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The **Global Journal of Agriculture, Forestry, and Food Systems (GLOAFFS)** is a **quarterly, peer-reviewed, international print and online research journal** dedicated to the advancement of knowledge in **agriculture, fisheries, forestry, agribusiness, food systems, and sustainability sciences**. It is published by **ETCOR Educational Research Center Research Consultancy Services**, located in **Sta. Ana, Pampanga, Philippines**.

GLOAFFS serves as a global platform for **agricultural scientists, foresters, fisheries experts, agribusiness researchers, food systems analysts, policymakers, and interdisciplinary scholars** to disseminate high-quality empirical, experimental, policy-oriented, and practice-based research that supports sustainable food production, natural resource management, and rural development.

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Aims and Scope

Aims

GLOAFFS aims to:

1. Promote high-quality research in agriculture, forestry, fisheries, and food systems
2. Advance sustainable and climate-resilient agricultural and forestry practices
3. Encourage interdisciplinary research linking natural resources, food systems, and agribusiness
4. Provide a venue for global, comparative, and applied agri-food research
5. Support evidence-based policies for food security, sustainability, and rural development

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- Animal science and livestock production
- Fisheries, aquaculture, and aquatic resources
- Forestry, agroforestry, and forest management
- Agribusiness, agricultural economics, and value chains
- Food systems, food security, and nutrition
- Climate-smart agriculture and natural resource management
- Soil science, land use, and environmental conservation
- Agricultural technology and innovation
- Interdisciplinary agriculture and food sustainability research

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areas experience delays in receiving social pensions, raising concerns about accessibility and efficiency."

- The **research objectives** represent the specific aims or intentions of the study, focusing on what the researcher seeks to accomplish. These are written in infinitive form such as "To determine…" or "To examine…," ensuring that the targets are clear, measurable, and achievable. Unlike the broad statement of the problem, objectives are narrower and centered on actionable outcomes. For instance, a general objective could be *"To assess the implementation of the Social Pension Program in Balbalan, Kalinga."* This may be broken down into specific objectives, such as: (1) To determine the accessibility of the program, (2) To examine its impact on beneficiaries, and (3) To identify challenges faced in its implementation.
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Editor's Note (Maiden Issue)

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It is with great pride and enthusiasm that we present the maiden issue of the *Global Journal of Agriculture, Forestry, and Food Systems (GLOAFFS)*. This inaugural publication reflects ETCOR's commitment to advancing rigorous and sustainability-focused research in agriculture and natural resource systems.

Agriculture, forestry, and fisheries are central to food security, livelihoods, and environmental stewardship. As global challenges such as climate change, population growth, and resource degradation intensify, evidence-based research becomes essential for resilient and sustainable food systems.

GLOAFFS provides a scholarly platform for research spanning crop and animal production, forestry management, fisheries, agribusiness, and food systems analysis. This maiden issue highlights the diversity of contemporary agri-food research through studies addressing productivity, sustainability, and value chain development.

As a peer-reviewed international journal, GLOAFFS upholds the highest standards of scientific integrity through a double-blind review process, strict adherence to publication ethics, and commitment to methodological rigor.

The journal seeks to bridge science, practice, and policy. Agricultural and food systems research achieves its greatest impact when it informs farmer practices, agribusiness decisions, environmental management, and public policy.

This maiden issue is the result of collaborative efforts among authors, reviewers, editors, and technical specialists who share a dedication to scholarly excellence and responsible resource management.

GLOAFFS is positioned as a global journal that values interdisciplinary and context-sensitive research. By welcoming contributions from researchers worldwide, the journal promotes comparative perspectives and international collaboration.

The journal is also committed to supporting early-career agricultural and environmental researchers. GLOAFFS aims to provide a supportive yet rigorous platform for emerging scholars to engage in global scientific discourse.

As we launch this first issue, we reaffirm our commitment to ethical research, environmental sustainability, and continuous improvement. GLOAFFS will continue to evolve alongside advances in agriculture, forestry, and food systems science.

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On behalf of the Editorial Board, we extend our sincere gratitude to all who contributed to this maiden issue. We invite agricultural scientists, foresters, fisheries experts, and food systems researchers worldwide to join us in shaping future issues of GLOAFFS.

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Implementation of Philippine Crop Insurance Corporation (PCIC) Registry System for Basic Sector in Agriculture (RSBSA) in the Province of Albay

Jordan V. Barela*[1], Dr. Manny B. Macabeo[2]
[1, 2] Bicol College, Daraga, Albay, Philippines

