phytic acid.

IV. CONCLUSION

Concentration-dependent lye peeling of garlic cloves was carried out, maintaining temperature and exposure time as a constant. The effective peeling was found with the 12% lye solution. At the optimized condition of peeling reducing sugar significantly reduced and helped in obtaining dehydrated garlic brighter without affecting other quality attributes. At the same time, anti-nutritional compounds, namely tannin, phytic acid, and saponin, decreased significantly. PCA showed that LP12 correlates better with TPC, TFC, AA, AC, PA, and RS, having a minimum unpeeled garlic surface area. The found regression correlations 1.00000, 0.99572, and 0.99054 for training, validation, and testing of ANN model reflected the applicability of the developed two-layered feed-forward ANN model in the process prediction in efficient manner. The application of ANN may be used to predict online garlic peeling and successfully estimate quality parameters at a commercial scale.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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Monitoring of Gram Pod Borer, *Helicoverpa armigera* through Pheromone Trap in Chickpea, *Cicer arietinum* L Crop and their Influence with Abiotic Parameters

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Abstract— *The present research experiments were carried out during Rabi season of the year 2022-23 at the Agricultural Research Farm of Baba Raghav Das Post Graduate College, Deoria (UP) to monitor the population of Helicoverpa armigera by using pheromone traps in chickpea (variety-'Pusa-261'). The male moth catches of H. armigera was recorded from 4th SMW (1.5 moths/trap/week) and the moths catches increased in subsequent weeks and reached at peak during 6th, 7th and 8th SMW with 4 moths/trap/week, 3.5 moths/trap/week and 4 moths/trap/week, respectively, between 2nd week of February to 4th week of February, at vegetative to reproductive stage of crop. Abiotic factors such as rainfall, maximum and minimum temperatures showed a non-significant negative correlation with male moth catches of Helicoverpa armigera, while maximum and minimum relative humidity exhibited a positive correlation. However, all the weathers parameters together influenced the H. armigera male moth's catches in the chickpea up to extent of 75.93%.*

Keywords— Pheromone trap, H. armigera, correlation, regression and abiotic factors.

I. INTRODUCTION

Chickpea *(Cicer arietinum* L.) commonly known as gram or Bengal gram is the most important pulse crop. Globally, India ranked first in area and production [1]. India produces 11.74 million tons of chickpea from 10.01 million ha with an average production of 1164 kg/ ha [2]. However, chickpea production is not fully achieved a mid-different biotic and abiotic stresses [3]. Among biotic factors, diseases, insect pests, nematodes, birds and vertebrates harm the crop but damage due to insects is more striking than others. Nearly 60 insect species are known to feed on chickpea [4,5]. In eastern Uttar Pradesh the major insect pests which attack on chickpea crop are mainly *H. armigera* (Hubn.), *Spodoptera litura* (F.), *Agrotis ipsilon* (Hubn.), *Plusia orichalsia* (F) *and Bemisia tabaci* (Genn). Among these, *H. armigera* is the most destructive and very notorious insect pests, bear polyphagous nature. Weather factors play a crucial role in the regulation of population of insects [6]. The yield losses vary from 6.88% to 50% in the chickpea due to pod borer infestation [7] and 50-100% in favourable weather conditions particularly when there are frequent rains and cloudy weather during the cropping seasons [8]. In India the population of *H. armigera* flourished during second half of February and outbreak situation were found throughout March. Pheromone traps play a crucial role in monitoring the population of *H. armigera* within integrated pest management (IPM) programs [9]. The incidence of this pest has been observed almost throughout the crop growing season. Therefore, an attempt has been made to develop an environmentally sound pest management strategy for this pest [10]. Keeping these points in view, the present investigation was carried out to monitor the population of *H. armigera* and its relationship with abiotic factors like; temperature (maximum and minimum), relative humidity (maximum and minimum) and rainfalls.

II. MATERIALS AND METHODS

The study was conducted during *Rabi* 2022-23 at the Agricultural Research Farm of Baba Raghav Das Post Graduate College, Deoria (UP), the variety 'Pusa-261' sown with spacing of 30x10 cm in 7x2 m^2 plot size. All the normal and recommended

agronomical practices for the region were applied, followed throughout the crop season for raising the crop, except the application of any plant protection measure. For monitoring of *H. armigera* two Pheromone traps were installed during 4th SMW (22nd January 2023) in the field with the help of bamboo sticks at 1 meter above the crop canopy. The pheromone traps used in this study were obtained from SK AGROTECH Pune, India. The pheromone traps were monitored regularly in morning and calculated moth population trap at weekly interval. The population of *H. armigera* obtained were correlated with the weather parameters and subjected to one way ANOVA by using IBM SPSS 16.0 software version.

III. RESULTS AND DISCUSSION

The perusal of Fig 1 revealed that the moth activity was initially recorded as 1.5 moths/trap/week during fourth week of January (4th SMW). Catches steadily increased, peaking between the second and fourth weeks of February (6th, 7th, and 8th SMW) with 3.5 to 4 moths/trap/week, coinciding with the crop's vegetative to reproductive stage. Following this peak, moth numbers gradually declined throughout March, reaching 1 moth/trap/week by the end of the month (12th SMW). A slight increase to 2 moths/trap/week was noted in the last week of March (13th SMW) just before harvest. Almost similar kind of observations were recorded by Bajia *et al.* [11] who reported that the male moth catches of *H. armigera* was recorded in 2nd SMW and reached its peak during 6th to 7th SMW. Bhagat *et al.* [12] noticed the activity of male moths of *H. armigera* during 51st SMW with 0.49 moths/trap/week which increased gradually and reached its peak (43.45 moths/trap/week) during 6th SMW followed by decreasing in 7th SMW and reached to a minimum 1.73 moths/trap/week in 11th SMW. Ramesh Babu *et al.* [13] observed that the moth populations were active from February to mid-April and decreased sharply in the late April.

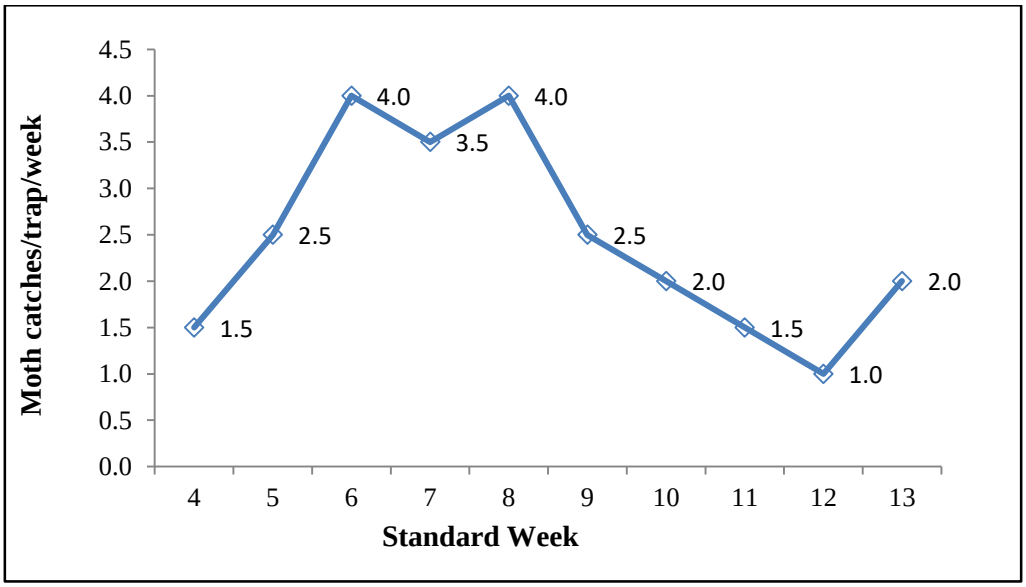

FIGURE 1: Average number male moths/trap/week of *H. armigera* catches on chickpea during *Rabi,* 2022-23

TABLE 1
CORRELATION STUDIES BETWEEN WEATHER PARAMETERS AND MALE MOTH CATCHES OF *H. ARMIGERA* ON CHICKPEA DURING *RABI,* 2022-23

Weather parameters	Populations of adult male moth catches of *H. armigera*
Maximum temperature (°C)	-0.361
Minimum temperature (°C)	-0.569
Maximum relative humidity (%)	0.236
Minimum relative humidity (%)	0.236
Rainfall (mm)	-0.548

TABLE 2
MULTIPLE REGRESSION MODEL OF MALE MOTH CATCHES OF *H. ARMIGERA* POPULATIONS WITH ABIOTIC FACTORS DURING *RABI*, 2022-23

Multiple regression equation	R^2
$Y=6.640+0.207X_1-0.558X_2+0.028X_3-0.078X_4-0.170X_5$	0.7593
Where, Y = *H. armigera* male moths catches, X_1 = maximum temperature, X_2= minimum temperature, X_3= maximum relative humidity, X_4= minimum relative humidity and X_5 = rainfall.	

The perusal of Table 1 revealed that male moth catches in pheromone traps showed non-significant negative correlation with the maximum, minimum temperature and rainfalls with r-value of -0.361,-0.569 and -0.548, respectively. However, it showed a positive and non-significant correlation with maximum and minimum relative humidity with r-value of 0.236 and 0.057, respectively. The findings are contrary to that of Varshney [14] who reported that the temperature was positively correlated with moth catches while relative humidity negatively correlated. Pathania *et al.* [15] and Khadse *et al.* [16] reported negative and non-significant correlation between maximum and minimum temperature with male moth catches which is agreement with present findings, whereas findings of Sagar *et al*. [17] and Rawat *et al.* [18] are not in accordance with the present findings. The multiple linear regression model (2022-23) was $Y=6.640+0.207X_1-0.558X_2+0.028X_3-0.078X_4-0.170X_5$. Where, Y = *H. armigera* male moths catches, X_1 = maximum temperature, X_2= minimum temperature, X_3= maximum relative humidity, X_4= minimum relative humidity and X_5 = rainfall. The present findings are in accordance with Pal *et al.* [19] who reported that weather factors together influenced 62.88 % to 69.13% on pheromone trap catches of adult moths in chickpea. Similarly, Ramesh Babu *et al.* [13] also reported that the various weather parameters influence the population adult moths *H. armigera* by trap catches is up to 88% in chickpea.

IV. CONCLUSION

These investigations therefore indicate that pheromone traps are important tools for monitoring of *H. armigera* population. The period of high moth catches suggests the potential for significant larval damage, emphasizing the need for timely intervention. Therefore, immediate control measures using Integrated Pest Management (IPM), rather than relying solely on widespread insecticide use, are essential to address this potential infestation.

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CONFLICT OF INTEREST

There is not any conflict of interest among the authors.

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Polymorphism Analysis of FecB and BMP15 Genes in Kenguri and Kenguri × NARI Suwarna Sheep

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Abstract— *Sheep production in India is constrained by low reproductive efficiency, with litter size being a major limiting factor in improving productivity. Prolificacy in sheep is largely regulated by fecundity genes such as* ***Booroola fecundity (FecB/BMPR1B)*** *and* ***BMP15****, which directly influence ovulation rate and litter size. The present investigation was carried out to detect polymorphisms in these two genes in* ***Kenguri*** *and* ***Kenguri × NARI Suwarna (F1)*** *sheep maintained at the Livestock Research and Information Centre, Veterinary College, Bidar. Blood samples were collected from 30 Kenguri and 30 crossbred sheep. Genomic DNA was isolated using the phenol–chloroform method and evaluated for purity and concentration. PCR amplification was performed using specific primers to amplify a 190 bp fragment of FecB and a 434 bp fragment of BMP15. The PCR products were subjected to* ***restriction fragment length polymorphism (RFLP)*** *using* ***AvaII*** *and* ***StuI*** *restriction enzymes, respectively, and separated by agarose gel electrophoresis. In Kenguri sheep, the FecB locus was monomorphic, with all animals showing the wild-type (++) genotype. However, in the Kenguri × NARI Suwarna (F1) crossbred population, three genotypes were identified:* ***BB (0.16), B+ (0.50), and ++ (0.34)****. The corresponding allele frequencies were* ***B = 0.41*** *and* ***+ = 0.59****. A Chi-square test for Hardy–Weinberg equilibrium revealed significant deviation (*$\chi^2 = 7.82, p < 0.05$*) in the crossbred group, indicating possible selection pressure, genetic drift, or non-random mating. At the BMP15 locus, no polymorphism was detected, and all animals across both populations were found to be monomorphic for the wild-type allele. The results clearly demonstrate the successful* ***introgression of the FecB allele*** *through crossbreeding with the NARI Suwarna strain, thereby enhancing the genetic potential for higher prolificacy in Kenguri sheep. These findings provide molecular evidence supporting the role of targeted crossbreeding in improving reproductive traits. The absence of variability at the BMP15 locus suggests that FecB plays a more prominent role in this population.*

Keywords— Kenguri sheep; NARI Suwarna; FecB polymorphism; BMP15; PCR-RFLP; Hardy–Weinberg equilibrium; Prolificacy.

I. INTRODUCTION

The livestock sector is an important sub-sector of Indian agriculture, contributing significantly to rural livelihoods and national GDP. Although the share of agriculture in the national GDP has been declining, the livestock sector has shown steady growth, contributing about 3.9% to total GDP and nearly 24% to agricultural GDP). Among livestock, sheep occupy an important position, contributing meat, wool, and skin. India has more than 65 million sheep, yet per-animal productivity remains low, mainly due to poor reproductive efficiency.

Prolificacy, or the ability of ewes to produce multiple offspring per lambing, is a key trait influencing mutton production. However, most indigenous Indian breeds are characterized by low twinning rates, thereby limiting productivity (Jain *et al.*, 2006a). The discovery of fecundity genes has opened new opportunities for improving reproductive traits through **marker-assisted selection (MAS)**. Among these, ***FecB (BMPR1B)*** and ***BMP15*** are the most studied. Mutations in these genes are known to increase ovulation rate and litter size in several prolific breeds such as Booroola Merino, Garole, and Hu sheep (Mulsant *et al.,* 2001; Wilson *et al.,* 2001; Davis, 2005).

Kenguri is a medium-sized sheep breed of northern Karnataka, valued for mutton production but known to have very low prolificacy. By contrast, NARI Suwarna, a crossbred strain developed by introgression of the FecB mutation from Garole sheep

into Deccani sheep, has demonstrated a 33% increase in productivity due to higher litter size (Appannavar *et al*., 2010). Crossbreeding of Kenguri with NARI Suwarna offers potential to introduce the FecB mutation into the Kenguri population.

Therefore, the present study was designed with the objective of detecting polymorphisms in ***FecB*** and ***BMP15*** genes in Kenguri and Kenguri × NARI Suwarna (F1) sheep using PCR-RFLP, and to estimate genotypic and allelic frequencies along with Hardy–Weinberg equilibrium.

II. MATERIALS AND METHODS

2.1 Experimental Animals:

The study was conducted on a total of 60 sheep comprising 30 purebred Kenguri and 30 Kenguri × NARI Suwarna (F1) animals. The animals were maintained at the Livestock Research and Information Centre, Veterinary College, Bidar, Karnataka. The Kenguri × NARI Suwarna (F1) animals had approximately 10–15% Garole inheritance through the NARI Suwarna strain.

2.2 Blood Collection and DNA Extraction:

Blood samples (10 ml) were collected aseptically from the jugular vein into sterile vacutainers containing EDTA as anticoagulant. Samples were transported on ice and stored at 4 °C until DNA extraction. Genomic DNA was extracted using the phenol–chloroform method (Andersson *et al*., 1986). DNA quality was assessed on 0.8% agarose gel electrophoresis, and concentration and purity were determined spectrophotometrically (OD260/OD280 ratio).

2.3 PCR Amplification:

A 190 bp fragment of the *FecB (BMPR1B)* gene was amplified using primers reported by Davis *et al.* (2002). For *BMP15*, primers were designed to amplify a 434 bp fragment of exon 2, based on the *Ovis aries* sequence (NCBI accession NC–019484.2). PCR reactions were carried out in 25 µl volumes containing 50 ng genomic DNA, 200 µM dNTPs, 1.5–3.0 mM $MgCl_2$, 10 pmol of each primer, 1 U of Taq DNA polymerase, and 1× buffer. Thermal cycling involved initial denaturation (95 °C, 5 min), 35 cycles of denaturation (95 °C, 30 s–1 min), annealing (61 °C for *BMP15* and 67 °C for *FecB (BMPR1B)*, 30–60 s), extension (72 °C, 30–45 s), and a final extension at 72 °C for 10 min. The details of primers for both *FecB (BMPR1B)* and *BMP15* genes are presented in table 1.

TABLE 1
PRIMER SEQUENCES OF *FECB (BMPR1B)* AND *BMP15* GENES

Candidate gene	5'-Primer sequence-3'		Length (bp)	Product Size (bp)
FecB	Forward	CCAGAGGACAATAGCAAAGCAAA	23	190
	Reverse	CAAGATGTTTTCATGCCTCATCAACACGGTC	31	
BMP15	Forward	AGAGCCACTGTGGTTTACCG	20	434
	Reverse	GATGCAATACTGCCTGCTTG	20	

2.4 RFLP Analysis:

PCR products were subjected to restriction digestion. *AvaII* enzyme was used to detect the FecB mutation in the BMPR1B gene, while *StuI* enzyme was used for the BMP15 amplicon. Digestion products were resolved on 3% agarose gel containing ethidium bromide and visualized under UV light using a Gel Doc system.

2.5 Statistical Analysis:

Genotype and allele frequencies were estimated following standard formulae. Hardy–Weinberg equilibrium was tested using the chi-square (χ^2) test (Falconer and Mackay, 1996).

III. RESULTS AND DISCUSSION

High-quality genomic DNA was extracted from all 60 animals, with concentrations ranging from 220.4 to 637.5 µg/ml and OD260/OD280 ratios between 1.7 and 1.9, indicating that the samples were suitable for PCR analysis. Amplification of the FecB and BMP15 loci produced single, sharp fragments of 190 bp and 434 bp, respectively, confirming primer specificity and template integrity (Figure 1). RFLP analysis of the *FecB* gene showed a marked contrast between the two populations studied. All Kenguri sheep were monomorphic for the wild-type genotype (++), confirming the absence of the *FecB* mutation in this breed. In contrast, the Kenguri × NARI Suwarna crossbred animals displayed clear polymorphism, with three genotypes detected: BB (16.6%), B+ (50.0%), and ++ (33.4%). The corresponding allele frequencies were B = 0.41 and + = 0.59 (Table 2). The genotype frequencies are also illustrated in a bar diagram (*Figure* 2), which highlights the predominance of the heterozygous B+ genotype in the crossbred population. The digestion pattern obtained with *AvaII* enzyme clearly differentiated the genotypes, with BB showing 160 bp and 30 bp bands, ++ showing an undigested 190 bp fragment, and B+ displaying all three fragments (Figure 3).