Abstract
Aim: This study evaluated the implementation of the PCIC RSBSA Rice Insurance Program in the province of Albay. It focused on assessing how effectively the program was carried out in the municipalities of Libon, Ligao, and Oas. The research identified challenges encountered during the enrollment and indemnity claim processes. Ultimately, the findings aimed to inform policymakers in improving agricultural insurance policies for rice farmers in Albay.
Methodology: The study used a descriptive quantitative research design to assess the implementation of the PCIC RSBSA Rice Insurance Program in Libon, Oas, and Ligao City, Albay. Data were gathered using structured, expert-validated questionnaires tailored for two respondent groups: 940 RSBSA-registered farmers and 20 PCIC personnel from the Marketing and Sales Division (MSD) and Claims and Adjustment Division (CAD). The farmer questionnaire assessed program effectiveness, challenges, and satisfaction, while the PCIC staff questionnaire focused on administrative and operational issues. Sample size for farmers was determined using Slovin's formula, and data collection was conducted through field surveys. Analysis was done using weighted mean and ranking, with guidance from a professional statistician to ensure accuracy and reliability.
Results: The study found that the PCIC RSBSA Rice Insurance Program was generally effective, particularly in claims processing and adjuster responsiveness. Farmers reported high satisfaction, especially with the speed of indemnity cheque issuance. However, challenges such as technical issues in enrollment, low awareness of document requirements, and limited availability of adjusters were identified. These issues highlighted the need for improved communication, digital systems, and staffing to enhance the program's efficiency and accessibility.
Conclusion: The evaluation concluded that while the PCIC RSBSA Rice Insurance Program in Albay was effective and well-received by farmers, key improvements in enrollment, claims processing, and communication are necessary to enhance its overall impact and sustainability.
Keywords: *Implementation, Crop Insurance, Effectiveness, Enrollment, Indemnity Claim, Satisfaction*

INTRODUCTION

The agricultural sector is vital to the economy, providing livelihoods for many, but it is vulnerable to natural disasters, pests, and diseases, which can cause significant crop losses. Over the past 30 years, disasters have resulted in nearly US$4 trillion in global losses, averaging US$123 billion annually, or 5% of the global agricultural GDP. Agricultural insurance helps mitigate these risks by offering financial protection to farmers against crop losses. However, many countries face challenges in effectively implementing insurance programs.

For example, the U.S. Federal Crop Insurance Program (FCIP), introduced in the 1930s, has supported numerous crops, but has also encouraged counterproductive behaviors due to its subsidies. (Rossetti, 2023) India's Pradhan Mantri Fasal Bima Yojana program has faced criticism for lack of transparency and delayed claims. (Nirmal & Babu, 2021) Vietnam's National Agricultural Insurance Pilot Program experienced low participation, despite heavy government subsidies. (International Fund for Agricultural Development, 2021).

The Philippines also has an agricultural insurance program through the Philippine Crop Insurance Corporation (PCIC), which offers subsidized insurance to protect farmers against natural disasters, pests, and diseases. The PCIC uses the the Registry System for Basic Sector in Agriculture (RSBSA) from the Department of Agriculture, which identifies eligible farmers for government subsidies.

The Bicol Region, including Albay, is particularly vulnerable to natural disasters such as typhoons and floods, which frequently damage rice crops. In 2024, farmers in Albay faced significant losses from events like El Niño and Typhoon Kristine, highlighting the importance of insurance. (Conde, 2024) Despite the PCIC's efforts, the RSBSA rice insurance program has faced challenges like administrative inefficiencies and delays in claims processing. Improving these issues would enhance financial security for farmers, increase confidence in government initiatives, and contribute to the long-term development of the agricultural sector.

Objectives

This study assessed the implementation of the Philippine Crop Insurance Corporation's (PCIC) Registry System for Basic Sectors in Agriculture (RSBSA) rice insurance program in selected municipalities of Albay Province.

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Specifically, it aims to:

1. assess the effectiveness of the PCIC RSBSA rice insurance program in terms of:
    a. Enrollment in program;
    b. Filling of application for claim;
    c. Team of adjuster's response; and
    d. Indemnity claim receives.
2. identify the challenges encountered by the PCIC and farmers along:
    a. Enrollment process; and
    b. Claiming indemnity benefit.
3. assess the level of satisfaction of farmers regarding the:
    a. Enrollment process in the program; and
    b. Processing of indemnity claim.
4. provide an action plan for improving the implementation and effectiveness of the PCIC RSBSA rice program in Albay Province.

METHODS

Research Design

The researchers used a descriptive quantitative study design to provide an overview of the PCIC RSBSA Rice Insurance Program's implementation in selected municipalities and city of Albay, focusing on key aspects such as enrollment, claims, and farmer challenges.

Population and Sampling

The respondents included in this study are farmers registered under the RSBSA who availed of PCIC rice insurance and PCIC employees involved in program implementation. Data was gathered from farmers across three municipalities—Libon, Ligao City, and Oas—with a total of 940 respondents from a sample size of 1,088, resulting in an 86.27% response rate, and 20 PCIC personnel from the Marketing and Sales Division (MSD) and Claims and Adjustment Division (CAD).

Instruments

A structured survey questionnaire was developed based on the PCIC Citizen Charter and refined through interviews with farmers and PCIC personnel, with separate sets for farmers and PCIC employees. The questionnaires assessed program effectiveness, challenges in enrollment and claims processes, and satisfaction for farmers, while for PCIC employees, they focused on enrollment challenges for the Marketing and Sales Division and claim processing difficulties for the Claims and Adjustment Division, with the instrument's reliability tested using Cronbach's Alpha.

Data Collection

The researchers obtained permission from the Philippine Crop Insurance Corporation (PCIC) Regional Office V to conduct the study and collaborated with the Administrative and Finance Division Chief to develop and validate a questionnaire. The study took place in Libon, Oas, and Ligao City in Albay, where respondents were encouraged to participate fully and accurately, with data collected for analysis. Additionally, permission was granted from the division chiefs of MSD and CAD to survey their employees, and the collected data was submitted to a statistician for proper analysis and interpretation.

Treatment of Data

The researchers used weighted mean to assess the effectiveness of the program regarding enrollment and indemnity benefit processing, as well as to measure farmer satisfaction with the enrollment process and claims. Additionally, ranking was employed to identify and prioritize the most significant challenges faced by farmers and PCIC employees during enrollment and indemnity claims processing.

RESULTS and DISCUSSION

This section presents all the results of the data-gathering procedures conducted by the researchers, including the corresponding analysis, interpretation, discussion, and implications for the current body of

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knowledge, policy, and practice. Key findings are triangulated with the relevant literature discussed in the preceding section.

1. Effectiveness of the PCIC RSBSA rice insurance program

The results discuss the effectiveness of the PCIC RSBSA Rice Insurance Program in key components—enrollment, indemnity claims processing, filing of applications, adjuster response, and claim receipt—based on data from farmers in Libon, Oas, and Ligao City, providing insights into the program's efficiency and impact on agricultural development.

A.) Enrollment in the program

This part of the research evaluates the effectiveness of the PCIC RSBSA Rice Insurance Program's enrollment process, focusing on key activities such as document submission, application processing, encoding, verification, and evaluation across Libon, Ligao, and Oas. The study shows that document submission is highly effective in all three municipalities, while the other stages, like processing and encoding, received lower effectiveness ratings, suggesting room for improvement. Despite these issues, the overall enrollment process is perceived as effective, with Ligao showing slightly better performance in most areas, followed by Oas and Libon. The consistency in document submission across locations indicates a well-managed and standardized process, while variations in processing and encoding reflect minor operational challenges. These findings align with previous studies, such as Reyes et al. (2019) and Dumilag et al. (2024), who emphasized that the RSBSA acts as an effective targeting mechanism for government assistance programs like crop insurance. Additionally, the high ratings for document submission are consistent with Fabregas et al. (2019) and Mapiye et al. (2021), who discussed the active involvement of LGUs and agricultural agencies in guiding farmers through the enrollment process. On the other hand, the observed challenges in processing and encoding are in line with Rola (2021) and Valcin et al. (2024), who pointed out the need for more streamlined administrative procedures to improve program efficiency.

B.) Filling of application for claim

This section of the study examines how effectively the PCIC RSBSA Rice Insurance Program handles the filing of indemnity claims, an essential process for ensuring farmers receive financial support following crop losses. The results from Libon, Ligao, and Oas demonstrate that the submission and review of indemnity claims are highly effective in all three areas. Both the submission of Claim for Indemnity forms and the review of their completeness by the Claims and Adjustment (CAD) processor were seen as efficient, indicating strong collaboration between PCIC staff, local officials, and farmers. The consistently high ratings across the municipalities suggest that the process is well-structured and operates smoothly without major delays or issues. These findings align with earlier studies by Rola and Querijero (2021) and Bitonio (2025), which emphasized the importance of better coordination and faster processing in indemnity claim procedures.

C.) Team of Adjuster's Response

This analysis examines the effectiveness of the PCIC RSBSA Rice Insurance Program's adjuster response. Adjusters play a vital role in assessing crop damage and determining compensation. The study evaluates the timeliness and effectiveness of their responses, as well as their communication with farmers. In Libon, adjusters performed highly effectively, efficiently verifying claimant information, conducting field adjustments, and submitting reports. The same level of effectiveness was observed in Ligao, where the adjusters' quick and accurate work strengthened the program's credibility. In Oas, while most indicators were highly effective, there is room to improve report submission efficiency. All three municipalities showed excellent performance in verifying claimant information, ensuring effective communication. The field assessments were also consistently strong, helping to prevent inaccurate claims. However, issues with outdated or duplicative RSBSA listings, as noted by Reyes et al. (2019), may limit the program's reach. Recommendations include improving farmer targeting through the Community-Based Monitoring System (CBMS) and extending the response time for adjusters (Rola and Querijero, 2017, as cited in Gaylican, 2023).

D.) Indemnity Claim Receive

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This section assesses the effectiveness of the PCIC RSBSA Rice Insurance Program in processing indemnity claims, which is critical for farmers' financial recovery after crop losses. The findings reveal that the indemnity claim process is highly effective across all three municipalities—Libon, Ligao, and Oas—but with some variations. In Libon, the process achieved high effectiveness in all stages, including document submission, verification, and cheque release, reflecting a smooth and well-organized system. This suggests that Libon's process is highly efficient, with minimal barriers for farmers, making it a potential model for other municipalities. Ligao also demonstrated a highly effective process, though the verification phase showed some room for improvement, as the validation process was slightly less efficient. Oas, while still effective, exhibited more challenges in the verification phase, which may result in delays or inefficiencies, affecting the overall speed of claims processing. However, the cheque release process remained highly effective in all municipalities.

The high effectiveness of indemnity claim processing in Libon, Ligao, and Oas aligns with findings from Nueca (2024), who emphasized that delays in indemnity claims, such as those experienced in San Jose, Batangas, led to decreased farmer satisfaction. This highlights the importance of timely claim disbursement, a strength observed in Libon. Similarly, Alemania (2022) found that farmers in Zambales preferred insurance programs with simplified and accessible claims systems, recommending online applications to improve efficiency. These studies underline the significance of user-focused practices and timely indemnity payments in ensuring the success of agricultural insurance programs. The results suggest that implementing best practices, such as those in Libon, could help improve the overall efficiency and farmer satisfaction in the PCIC RSBSA Rice Insurance Program.