TABLE 2
GENOTYPIC AND ALLELIC FREQUENCIES AT *FECB* LOCUS IN *KENGURI* AND CROSSBRED SHEEP

Breed/Group	Sample size (n)	Genotype frequencies (%)	Allele frequencies
		BB	B+
Kenguri	30	0	0
Crossbred	30	16.6	50

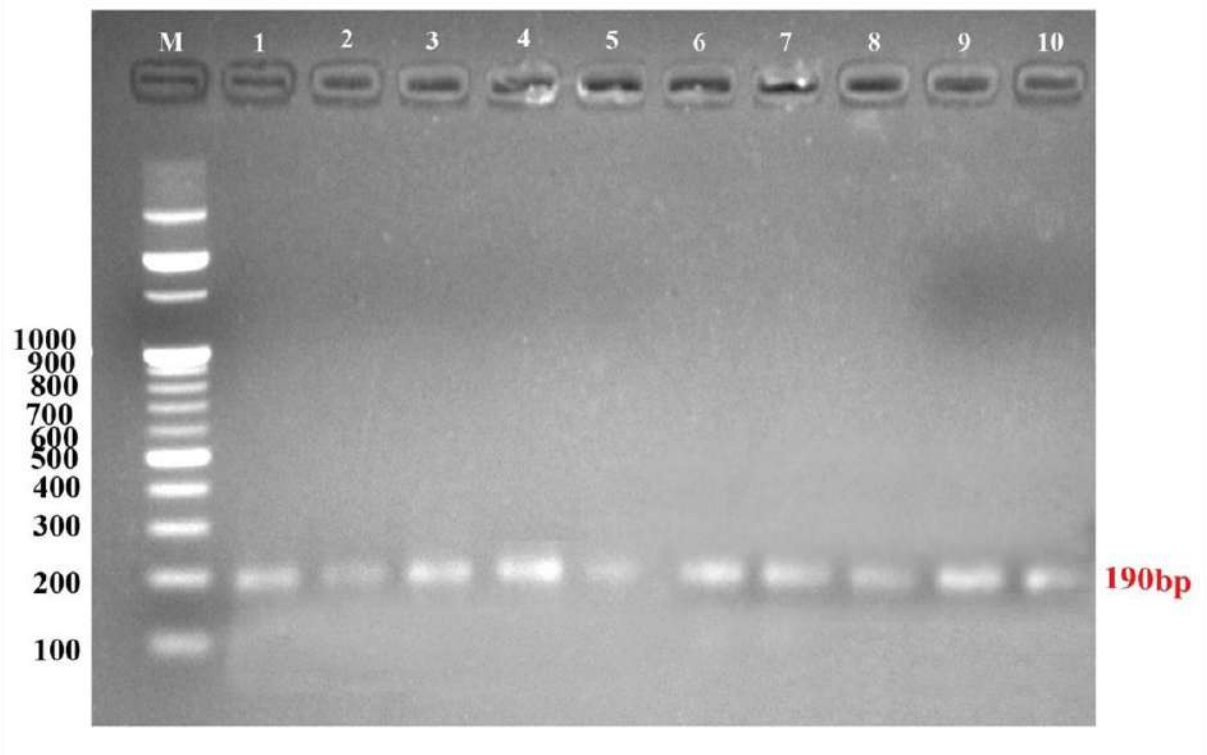

FIGURE 1: PCR amplification of *FecB* gene

A chi-square test revealed a significant deviation from Hardy–Weinberg equilibrium ($\chi^2 = 7.82$, $p < 0.05$) in the crossbred group (Table 3), suggesting that the population may be under selection pressure, genetic drift, or non-random mating. The excess of heterozygotes (50%) supports the view that the population is at an early stage of allele introgression, where crossbreeding with NARI Suwarna has contributed the mutant allele. Similar deviations from Hardy–Weinberg equilibrium have been reported in prolific breeds undergoing selection for litter size (Davis *et al.,* 2002).

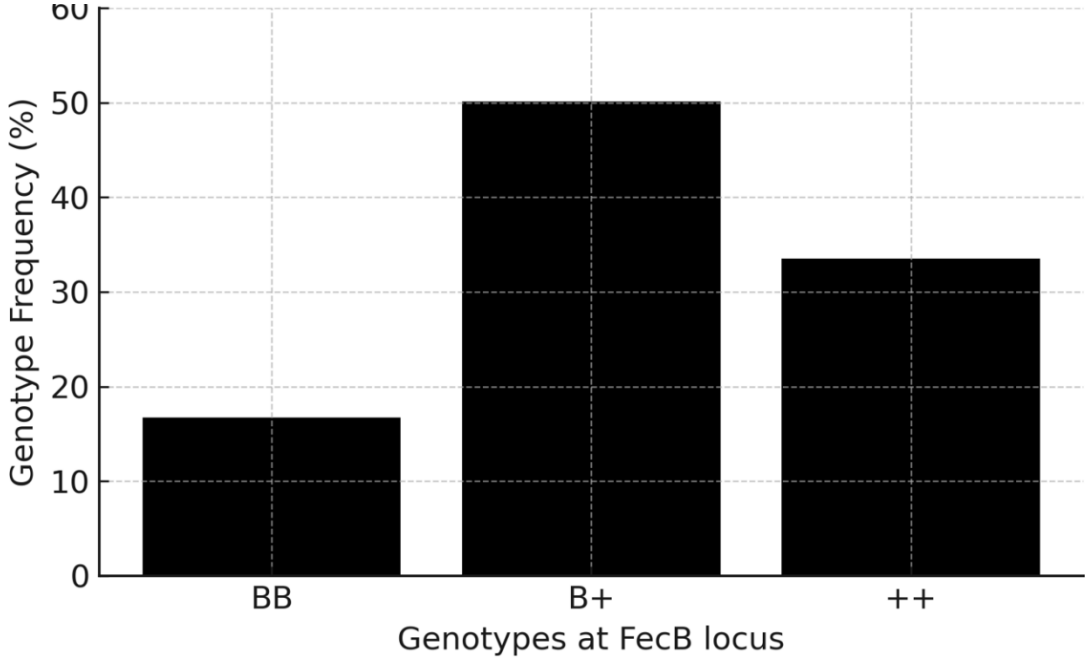

FIGURE 2: Genotype frequencies at *FecB* locus

TABLE 3
HARDY–WEINBERG EQUILIBRIUM TEST FOR *FECB* LOCUS IN CROSSBRED SHEEP

Genotype	Observed (O)	Expected (E)	$(O–E)^2/E$
BB	5	7.56	0.87
B+	15	14.28	0.03
++	10	8.16	0.41
Total $\chi^2 = 7.82$ ($p < 0.05$)			

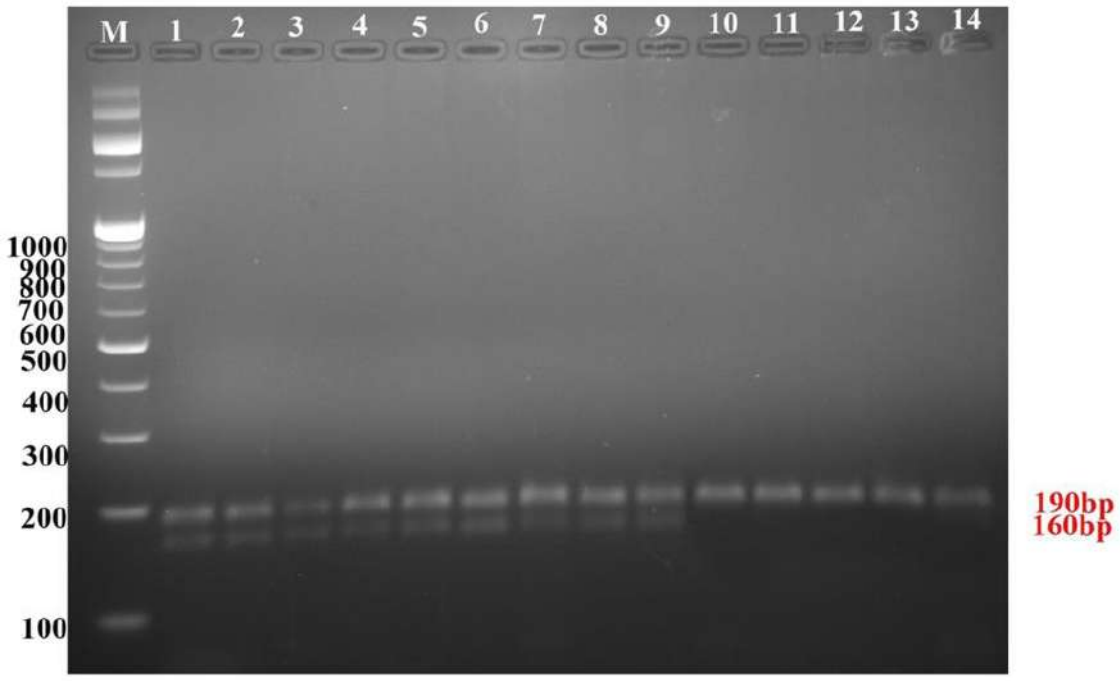

FIGURE 3: *AvaII* enzyme Digestion of *FecB* gene

In the case of the *BMP15* gene, no polymorphism was observed in either Kenguri or crossbred populations. All animals displayed the wild-type allele, with a single undigested 434 bp band observed following *StuI* digestion (Figure 4). This finding is consistent with earlier reports in Indian sheep such as Nilagiri and Kendrapada (Sudhakar *et al.*, 2013; Roy *et al.*, 2011), which were also monomorphic at the *BMP15* locus. By contrast, prolific breeds such as Inverdale and Hanna carry *BMP15* mutations that significantly increase ovulation rates but result in sterility when present in homozygous state (Galloway *et al.*, 2000; Hanrahan *et al.*, 2004).

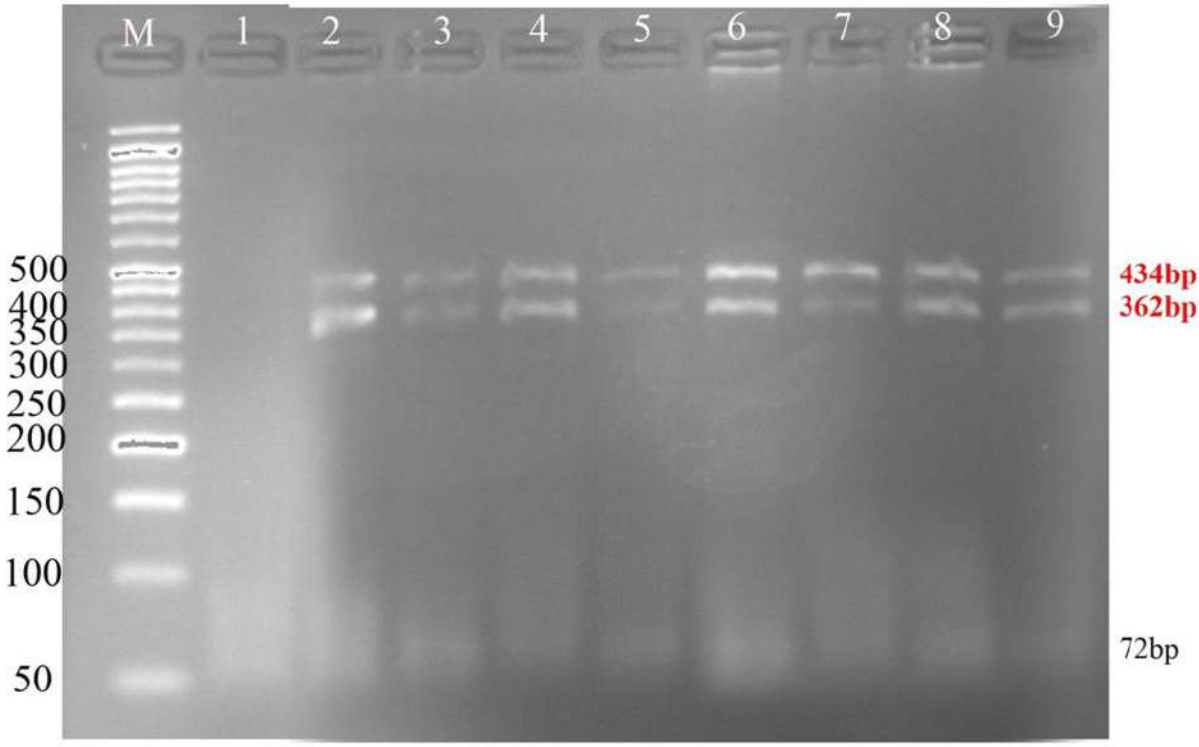

FIGURE 4: *StuI* enzyme digestion of *BMP15* gene

The results of this study clearly establish that the *FecB* mutation has been successfully introgressed into Kenguri sheep through crossbreeding with NARI Suwarna. The presence of polymorphism in the crossbred population but not in pure Kenguri indicates that the observed genetic variation is a direct outcome of the breeding program. The moderate frequency of the B allele (0.41) suggests that with systematic selection, the allele can be fixed or maintained at an optimal frequency to maximize reproductive efficiency. Comparable findings have been reported in Garole, Kendrapada, and Small Tailed Han sheep, where the FecB mutation has been strongly associated with higher litter size (Kumar *et al.*, 2008; Chu *et al.*, 2007).

IV. CONCLUSION

This study confirms the absence of the *FecB* mutation in purebred Kenguri sheep and its successful introgression into Kenguri × NARI Suwarna (F1) sheep. The presence of three genotypes at the *FecB* locus in crossbred animals, along with significant deviation from Hardy–Weinberg equilibrium, suggests ongoing selection pressure. The BMP15 locus was monomorphic in both populations. These findings provide a molecular basis for incorporating **FecB-based marker-assisted selection** in breeding strategies aimed at enhancing reproductive efficiency in Kenguri sheep. Future studies involving larger populations and direct association with reproductive performance traits are essential to validate these findings and ensure sustainable genetic improvement.

CONFLICT OF INTEREST

Author declares no conflict of interest.

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Analysis of Growth Hormone Gene Polymorphism and Its Association with Growth Traits in Kenguri Sheep

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Abstract— *The present study investigated polymorphisms of the growth hormone (GH) gene and their association with morphometric traits in Kenguri sheep, an important meat-type breed of Karnataka, India. A total of 60 adult sheep (16 males and 44 females) were sampled for genomic DNA isolation using a modified high-salt method. The GH gene fragment (422 bp) spanning exon 2–3 was amplified through polymerase chain reaction (PCR) and genotyped by PCR–restriction fragment length polymorphism (PCR-RFLP) using the HaeIII enzyme. Two genotypes, AA and AB, were detected, while BB was absent. The frequencies of AA and AB genotypes were 0.417 and 0.583, respectively, with allele frequencies of 0.708 (A) and 0.292 (B). Chi-square analysis indicated significant deviation from Hardy–Weinberg equilibrium ($\chi^2=10.29$, $p<0.05$). Morphometric traits including body weight, body length, height at wither, and chest girth were recorded. Males showed significantly ($p<0.05$) higher body weight and chest girth than females, while other traits were comparable. Within genotypes, no significant association ($p>0.05$) was found between GH polymorphisms and body measurements in either sex. The findings confirm the presence of GH gene variability in Kenguri sheep, with predominance of heterozygotes, although no strong phenotypic association was evident. This suggests that while the GH gene harbours genetic variability, additional markers or larger populations may be required to elucidate its role in growth performance. The study provides baseline molecular information that could support marker-assisted selection (MAS) strategies for sheep improvement programs in India.*

Keywords— Kenguri sheep, growth hormone gene, PCR-RFLP, polymorphism, morphometric traits, marker-assisted selection.

I. INTRODUCTION

India harbours one of the world's richest livestock genetic resources, with 65 million sheep distributed across diverse agro-climatic regions [1]. Sheep play a vital role in rural livelihood through meat, wool, and skin production. In recent decades, the demand for mutton has increased steadily, underscoring the need for scientific breeding strategies that improve productivity while conserving indigenous breeds. Kenguri sheep, primarily reared in the Koppal and Raichur districts of Karnataka, are a medium-to-large sized mutton-type breed characterized by their adaptability, disease resistance, and increasing popularity in stall-feeding systems [2]. Despite their potential, genetic improvement efforts in Kenguri sheep remain limited. Molecular markers, particularly those associated with growth, offer an opportunity to accelerate breed improvement.

The growth hormone (GH) gene, synthesized by somatotroph cells of the pituitary gland, is a crucial regulator of postnatal growth, lactation, reproduction, and metabolism [3,4]. It influences body weight, height, and carcass quality both directly and through the insulin-like growth factor (IGF) pathway [5]. Due to its central role, GH has been widely investigated as a candidate gene for marker-assisted selection (MAS) in livestock [6].

Polymorphisms in GH have been reported in several sheep breeds worldwide, including Indian populations such as Nellore, Patanwadi, and Vembur [7–9]. However, the extent of GH variability in Kenguri sheep and its association with growth traits has not been systematically studied. So this study was designed to detect polymorphisms of the GH gene in Kenguri sheep using PCR-RFLP, estimate genotype and allele frequencies and test Hardy–Weinberg equilibrium and assess associations between GH polymorphism and morphometric traits (body weight, body length, chest girth, and height at wither).

II. MATERIALS AND METHODS

2.1 Experimental Animals:

A total of 60 adult Kenguri sheep (16 males and 44 females) were randomly sampled from flocks maintained at Veterinary College, Bidar, and in their breeding tract.

2.2 DNA extraction and quantification:

Blood samples (10 ml) were collected aseptically from the jugular vein into sterile vacutainers containing EDTA as anticoagulant. Samples were transported on ice and stored at 4 °C until DNA extraction. Genomic DNA was extracted using the phenol–chloroform method (Andersson *et al.*, 1986). DNA quality was assessed on 0.8% agarose gel electrophoresis, and concentration and purity were determined spectrophotometrically (OD260/OD280 ratio).

2.3 PCR amplification of GH gene:

Primers amplifying a 422 bp fragment spanning exon 2–3 were used [4]. PCR conditions included: 35 cycles of denaturation at 95°C (30 s), annealing at 62°C (30 s), and extension at 72°C (30 s), followed by a final extension at 72°C (8 min).

TABLE 1
PRIMER SEQUENCES OF *FECB (BMPR1B)* AND *BMP15* GENES

Candidate gene	5'-Primer sequence-3'		Length (bp)	Product Size (bp)
FecB	Forward	CCAGAGGACAATAGCAAAGCAAA	23	190
	Reverse	CAAGATGTTTTCATGCCTCATCAACACGGTC	31	
BMP15	Forward	AGAGCCACTGTGGTTTACCG	20	434
	Reverse	GATGCAATACTGCCTGCTTG	20	

2.4 Restriction digestion and genotyping:

PCR products were digested with *HaeIII* enzyme, which recognizes the sequence GGCC. Products were separated on 2.5% agarose gel and visualized under UV. Genotypes were classified as:

- AA: 366 bp + 56 bp
- AB: 422 bp + 366 bp + 56 bp
- BB: absent

2.5 Morphometric traits:

Each animal was measured for body weight (kg), body length (cm), height at wither (cm), and chest girth (cm).

2.6 Statistical analysis:

- Genotypic and allelic frequencies estimated by direct count.
- Hardy–Weinberg equilibrium tested using χ^2 [11].
- Association between genotypes and morphometric traits tested using t-test [12].

III. RESULTS AND DISCUSSION

Genomic DNA isolated from 60 Kenguri sheep ranged between 220 and 637 µg/ml, with a mean concentration of 296.7 ± 15.9 µg/ml and OD ratios averaging 1.75, confirming its suitability for PCR amplification. A clear 422 bp amplicon of the GH gene was consistently obtained (Fig. 1). Following *HaeIII* digestion, two genotypes were identified: AA (366 and 56 bp) and AB (422, 366, and 56 bp). The BB genotype was absent in the population (Fig. 2). Among the 60 animals, 25 were AA and 35 were AB, corresponding to genotype frequencies of 0.417 and 0.583, respectively. Allele frequencies were 0.708 for A and 0.292 for B (Table 2).