2. Challenges Encountered by PCIC and farmers

This section highlights the challenges faced by both PCIC employees and farmers in the enrollment and indemnity claims processing of the PCIC RSBSA Rice Insurance Program. These challenges impact the program's efficiency, accessibility, and the timeliness of financial assistance.

A.) Challenges encounter by farmers in PCIC RSBSA Rice insurance program in terms of Enrollment in the Program

Table 1-A presents the challenges faced by farmers in terms of enrollment in the program.

Table 1-A

Challenges encounter by farmers in PCIC RSBSA Rice insurance program in terms of Enrollment in the Program

INDICATORS	LIBON	RANKED	LIGAO	RANKED	OAS	RANKED	TOTAL	RANKED
A. Awareness about the documents required for enrollment in the RSBSA rice insurance program.	250	1	315	1	186	1	**751**	**1**
B. Accessibility of the enrollment sites.	13	3	21	2	56	2	**90**	**2**
C. Completion of the required documents for enrollment in the RSBSA rice insurance program.	31	2	7	3	35	3	**73**	**3**

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D. Contacting the Insurance Underwritter (I.U.) for clarification regarding the enrollment in the program.	11	4	3	4	5	4	**19**	**4**

This section discusses the challenges farmers face during the enrollment process in the PCIC RSBSA Rice Insurance Program, which is critical for gaining insurance coverage. The main issues identified include a lack of awareness about required documents, difficulties in accessing enrollment sites, challenges in completing necessary documentation, and limited communication with the Insurance Underwriter. The study highlights that inadequate information dissemination between PCIC, local government units, and farming communities leads to confusion about enrollment requirements. It also points to systemic issues such as logistical problems with enrollment site accessibility and unclear forms, as well as policy inconsistencies that hinder participation. Literature from Tiri (2022), Rearío (2024), and others underscores how these barriers contribute to low insurance uptake and inefficiency in the system, with further complications due to reliance on paper-based systems and gaps in digital infrastructure.

B.) Challenges by PCIC in processing of indemnity claim

Table 1-B presents the challenge faced by farmers in processing indemnity claim

Table 1-B
Challenges encountered by farmers in processing indemnity claim

INDICATOR	LIBON		LIGAO		OAS		TOTAL F	RANKED
Claiming of indemnity benefit	**F**	**RANKED**	**F**	**RANKED**	**F**	**RANKED**		
A. Reporting to the PCIC office the damages occurred in the rice plantation.	10	4	10	4	3	4	**23**	***4***
B. Gathering the required documents for indemnity claim processing.	31	2	15	3	17	3	**63**	***3***
C. Availability of the team of adjusters to inspect the damages on the rice field.	274	1	293	1	240	1	**807**	***1***
D. Reaching out to the CAD claims processor to follow up the indemnity claim.	17	3	28	2	29	2	**74**	***2***

The findings in Table 1-B reveal the primary challenges faced by farmers in processing indemnity claims under the PCIC RSBSA Rice Insurance Program, as experienced in Libon, Ligao, and Oas. The unavailability of adjusters for damage appraisal emerged as the most significant issue, followed by difficulties in contacting the CAD claims processor and gathering the necessary documents. Reporting damage to the PCIC was the least problematic. These results underscore systemic inefficiencies—particularly human resource limitations and bureaucratic delays—that slow down the claim process. Prior studies, including those by Briones (2020) and Reyes et al. (2019), have

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similarly identified a lack of timely adjuster response, insufficient training, and weak communication systems as recurring problems. Himmelfarb (2023) and the World Bank Group (2023) further emphasized that the manual, paper-based system and limited staff capacity contribute to the delays, reducing the program's credibility and efficiency. These insights highlight a critical need for improvements in staffing, digital systems, and communication protocols to ensure timely and effective indemnity delivery.

C.) Challenges of PCIC personnel during enrollment

Table 1-C presents the challenge faced by PCIC employee during enrollment in the program

Table 1-C Challenges of PCIC personnel in the enrollment of the PCIC RSBSA rice insurance program

INDICATORS	F	RANKED
1. Completeness of the documents required in the enrollment for rice insurance under RSBSA.	8	2
2. Clarity of the information written in the application submitted by the farmer.	10	1
3. Numbers of personnel assign in enrollment process of the rice insurance under RSBSA	6	4
4. Number of facilities needed for the smooth enrollment process	3	5
5. Validation of the farmer's RSBSA number in the RSBSA list.	8	2
6. Contacting the farmer to clarify some details on the application form.	2	6

Table 1-C identified that the common issue faced by MSD employee during enrollment process was the lack of clarity in the information written on farmers' application forms (Rank 1, F=10), suggesting either limited farmer understanding or inadequate guidance during form completion. Tied at Rank 2 (F=8) were incomplete documentation and difficulty validating farmers' RSBSA numbers, both critical to enrollment finalization. Other concerns included the limited number of personnel handling enrollment (Rank 4, F=6), insufficient facilities (Rank 5, F=3), and difficulty contacting farmers for clarification (Rank 6, F=2). These findings point to administrative and logistical bottlenecks that slow down enrollment. According to Tiri (2022), poor data accuracy and inclusion of ineligible applicants compromise the program's integrity. Rearío (2024) further noted issues with unclear forms and missing identification or land documents. Himmelfarb (2023) and Gupta (2022) both highlighted that manual, paper-based systems—combined with low awareness and complex procedures—discourage participation and hinder efficiency. These challenges underscore the need for streamlined forms, better farmer orientation, digitization of records, and increased support staff to improve enrollment outcomes.

D.) Challenges by PCIC in processing of indemnity claim

Table 1-D presents the challenge faced by PCIC employee in processing the indemnity claim

Table 1-D Challenges encountered by PCIC employee in processing the indemnity claim under the PCIC RSBSA rice insurance program

Challenges	F	RANKED
1. Accessibility of the farm location during the conduct of adjustment	4	4
2. Completeness of the information in the Claim for Indemnity	3	5
3. Weather condition during the visitation of the adjuster	2	7
4. Stability of internet connection (signal) specially during the uploading of Claims Adjustment and Verification Report (CAVR) on PABS.	3	5
5. Volumes of Claim for Indemnity (C.I.) filed particularly after the calamity such as typhoon, heavy flood, drought or pest infestation.	10	1
6. Number of adjusters and CAD office personnel available after the calamity	8	2
7. Contacting or coordinating with the farmer for verification of information before	5	3

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conducting the adjustment visitation		

Table 1-D show that the most reported issue of the PCIC employee during processing of indemnity benefit is the high volume of claims filed after calamities (F=10, Rank 1), followed by the shortage of adjusters and CAD staff (F=8, Rank 2). Difficulty in contacting farmers for verification ranks third (F=5), while accessibility of farms during assessments comes next (F=4, Rank 4). Tied at Rank 5 (F=3) are incomplete claim information and unstable internet connectivity during CAVR uploads. The least-cited issue is poor weather during adjuster visits (F=2, Rank 7).

These findings reveal operational strains within PCIC, particularly during peak periods following disasters. Limited personnel and poor digital infrastructure lead to slow claim assessments and delayed payouts, frustrating both staff and farmer-claimants. As Briones (2020) and Reyes et al. (2019) note, lack of coordination, inadequate staffing, and manual processes significantly undermine the efficiency of the system. Himmelfarb (2023) and the World Bank Group (2023) further highlight the need to digitize workflows and expand the workforce, especially adjusters. Persistent issues—ranging from inaccessible farms to weak communication channels—hinder timely claim resolution and damage the credibility of the insurance scheme. Addressing these structural inefficiencies is crucial to ensuring faster, fairer, and more transparent indemnity processing for farmers under the PCIC RSBSA program.

3. Level of farmer's satisfaction

This section summarizes farmers' satisfaction with the PCIC RSBSA Rice Insurance Program's enrollment and claims processes, highlighting key factors like clarity, timeliness, and staff responsiveness that influence their overall experience and participation.

A.) Enrollment in the program

This section examines farmer satisfaction with the enrollment process of the PCIC RSBSA Rice Insurance Program in Libon, Ligao, and Oas. Overall, farmers in all three municipalities expressed high levels of satisfaction, noting that the process is generally organized, clear, and timely. In Libon, farmers found the process particularly smooth, appreciating its simplicity and efficiency. Ligao also showed strong satisfaction, though there were indications that certain aspects, such as simplicity and orderliness, could be improved. In Oas, while the enrollment procedures were seen as clear and well-structured, farmers noted challenges in receiving adequate assistance from PCIC personnel, suggesting a need for more effective support. Common strengths across all areas include the clarity of instructions and the orderly conduct of enrollment activities, which help minimize confusion. However, variation in the quality of assistance and the perceived complexity of the process suggest opportunities for further enhancement.

These findings contrast with existing literature on agricultural insurance programs. Rearío (2024) highlighted that some farmers are deterred from enrolling due to complicated documentation requirements and unclear forms, which may affect overall satisfaction. Similarly, Reyes et al. (2019) noted that many farmers learn about the RSBSA program through local barangay officials, indicating that the success of the enrollment process is heavily dependent on localized support rather than the central PCIC system. This suggests that while the enrollment process is functioning well in certain municipalities, the broader program may still face challenges in reaching all farmers effectively. Furthermore, the COA (2021) report on delays and backlogs in the insurance process raises concerns about long-term satisfaction. Despite initial positive responses, Himmelfarb (2023) and Rearío (2024) warned that such satisfaction may not be sustained if complicated, paper-based processes and delayed service delivery persist. Thus, while localized enrollment processes show success, there remains a need for broader systemic reforms to maintain and deepen farmer satisfaction and trust.

B.) Processing of Indemnity Claim

This section explores farmers' satisfaction with the indemnity claims process under the PCIC RSBSA Rice Insurance Program, focusing on aspects like timeliness, clarity, and fairness. While overall satisfaction remains high, concerns arise over delays in adjuster responses and the duration of claim processing, particularly in Ligao and Oas.

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These delays suggest bureaucratic bottlenecks and staff limitations. The findings align with Himmelfarb (2023), who highlighted the strain on adjusters managing a high volume of claims, and the COA (2021) audit, which reported delays of up to 797 days in claim settlements. These delays point to a need for improvements in timeliness and fairness. The study also supports recommendations from Reyes et al. (2019) and Tatuco et al. (2024) to modernize and streamline PCIC operations, suggesting innovations such as remote-sensing tools for claim verification and the deployment of LGU officers as adjusters to expedite and standardize the process, ultimately improving efficiency and farmer satisfaction.