TABLE 2
GENOTYPE AND ALLELE FREQUENCIES OF GH GENE IN KENGURI SHEEP

Genotype	Male (n=16)	Female (n=44)	Total (n=60)	Frequency
AA	9	16	25	0.417
AB	7	28	35	0.583
BB	0	0	0	0

FIGURE 1: PCR amplification of growth hormone gene (422bp) of Kenguri sheep

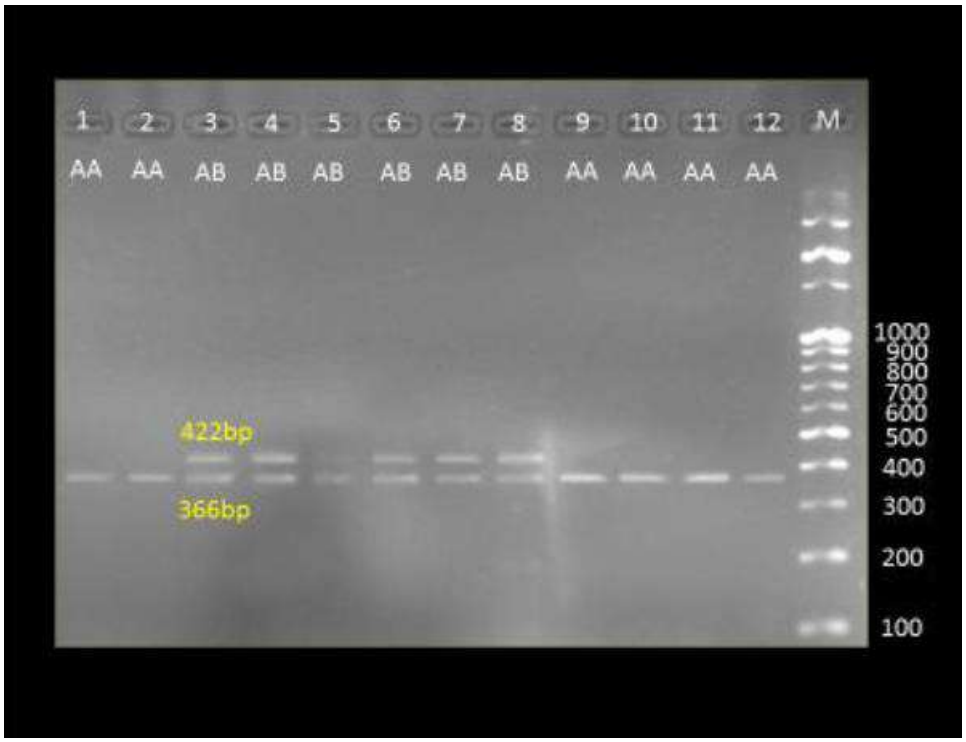

FIGURE 2: PCR-RFLP pattern of growth hormone gene (422bp) of Kenguri sheep

The predominance of the heterozygous AB genotype and the absence of BB mirror earlier findings in Indian breeds such as Vembur and Dumba [8,9]. This suggests restricted allelic diversity at this locus, which may be the result of historical selection pressures or drift. Chi-square testing showed significant deviation from Hardy–Weinberg equilibrium ($\chi^2 = 10.29$, $p<0.05$), indicating non-random mating or selection effects within the studied population. Similar disequilibrium has been reported in other Indian sheep breeds, including Marwari and Patanwadi [9].

Morphometric comparisons between sexes revealed that males were significantly heavier (37.46 ± 0.69 kg vs. 34.98 ± 0.59 kg) and broader-chested (83.18 ± 0.84 cm vs. 79.72 ± 0.72 cm) than females (Table 3). Height at wither and body length did not differ significantly between sexes. When analysed by genotype, however, no significant differences were observed for body weight, body length, height at wither, or chest girth in either males or females (Tables 4 and 5). For example, male AA animals averaged 38.31 kg in body weight compared to 36.38 kg for AB, but the difference was non-significant. Similarly, female AA animals averaged 34.76 kg against 35.10 kg in AB animals. These results demonstrate that GH gene polymorphism at the A781G locus is not strongly associated with morphometric traits in Kenguri sheep.

TABLE 3
MEAN MORPHOMETRIC TRAITS OF MALE AND FEMALE KENGURI SHEEP

Trait	Male (Mean ± SE)	Female (Mean ± SE)	p-value
Body weight (kg)	37.46 ± 0.69	34.98 ± 0.59	0.03*
Height at wither (cm)	71.25 ± 0.59	70.97 ± 0.38	0.41
Body length (cm)	69.18 ± 0.90	69.22 ± 0.50	0.47
Chest girth (cm)	83.18 ± 0.84	79.72 ± 0.72	0.02*

TABLE 4
BODY MEASUREMENTS OF FEMALE KENGURI SHEEP BY GENOTYPE

Trait	AA (n=16)	AB (n=28)	p-value
Body weight (kg)	34.76 ± 1.15	35.10 ± 0.69	0.62
Height at wither (cm)	71.00 ± 0.72	70.96 ± 0.44	0.88
Body length (cm)	69.56 ± 1.09	69.03 ± 0.51	0.57
Chest girth (cm)	79.37 ± 1.30	79.92 ± 0.88	0.49

TABLE 5
BODY MEASUREMENTS OF MALE KENGURI SHEEP BY GENOTYPE

Trait	AA (n=9)	AB (n=7)	p-value
Body weight (kg)	38.31 ± 1.18	36.38 ± 0.38	0.11
Height at wither (cm)	71.88 ± 0.80	70.42 ± 0.91	0.09
Body length (cm)	69.89 ± 0.79	68.28 ± 1.92	0.27
Chest girth (cm)	84.00 ± 1.26	82.14 ± 1.09	0.12

Comparable outcomes have been reported in Baluchi and Avikalin sheep, where GH polymorphisms showed little or no significant correlation with growth traits [13,14]. Nonetheless, studies in Indonesian sheep have shown that AA genotypes may be associated with higher weaning weights compared to BB [15], indicating breed- and environment-specific effects. The lack of association in Kenguri sheep could be due to small sample size, breed-specific genetic architecture, or the polygenic nature of growth traits.

While the present results do not support GH polymorphism as a direct marker for growth in Kenguri sheep, the presence of variability highlights its potential utility for diversity monitoring. Moreover, the predominance of heterozygotes suggests that the population retains genetic variability that could be exploited in future breeding programs. For effective marker-assisted selection, however, multi-gene panels including GH, IGF-1, MSTN, and LEP, along with larger population sizes, should be evaluated.

IV. CONCLUSION

This study documents the presence of GH gene polymorphism in Kenguri sheep, identifying two genotypes (AA and AB) with a predominance of heterozygotes and absence of BB. The population deviated significantly from Hardy–Weinberg equilibrium, suggesting non-random mating or selection effects. Although no significant associations were detected between GH polymorphism and morphometric traits, the findings provide baseline molecular information useful for breed conservation and genetic diversity studies. Future research with larger populations and multiple candidate genes is required to clarify the role of GH and related markers in growth performance and to establish effective marker-assisted selection strategies in Kenguri sheep.

CONFLICT OF INTEREST

Author declares no conflict of interest

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Efficacy of Fungicides against Anthracnose of Green Gram Caused by *Colletotrichum lindemuthianum*

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Abstract— *Green gram (Vigna radiata L.) is autogamous diploid grain legume crop belonging to Leguminosae family. Anthracnose caused by Colletotrichum lindemuthianum is a serious disease in almost all green gram growing areas. Five systemic, five non-systemic and five ready mixed fungicides were evaluated against C. lindemuthianum under in vitro by poison food technique. Among the systemic fungicides, highest mean inhibition of mycelial growth obtained with tebuconazole (100%) followed by carbendazim (78.33%) and difenoconazole (75.18%). Among the non-systemic fungicides, highest mean mycelial growth inhibition was obtained by copper oxychloride with 100 per cent followed by mancozeb with 84.62 per cent. Among ready mixed fungicides, carbendazim + mancozeb and tebuconazole + trifloxystrobin were significantly higher than the rest of the ready mixed fungicides with 100 per cent mycelial growth inhibition followed by azoxystrobin + difenoconazole and captan + hexaconazole with percentage of 95.37 and 83.42, respectively.*

Keywords— Green gram, Anthracnose, Colletotrichum lindemuthianum, Fungicides.

I. INTRODUCTION

The green gram [*Vigna radiata* (L.) Wilczek] is one of the third most important pulse crop of India after chickpea and pigeonpea. It is autogamous diploid (2n=22) grain legume crop belonging to Leguminosae family. It is also commonly known as mung, mungbean, green gram in India and mungo in Philippines. It is an erect, sub-erect, deep rooted, much branched, somewhat hairy, herb with the height from 30 to 160 cm. It is an ancient and well-known leguminous crop of Asia and India. It is quite versatile crop grown for seeds, green manure and forage.

India is the principal producer of green gram in the world with an annual production of 3.17 million tonnes from an area of 5.5 million hectares with productivity of 570 kg/ha. (Anonymous, 2022a). Green gram total area in Gujarat is 1690.29 ha, productivity 1368.88 MT and yield is 809.85 kg/ha (Anonymous, 2022b). In recent years, anthracnose of green gram caused by *Colletotrichum lindemuthianum* (Sacc. & Magn.) Briosi and Cavara has become one of the serious disease of green gram. In India, the green gram anthracnose was first reported from Jorhat of Assam state during 1951 (Majid, 1953). The average seed yield loss of 40.18 per cent and stalk yield loss of 46.90 per cent was noticed due to anthracnose of green gram (Kulkarni, 2009). Considering the severity of this disease and frequent occurrence in the fields, it has been felt necessity to develop effective management strategies. Thus, attempts have been made to evaluate the efficacy of fungicides against anthracnose disease caused by *C. lindemuthianum.*

II. MATERIAL AND METHODS

The *in vitro* efficacy of five systemic with 100, 250 and 500 ppm, five non-systemic with 1000, 1500 and 2000 ppm and five ready mixed fungicides with 500, 1000 and 1500 ppm were tested against *C. lindemuthianum* by poison food technique (Nene and Thapliyal, 1993) with Completely Randomized Design. This experiment was conducted in Department of Plant Pathology, C. P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar, Gujarat during 2024-25. The measured quantities of fungicides were incorporated in melted sterilized PDA medium and poured it into sterilized Petri dishes aseptically. The Petri dishes were inoculated with pathogen in the centre by placing seven days old mycelial disc of 5 mm diameter and then incubated at 25±1ºC temperature. Simultaneously, a suitable control was maintained by growing the fungus

on fungicides free PDA medium. Radial mycelial growth of fungus was recorded on daily basis in control plates starting from the initiation of the fungal growth in correspondence to treatment plated till full mycelial growth of fungus was observed in control. The per cent inhibition of growth of fungus was observed in control. The per cent inhibition of growth of the fungus in comparison with control was calculated by the equation given by Vincent (1947).

III. RESULTS AND DISCUSSION

3.1 Efficacy of systemic fungicides against *C. lindemuthianum:*

Among systemic fungicides, the highest mean mycelial growth inhibition was obtained with tebuconazole (100%) followed by carbendazim (78.33%) and difenoconazole (75.18%). Thiophanate methyl recorded least inhibition of only 65.74 per cent mycelial growth inhibition of the fungus. Tebuconazole at 100, 250 and 500 ppm inhibited 100 per cent mycelial growth of the pathogen. The next best treatment in order of merit were azoxystrobin at 500 ppm, carbendazim at 500 ppm and difenoconazole at 500 ppm which inhibited 83.06, 81.39 and 79.44 per cent mycelial growth inhibition, respectively. Thiophanate methyl at 100 ppm found the least inhibition of only 60.83 per cent mycelial growth of test pathogen (Table 1). Aggarwal *et al.* (2015) reported that tebuconazole was found superior with 100 per cent mycelial inhibition of *C. lindemuthianum* at 250, 500, 1000 and 2000 ppm concentrations. Vani and Somashekhara (2018) also found that tebuconazole (100%) was effective at 1000 ppm *in vitro* for inhibition of mycelial growth of *C. capsici.*

TABLE 1
EFFICACY OF SYSTEMIC FUNGICIDES AGAINST *C. LINDEMUTHIANUM IN VITRO* CONDITION

Tr. No.	Treatments	Per cent growth inhibition			
		Concentration (ppm)			Mean
		100	250	500	
T_1	Difenoconazole 25 EC	57.77	59.83	63.02	60.17
		(71.39)*	(74.72)	(79.44)	(75.18)
T_2	Thiophanate methyl 70 WP	51.24	54.05	57.29	54.19
		(60.83)	(65.56)	(70.83)	(65.74)
T_3	Tebuconazole 25.9 EC	85.91	85.91	85.91	85.91
		(100)	(100)	(100)	(100)
T_4	Carbendazim 50 WP	60.95	61.58	64.57	62.36
		(76.39)	(77.22)	(81.39)	(78.33)
T_5	Azoxystrobin 23 SC	52.9	59.56	65.85	59.43
		(63.61)	(74.17)	(83.06)	(73.61)
T_6	Control	4.05	4.05	4.05	4.05
		(0)	(0)	(0)	(0)
Mean		52.11	54.16	56.78	-
		(62.03)	(65.27)	(69.12)	
S. Em. ±		Treatment	Concentration	Treatment × Concentration	
		0.66	0.46	1.14	
C. D. @ 5%		1.87	1.32	3.25	
C. V. %		4.22			

Figures in parentheses are original values and outside are arc-sine transformed values

3.2 Efficacy of non-systemic fungicides against *C. lindemuthianum*:

Among the five non-systemic fungicides, copper oxychloride was found most effective with highest mean mycelial growth inhibition with 100 per cent per cent found significantly superior over rest of fungicides. Next best fungicides was mancozeb 84.62 per cent mean mycelial growth inhibition. Propineb was found next effective to inhibit 74.25 per cent mycelial growth

inhibition of the fungus and significantly superior over chlorothalonil (68.79%). Cent per cent (100%) growth inhibition of *C. lindemuthianum* was recorded with all the concentrations of copper oxychloride. The next best fungicide was mancozeb at 2000 ppm which inhibited the fungal growth as 88.61 per cent. Fungal growth of the pathogen generally decreased with increased concentration of the tested fungicides (Table 2). Rewale *et al.* (2016) found copper oxychloride and mancozeb were most effective with highest average mycelial growth inhibition of *C. graminicola*. Patel *et al*. (2025) found that copper oxychloride reported superior for mean mycelial inhibition (94.43%) of *C. gloeosporioides* followed by mancozeb (89.10%).

TABLE 2
EFFICACY OF NON-SYSTEMIC FUNGICIDES AGAINST *C. LINDEMUTHIANUM IN VITRO*

Tr. No.	Treatments	Per cent growth inhibition			
		Concentration (ppm)			Mean
		1000	1500	2000	
T1	Propineb 70 WP	55.25	60.37	63.25	59.62
		(67.50) *	(75.55)	(79.72)	(74.25)
T2	Copper oxychloride 50 WP	85.91	85.91	85.91	85.91
		(100)	(100)	(100)	(100)
T3	Chlorothalonil 75 WP	52.54	55.91	59.81	56.08
		(63.05)	(68.61)	(74.72)	(68.79)
T4	Zineb 75 WP	52.22	53.89	55.07	53.72
		(62.5)	(65.27)	(67.22)	(64.99)
T5	Mancozeb 75 WP	64.88	65.95	70.69	67.17
		(81.94)	(83.33)	(88.61)	(84.62)
T6	Control	4.05	4.05	4.05	4.05
		(0)	(0)	(0)	(0)
Mean		52.47	54.34	56.46	-
		(62.49)	(65.46)	(68.37)	
S. Em. ±		Treatment	Concentration	Treatment × Concentration	
		0.57	0.4	0.99	
C. D. @ 5%		1.63	1.15	2.82	
C. V. %		3.66			

Figures in parentheses are original values and outside are arc-sine transformed values

3.3 Efficacy of ready-mix fungicides against *C. lindemuthianum*:

All ready-mix fungicides were found effective at 1500 ppm concentrations. Among them, carbendazim + mancozeb and tebuconazole + trifloxystrobin was found significantly higher than the rest of the ready-mix fungicides with 100 per cent mean mycelial growth inhibition followed by azoxystrobin + difenoconazole and captan + hexaconazole with percentages of 95.37 and 83.42, respectively. Metiram + pyraclostrobin recorded the least mean mycelial growth inhibition of only 74.90 per cent of test pathogen. In combine fungicides, carbendazim + mancozeb and tebuconazole + trifloxystrobin both inhibited 100 per cent mycelial growth at all concentrations tested (500, 1000 and 1500 ppm) and it was at par with azoxystrobin + difenoconazole (99.17%) at 1500 ppm. The next treatment were azoxystrobin + difenoconazole at 1000 and 500 ppm concentrations with 96.39 and 90.56 per cent, respectively. Captan + hexaconazole at 1500, 1000 and 500 ppm concentration with 87.78, 83.33 and 79.17 per cent, respectively. Metiram + pyraclostrobin at 500 ppm was found least effective concentration which recorded 72.78 per cent mycelial growth inhibition of the *C. lindemuthianum* (Table 3). Similar results were obtained in the investigations by Madhusudhan (2002) reported that carbendazim + mancozeb was found superior among the ready-mix fungicides by inhibiting 99.22 and 85.92 per cent growth of *C. truncatum* at 0.25 and 0.2 per cent concentration, respectively. Padghan *et al.* (2023) found trifloxystrobin + tebuconazole with highest efficiency achieving cent per cent inhibition of *C. capsici*. Next best fungicide was Azoxystrobin + difenoconazole.

TABLE 3
EFFICACY OF READY-MIX FUNGICIDES AGAINST *C. LINDEMUTHIANUM IN VITRO*

Tr. No.	Treatments	Per cent growth inhibition			
		Concentration (ppm)			Mean
		500	1000	1500	
T1	Azoxystrobin 18.2 + difenoconazole 11.4 SC	72.33	79.37	84.28	78.66
		(90.56) *	(96.39	(99.17	(95.37
T2	Captan 70 + hexaconazole 5 WP	62.9	65.94	69.55	66.13
		(79.17)	(83.33)	(87.78)	(83.42)
T3	Carbendazim 12 + mancozeb 63 WP	85.91	85.91	85.91	85.91
		(100)	(100)	(100)	(100)
T4	Metiram 55 + pyraclostrobin 5 WG	58.53	59.63	61.67	59.94
		(72.78)	(74.44)	(77.5)	(74.9)
T5	Tebuconazole 50 + trifloxystrobin 25 WG	85.91	85.91	85.91	85.91
		(100)	(100)	(100)	(100)
T6	Control	4.05	4.05	4.05	4.05
		(0)	(0)	(0)	(0)
Mean		61.05	63.46	65.22	-
		(73.75)	(75.69)	(77.4)	
S. Em. ±		**Treatment**	**Concentration**	**Treatment × Concentration**	
		0.5	0.35	0.86	
C. D. @ 5%		1.41	1	2.45	
C. V. %		2.73			

Figures in parentheses are original values and outside are arc-sine transformed values

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The Role of Mobile Phones in Production and Agricultural Information Access for Farmers in Dhamar Governorate, Yemen

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Abstract— *Farmers in Dhamar Governorate, Yemen, face persistent challenges in accessing timely and relevant agricultural information due to limited extension services, poor infrastructure, low digital literacy, and constrained mobile network coverage. These limitations hinder informed decision-making, reduce agricultural productivity, and restrict the adoption of modern farming techniques. This study investigates how mobile phones are utilized to access production and agricultural information and identifies the factors and challenges that affect their usage among farmers in Dhamar. To achieve these goals, the study conducted a thorough analysis of the existing literatures. A quantitative research design was employed through a structured questionnaire distributed to 181 agricultural holders in Jabal Ash sharq District. Data analysis using SPSS included descriptive statistics, factor analysis, and reliability tests. The study used the Kaiser-Meyer-Olkin (KMO = 0.851) and Bartlett's Test of Sphericity ($p < 0.001$) to assess sampling adequacy and suitability for factor analysis, and the Cronbach's alpha ($\alpha = 0.920$) confirmed strong internal consistency. In descriptive statistics test, results were carried out of maximum value of 5. Key findings indicate that mobile phones play a modest yet significant role in improving access to farming techniques and agricultural services. Two dominant utilization components were identified: (1) direct access to agricultural information and enhanced decision-making, and (2) participatory communication, including networking with input suppliers and fellow farmers. The highest reported use was communication with input suppliers (Mean = 3.87), followed by access to farming techniques (Mean = 2.55). However, the study revealed substantial barriers, classified into three main categories: (1) Individual Capability Constraints such as lack of training and digital skills (Mean = 4.20), (2) Institutional and Economic Barriers including insufficient promotion by extension agents and lack of organizational support (Mean = 4.59 and 4.48, respectively), and (3) Infrastructural Barriers like poor network coverage and limited access to charging facilities (Mean = 3.52 and 3.64). The study concludes with recommendations aimed at enhancing digital inclusion and agricultural development. These include localized content development in native languages, capacity-building programs for farmers, and significant investments in infrastructure to support broader and more effective use of mobile technologies in rural Yemen.*

Keywords— Mobile Phones, Agricultural Information Access, Smallholder Farmers, ICT in Agriculture, Dhamar Governorate, Agricultural Extension Services.