Conclusion

This study evaluated the effectiveness, challenges, and satisfaction with the PCIC RSBSA Rice Insurance Program in Albay, revealing high effectiveness in claims processing and adjuster responsiveness. While the enrollment process was generally effective, challenges such as document requirements and limited adjuster availability were identified. Farmers expressed high satisfaction, particularly with enrollment and claims processing, but concerns about claim duration and support availability suggest room for improvement. The action plan recommends improving digital systems, enhancing stakeholder collaboration, and implementing capacity-building programs to address challenges and ensure the program's long-term sustainability.

Recommendations

Based on the study's findings, several recommendations are made to improve the PCIC RSBSA Rice Insurance Program's effectiveness and address existing challenges. First, PCIC should adopt technology-driven solutions like online enrollment and digital claim submissions, and create "one-stop-shop" centers in rural areas to streamline processes. Second, comprehensive communication strategies, including localized campaigns and collaborations with local government units, should be developed to ensure farmers fully understand enrollment procedures and requirements. Third, PCIC should expand its workforce, particularly adjusters, during peak periods and provide ongoing training to improve efficiency. Lastly, a robust monitoring and evaluation system should be implemented, alongside capacity-building initiatives, to enhance service delivery, address emerging challenges, and empower both farmers and PCIC employees.

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Learning Sites for Agriculture (LSA) as an Extension Delivery Pathway

Jennifer P. Miranda*[1], Victoriano V. Casco,Ph.D.[2], Jhimcelle V. Salvador[3]
[1,2,3] Isabela State University, Echague Campus, Echague, Isabela, Philippines

Abstract
Aim: This study aimed to assess the socioeconomic profile, services rendered, capacity-building needs, enabling and limiting factors, and physical development of Rice Competitiveness Enhancement Fund – Learning Site for Agriculture (RCEF-LSA) owner-operators in Isabela. It also sought to evaluate the effectiveness of various nutrient management strategies in rice production.
Methodology: A total of 28 LSA owner-operators in Isabela were surveyed using a structured questionnaire and one-on-one interviews, coordinated with local government units. Data were analyzed to determine profiles, services, challenges, and training needs. To validate findings, a field experiment was conducted at the A.R. Santiago Agri-Fishery Farm & Training Center in San Mateo, Isabela, testing seven nutrient management strategies in rice production. The trial covered a 300 m² area, using a randomized complete block design, and measured yield, income, and return on investment (ROI).
Results: Most LSA operators were male (67.86%), over 60 years old (35.71%), college-educated (78.56%), and had significant agricultural experience (75%). Extension services mainly focused on rice farming, with regular training sessions conducted for farmers, students, and local stakeholders. Enabling factors included strong institutional and family support, while major challenges were limited funding, unfavorable weather, and insufficient technical assistance. Capacity-building needs focused on technical agriculture, leadership, and communication skills, with a preference for face-to-face, hands-on training. While infrastructure was generally adequate, concerns about sustainability and funding remain. In the field trial, the Minus One Element Technique (MOET) produced the highest yield (8,303.27 kg/ha), net income (₱56,278.52), and ROI (66.31%). The Abonong Swak package (T7) offered a cost-effective alternative with a 56.88% ROI. The Farmer's Practice (T1) also showed acceptable results under resource-limited conditions.
Conclusion: The study highlights the critical role of RCEF-LSA owner-operators in agricultural extension and rice production in Isabela. While they exhibit strong potential through established experience, infrastructure, and training activities, significant challenges–particularly in funding, technical support, and sustainability—remain. Addressing these constraints through targeted capacity-building programs and institutional support can enhance the effectiveness and long-term viability of LSAs. Additionally, the field validation underscores the importance of adopting site-specific nutrient management technologies, such as MOET and Abonong Swak, to improve productivity and economic returns in rice farming.
Keywords: Learning Site for Agriculture (LSA), Rice Competitiveness Enhancement Fund (RCEF), Nutrient management, Minus One Element Technique, Zero hunger

INTRODUCTION

Agriculture remains a vital yet challenging sector in the Philippines, facing issues such as population growth, land conversion, climate change, and declining enrollment in agriculture courses (Agricultural Training Institute [ATI], 2017). Despite these challenges, the country continues efforts to ensure food security.

Agriculture employs approximately 24% of the Filipino workforce and contributes around 8.9% to the national GDP (Philippine Statistics Authority, 2022; World Bank, 2023). Its role in food production, rural development, and poverty reduction underscores its economic and social importance.

The Department of Agriculture (DA) promotes agricultural development, while the Agricultural Training Institute (ATI) leads extension and training efforts. Among ATI's various programs is the Learning Site for Agriculture (LSA), under the Rice Competitiveness Enhancement Fund – Rice Extension Services Program (RCEF-RESP). LSAs are model farms that demonstrate applicable technologies and serve as venues for training, hands-on learning, and extension delivery.

In 2022, ATI launched the EdGE (Educational Grants for Extension Workers) program, supporting agricultural professionals pursuing graduate studies. One focus of the program is research on LSAs under RCEF-RESP, emphasizing the importance of enhancing rice productivity and competitiveness.