I. INTRODUCTION

Agriculture is the cornerstone of livelihoods and economic stability in Dhamar Governorate, Yemen, where smallholder farmers form the backbone of food production. However, the agricultural sector faces numerous systemic challenges, including limited access to modern agricultural techniques, unreliable extension services, inadequate infrastructure, and insufficient dissemination of market information. These challenges are exacerbated by Yemen's ongoing political instability, climate variability, and socio-economic conditions. One of the most pressing problems is the lack of timely and accurate agricultural information available to farmers. Traditional information channels such as direct extension services are limited in their reach, especially in remote rural areas. As a result, farmers are often left without critical knowledge about farming techniques, pest control, weather forecasts, market prices, and post-harvest practices. This information gap leads to suboptimal decision-making and reduced agricultural productivity.

In recent years, the proliferation of mobile phones has presented new opportunities to bridge this information gap. Mobile phones offer farmers an accessible platform to receive, share, and interact with agricultural content and extension services.

Despite the growing penetration of mobile technology in Yemen, there is limited empirical evidence on how smallholder farmers in regions like Dhamar Governorate utilize mobile phones for agricultural purposes, and what obstacles they encounter in doing so. The integration of Information and Communication Technologies (ICTs), particularly mobile phones, into agricultural systems has received considerable scholarly attention. Numerous studies have highlighted how mobile phones facilitate real-time communication, improve market transparency, and enable farmers to make informed decisions regarding crop management, pest control, and input use. For instance, research in India revealed that mobile access to agricultural call centers significantly improved productivity by enabling farmers to adopt high-yielding seed varieties and manage inputs more effectively (Gupta et al., 2020). Similarly, Munawaroh (2023) found that farmers using mobile services in East Java reported an average increase in rice yields of 841.3 kg per hectare compared to non-users.

In African contexts, mobile phones have demonstrated transformative potential as tools for agricultural development. Studies by Mwaseba et al. (2024); Kisena & Kwesigabo, (2023) in Kenya and Tanzania, respectively, show that widespread mobile adoption among smallholder farmers has been linked to improved market access, enhanced extension services, and the adoption of climate-smart practices. Notably, applications such as mFarms, Kilimo Salama, and M-Farm have helped farmers to reduce transaction costs, receive localized weather forecasts, and access mobile insurance schemes. These tools not only address information asymmetry but also bolster farmers' resilience to economic and climatic shocks.

Despite their promise, several barriers hinder the full utilization of mobile phones in agriculture. Language remains a critical barrier especially in regions where mobile content is predominantly in English. Dissanayeke & Wanigasundera, (2014); Ajani & Agwu, (2012) emphasized that the lack of localized language content limits the utility of mobile-based services. Additionally, the technical literacy of users plays a major role in determining effective usage. Farmers unfamiliar with mobile applications or SMS-based systems may struggle to access the benefits of digital tools. The role of mobile service providers is also significant. In countries such as Bangladesh and Tanzania, telecom companies have partnered with agricultural institutions to develop targeted mobile services. For example, Grameen Phone in Bangladesh established dedicated agricultural call centers that deliver expert advice directly to rural users, as noted by Al Kibria et al. (2023).

In contrast, the situation in Yemen is complicated by infrastructural deficits and political instability. Although companies like Yemen Mobile and MTN Yemen operate in the region, their coverage and service reliability are inconsistent, particularly in remote farming communities. According to Al-Baltah et al. (2024), there is a growing reliance on mobile platforms such as WhatsApp among Yemeni farmers, despite limited formal extension support. However, widespread adoption is curtailed by low smartphone penetration, intermittent electricity, and the absence of structured support systems. Khalil et al. (2022) asserted that the increasing demand for real-time agricultural information signals the urgency for scalable, locally adapted mobile solutions that cater to the needs of smallholder farmers.

This body of literature collectively underscores the relevance of mobile phones as a mechanism for improving agricultural information access, while also drawing attention to persistent gaps in infrastructure, training, and institutional backing. It provides a foundational basis for the current study, which seeks to contextualize and evaluate mobile phone use among farmers in Dhamar Governorate, Yemen, through empirical field data. While these global and regional studies affirm the potential of mobile phones in transforming agricultural extension, they often focus on contexts with relatively stable infrastructure and governance. Yemen, in contrast, faces a unique convergence of constraints including economic fragility, weak institutional capacity, and geographic disparities in mobile network coverage. Moreover, prior research tends to generalize mobile phone usage without distinguishing between its communicative functions (e.g., contacting input suppliers) and informational functions (e.g., receiving weather or market data), especially among smallholder farmers in underserved regions. Hence, there remains a significant gap in localized empirical studies that systematically explore how mobile phones are actually used by farmers in marginalized contexts like Dhamar, and what specific factors hinder or promote their usage.

Accordingly, this study aims to address this gap by focusing on two main objectives: first, to assess the role of mobile phones in accessing agricultural information; and second, to identify the factors and challenges that influence their utilization among farmers in Dhamar Governorate. The research provides crucial insights for policymakers, agricultural development organizations, and digital service providers seeking to enhance the impact of mobile-based interventions in rural Yemen.

II. MATERIAL AND METHODS

2.1 Research Design:

A quantitative research approach was utilized in this study to address the problem statement and achieve the study objectives. Data collection was conducted through a structured questionnaire, which is designed to ensure consistency and reliability in

sampling and information gathering from the study area. The questionnaire was developed through a rigorous process that included a comprehensive review of related literature and previous studies in the field of agricultural information systems and mobile phone usage. To ensure the effectiveness of the questionnaire in meeting the research objectives, a pilot study was conducted prior to the main data collection which involved an academic expert, and other experts in agricultural engineering field whose feedbacks were used to refine the questionnaire and confirm its suitability for capturing the required quantitative data. This preliminary step was essential for enhancing the validity and reliability of the research instrument, ensuring that the subsequent data collection accurately reflects the perspectives and conditions of the target population. The survey included 22 questions designed to measure respondents' perceptions of mobile phone utilization in agricultural information access, and factors and challenges affecting usage. The final instrument was divided into sections covering socio-demographic profiles, types of agricultural information accessed, mobile phone functions utilized, frequency of use, and perceived challenges. Responses were rated using a five-point Likert scale ranging from 1 (Not Existing) to 5 (High) to measure respondents' perceptions and experiences with greater accuracy.

2.2 Data Collection Methods:

The targeted population for this study consists of agricultural holders who work in the farming sector in Dhamar Governorate, Yemen. According to General Authority for Agricultural Researches and Extension (AREA), the total number of agricultural holders in the governorate is 12641 distributed across 9 different administrative districts (AREA, 2024). Due to the various limitations of the research, including time and funding, Jabal Ash sharq District was chosen as the study area because it has the lowest percentage of agricultural holders in the governorate with 343 agricultural holders, and it is also a predominantly rural area, characterized by its mountainous terrain and fertile valleys suitable for agriculture. Moreover, most of the region's residents work in agriculture, which facilitates access to the study community and data collection. According to Krejcie & Morgan, (1970); sample size determination, for a population of 343, the sample size should be 181. Relatively, the sample size for the survey will be 181 agricultural holders.

The survey was conducted using Google Forms to facilitate the distribution and a timely collection of responses from farmers across the study area. This digital approach guaranteed accessibility and efficiency in managing the data collection process, particularly in areas with reliable internet connectivity. Furthermore, an academic researcher was trained and authorized to oversee the fieldwork, which involved distributing questionnaires to selected farmers in remote and rural locations where digital access was limited. For respondents with limited literacy, the researcher provided verbal explanations and filled in responses based on their input. This approach improved the inclusiveness and reliability of the data. To ensure quality control and swiftly resolve any logistical or methodological concerns, the data collection procedure was facilitated by periodic online sessions, maintaining consistent communication and guidance between the principal investigator and the field researcher. This collaborative approach helped streamline operations and uphold the integrity of the research process.

2.3 Data Analysis Methods:

Once data collection was completed, the data were analyzed using Statistical Package for the Social Sciences (SPSS). The analysis included descriptive statistics (mean, standard deviation, frequency, and percentage) to summarize the demographic profile and usage patterns. To assess the internal consistency and validity of the measurement items, the Kaiser-Meyer-Olkin (KMO) test, Bartlett's Test of Sphericity, and Cronbach's alpha were applied. Exploratory factor analysis (EFA) was conducted to identify latent variables influencing mobile phone usage and to categorize key challenges into distinct dimensions.

III. RESULT AND DISCUSSION

3.1 Demographic Analysis of Respondents:

3.1.1 Gender Distribution:

The demographic analysis initiates with the gender distribution of participants. The analysis revealed that the majority of respondents 174 (96.1%) were male, whilst only 7 (3.9%) were female. This gender imbalance reflects the traditional agricultural practices in the study area, where farming is predominantly managed by men. Such a distribution also suggests that men are more involved in decision-making related to agricultural activities and possibly more exposed to technological tools like mobile phones.

3.1.2 Age Category Distribution:

The age distribution showed that among agricultural holders polled, the predominant age group was 26–35 years, consisting of 91 individuals (50.3%). The subsequent age group was 36–45 years, comprising 39 respondents (21.5%), followed by 18–25 years with 36 respondents (19.9%), and those aged 46 years and above with 15 respondents (8.3%). This distribution indicates that more than 70% of respondents are aged between 18 and 35 years, demonstrating a primarily youthful agricultural demographic in Jabal Ash sharq District. This demographic insight is crucial for analyzing mobile phone usage patterns in agriculture, as younger farmers are generally more predisposed to embrace modern technology, including mobile phones, than their older counterparts.

3.1.3 Educational Level Distribution:

In terms of education, a majority of the farm holdings, 95 persons (52.5%), indicated that they have completed primary education. Subsequently, there were 57 respondents (31.5%) with secondary education, 20 respondents (11.0%) with university education, and merely 9 persons (5.0%) who indicated no formal education. This distribution indicates that a substantial percentage of farmers in the study area had at least basic literacy, with more than 95% having attained some sort of formal schooling. The prevalence of primary education suggests that although numerous respondents can comprehend fundamental information, they may encounter difficulties in deciphering intricate or technical agricultural content, particularly when presented via digital platforms or in non-native languages. In contrast, the existence of farmers lacking formal education (5.0%) signifies a demographic that may have difficulties in utilizing mobile-based services, especially text-intensive forms such as SMS. For these individuals, different approaches such as voice-based services or assistance from agricultural extension agents to bridge the gap between agricultural information systems and farmers with low literacy or no formal education to ensure inclusive access to information.

3.1.4 Years of Experience in Farming:

Regarding farming experience, the majority of surveyed farmers had substantial experience in agriculture. Most notably, 32.0% had 11 to 15 years of farming experience, followed by 29.8% with 5 to 10 years, and 28.7% with over 15 years. Only 9.4% had less than 5 years of experience. This distribution reflects a strong presence of mid-career and experienced farmers in the region, suggesting a high level of practical agricultural knowledge. Those with 11–15 years of experience are especially well-positioned to adopt mobile-based agricultural innovations, balancing traditional practices with openness to new technology. Farmers with 5–10 years are similarly adaptive and likely to benefit from mobile information services. Meanwhile, the least experienced group may lack exposure to both traditional and digital extension tools, and the most experienced group may encounter challenges related to digital literacy or resistance to change.

3.2 Factor Analysis:

The empirical factor analysis (EFA) was conducted using principal components factor analysis with Varimax rotation to identify a limited number of factors that accurately represented the relational structure among the variables related to utilization, factors, and challenges. Hair et al. (2010) asserted that, to validate factorability, the following criteria must be satisfied: all communalities must exceed 0.3, the Bartlett's Test of Sphericity (BTS) must show significance at $p < .05$, and items within the same scales must exhibit correlations of at least 0.3 with other items.

3.2.1 Kaiser-Meyer-Olkin (KMO) and Bartlett’s Test of Sphericity

To ensure the data collected from respondents was suitable for factor analysis, preliminary assessments were conducted using the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett’s Test of Sphericity. These tests were essential to confirm whether the variables under study were adequately interrelated to justify a factor analysis approach. The KMO value for the role of mobile phones in agricultural information access was 0.917, categorizing it as 'marvelous'. This outcome verifies that the dataset possesses sufficient variation to facilitate factor extraction. Bartlett’s Test of Sphericity produced a chi-square value of 1843.445 with 66 degrees of freedom and a significance threshold of $p < 0.001$, indicating that the correlation matrix is not an identity matrix and that the variables are adequately correlated for factor analysis. The KMO value analysis for factors and challenges in mobile phone utilization was 0.815, classified as 'meritorious', signifying satisfactory sample adequacy.

Bartlett's Test of Sphericity yielded a chi-square value of 851.213 with 45 degrees of freedom and a significance threshold of $p < 0.001$, further affirming the appropriateness of the data for factor analysis. The elevated KMO values indicate a considerable degree of common variance among the variables, rendering them suitable for factor analysis. Additionally, the significant

outcomes from Bartlett's Test of Sphericity in both instances confirm that the correlation matrices are not identity matrices, thereby affirming the interrelatedness of the variables and their appropriateness for structural detection.

The results from the KMO and Bartlett's tests corroborate previous studies emphasizing the importance of an adequate sample size and significant inter-variable correlations for effective factor analysis. Murmura et al. (2024) stated that, KMO values above 0.8 denote extremely sufficient sampling, while the highly significant Bartlett's tests affirm the structural links within the dataset. The results affirm the reliability and validity of the survey data, suggesting that subsequent analyses, such as factor extraction and Cronbach's alpha reliability tests, will yield valuable insights into farmers' utilization of mobile phones for agricultural information access in Dhamar Governorate. Therefore, based on these statistically significant findings, it is appropriate to proceed with factor extraction to identify specific constructs or dimensions influencing farmers' use of mobile phones for agricultural information distribution and acquisition.

3.2.2 Communalities Analysis:

In order to determine the extent to which each variable shared common variance with the extracted factors, a communalities analysis was conducted as shown in Table 1 and 2. This procedure is a crucial step in exploratory factor analysis (EFA), as it reveals how much of the variance in each observed variable is explained by the underlying factors extracted during the analysis. The communalities for the mobile phone utilization variables were initially set at 1.000, indicating that the total variance for each variable was considered before extraction. After extraction, all variables retained substantial communalities, with values well above the commonly accepted threshold of 0.30, signifying that the variables were adequately explained by the identified factors. For instance, "Access to Farming Techniques via Mobile Phone" exhibited a high communality score of 0.770, suggesting that a significant proportion of its variance was captured by the extracted factors. Similarly, "Participation in Mobile-based Farmer Networks" and "Access to Weather Forecasts and Market Prices" showed strong communalities of 0.751 and 0.719, respectively. These results highlight the integral role of these components in shaping the latent constructs related to mobile phone use in agricultural information access.

TABLE 1
COMMUNALITIES ANALYSIS (MOBILE PHONE UTILIZATION)

Variable	Initial	Extraction
Access to Farming Techniques via Mobile Phone	1	0.746
Access to Market Price Information	1	0.687
Communication with Agricultural Extension Agents	1	0.554
Access to Weather Forecasts	1	0.783
Receiving Agricultural Advice through Mobile Platforms	1	0.733
Pest and Disease Management Information Access	1	0.761
Communication with Input Suppliers	1	0.814
Enhanced Farming Decision-making	1	0.809
Participation in Mobile-based Farmer Networks	1	0.72
Awareness of Agricultural Support Programs	1	0.726
Improved Crop Productivity through Mobile Use	1	0.775
Reduced Dependence on Physical Extension Services	1	0.669

In terms of challenges and constraints associated with mobile phone use, the communalities also reflected meaningful levels of explained variance. Variables such as "Lack of Training and Guidance" and "Insufficient Promotion by Agricultural Extension Agents" displayed particularly strong communalities of 0.812 and 0.799, respectively. These values indicate that these challenges are not isolated issues but are deeply embedded within broader systemic or institutional constraints influencing mobile phone utilization. Even variables with comparatively lower communalities, such as "Language Barriers" and "Affordability of Mobile Phones," still retained acceptable levels of explanation, affirming their relevance in the model. Collectively, the communalities analysis demonstrates the robustness of the factor structure, as all items retained in the analysis contributed meaningfully to the variance captured by the factor solution. This finding validates the inclusion of the observed variables in subsequent components and supports the reliability of the factor model in examining both the utilization patterns and the challenges associated with mobile phone use among farmers in Dhamar Governorate.

TABLE 2
COMMUNALITIES ANALYSIS (FACTORS AND CHALLENGES)

Variable	Initial	Extraction
Literacy Barriers to Mobile Usage	1	0.821
Mobile Network Accessibility	1	0.762
Mobile Data Affordability	1	0.563
Lack of Training and Guidance	1	0.612
Power and Charging Constraints	1	0.615
Lack of Promotion by Agriculture Extension Agents	1	0.753
Technical Skill Limitations	1	0.794
Language Accessibility of Agricultural Information	1	0.832
Awareness of Mobile Agricultural Services	1	0.789
Institutional Support Deficiency	1	0.508

3.2.3 Cronbach's Alpha

The reliability analysis of survey variables, including roles, factors, and challenges in mobile phone utilization scales, demonstrates high internal consistency, verifying the coherence of the underlying constructs. In the first context of mobile phone utilization, the Cronbach's Alpha score was exceptionally high at 0.947, indicating excellent reliability and suggesting that the variables consistently measure aspects pertinent to mobile phone usage in agriculture. The second context; factors and challenges in mobile phone utilization, attained an Alpha of 0.836, indicating good reliability within the range of 0.8 to 0.9. The results confirm that the items effectively reflect the participants' perceptions of barriers and enabling conditions influencing their mobile phone use for agriculture information access.

According to Nunnally (1975); SÜRÜCÜ & MASLAKÇI, (2020); the minimum reliability coefficient of 0.7 for exploratory research and 0.8 for applied studies. Both scales surpass these benchmarks, confirming their appropriateness for empirical analysis. The disparity in reliability coefficients between the two objectives is noteworthy. The mobile phone utilization scale's Cronbach's Alpha value, nearing 0.95, suggests a highly cohesive construct; nonetheless, it is essential to consider the trade-off between reliability and item distinctiveness. The factors and challenges scale (Alpha = 0.836) effectively encompasses various dimensions, including technical literacy, language constraints, and infrastructural limitations, while maintaining coherence. The combined Cronbach's Alpha analysis indicates that the survey items for both contexts are psychometrically robust, providing a reliable basis for interpreting factor analysis results and supporting valid conclusions regarding farmers' mobile phone usage and the factors influencing that usage in Dhamar Governorate.

3.2.4 Ranking Analysis

In descriptive statistics analysis illustrated in Table 3 and 4, results were measured on a scale ranging from 1 to 5, with 1 representing the minimum value and 5 representing the maximum value. This scale facilitated a standardized interpretation of respondents' perceptions and allowed meaningful comparisons across different variables according to the study.

For the first objective; the role of mobile phones in accessing agricultural information, Key findings indicate that mobile phones play a modest yet significant role in improving access to farming techniques and agricultural services. Two dominant components were identified. The first component; information access and decision-making, showed that "Access to Farming Techniques via Mobile Phone" scored the highest mean (2.55), followed by "Communication with Agricultural Extension Agents" (2.33), indicating their importance in delivering technical knowledge. The second component; participatory and communication functions, highlighted "Communication with Input Suppliers" as the highest-scoring variable (3.87), suggesting mobile phones are more actively used for logistical coordination. However, "Participation in Mobile-based Farmer Networks" received a lower mean (2.32), pointing to limited engagement in peer communication networks.

TABLE 3
DESCRIPTIVE STATISTICS (MOBILE PHONE UTILIZATION)

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Information Access and Immediate Decision-Making Benefits					
Access to Farming Techniques via Mobile Phone	181	1	5	2.55	1.137
Communication with Agricultural Extension Agents	181	1	5	2.33	0.948
Improved Crop Productivity through Mobile Use	181	1	5	2.32	1.109
Access to Market Price Information	181	1	5	2.17	0.928
Reduced Dependence on Physical Extension Services	181	1	5	2.15	0.924
Access to Weather Forecasts	181	1	5	2.15	0.992
Receiving Agricultural Advice through Mobile Platforms	181	1	5	2.11	0.888
Interactive or Participatory Functions of Mobile Technology					
Communication with Input Suppliers	181	1	5	3.87	1.256
Pest and Disease Management Information Access	181	1	5	3.1	1.265
Enhanced Farming Decision-making	181	1	5	2.59	1.1
Awareness of Agricultural Support Programs	181	1	5	2.5	1.047
Participation in Mobile-based Farmer Networks	181	1	5	2.32	0.959

Objective 2 addressed the factors and challenges constraining effective mobile phone use. Three major categories emerged. First, Individual Capability Constraints were led by "Lack of Training and Guidance" (mean = 4.20), indicating poor digital literacy among farmers. Second, Institutional and Economic Barriers showed strong negative influence, with "Insufficient Promotion by Agricultural Extension Agents" (4.59) and "Deficiency in Institutional Support" (4.48) being dominant issues. These findings underscore the lack of systemic support structures. Third, Infrastructural Barriers included "Power and Charging Constraints" (3.64) and "Mobile Network Accessibility" (3.52), both of which limited consistent access to mobile-based services. The results indicate that while mobile phones offer promising avenues for enhancing agricultural information access in Dhamar Governorate, their full potential remains constrained by digital skill gaps, insufficient institutional support, and infrastructural limitations. Addressing these barriers through targeted capacity-building, localized content development, and improved service infrastructure is essential to optimizing mobile phone utilization for rural agricultural development.

TABLE 4
DESCRIPTIVE STATISTICS (FACTORS AND CHALLENGES)

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Individual Capability Constraints					
Lack of Training and Guidance	181	1	5	4.2	1.015
Language Accessibility of Agricultural Information	181	1	5	3.72	1.066
Awareness of Mobile Agricultural Services	181	1	5	3.64	1.064
Technical Skill Limitations	181	1	5	3.13	1.185
Literacy Barriers to Mobile Usage	181	1	5	2.98	1.39
Institutional and Economic Barriers					
Lack of Promotion by Agriculture Extension Agents	181	1	5	4.59	0.698
Institutional Support Deficiency	181	1	5	4.48	0.814
Mobile Data Affordability	181	1	5	4.31	0.832
Infrastructural Barriers					
Power and Charging Constraints	181	1	5	3.64	0.85
Mobile Network Accessibility	181	1	5	3.52	1.031

IV. CONCLUSION

This study has comprehensively assessed the use of mobile phones to access agricultural information for farmers in Dhamar Governorate, Yemen. These findings clearly demonstrate the significant benefits that mobile technology provides in improving agricultural output, decision-making, and market access. Farmers primarily utilized mobile phones to access timely information on market prices, weather forecasts, pest and disease management, and to communicate with agricultural extension agents. These applications have significantly enhanced farming practices and decision-making processes, underscoring mobile technology as a vital instrument in modern agriculture. Despite those benefits, the study identified numerous critical factors and challenges that impede the effective utilization of mobile technology by local farmers.

Significant obstacles comprised restricted literacy, inadequate technical proficiency, insufficient network availability, elevated expenses related to mobile devices and internet data plans, linguistic difficulties, and a deficiency in suitable institutional support. These constraints collectively hinder the deployment of mobile technology and limit its potential influence on agricultural productivity in the region. Overcoming these obstacles is essential for optimizing the advantages of mobile phones in rural agricultural environments. The study highlights the transformative capacity of mobile phones in disseminating agricultural information and their substantial positive effects on rural livelihoods and agricultural productivity in Dhamar Governorate. Successfully addressing identified obstacles through focused interventions can markedly improve the efficacy of mobile technologies, equipping farmers with essential and timely agricultural information.

V. RECOMMENDATIONS FOR FUTURE WORK

This study establishes a robust foundation for future research by highlighting the role of mobile phones in facilitating agricultural information access among farmers in Dhamar Governorate. Nonetheless, several critical dimensions remain insufficiently examined and warrant deeper investigation. Future research should focus on the longitudinal impacts of mobile phone utilization on agricultural productivity, income stability, and rural livelihoods. By implementing long-term studies, scholars can uncover the sustained influence of mobile-based information access on crop yield improvements, market participation, and household economic resilience. These longitudinal insights are essential to inform policy and development programs aimed at leveraging digital tools for sustainable agricultural growth. Furthermore, comparative assessments between mobile-based agricultural extension services and conventional face-to-face extension methods should be prioritized. Such studies should systematically evaluate effectiveness in terms of knowledge transfer, behavioural change, cost efficiency, and user satisfaction among smallholder farmers. Insights from these comparisons can help determine the relative strengths and limitations of each approach and support the design of hybrid models that blend traditional and digital extension methods to maximize outreach and impact.

Future research should also adopt a broader geographic scope by conducting similar studies in other governorates across Yemen. Regional disparities in mobile infrastructure, literacy levels, agricultural practices, and socio-political stability may influence the effectiveness of mobile phone adoption for agricultural information dissemination. Comparative regional analysis would provide a nuanced understanding of context-specific challenges and opportunities, thereby enhancing the scalability and relevance of mobile-based interventions nationwide.

Additionally, researchers should explore the integration of advanced and emerging digital technologies into mobile agricultural services. The incorporation of Artificial Intelligence (AI) for predictive analytics, the Internet of Things (IoT) for real-time environmental monitoring, and blockchain for transparent and secure transactions could significantly enrich the functionality and trustworthiness of mobile platforms. Investigating the feasibility, inclusivity, and sustainability of such technologies within the Yemeni agricultural context is crucial, particularly considering infrastructure limitations, digital literacy gaps, and socioeconomic constraints. Moreover, research should evaluate the extent to which these innovations can be localized and adapted to meet the unique needs of smallholder farmers, with a focus on ensuring equitable access and minimizing digital exclusion.

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Molecular Characterization of Corticotrophin Releasing Hormone Gene and its Expression in Deoni Cows

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Abstract— *Improving the production performance in dairy cattle is the main concern of breeding policies, as the production traits are low to medium heritable and it is difficult to select best animals based only on phenotype. Deoni is hardy indigenous cattle with moderate milk production potential. Identification of gene polymorphism and its association with production performance of animals can be very useful for selection of superior animals. The aims of study were: (i) Molecular characterization and expression of CRH gene in Deoni cattle, (ii) Association of CRH gene polymorphism with milk yield and fat content and (iii) Breeding value estimation based on lactation performance. Genomic DNA was isolated from 152 Deoni cattle maintained at SRS of ICAR-NDRI, Bengaluru to evaluate genetic variability through PCR-RFLP method. PCR-RFLP analysis revealed monomorphism in CRH gene and was found to be highly conserved with a single nucleotide change at 19th position in all the Deoni animals compared to Bos taurus sequence. Association studies could not be carried out further because of lack of polymorphism. Mean phenotypic performances of AFC, FLMY, and Fat content were 44.35 ± 0.48 months, 577.64 ± 32.54 kg, and 4.61 ± 0.06 per cent, respectively. Heritability of FLMY of Deoni cattle was found to be 0.24 ± 0.20. MPPA and breeding value for FLMY were estimated by LSA method using GLM procedure of SAS 9.3 based only on phenotypic data without incorporating the genotype information. MPPA was estimated to be 350.77 to 947.25 kg. PBV obtained through LSA method without taking genotype information were in the range from 139.32 to 1520.15 kg. Expression profiling of CRH gene was carried out in PBMC in eight Deoni cows in different lactations from the day of parturition to 60th day postpartum. Expression profiling of CRH mRNA was carried out using quantitative RT-PCR with SYBR green as fluorescent dye. Present study revealed a significant decrease of CRH mRNA expression from day 10 of calving to day 60 post calving, indicating that levels of stress is higher during parturition than during lactation. This is the first report on characterization and expression of CRH mRNA in Deoni cows.*

Keywords— CRH gene, Indigenous Cattle, Deoni, FLMY, Breeding Value.

I. INTRODUCTION

In dairy enterprise the principal goal of selection is to increase the milk yield and improve its composition. Milk production genes involved in controlling milk fat, protein content and the hormones are excellent candidate genes for linkage analysis with Quantitative Trait Loci (QTL) because of their biological significance on quantitative traits of interest. It is noteworthy that QTLs for milk performance traits has been mapped in all the bovine autosomes, mostly in 6, 14 and 20 [1]

Corticotrophin - releasing hormone (CRH), also called as corticotrophin -releasing factor (CRF), is a 41 amino acid peptide deriving from a 191 amino acid precursor which is mainly synthesized in the hypothalamus, and also in other parts of brain. CRH functions as a neuropeptide hormone participating mainly in the stress response in vertebrates. CRH is involved in controlling the energy balance of an organism, which affects body weight and it also participates in modulating immune and reproductive systems [2]. CRH gene expression was found highest in hypothalamus, but the gene is also expressed in many

other places, such as ovaries, testes, placenta, uterus, liver, stomach, skin, and immune system. Gene encoding corticotrophin releasing hormone with many QTLs has been mapped in bovine chromosome 14 [3], which govern postnatal growth and it has been considered as a candidate gene for growth traits in cattle [4]. Several single nucleotide polymorphic (SNP) sites have been identified within CRH gene of Bos taurus cattle breeds viz. C22G which causes substitution of amino acids in signal sequence, A145G and C240G, leading to changes of amino acids in a propeptide [4] as well as two SNPs in exon 2 [5].

The present study was undertaken to determine the frequencies of alleles and genotypes with regard to gene polymorphism encoding corticotrophin releasing hormone (CRH-A145G) in Deoni cows and to study the association between genotypes and milk production traits of Deoni cows along with expression levels of CRH mRNA in postpartum Deoni cows during different days of lactation as well as its effect on milk yield and also to estimate the heritability and breeding value of Deoni cows based on First Lactation Milk Yield (FLMY).

II. MATERIALS AND METHODS

2.1 Experimental Animals:

152 Deoni animals maintained under standard management conditions adhering to minimum standard protocols as recommended by the department of Dairying, Animal Husbandry & Fisheries, Govt. of India at Livestock Research Centre (LRC) of ICAR – NDRI SRS Bengaluru were used in this experiment. For polymorphism study cows in different age groups and in different stages of lactation which were milked twice daily were considered. Data was collected from daily milking records available in the farm and Gerber's method was used to estimate fat content from test day milk samples.

2.2 Blood Collection and DNA Extraction:

DNA was isolated from peripheral blood drawn from external jugular vein of cows into Ethylene Diamine Tetra Acetic acid (EDTA) vacutainers and processed immediately for DNA isolation. DNA was isolated using a modified high salt method described by [6].The investigated SNP consists in changing adenine to guanine at position 145 in exon1– *CRH- A145G* (GenBankAF340152). As a result of this transition, a change of serine to asparagine occurs at the polypeptide level. The gene fragment of 156 bp was amplified and genotyped using PCR-RFLP method. To conduct this reaction, a pair of primers proposed by [4] was used and is listed in TABLE 1.

TABLE 1
DETAILS OF THE PRIMER SEQUENCE USED FOR PCR AMPLIFICATION OF *CRH* GENE

GENE	Primer Name	Sequence (5'-3')	Primer Length	Product Size (bp)	Reference
CRH	Forward	GCGCCCGCTAAAATGCGACTGA	22	156	[4]
	Reverse	CTGTGATGCCTGCCGGGCAC	20		

2.3 PCR amplification and restriction enzyme digestion:

PCR programme consisted of cycles of initial denaturation at 95 °Cfor4 min, followed by 34 cycles of 94 °C for 1 min (denaturation), 59 °C for 1 min (primer hybridization), 72 °C for 1 min (product synthesis), and final extension at 72 °C for 5 min. The PCR products were digested with 4 U of the *Dde* I restriction enzyme.

2.4 Expression studies of CRH mRNA:

For expression profiling of CRH mRNA, 8 low yielding post parturient Deoni cows in different age groups and in different parity were studied. Approximately 15 ml of blood was collected by external jugular venipuncture of each animal from the day of parturition up to 60 days post-partum with an interval of 10 days in to a vacutainer containing EDTA as the anticoagulant. Soon after collection, blood samples were stored at 4 ˚C and immediately transferred to lab for isolation of RNA.

2.4.1 Isolation, Quantity and Quality Check of Total RN:

Ribonucleic acid was isolated from Peripheral Blood Mononuclear Cells (PBMC) using RNeasy Mini Kit (Quiagen, USA) using manufacturer's protocol. RNA was checked for quantity and integrity through agarose gel electrophoresis and quantity was measured using nanodrop spectrophotometer (Eppendorf, Germany). The purified RNA was stored at -80 ˚C until use.

2.4.2 Synthesis of first strand cDNA:

The first strand cDNA was synthesized from the extracted RNA using iScript® cDNA synthesis kit (Bio-rad, California). From each PBMC sample 100 ng of total RNA was reverse transcribed using 4 µl of iScript® reaction mixture and 1 µl of iScript® enzyme to make a final volume of 20 µl with nuclease free water in a sterile PCR tube on ice. This reaction mixture was incubated at 25 ˚C for 5 min, later at 42 ˚C for 30 min, after which the reaction was terminated at 85 ˚C for 5 min. The cDNA was stored at -20 ˚C.

2.4.3 Real time quantitative polymerase chain reaction:

PCR analyses were performed with three replicates per sample of each gene using the STEP ONE PLUS real time PCR system (Applied Bio systems, USA) Fast SYBR Green master mix (Applied Bio systems, USA) and gene specific primers (**Table 2**). Primers were designed using the Primer3 programme with an annealing temperature of 60 ˚C and amplification size of less than 250 bp. B-actin was used as endogenous control. Thermal cycling was carried out as per manufacturer's protocol (95 ˚C, 20 s; followed by 40 cycles of 95 ˚C for 3 s; and 60 ˚C for 30 s) and a melt curve of 95 ˚C (15 s), 60 ˚C (1 min) and 95 ˚C (15 s). The specificity of each PCR product was determined by a melt curve analysis and amplicon size determination by agarose gel (0.2 %). Negative control which consisted of all components of qRT-PCR mix except cDNA was used. The relative quantification of gene expression changes were recorded after normalizing for β – actin gene expression computed using the $2^{-\Delta\Delta c}T$ method in which C_T value from controls served as calibrator.

TABLE 2
DETAILS OF PRIMERS USED IN RT – PCR

Primer Name	Primer Sequence	Length (bp)	Product Size (bp)
CRH Forward	AAGCAGCAGTCGCCTTTCT	19	156
CRH Reverse	CCTTGGTCATTTCCAAGACTTC	22	

2.5 Data adjustment and statistical analysis:

The recorded FLMY data were adjusted for various non –genetic factors like period of birth, lactation number of animal, period of calving, season of calving and age at first calving (AFC) before estimating the heritability. The model used for study was:

$$Y_{ij} = \mu + F_i + e_{ij} \quad (1)$$

Where:

Y_{ij} = Phenotypic data of j^{th} observation in the i^{th} subclass

µ = Overall population mean of the traits (FLMY and Fat %)

F_i = Fixed effect of non-genetic factor of i^{th} subclass

e_{ij} = Random error, assumed to be normally and independently distributed with mean zero and constant variance, i.e NID $(0, \sigma_e^2)$

Heritability was estimated by paternal half sib correlation method (intra – sire correlation among daughter) as described by [7] using the following model:

$$Y_{ij} = \mu + S_i + e_{ij} \quad (2)$$

$Y_{ij=}$ Adjusted data of the j^{th} progeny under the i^{th} sire.

($I = 1, 2, 3, \ldots, s$; $j = 1,2,3, \ldots, n_i$)

μ = Population mean

S_i = Effect of i^{th} sire

S = number of sires

` n_i= number of progeny under i^{th} sire

e_{ij}= Random error, assumed to be normally and independently distributed with mean zero and constant variation *i.e.* NID $(0, \sigma_e^2)$

And the formula used was:

$$h^2 = 4 * t = 4 * \frac{\sigma_s^2}{(\sigma_s^2 + \sigma_e^2)} \quad (3)$$

Most Probable Producing Ability (MPPA) was calculated before estimating the breeding value of FLMY using the model:

$$\text{MPPA of cow} = \mu + h^2(Y_i - \mu) \quad (4)$$

Where,

μ = Population mean

h^2 = Heritability of first lactation milk yield of Deoni cattle.

Y_i = Phenotypic value of FLMY of i^{th} cow

Generalized Linear Model was used to predict Breeding Value (BV) through Least Square Analysis (LSA) method. The mixed linear model was chosen without incorporating molecular information of the loci of CRH gene. The model is as follows:

$$Y_{ijklmnox} = \mu + S_i + POB_j + LND_k + POC_l + SOC_m + CAFC_n + CFLL_O + e_{ijklmnox} \quad (5)$$

Where,

$Y_{ijklmnox}$ = x^{th} cow of i^{th} sire born in j^{th} period at k^{th} lactation of its dam, calving at m^{th} season of l^{th} period under n^{th} and o^{th} group of AFC and FLL

μ = Population mean

S_i = i^{th} sire ($i = 1,2,3,..7$)

POB = j^{th} period of birth ($j = 1$ and 2)

LND = k^{th} lactation number of dam ($k = 1, 2, 3, \ldots, 5$)

POC = l^{th} period of calving ($l = 1, 2, 3$ and 4)

SOC = m^{th} season of calving ($m = 1, 2$ and 3)

CAFC = n^{th} class of age at first calving ($n = 1, 2, 3, \ldots, 6$)

CFLL = o^{th} class of first lactation length ($o = 1, 2, 3, \ldots, 6$)

III. RESULTS AND DISCUSSION

Molecular characterization through PCR–RFLP analysis of CRH gene exhibited monomorphism in 152 Deoni samples revealing two fragments *viz.*, 120 bp and 36 bp **(Figure 1)**. DNA sequencing samples revealed a change in nucleotide at 19^{th} position from 'T' to 'C' in all Deoni (*Bos indicus*) cattle as compared to reference sequence of *Bos taurus* species **(Figure 2)**. Due to lack of presence of SNP in exon 2 of CRH gene, exonic region was found to be conserved and probably gene is fixed in the present population studied. [8] reported the presence of SNP in exon 2 of CRH gene in Jersey breed of *Bos taurus* cattle affecting the milk production traits. Due to absence of polymorphism in CRH gene exon 2, the association study could not be carried out. Rat [9] and ovine [10] *CRH* also consist of two exons with the coding region in exon 2.