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This study focuses on RCEF-LSA sites in Isabela, aiming to evaluate their socioeconomic profiles, services, challenges, capacity-building needs, and physical infrastructure. It also includes a field trial on nutrient management technologies promoted by LSAs. The study aligns with several Sustainable Development Goals (SDGs), particularly Zero Hunger (SDG 2), Good Health and Well-being (SDG 3), Responsible Consumption and Production (SDG 12), Climate Action (SDG 13), and Life on Land (SDG 15), by promoting sustainable, efficient, and climate-resilient farming practices.

Objectives

The study assessed the LSAs as an extension delivery pathway of the ATI-RTC2 in the Province of Isabela. The specific objectives are the following:

1. determine the socioeconomic profile of the LSA owner-operators in terms of Age, Sex, Educational Attainment, Years of Experience in Agriculture, LSA owner-operator in the field, Years as LSA, Status of LSA, Farm size, Land ownership, Training, and seminars attended.
2. determine the services rendered and clientele served by the LSA owner-operators.
3. identify the facilitating and hindering factors by the LSA encountered in implementing ATI programs.
4. identify capacity-building needs of the LSAs as agents of extension service delivery.
5. evaluate the productivity and income from rice nutrient management technologies implemented by LSA's, using the data derived from the survey study.

METHODS

Research Design

This study utilized a combination of survey research design and a field experiment. The survey aimed to gather data from RCEF-certified Learning Sites for Agriculture (LSAs) in the Province of Isabela to determine their status, operations, challenges, and capacity-building needs. Meanwhile, the field experiment was conducted to validate the effectiveness of various nutrient management practices in rice farming, as taught by the RCEF-LSAs.

Population and Sampling

The survey covered 28 RCEF-LSAs in Isabela, Region 02, Philippines. These included active and inactive. Despite their varied operational status, all were included to evaluate their strengths, weaknesses, and intervention needs. For the field experiment, one RCEF-LSA—A.R. Santiago Agri-Fishery Farm and Training Center in Barangay Gaddanan, San Mateo, Isabela, was selected as the experimental site due to its suitable location, facilities, and continuous irrigation support.

Instrument

A structured questionnaire was used as the primary research instrument for the survey. It was designed to gather relevant data aligned with the study's objectives, including demographic information, services rendered, operational factors, and capacity-building needs. For the field experiment, standard protocols and kits such as the Minus One Element Technique (MOET) and Rice Crop Manager (RCM) were utilized to assess soil health and guide nutrient management treatments.

Data Collection

Data for the survey were obtained through one-on-one interviews with the LSA owner-operators. The interviews were coordinated with local government units and barangay officials to ensure availability of the respondent and cooperation. Prior to each interview, the contents of the questionnaire were discussed to facilitate accurate responses. The interview process lasted two months. Field experiment data collection included land preparation, soil sampling and analysis, seedling production, transplanting, and implementation of various fertilizer treatments. Treatments included Farmers' Practice, Soil-Analysis-Based Recommendation, RCM, MOET, Soil Analysis with Leaf Color Chart, and Balanced Fertilization Strategy (BFS) with varying yield targets.

Treatment of Data

All data gathered from the survey were collated, summarized, and subjected to descriptive statistical analysis, focusing on frequencies, means, and percentages to present demographic and operational profiles of LSAs. For the field experiment, quantitative data on crop growth and yield under each treatment were analyzed using appropriate statistical tools to determine the effectiveness of each nutrient management approach.

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Ethical Considerations

The researchers sought permission to access data from the Agricultural Training Institute – Regional Training Center 2 (ATI-RTC 2) via a formal request letter. Respondents were informed of the study's purpose, and informed consent was obtained before interviews. Participation was voluntary, and confidentiality of all information gathered was ensured. The research adhered to ethical standards in conducting both the survey and the field experiment.

RESULTS and DISCUSSION

This section discusses the study's findings based on the data gathered from RCEF-LSA respondents in Isabela. It focuses on the socioeconomic profile of the participants. It integrates the results of the experimental design related to nutrient management, which was implemented on the farm of one of the LSA operators. The discussion aims to understand the respondents' background and the practical outcomes observed from the nutrient management interventions.

Socioeconomic Profile of RCEF-LSA Cooperator. The table below presents the socioeconomic profile of the RCEF-LSA operators in Isabela. It reveals that significant trends are relevant to agricultural development and extension programming.

Table 1. Socioeconomic profile of RCEF-LSA operators in Isabela in terms of Profile variables

Profile	Cluster	Frequency (n=28)	Percentage (%)
Age	21 – 30	3	10.71
	31 – 40	1	3.57
	41 – 50	8	28.57
	51 – 60	6	21.43
	Over 60	10	35.71
Sex	Male	19	67.86
	Female	9	32.14
Educational Attainment	High School graduate	1	3.57
	Vocational/ Technical	1	3.57
	Bachelor's Degree	22	78.56
Years of experience in Agriculture	Less than 5	1	3.57
	5 – 10	6	21.43
	11 – 20	21	75.00
Status of LSA	0.5 – 1.0	161	72.85
	1.1 – 1.5	42	19.00
	Active	24	85.71
	Inactive	4	14.29
Farm Size	0.5 – 1.0	5	17.86
	1.1 – 1.5	2	7.14
	1.6 – 2.0	4	14.29
	2.0 up	14	50.00
Land Ownership	Owned	24	85.71
	Shared	1	3.57