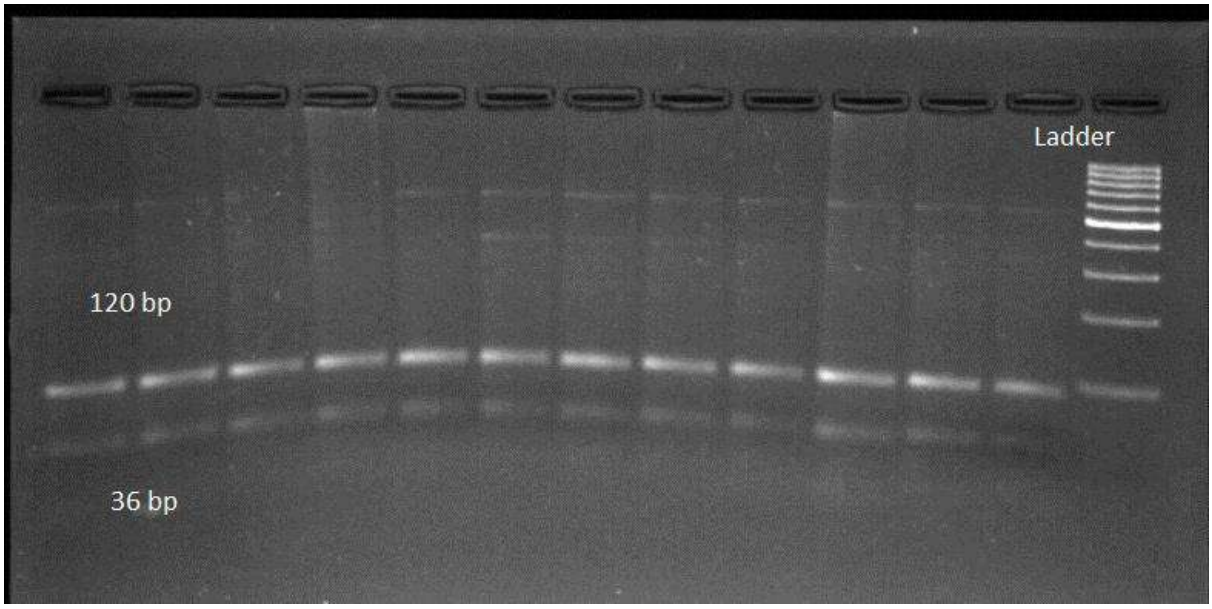

FIGURE 1: Restriction enzyme digestion of *CRH* gene

BLAST sequence of exon 2 of CRH gene revealed 99 per cent identity with *Bos taurus* (AF340152.1), 98 per cent with *Bubalus bubalis* (XM006044572.1) and 97 per cent identity with both *Ovis aries* (XM015097787.1) and *Capra hircus* (XM013969156.1).Upon amplification of porcine CRH by [11], they determined that the porcine coding sequence was 84 per cent and 85 per cent identical to sheep and rat sequences respectively; the porcine amino acid sequence is 74 per cent and 75 per cent identical to the sheep and rat amino acid sequence, respectively.

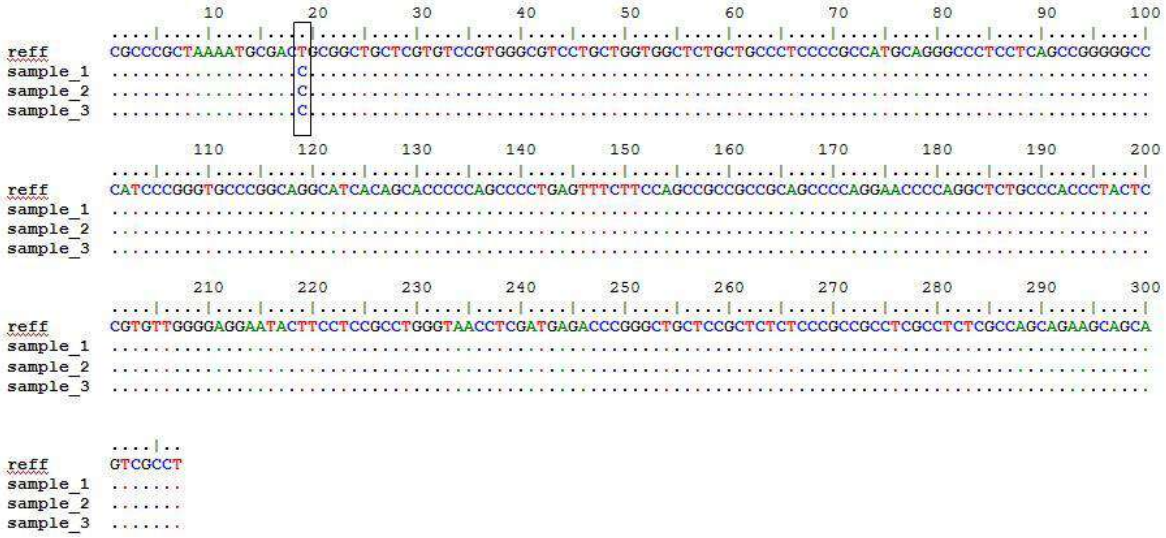

FIGURE 2: Clustal W-Alignment of CRH gene in Deoni breed

Heritability of first lactation milk yield in Deoni cattle was calculated using paternal half – sib correlation (PHC) method. Data on First Lactation Milk Yield (FLMY) and sire information of 152 Deoni cows was used to calculate heritability and was estimated as 0.24 ± 0.20. Previous report on heritability of FLMY in Deoni cattle was reported as 0.38 ± 0.29 by [12] which was higher than the present findings. Lower estimate of heritability value may be attributed due to more number of observation considered in this study which provided more accurate estimate of heritability. Estimated heritability of FLMY in different breeds were 0.13 ± 0.12 and 0.1 ± 0.43 in Hariana and Tharparkar cattle as reported by [13] and [14] respectively. Reports on higher estimates of heritability in PHC method was observed in Sahiwal cattle as 0.48 ± 0.15 [14]. Predicted breeding values (PBV) of cattle were obtained through LSA method without taking genotype information and were found to be in the range from 139.32 to 1520.15 kg with CV value of 79.59 per cent. Breeding values of 7 sires used in the herd are tabulated and

ranked in the **Table 3**. Sire no. 3 used in the herd was ranked first followed by sire no. 30 and sire no. 24 respectively based on the breeding value, Sire no. 48 was found to be having the least breeding value among all the sires.

TABLE 3
BREEDING VALUE OF SIRES

Sire no.	No. of Daughters	Breeding value	Rank
1	14	565.96 ± 96.44	5
2	13	601.31 ± 92.93	4
3	36	693.53 ± 64.18	1
24	16	609.15 ± 92.73	3
26	40	544.70 ± 63.22	6
30	8	641.45 ± 103.09	2
48	25	533.22 ± 74.78	7

To the best of our knowledge this is the first study to report expression of CRH mRNA. In the present study we investigated the expression of CRH mRNA in Deoni animals over a period of 60 days from the day of calving, with an interval of every 10 days. Primer concentration was optimized for the gene under study using 0.25 picomolar (pM), 0.5 pM, 0.75 pM and 1.0 pM concentrations, and 0.75 (pM) concentration was found to be ideal for amplification of CRH mRNA. Housekeeping gene, β – actin was selected for comparative quantitation studies. The primer efficiency ranged between 96 per cent to 104 per cent. The present study revealed that CRH mRNA increased from day of parturition (Day 0) to Day 10 and then a decreasing trend was observed till day 60 post-partum in low yielding Deoni cows and milk yield also dropped over the same period in the animals studied. The decreasing levels of CRH mRNA suggests decreased stress levels after parturition which may be due to low milk production ability of Deoni breed of cows and involution of uterus post-partum.

Mean daily milk yield of animals studied for expression profiling was 1.8 ± 0.2 kg with highest yield being 2.5 kg on 10^{th} day post-partum which gradually declined significantly over the lactation length and the lowest production was observed as 0.5 kg on day 60 post-partum.

Among the eight animals studied one animal exhibited highest expression of CRH mRNA on day 30 post-partum whereas; in all other animals peak level of expression was observed on 10th day post calving. This indicated that among low yielding Deoni cows, first 10 days post-partum period is more important and which may help in deciding selection of better yielder if more number of observations are included for expression study.

IV. CONCLUSION

CRH gene primarily being a stress regulator was found to be highly conserved in the Deoni breed of *Bos indicus* cattle. The lack of polymorphism in CRH gene made it difficult to flag it as a candidate gene for production traits in indigenous dairy cattle breeds. Further studies on same gene in other zebu breeds of cattle are to be carried out to ascertain the polymorphic nature of gene. Expression studies of CRH mRNA revealed higher level of stress in Deoni animals during the parturition than the lactation stress. A positive correlation was found among the expression Relative Quantitation (RQ) values and the daily milk yield of Deoni animals, in which both of them revealed a declining trend from the day of calving to day 60 post calving. Heritability of the FLMY was estimated to be 0.24 ± 0.20 and bulls used in the herd were ranked based on the Breeding values of FLMY calculated only on adjusted phenotype records excluding the genotypes. The study suggests scope for further evaluation of same gene in different *Bos indicus* breeds of cattle yielding higher quantum of milk to undertake appropriate breeding strategies to decrease the stress levels in lactating animals.

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Improving Nutrient Uptake and Protein Yield of Rice through Integrated Nitrogen Management and Foliar Fe and Zn Application in Calcareous Soils

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Abstract— *Rice productivity and grain nutritional quality are strongly influenced by nutrient management, particularly under calcareous soils where nitrogen (N) use efficiency is low and micronutrient deficiencies of iron (Fe) and zinc (Zn) are widespread. A field experiment was conducted during the Kharif seasons of 2018 and 2019 at Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, to evaluate the effects of integrated nitrogen management (INM) and foliar micronutrient application on nutrient uptake and protein yield of aerobic rice (*Oryza sativa *L.). The trial was laid out in a factorial randomized block design comprising six INM practices (75-125% recommended dose of nitrogen, partly substituted with vermicompost, poultry manure or farmyard manure) and three foliar regimes ($FeSO_4$ 1%, $ZnSO_4$ 0.5% and combined $FeSO_4$ + $ZnSO_4$). Results indicated that 100% RDN through chemical fertilizers with 25% RDN through vermicompost (N4) significantly enhanced total N, P and K uptake, recording 115.33, 20.13 and 91.87 kg ha^{-1}, respectively, corresponding to increases of 34%, 44% and 38% over sole chemical fertilization (N5). Foliar application of Fe + Zn (F3) further improved nutrient uptake, with total N and P uptake 9% and 12% higher, respectively, than Fe spray alone. Protein content was not significantly affected, but protein yield reached a maximum under N4 (531.37 kg ha^{-1}), 34% greater than N5, while F3 increased protein yield by 10% compared with Fe alone. The combination of N4 and F3 proved most effective, offering a viable strategy for enhancing both productivity and biofortification potential of rice under calcareous soil conditions*.

Keywords— Integrated nutrient management, Vermicompost, Poultry manure, Nutrient uptake, Protein yield, Calcareous soils.

I. INTRODUCTION

Rice (Oryza sativa L.) is one of the most important cereal crops worldwide, serving as the primary source of calories and nutrition for more than half of the global population. In Asia, where nearly 90% of rice is produced and consumed, it forms the dietary backbone for millions of smallholder farmers and consumers alike (Paramesha et al., 2025). However, sustaining high rice productivity while ensuring grain nutritional quality remains a major challenge under current production systems. Intensive cultivation practices with high dependency on chemical fertilizers have resulted in soil nutrient depletion, reduced factor productivity, and deterioration of soil health (Walia et al., 2024). Among macronutrients, nitrogen (N) is the most yield-limiting element, but imbalanced application and low recovery efficiency often less than 40% lead to nutrient losses and environmental risks (Shrestha et al., 2020).

Integrated nutrient management (INM), which combines chemical fertilizers with organic sources such as farmyard manure (FYM), poultry manure, and vermicompost, has emerged as a sustainable approach for improving soil fertility, enhancing microbial activity, and increasing nutrient use efficiency (Paramesha et al., 2025). The addition of organic sources not only

supplements plant nutrients but also improves soil physical properties and supports long-term productivity. Recent studies highlight that substitution of a portion of N fertilizers with organic manures can enhance nitrogen-use efficiency, reduce dependency on chemicals, and maintain yield stability in rice-based systems (Shrestha et al., 2020).

Alongside macronutrient management, micronutrient deficiencies have gained increasing attention due to their dual role in crop productivity and human nutrition. Iron (Fe) and zinc (Zn) deficiencies are among the most widespread constraints in paddy soils, particularly under flooded anaerobic conditions that reduce micronutrient availability (Singh et al., 2018). These deficiencies not only lower rice yields but also contribute to "hidden hunger" in human populations dependent on rice as a staple food. Zinc is vital for enzyme activation, auxin metabolism, and grain filling, while iron plays a central role in chlorophyll synthesis, respiration, and electron transport. Global estimates suggest that more than two billion people suffer from Zn and Fe deficiencies and biofortification of rice grains with these nutrients is considered a promising solution to combat malnutrition (Ram et al., 2024; Liu et al., 2023).

Foliar application of micronutrients has been widely recommended as an efficient strategy to overcome soil-related limitations and improve nutrient uptake at critical growth stages. In rice, foliar sprays of $FeSO_4$ and $ZnSO_4$ during tillering and panicle initiation have been reported to improve nutrient accumulation, enhance photosynthetic efficiency, and increase grain micronutrient content (Ram et al., 2024). Moreover, the interaction between nitrogen management and micronutrient uptake is particularly important: higher nitrogen supply stimulates root activity and transporter expression, thereby enhancing Fe and Zn assimilation in rice plants (Singh et al., 2018). However, the combined impact of integrated N sources with foliar Fe and Zn application on rice yield and nutritional enrichment has not been adequately studied.

Given these gaps, the present study was undertaken to investigate the interactive effects of integrated nitrogen management and foliar application of Fe and Zn on rice. The aim was to assess how different combinations of organic and inorganic nitrogen sources, along with targeted foliar micronutrient supplementation, influence crop productivity, nutrient uptake, and grain nutritional quality under irrigated conditions.

II. MATERIALS AND METHODS

2.1 Experimental site:

The field investigation was conducted during the *Kharif* seasons of 2018 and 2019 at the experimental farm of Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India. The site is located at 25.59°N latitude, 84.40°E longitude, at an altitude of 52.14 m above mean sea level and falls under a sub-humid, subtropical climate.

2.1.1 Experimental design and treatment details:

The experiment was laid out in a randomized block design (RBD) with a factorial arrangement to evaluate the combined effects of integrated nitrogen management (INM) practices and foliar application of micronutrients on aerobic rice in calcareous soil. Six INM treatments were imposed, consisting of 75% of the recommended dose of nitrogen (RDN) through chemical fertilizers and 25% through vermicompost (N1), 75% RDN through chemical fertilizers and 25% through poultry manure (N2), 75% RDN through chemical fertilizers and 25% through farmyard manure (N3), 100% RDN through chemical fertilizers along with 25% through vermicompost (N4), 100% RDN through chemical fertilizers alone (N5), and 125% RDN through chemical fertilizers (N6). These were combined with three micronutrient foliar spray treatments: $FeSO_4$ @ 1% applied at tillering and panicle emergence (F1), $ZnSO_4$ @ 0.5% applied at tillering and panicle emergence (F2), and $FeSO_4$ @ 1% + $ZnSO_4$ @ 0.5% applied at the same stages (F3). The recommended dose of fertilizers was 120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1}, and 40 kg K_2O ha^{-1}, supplied through prilled urea, diammonium phosphate (DAP), and muriate of potash (MOP), while organic manures were incorporated according to the treatment combinations and analyzed for nutrient content (Table 1).

2.2 Crop management:

The experimental field was prepared by two primary ploughings followed by secondary tillage and planking. Seeds of the rice variety *Abhishek* were directly sown using a seed rate of 30 kg ha^{-1} with an inter row spacing of 20 cm. A full basal dose of phosphorus and potassium was applied at sowing. Nitrogen was applied in three splits: 50% as basal (partially substituted with organic manures as per treatment), 25% at tillering, and 25% at panicle initiation.

2.3 Plant sampling and analysis:

At harvest, composite plant samples were collected from each treatment plot, washed with dilute HCl followed by deionized water, oven-dried at 65 ± 5 °C for 48 hours, and ground using a Willey grinder. The powdered samples were digested and analyzed for nutrient content following standard procedures: nitrogen by the modified Kjeldahl method (Bremner and Mulvaney, 1982), and phosphorus and potassium by the tri-acid digestion method (Jackson, 1967). Protein content was estimated using the factor proposed by Merill and Watt (1973), calculated as:

Protein content (%) = N % x 6.25

Protein yield was computed using the formula:

Protein yield (kg ha-1) = Protein content (%) x Grain yield (kg ha-1)/100

2.4 Statistical analysis:

The data obtained from the experiment were subjected to analysis of variance (ANOVA) for randomized block design with factorial concept as described by Gomez and Gomez (1984). Statistical significance was tested at the 5% probability level using the F-test, and the critical difference (CD) was computed for mean separation wherever treatment effects were significant.

III. RESULTS AND DISCUSSION

Nitrogen uptake varied significantly among integrated nutrient management (INM) treatments, with N4 (100% RDN through chemical fertilizers + 25% RDN through vermicompost) recorded the highest total N uptake (115.33 kg ha^{-1}), about 34% greater than sole chemical fertilization (N5, 85.83 kg ha^{-1}) (Table 1). Substitution with poultry manure (N2) and vermicompost (N1) also improved uptake by 31% and 26% over N5, respectively. Similar positive effects of organic substitution on nitrogen uptake and efficiency have been reported in rice and maize systems, where organic amendments enhanced microbial biomass and reduced nitrogen losses (Bhattacharyya et al., 2015; Xu et al., 2018; Li et al., 2019). Foliar supplementation further influenced N uptake, with the combined Fe + Zn spray (F3) improving total uptake by 9% compared with sole Fe spray. The advantage of combined sprays aligns with findings that Fe and Zn interact synergistically with nitrogen to improve transporter activity and assimilation (Cakmak and Kutman, 2018; Wang et al., 2021).

TABLE 1
N UPTAKE (kg ha^{-1}) OF RICE AS AFFECTED BY INM AND MICRONUTRIENT APPLICATION PRACTICES (2018, 2019 AND MEAN)

Treatments	N Uptake (kg ha^{-1})								
	2018			2019			Mean		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Integrated Nutrient Management									
N_1	75.17	26.28	101.45	85.20	30.07	115.28	80.19	28.17	108.36
N_2	78.49	26.56	105.05	88.43	31.75	120.19	83.46	29.16	112.62
N_3	66.92	22.70	89.62	71.37	25.16	96.53	69.15	23.93	93.08
N_4	81.43	28.85	110.28	88.61	31.48	120.39	85.02	30.31	115.33
N_5	62.53	22.52	85.05	64.05	22.56	86.61	63.29	22.54	85.83
N_6	71.37	26.14	97.51	78.69	28.95	107.64	75.03	27.54	102.57
SEm(±)	2.91	1.43	3.09	2.15	1.08	2.44	2.21	1.06	2.35
CD $_{(P=0.05)}$	8.35	4.11	8.87	6.17	3.11	7.02	6.36	3.05	6.74
Micronutrients									
F_1	69.54	24.85	94.49	76.69	27.81	104.51	73.17	26.33	99.50
F_2	71.51	25.10	96.61	77.88	27.93	105.81	74.70	26.52	101.21
F_3	76.80	26.57	103.37	83.60	29.40	112.99	80.20	27.98	108.18
SEm(±)	2.05	1.01	2.18	1.52	0.76	1.73	1.57	0.75	1.66
CD $_{(P=0.05)}$	NS	NS	6.27	4.36	2.20	4.96	4.49	NS	4.77
Interaction (NxF)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Phosphorus uptake also increased under INM, with N4 achieving 20.13 kg ha^{-1}, which was 44% higher than N5 (13.99 kg ha^{-1}) (Table 2). Substitution with poultry manure (N2) raised uptake by 38% over N5, highlighting the role of organics in enhancing P mobilization. Foliar Fe + Zn sprays further increased P uptake by 12% compared with Fe alone. This response may be due to increased enzymatic activity and organic acid exudation that improve solubilization and root uptake (Zhou et al., 2017; Adhikari et al., 2019). Integrated nutrient sources have also been shown to stimulate phosphatase activity and enhance P availability in calcareous soils (Zhang et al., 2020).

TABLE 2
P UPTAKE (kg ha^{-1}) OF RICE AS AFFECTED BY INM AND MICRONUTRIENT APPLICATION PRACTICES (2018, 2019 AND MEAN)

Treatments	P uptake (kg ha^{-1})								
	2018			2019			Mean		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Integrated Nutrient Management									
N_1	9.12	6.03	15.15	11.81	7.79	19.59	10.46	6.91	17.37
N_2	10.05	7.13	17.18	12.68	8.83	21.51	11.36	7.98	19.35
N_3	7.84	5.24	13.08	9.79	6.56	16.35	8.82	5.90	14.71
N_4	11.00	7.44	18.44	13.26	8.57	21.82	12.13	8.00	20.13
N_5	7.96	4.92	12.88	9.38	5.71	15.09	8.67	5.32	13.99
N_6	9.25	6.47	15.72	11.55	7.79	19.34	10.40	7.13	17.53
SEm(±)	0.43	0.41	0.61	0.45	0.42	0.57	0.37	0.41	0.54
CD $_{(P=0.05)}$	1.24	1.19	1.75	1.29	1.21	1.65	1.07	1.17	1.56
Micronutrients									
F_1	8.71	5.70	14.41	10.92	7.22	18.14	9.81	6.46	16.27
F_2	9.08	6.17	15.24	11.22	7.49	18.71	10.15	6.83	16.98
F_3	9.83	6.75	16.58	12.10	7.92	20.02	10.96	7.33	18.30
SEm(±)	0.30	0.29	0.43	0.32	0.30	0.41	0.26	0.29	0.38
CD $_{(P=0.05)}$	0.88	NS	1.23	0.91	0.85	1.17	0.76	NS	1.10
Interaction (NxF)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Potassium uptake followed a similar trend, with N4 and N2 producing mean total uptake of 91.87 and 90.35 kg ha^{-1}, representing 38% and 36% increases over N5, respectively (Table 3). Although foliar micronutrient sprays produced small numerical gains, the differences were non-significant. The improvement in K uptake under organic–inorganic integration can be attributed to increased cation exchange capacity and improved root proliferation due to organic matter addition (Badole et al., 2019; Jat et al., 2021). Earlier studies also confirm that INM systems improve soil aggregation, thereby facilitating better potassium availability and uptake (Choudhary et al., 2018).

TABLE 3
K UPTAKE (kg ha^{-1}) OF RICE AS AFFECTED BY INM AND MICRONUTRIENT APPLICATION PRACTICES (2018, 2019, MEAN)

Treatments	K uptake (kg ha^{-1})								
	2018			2019			Mean		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Integrated Nutrient Management									
N_1	8.89	68.79	77.67	13.13	77.66	90.78	11.01	73.22	84.23
N_2	9.78	72.49	82.28	13.96	84.6	98.42	11.87	78.47	90.35
N_3	7.91	59.34	67.26	11.01	64.14	75.15	9.46	61.74	71.20
N_4	9.98	77.54	87.52	13.85	82.36	96.21	11.92	79.95	91.87
N_5	7.44	57.85	65.28	9.76	58.16	67.92	8.60	58.00	66.60
N_6	8.41	63.89	72.30	11.88	72.96	84.84	10.15	68.42	78.57
SEm(±)	0.31	2.61	2.63	0.68	2.65	2.62	0.44	2.57	2.56
CD $_{(P=0.05)}$	0.89	7.49	7.55	1.96	7.60	7.53	1.27	7.39	7.35
Micronutrients									
F_1	8.50	65.71	74.21	12.14	72.42	84.57	10.32	69.07	79.39
F_2	8.58	65.33	73.91	12.00	72.31	84.31	10.29	68.82	79.11
F_3	9.12	68.91	78.03	12.66	75.13	87.79	10.89	72.02	82.91
SEm(±)	0.21	1.84	1.85	0.48	1.87	1.85	0.32	1.82	1.81
CD $_{(P=0.05)}$	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (NxF)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Protein content of rice grains did not show significant variation among treatments, although numerically higher values were noted in N4 (9.64%) and F3 (9.70%) compared with N5 (9.26%) (Table 4). Protein yield, however, differed markedly: N4 produced 531.37 kg ha^{-1}, 34% greater than N5 (395.55 kg ha^{-1}). N2 and N1 improved protein yield by 32% and 27% over N5, respectively. Foliar Fe + Zn sprays further enhanced protein yield by 10% compared with Fe alone. These results confirm that greater nitrogen uptake under INM directly translated into higher protein synthesis and yield. Similar enhancements in rice protein quality and nutritional value under integrated nutrient supply and micronutrient supplementation have been observed in multiple studies (Saha et al., 2015; Suryapani et al., 2019; Li et al., 2021). Additionally, foliar Zn application has been shown to increase protein content by improving enzymatic activities involved in amino acid synthesis (Zou et al., 2012; Hafeez et al., 2013).

TABLE 4
PROTEIN CONTENT (%) AND PROTEIN YIELD (kg ha^{-1}) AS INFLUENCED BY INM AND MICRONUTRIENT APPLICATION PRACTICES (2018, 2019 AND MEAN)

Treatments	Protein content (%)			Protein yield (kg ha^{-1})		
	2018	2019	Mean	2018	2019	Mean
Integrated Nutrient Management						
N_1	9.45	9.52	9.48	469.79	532.53	501.16
N_2	9.51	9.72	9.62	490.55	552.70	521.62
N_3	9.34	9.48	9.41	418.23	446.09	432.16
N_4	9.54	9.74	9.64	508.94	553.80	531.37
N_5	9.16	9.37	9.26	390.82	400.28	395.55
N_6	9.28	9.44	9.36	446.05	491.82	468.94
SEm(±)	0.28	0.27	0.24	18.17	13.42	13.83
CD $_{(P=0.05)}$	NS	NS	NS	52.22	38.56	39.76
Micronutrients						
F_1	9.11	9.25	9.18	435.27	479.34	457.30
F_2	9.40	9.60	9.50	446.95	486.78	466.86
F_3	9.63	9.78	9.70	479.97	522.49	501.23
SEm(±)	0.20	0.19	0.17	12.85	9.49	9.78
CD $_{(P=0.05)}$	NS	NS	NS	NS	27.26	28.11
Interaction (NxF)	NS	NS	NS	NS	NS	NS

Overall, the integration of organic amendments with mineral fertilizers significantly improved nutrient uptake and protein yield compared with sole chemical fertilization, with vermicompost and poultry manure proving particularly effective. Foliar supplementation with Fe and Zn further enhanced N and P uptake and protein yield, with combined application consistently outperforming individual sprays. These findings corroborate evidence that INM improves nutrient cycling, soil fertility, and crop productivity (Pathak et al., 2019; Somanath and Sharma, 2020; Li et al., 2022). In addition, foliar micronutrient supplementation has been shown to overcome soil fixation constraints and improve nutrient bioavailability in rice, leading to both yield gains and nutritional enrichment (Phattarakul et al., 2012; Prom-u-Thai et al., 2020; Zhao et al., 2020). Therefore, adopting INM along with targeted Fe and Zn sprays is a promising approach to improve both productivity and nutritional quality of rice grown in calcareous soils.

IV. CONCLUSION

The present investigation demonstrated that integration of organic manures with chemical fertilizers substantially improved nutrient uptake and protein yield of rice compared with sole chemical fertilization. Among the INM practices, the application of 100% RDN through chemical fertilizers supplemented with 25% RDN through vermicompost (N4) consistently achieved the highest nitrogen, phosphorus, and potassium uptake as well as protein yield, followed closely by 75% RDN with poultry manure (N2). Foliar supplementation with Fe and Zn further enhanced nutrient assimilation, with the combined spray (F3) proving superior to individual applications. The synergistic effects of organic substitution and micronutrient foliar feeding highlight the importance of adopting integrated strategies for sustaining yield and improving grain nutritional quality in calcareous soils. These findings support the use of INM, particularly vermicompost-based substitution coupled with Fe + Zn foliar sprays, as a viable approach for enhancing productivity, nutrient use efficiency, and biofortification potential of rice under resource-intensive production systems.

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Comparative Quality of Cow Manure based Compost with or without Fermentation Additive and its Effect on the Germination of Pechay

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Abstract— *Utilizing cow manure for composting at the same time addressing environmental issues can be a feasible alternative for cow raisers. The study aimed to determine the effects of adding a rapid odor erasing and composting microbes (OECM) at different inclusion rates of; 350 grams per 110 kg raw material (50 kg cow manure + 60 kg fly ash) T2; 400 grams per 110 kg raw material (50 kg cow manure + 60 kg fly ash) T3, and 450 grams per 110 kg or raw material (50 kg cow manure + 60 kg fly ash) T4 on physical properties, temperature, pH, germination rate, and percentage compost recovery. The control T1 was 110 kg raw material with no OECM. A Randomized Complete Block Design (RCBD) was used consisting of 4 treatments with each treatment replicated thrice. Tukey HSD was used to further analyze significant differences.*

The odor of treated compost disappeared by day 13 in T2, T3, and T4. On the same day, the texture changed from coarse to fine, and the color shifted from black to brown in these treatments.

The temperature ($p. < 0.01$), pH ($p. < 0.01$), compost recovery ($p. < 0.01$), and germination rate ($p. < 0.01$) were significantly different over the control. Therefore, the OECM at 350 grams, 400 grams, and 450 grams per 110 kg raw material is an indispensable additive for cow-based manure as it significantly improved the varying compost quality parameters.

Keywords— Cow manure, Composting, OECM, Fly ash, Organic fertilizer, Waste management, Germination rate, Compost recovery, pH, Temperature.

I. INTRODUCTION

In the Philippines, farming is one of the main sources of income. Many farmers have found cows to be helpful in their agricultural endeavors. Cattle farming is commonly carried out in backyards or on commercial farms. Besides the meat and milk products that can be derived from rearing cows, this livestock animal can also be utilized for early grazing to control unnecessary weeds in the farm surroundings. According to the Philippine Statistics Authority Cattle Situation Report, as of March 31, 2023, the total cattle inventory reached 2.57 million heads. 3.6% of the total cattle population comes from commercial, 14.3% from semi-commercial, and 82.1% from smallholdings.

Environmental concerns relating to cattle in livestock production are taken for granted as this industry in the Philippines continues to grow. In fact, due to the methane and nitrous oxide emitted during digestion and excrement, cattle are said to be the major contributor to environmental degradation among livestock, with an emphasis on greenhouse gas emissions. Therefore, considering these environmental concerns, raisers should adopt a more consumer-friendly production strategy.

In recent years, organic farming has been gaining rapid popularity. This was made possible because of the government's ongoing support to the Organic Agriculture Act (RA 10068). There have been several technological interventions for waste

utilization as a resource. Examples include research-based innovative strategies in animal feeding and nutrition; alternative approaches in cattle production; and an environmentally friendly waste management system.

Research and several studies have been conducted to improve agricultural practices by effectively using byproducts. Cow manure and other farm wastes, such as fly ash, rice straw, sawdust, and coco husk, are being utilized in a composting method to produce organic fertilizer that can be used to grow healthy plants, negating the need for synthetic chemical fertilizers. According to Zainudin et al. (2022), utilizing compost additives such as odor erasing and composting microbes (OECM) is one of the most efficient and suitable methods to accelerate the decomposition process when creating compost. OECM contains combinations of bacteria and fungi that work together to speed up the composting process. Composting is referred to as "natural recycling." Invertebrates eat carcasses after they have been broken down by microbes. The "compost" or nutrients formed are added back to the soil to help plants thrive. Compost improves the soil's water-holding capacity and overall quality. Composting could therefore contribute to a better environment for both people and other living organisms.

Composting is done all over the world. However, due to the time required for the mixture of byproducts to degrade, it is not a quick process. Composting can take up to two years, but by manually stirring the compost, it can be completed in two to six months. As science and technology advances, it opens the door for many scientists to develop a product that may help accelerate the process of decomposition. Recently, there has been a composting product on the market that can convert livestock manure into organic fertilizer in 14 days, and this investigation was done to confirm it.

II. METHODOLOGY

2.1 Cow Manure Collection:

The cattle manure used in this study was collected from the Beef Cattle Project of the University Business Affairs Program of Central Luzon State University Agribusiness Center. The cow manure was delivered directly to ELR Family Trading Co., Inc., located at Barangay Bagong Sikat Science City of Muñoz, Nueva Ecija, where the study was conducted.

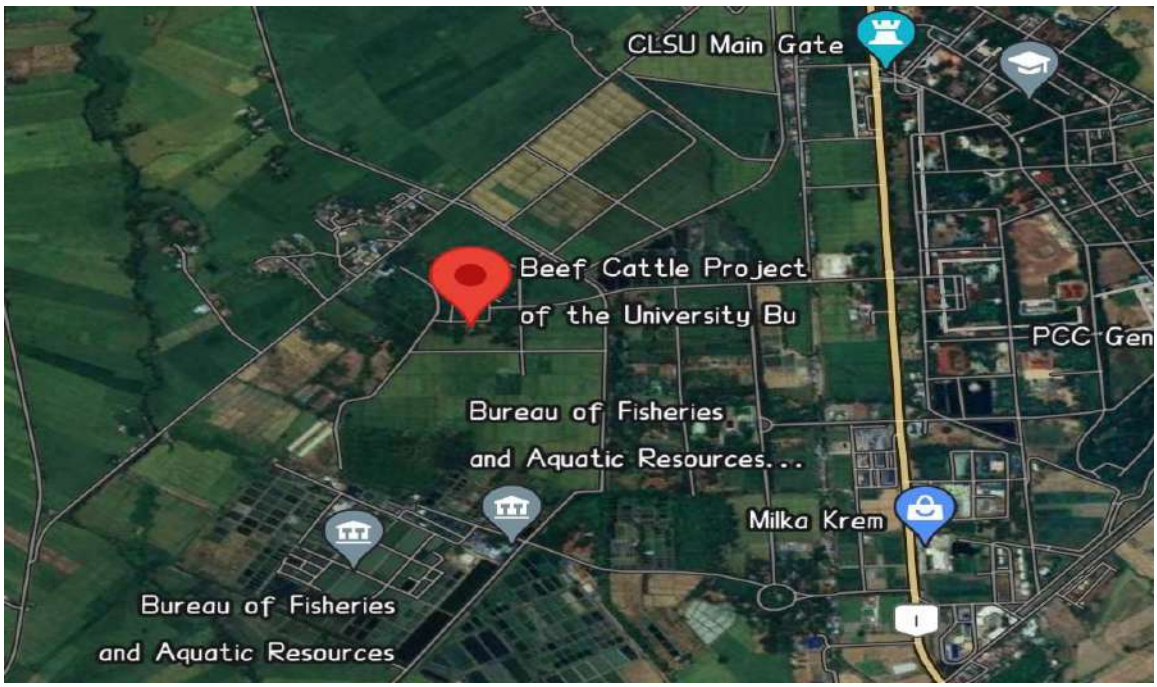

FIGURE 1: Cow Manure Collection Trace Map

2.2 The Composition and Preparation Process of the Odor Erasing Composting Microbes (OECM):

The OECM is organic based and was prepared as a concoction using the following: 7 bacteria for decomposition, enzyme production, and nutrients transformation; 3 bacteria for decomposition of polysaccharides and enzyme production; 3 bacteria for enhance decomposition, compost “sweetening” and probiotics; 5 bacteria for nitrogen fixation and nutrients transformation; 7 fungi for decomposition, probiotics production and nutrients transformation.

The preparation process involved the following: Classification of the substrate materials based on the modified growth media; comminution or griding of the substrate materials; mixing and blending of substrate materials for homogeneity; nutrient

fortification of the substrate to enhance the growth of the super stain beneficial microbes; sterilization; inoculation and subsequent incubation of the beneficial microbes; and propagation and subsequent multiplication of the beneficial microbes in the prepared substrate.

The source of substrate were haystack and decaying woods, cattle manure and silage, dairy processing plant sewerage, fermented vegetables fruits, pineapple pulp, stale bread, waste lagoons, garbage landfills, biogas digester, soil in organic fertilizer plants, oxidation of sewage plants, decomposed sugar cane and waste mushroom substrate and waste effluent.

2.3 Compost Plot Preparation:

Twelve plots measuring 4 ft. x 4 ft. x 1 ft., representing 4 treatments, were replicated three times. Temperature, pH, and moisture were taken from three sampling sites (top, middle, and bottom of the treated plots). Replicates of samples from these treated plots were analyzed for temperature, pH, and moisture by a 4-in-1 soil survey instrument, while the odor, color, and texture were physically observed and recorded.

2.4 Treatment Assignments:

TABLE 1
TREATMENTS AND COMPOSITION OF COMPOST IN THIS STUDY

Treatments	Composition
Treatment 1 (control)	50 kg Cow Manure + 60 kg Fly Ash
Treatment 2	50 kg Cow Manure + 60 kg Fly Ash + 350 grams OECM
Treatment 3	50 kg Cow Manure + 60 kg Fly Ash + 400 grams OECM
Treatment 4	50 kg Cow Manure + 60 kg Fly Ash + 450 grams OECM

2.5 Treatment Plots Management:

All the experimental treatment plots were stirred vigorously and done at 6:00 AM; 2:00 PM, and 10:00 PM from Day 1 to Day 7, and 6:00 AM; 6:00 PM from Day 8 to Day 14. The following compost parameters were recorded immediately after every stirring session.

2.6 Data Gathered:

To address production performance and improvements, the following data was collected in order.

1. (%) Percent compost recovery = $\frac{\text{initial weight} - \text{final weigth}}{\text{initial weight}}$ x 100
2. Temperature, pH, and moisture – measured by a portable soil test kit and taken from three sampling sites (top, middle, and bottom of the treated plots).
3. Texture, Color and Smell – physically observed and recorded.
4. Germination Rate, (%) = $\frac{\text{numbers of seeds germinated}}{\text{total number of seeds sown}}$ x 100

2.7 Germination of Pechay Seed:

100 pechay seeds were sown directly into the treated compost media, keeping the compost moist until sprouts appeared. The counting of germination begins the moment the pechay seed sprouts. Counting terminates after 7 days only.

2.8 Statistical Analysis:

The variations in compost parameters between four combination ratios of treatment 1, 2, 3, and 4 were analyzed using two-way ANOVA, followed by a Tukey HSD mean comparison. SPSS version 20 was used for statistical analysis, and statistical mean differences were identified as significant at $p<0.05$.

III. RESULT AND DISCUSSION

3.1 Compost Temperature:

(Table 2a-b) shows the 14 days temperature mean values gathered during composting period from T1 (50 kg cow manure + 60 kg fly ash), T2 (50 kg cow manure + 60 kg fly ash + 350 grams OECM), T3 (50 kg cow manure + 60 kg fly ash + 400 grams OECM), and T4 (50 kg cow manure + 60 kg fly ash + 450 grams OECM).

TABLE 2 (a)
COMPARATIVE TEMPERATURE OF COW-BASED MANURE COMPOST WITH OR WITHOUT OECM

Treatment	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Treatment 1	29.67^{a}	29.33^{a}	29.22^{a}	30.33^{a}	30.56^{a}	29.56^{b}	29.78^{b}
Treatment 2	30.11^{a}	29.22^{a}	29.78^{a}	30.89^{a}	30.78^{a}	30.44^{a}	30.67^{a}
Treatment 3	30.00^{a}	29.89^{a}	30.11^{a}	30.22^{a}	30.56^{a}	30.22^{a}	31.00^{a}
Treatment 4	29.67^{a}	29.22^{a}	29.89^{a}	30.67^{a}	30.44^{a}	29.89^{ab}	30.56^{a}
p-value	0.337	0.27	0.067	0.112	0.614	0.013*	0.003*

*Note: *significant at 5% level*
Means with the common letters are not significantly different

TABLE 2 (b)
COMPARATIVE TEMPERATURE OF COW-BASED MANURE COMPOST WITH OR WITHOUT OECM

Treatment	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
Treatment 1	30.33^{a}	29.67^{b}	28.33^{b}	28.67^{b}	29.00^{b}	29.17^{b}	28.83^{c}
Treatment 2	30.83^{a}	31.00^{a}	31.00^{a}	30.17^{a}	31.00^{a}	30.33^{a}	30.00^{a}
Treatment 3	30.67^{a}	30.83^{a}	30.50^{a}	30.00^{a}	30.50^{a}	30.67^{a}	30.50^{a}
Treatment 4	30.67^{a}	30.83^{a}	30.83a	30.17^{a}	31.00^{a}	30.67^{a}	30.50^{a}
p-value	0.614	<0.001*	<0.001*	0.002*	<0.001*	0.004*	<0.001*

*Note: *significant at 5% level*
Means with the common letters are not significantly different

The data results showed that there was no significant difference between T2, T3, and T4, whereas T1 was significantly different from T2, T3, and T4. Moreover, temperatures in compost piles range from 29 to 30 °C at the initial phase of composting. The mean temperature recorded after 14 days of composting ranged from a minimum of 28 °C for T1 (50 kg cow manure + 60 kg fly ash) to a maximum temperature of 31 °C. For T2 (50 kg cow manure + 60 kg fly ash + 350 grams OECM), 29 °C to 31 °C; the same for T3 (50 kg cow manure + 60 kg fly ash + 400 grams OECM) and T4 (50 kg cow manure + 60 kg fly ash + 450 grams OECM) (Table 2a-b).

According to Smith et al. (2017), the increase in heat during composting is a byproduct of bacterial replication in compost. The compost grows hot when there is a lot of bacterial activity. However, throughout the composting period, all experimentally treated piles were unable to attain the three temperature phases required for effective sanitization (CCME 2005; Eusufzai et al. 2013) of the feedstock and process efficiency: the mesophilic phase, where temperatures are between 15 and 45 °C; the thermophilic phase, with temperatures between 45 and 70 °C; and the cooling phase, when the pile temperatures drop below 60 °C. The study results showed that T1, T2, T3, and T4 failed to satisfy these criteria. The nitrogen source in this experiment was confined to cow manure. Compost nitrogen sources boost bacterial growth and cell yields. (Adnan, A., & Chai, J. M. 2018). Furthermore, the manure utilized in the study was gathered from a continuous pile that was exposed to direct sunlight and rainfall, which could have influenced the macronutrients present in the manure. The lack of nitrogen in the pile inhibits microbial activity throughout composting days, resulting in a constant temperature ranging from 28 to 32 °C.

3.2 Compost pH:

(Table 3a-b) shows the 14 days pH mean values gathered during the 14 days composting from T1 (50 kg cow manure + 60 kg fly ash), T2 (50 kg cow manure + 60 kg fly ash + 350 grams OECM), T3 (50 kg cow manure + 60 kg fly ash + 400 grams OECM), and T4 (50 kg cow manure + 60 kg fly ash + 450 grams OECM).

TABLE 3 (a)
COMPARATIVE PH OF COW-BASED MANURE COMPOST WITH OR WITHOUT OECM

Treatment	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Treatment 1	5.99^{b}	5.31^{b}	5.00^{b}	5.93^{a}	5.53^{a}	5.37^{a}	5.39^{b}
Treatment 2	6.31^{a}	6.37^{a}	5.40^{a}	5.60^{b}	5.46^{a}	5.56^{a}	5.51^{ab}
Treatment 3	5.70^{c}	6.07^{a}	5.18^{ab}	5.59^{b}	5.30^{a}	5.52^{a}	5.63^{a}
Treatment 4	5.48^{d}	6.33^{a}	5.27^{ab}	5.51^{b}	5.36^{a}	5.46^{a}	5.37^{b}
p-value	<0.001*	<0.001*	0.042*	0.010*	0.438	0.157	0.003*

*Note: *significant at 5% level*
Means with the common letters are not significantly different

TABLE 3 (b)
COMPARATIVE PH OF COW-BASED MANURE COMPOST WITH OR WITHOUT OECM

Treatment	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
Treatment 1	5.30^{a}	5.45^{a}	5.22^{b}	5.08^{b}	4.95^{b}	5.30^{b}	5.22
Treatment 2	5.42^{a}	5.62^{a}	5.97^{a}	5.85^{a}	5.73^{a}	5.77^{a}	5.68
Treatment 3	5.30^{a}	5.70^{a}	5.90^{a}	5.72^{a}	5.90^{a}	5.55^{ab}	5.78
Treatment 4	5.40^{a}	5.48^{a}	5.87^{a}	5.62^{a}	5.73^{a}	5.70^{a}	5.73
p-value	0.521	0.313	0.006*	0.003*	<0.001*	0.007*	<0.001*

*Note: *significant at 5% level*
Means with the common letters are not significantly different

pH of compost piles ranges from 5.48 to 6.31 at the initial phase of composting. The mean pH values recorded after 14 days of composting ranged from 4.95 to 5.99 for T1, 5.4 to 6.37 for T2, 5.18 to 6.07 for T3, and 5.27 to 6.33 for T4. During 14 days of composting, the mean pH values recorded on T2, T3, and T4 were not significantly different, whereas T1 was significantly different to T2, T3, and T4.

Moreover, the final pH value gathered from different compost piles was 5.22 for T1, 5.68 for T2, 5.78 for T3, and 5.73 for T4. Based on the categories provided by the United States Department of Agricultural National Resources Conservation Service, T2, T3, and T4 pH values fall under moderate acidic (5.6–6.0), whereas T1 pH value were included as strongly acidic (5.1–5.5) (Burt, 2014). Beck-Friis et al. (2001) noted that the transition from mesophilic to thermophilic conditions correlated with a change in pH from acidic (pH = 4.5–5.5) to alkaline (pH = 8–9); however, none of the experimental plots in this study reached the thermophilic phase (45–70 °C) (Papale et al. 2021). The constant temperature (29–31 °C) throughout composting resulted in stable pH levels ranging from 4.95–6.37 from days 1–14. In accordance with Bunt (1988), the final pH values recorded from all experimental piles (Table 3b) were within the ideal range for growing media, which is between 5.2 and 7.3.

3.3 Harvest Recovery:

Harvest recovery is measured to differentiate the influence of compost additive to the mass of different compost treatments used in the study. Higher values in the provided data below means greater weight loss (Table 4).

TABLE 4
COMPARATIVE WEIGHT LOSS OF COMPOST WITH OR WITHOUT COMPOST ADDITIVE (%)

Treatment	Weight Loss
Treatment 1	30.303^{c}
Treatment 2	41.212^{b}
Treatment 3	43.939^{ab}
Treatment 4	44.848^{a}
p-value	<0.001*

*Note: *significant at 5% level*
Means with the common letters are not significantly different
**The weight of OECM in the treated plot was not included in the initial weight*

(Table 4) shows that there was a significant difference (p-<0.01) between T1 (control), T2, T3, and T4. The data results show that T1 was significantly different from T2, T3, and T4; T2 was not significantly different from T3 but significantly different from T1 and T4; T3 was not significantly different from T4 and T2 but significantly different from T1; and T4 was not

significantly different from T3 but significantly different from T1. Among all the treatments, T1 had the lowest weight loss at 30.303, followed by T2 at 41.212, T3 at 43.939, and T4 had the highest weight loss recorded after the 14-day composting. In accordance with the study of (Breitenbeck and Schellinger, 2013; Tiquia et al., 2002; Van Lier et al., 1994), all experimentally treated piles in the study lost 10 to 50% of their initial weight (Table 4).

3.4 Odor, Color, and Texture:

Physical properties of compost, such as odor, color, and texture, are widely used as indicators to assess if the compost is mature enough and ready to harvest. During the 14-day composting period, the odor, color, and texture parameters were evaluated and recorded to determine the extent to which different compost treatments will degrade.

TABLE 5 (a)
DAILY PHYSICAL PARAMETERS OF COW-BASED MANURE WITHOUT OECM

Day	Treatment 1		
	Texture	Color	Odor
1	Coarse	Black	Slightly Offensive
2	Coarse	Black	Slightly Offensive
3	Coarse	Black	Slightly Offensive
4	Coarse	Black	Slightly Offensive
5	Coarse	Black	Slightly Offensive
6	Coarse	Black	Slightly Offensive
7	Coarse	Black	Slightly Offensive
8	Coarse	Black	Slightly Offensive
9	Coarse	Black	Slightly Offensive
10	Coarse	Black	Slightly Offensive
11	Coarse	Black	Slightly Offensive
12	Coarse	Black	Slightly Offensive
13	Coarse	Black	Slightly Offensive
14	Coarse	Black	Slightly Offensive

Table 5a shows that from day 1 to day 14, the texture of the cow-based manure compost appeared to be coarse, black in color, and had a slightly odor. There were no changes observed in treatment 1 physical parameters during 14 days of composting.

TABLE 5 (b)
DAILY PHYSICAL PARAMETERS OF COW-BASED MANURE WITH 350 GRAMS OECM

Day	Treatment 2		
	Texture	Color	Odor
1	Coarse	Black	Slightly Offensive
2	Coarse	Black	Slightly Offensive
3	Coarse	Black	Slightly Offensive
4	Coarse	Black	Slightly Offensive
5	Coarse	Black	Slightly Offensive
6	Coarse	Black	Slightly Offensive
7	Coarse	Black	Slightly Offensive
8	Slightly coarse	Black	Slightly Offensive
9	Slightly coarse	Black	Slightly Offensive
10	Slightly coarse	Brown	Odorless
11	Slightly coarse	Brown	Odorless
12	Slightly coarse	Brown	Odorless
13	Fine	Brown	Odorless
14	Fine	Brown	Odorless

Table 5b shows that from day 1 to day 7, the texture of the cow-based manure compost appeared to be coarse; on days 8 to 12, it was slightly coarse, then appeared to be fine on days 13 to 14. The color on days 1–9 was black and became brown on days 10–14. Further, the odor of the compost from day 1 to day 9 was slightly offensive, and on day 10 of composting, it became odorless. The result showed that the compost was ready to be used after 14 days of composting.

TABLE 5 (c)
DAILY PHYSICAL PARAMETERS OF COW-BASED MANURE WITH 400 GRAMS OECM

Days	Treatment 3		
	Texture	Color	Odor
1	Coarse	Black	Slightly Offensive
2	Coarse	Black	Slightly Offensive
3	Coarse	Black	Slightly Offensive
4	Coarse	Black	Slightly Offensive
5	Coarse	Black	Slightly Offensive
6	Coarse	Black	Slightly Offensive
7	Coarse	Black	Slightly Offensive
8	Slightly coarse	Black	Slightly Offensive
9	Slightly coarse	Black	Slightly Offensive
10	Slightly coarse	Brown	Odorless
11	Slightly coarse	Brown	Odorless
12	Slightly coarse	Brown	Odorless
13	Fine	Brown	Odorless
14	Fine	Brown	Odorless

Table 5c shows that from day 1 to day 7, the texture of the cow-based manure compost appeared to be coarse; on days 8 to 12, it was slightly coarse, then appeared to be fine on days 13 to 14. The color on days 1–9 was black and became brown on days 10–14. Further, the odor of the compost from day 1 to day 9 was slightly offensive, and on day 10 of composting, it became odorless. The result showed that the compost was ready to be used after 14 days of composting.

TABLE 5 (d)
DAILY PHYSICAL PARAMETERS OF COW-BASED MANURE WITH 450 GRAMS OECM

Days	Treatment 4		
	Texture	Color	Odor
1	Coarse	Black	Slightly Offensive
2	Coarse	Black	Slightly Offensive
3	Coarse	Black	Slightly Offensive
4	Coarse	Black	Slightly Offensive
5	Coarse	Black	Slightly Offensive
6	Coarse	Black	Slightly Offensive
7	Coarse	Black	Slightly Offensive
8	Slightly coarse	Black	Slightly Offensive
9	Slightly coarse	Black	Slightly Offensive
10	Slightly coarse	Brown	Odorless
11	Slightly coarse	Brown	Odorless
12	Slightly coarse	Brown	Odorless
13	Fine	Brown	Odorless
14	Fine	Brown	Odorless

Table 5d shows that from day 1 to day 7, the texture of the cow-based manure compost appeared to be coarse; on days 8 to 12, it was slightly coarse, then appeared to be fine on days 13 to 14. The color on days 1–9 was black and became brown on days 10–14. Further, the odor of the compost from day 1 to day 9 was slightly offensive, and on day 10 of composting, it became odorless. The result showed that the compost was ready to be used after 14 days of composting.

In general, tables 5a–d showed that there was no significant variation in physical parameters (odor, color, and texture) observed over 14 days of composting between treatments 2, 3, and 4, however T1 was found to be different throughout all the treatments treated with OECM. The final form of compost does not resemble the original form because it has been destroyed due to natural decomposition by microorganisms that live in the compost. *Thiobacillus thiooxidans* and *Thiobacillus ferrooxidans* microbes eliminated the slightly offensive odor in the piles. Furthermore, as described by Ayunin et al. (2016), characteristics of compost with inclusion rates of 350 grams, 400 grams, and 450 grams of OECM in this study display signs of maturation after only 13–14 days of composting, having a brown color, no foul odor, and a fine texture (Table 5a–d).

3.5 Germination Rate:

Germination Rate is measured to differentiate the effectiveness of cow manure-based compost on pechay germination, further, to showcase which among experimental treatments will stand out. Higher values for this measure indicate a greater rate of germination.

TABLE 6
GERMINATION RATES OF DIFFERENT COMPOST TREATMENTS (%)

Treatment	Germination
Treatment 1	28.333[b]
Treatment 2	65.667[a]
Treatment 3	77.667[a]
Treatment 4	62.333[a]
p-value	<0.001*

*Note: *significant at 5% level*
Means with the common letters are not significantly different

(Table 6) shows that there was a significant difference (p-<0.01) between T1 (control), T2, T3, and T4. T1 had the lowest germination rate having 28.333, followed by T4 62.333, T2 65.667 and T3, which get the highest germination rate among all the treatments having 77.667. (Table 6) revealed that there was no significant difference between T2, T3, and T4, whereas T1 is significantly different to T2, T3 and T4.

Germination rate has been widely used to assess, phytotoxicity and maturity of compost (Luo et al., 2018). The study by Kim et al. (2005) shows that adding 0.05% of microbial inoculants enhances the pig liquid fertilizer (PLF) and increases the germination index of Chinese cabbage. The study findings also indicated that aerobic processing of PLF for 107 days was superior to anoxic processing and produced more macronutrient fertilizer material such as nitrogen, potassium, and phosphorus. Furthermore, Sace (2018) stated that if the pH was too high (alkaline) or too low (acidic) the plants cannot absorb the nutrients properly that would show signs of deficiencies. As shown in (Table 3b), the final pH level recorded from T2, T3, and T4 satisfied the ideal pH level needed by pechay plant around 5.4 to 6.7 (Balce1 et al. 2016) that results in a higher germination rate in compared to T1 (control).

IV. SUMMARY

The aim of the study was to evaluate the effects of different inclusion rates of compost additive (OECM) in cow manure-based composts and how this compost will affect the germination rate of pechay. Specifically, the main objectives of the study were to (a) determine the odor, color, texture, temperature, pH, and moisture of the various compost treatments; (b) determine the harvest recovery of the various compost treatments; and (c) determine the germination rate of pechay seeds from the various compost media. 4 different treatments were used in the study: T1 (control) having 50 kg of cow manure and 60 kg of fly ash; T2 (50 kg of cow manure + 60 kg of fly ash + 350 grams OECM); T3 (50 kg of cow manure and 60 kg of fly ash + 400 grams OECM); and T4 (50 kg of cow manure and 60 kg of fly ash + 450 grams OECM). The study was conducted for 21 days: 14 days for composting and 7 days for pechay germination.

V. FINDINGS

There was a significant difference (p. <0.001) in pH level. T2, T3, and T4 were not significantly different, having a final pH of 5.68 for T2, 5.78 for T3, and 5.73 for T4. Furthermore, T1 had the lowest pH level. The recorded mean pH value for T1 (5.22) makes it significantly different from T2, T3, and T4.

There was a significant difference (p. <0.001) in harvest recovery: T1 got 30.303 weight loss, followed by T2 at 41.212, T3 at 43.939, and T4 at 44.848. Based on statistical analysis, treatments 2, 3, and 4 were not significantly different, whereas T1 recorded harvest recovery mean value was significantly different from T2, T3, and T4.

There was a significant (p. <0.01) difference in the germination rate between T1 (control), T2, T3, and T4. T1 had the lowest germination rate at 28.333, followed by T4 at 62.333, T2 at 65.667, and T3 at 77.667. Based on statistical analysis, treatments 2, 3, and 4 were not significantly different, whereas T1 recorded germination rate mean value was significantly different from T2, T3, and T4.

On physical parameters such as odor, color, texture, and moisture, all piles treated with OECM had the same outcome and decomposed on days 13–14 of composting.

In general, the study findings showed that all compost plots with inclusion rates of 350 grams, 400 grams, and 450 grams of OECM were not significantly different from all compost parameters used in the study. Moreover, all piles treated with OECM were significantly different from treatment 1 (control).

VI. CONCLUSION

- The temperature of the compost with OECM inclusion rates of 350 grams, 400 grams, and 450 grams were significantly different over the control.
- The pH of the compost with OECM inclusion rates of 350 grams, 400 grams, and 450 grams were significantly different over the control.
- The harvest recovery of the compost with OECM values rates of 350 grams, 400 grams, and 450 grams were significantly different over the control.
- The germination rate of the compost with OECM values rates of 350 grams, 400 grams, and 450 grams were significantly different over the control.

VII. RECOMMENDATION

Based on the findings of this study, all the OECM inclusion rates were significantly different over the control indicating the necessity of compost additive to improve germination rate and harvest recovery.

Considering the economics of the utilization of the OECM, a lower inclusion rate can thus be recommended to lower the production cost of the compost. Furthermore, in future investigation, other compost parameters namely; heavy metals, porosity, NPK, and C:N ratio can be included.

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