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	Government	2	7.14
	others	1	3.57
	Rice	28	100.00
	Livestock	13	46.43
	Corn	10	35.71
Type of Training and Seminars Attended	HVCC	13	46.43
	Fisheries	13	46.43
	Coconut	6	21.43
	Organic	19	67.86
	RCEF	28	100.00
Sources of	Local Government Unit	15	53.57
Technical Support/ Assistance	Department of Agriculture	28	100.00
Availed	Private Companies/ Organizations	4	14.29

Most respondents were aged 41 and above, with 35.71% over 60 years and 28.57% between 41 and 50 years, reflecting the aging profile of Filipino farmers, as the Philippine Statistics Authority (2021) reports an average age exceeding 57 years. Male operators predominated (67.86%), aligning with traditional gender roles in agriculture, where men often control farm ownership and decision-making (Food and Agriculture Organization [FAO], 2019). Notably, 78.56% held a bachelor's degree, higher than the national average for farmers, suggesting favorable conditions for technology adoption and training uptake, as linked by Bordey et al. (2018).

In terms of farming experience, 75% had worked in agriculture for 11 to 20 years, reflecting substantial field knowledge. Most Learning Sites for Agriculture (LSAs) were active (85.71%) and located on farms larger than two hectares (50%), consistent with Department of Agriculture standards for demonstration farms (ATI, 2020). Land ownership was also high (85.71%), a factor associated with greater investment in long-term productivity and sustainability (FAO, 2018).

All respondents were engaged in rice farming—the core of RCEF programs—but many also practiced diversification: livestock (46.43%), corn (35.71%), high-value crops (46.43%), and fisheries (46.43%). This reflects findings by Cuyno et al. (2020) on diversification enhancing income and resilience. Additionally, all had attended RCEF training, with many also involved in organic farming (67.86%) and coconut farming (21.43%), indicating a strong commitment to innovation and capacity-building (Gerpacio et al., 2016). While all received technical support from the Department of Agriculture and over half from local governments, only 14.29% reported private-sector support, suggesting a need to enhance public–private partnerships.

Services Rendered and Clientele Served by RCEF-LSA Owner-Operators

This section shows the types of services rendered and the clientele served by RCEF-LSA owner-operators in Isabela.

Table 2. Services Rendered and Clientele Served by RCEF-LSA Owner-Operators

Particular	Cluster	Frequency (n=28)	Percentage (%)
Type of Training Conducted	Rice	28	100.00
For the Clientele	Livestock	5	17.86
	Corn	2	7.14
	HVCC	6	21.43
	Fisheries	2	7.14
	Organic	12	42.85
	RCEF	28	100.00
Number of Trainings	1 – 3	2	7.14
Conducted	4 – 5	2	7.14

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	5 – 10	5	17.86
	Above 10	19	67.86
Frequency of training conducted	Weekly	28	100
	Others (daily)	10	35.71
Type of participants trained.	Farmers	28	100.00
	Farm Youth	20	71.43
	LGU AEWs	19	67.86
	LGU Officials	18	64.29
	Agency Personnel	15	53.57
	NGOs	14	50.00
	Private Groups	18	64.29
	SUC Personnel	16	57.14
	Students	18	64.29
	Tourist	15	53.57

All respondents conducted rice-related training in alignment with RCEF's objective of improving rice productivity through knowledge dissemination (Department of Agriculture, 2020). Some extended this to livestock (17.86%), high-value crops (21.43%), organic agriculture (42.85%), corn (7.14%), fisheries (7.14%), and coconut farming (0%), showing responsiveness to community needs and promoting integrated, sustainable farming (ATI, 2020).

Most operators (67.86%) had conducted over ten training sessions, all every week, reflecting a strong institutional commitment to farmer-to-farmer extension (Rivera & Alex, 2008). Trainees included farmers, youth, LGU extension workers, NGOs, private companies, students, and tourists, positioning LSAs as multi-sectoral hubs for capacity-building and agri-tourism (Pascual et al., 2019). Youth and academic involvement promote innovation and address generational gaps, aligning with ATI's vision of resilient, empowered rural communities (ATI, 2020).

Facilitating and hindering factors

This section outlines the key facilitating and hindering factors encountered by RCEF-LSA owner-operators in Isabela.

Table 3. Facilitating and hindering factors encountered by RCEF-LSA owner-operators in Isabela

Particular	Cluster	Frequency (n=28)	Percentage (%)
Facilitating Factors	Supportive organization	17	60.71
	Supportive family	19	67.85
	Supportive LGU	17	60.71
	Support from other agencies	15	53.57
	Available land area of the family	16	57.14
	Adequate land area of the family Technical	14	50.00
	Assistance from LGU	16	57.14
	Financial assistance from LGU	6	21.43
	Favorable weather condition	16	57.14
	Strong personal conviction	18	64.29
	others, please specify	1	3.57
Hindering Factor	Lack of/ no Support from organization	5	17.86
	Lack of/ no Support from family	3	10.71
	Lack of/ no Support from the LGU	5	17.86
	Lack of/ no Support from other agencies	7	25.00

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Inadequate land area for the family	1	3.57
Lack of/ no support from Technical Assistance from LGU	5	17.86
Lack of/ no support from Financial assistance from LGU	6	21.43
Lack of/ no support from Financial assistance from DA	3	10.71
Unfavorable weather conditions	18	64.29
Weak personal conviction	1	3.57
Others, please specify	3	10.71

Key facilitators identified (Table 3) included supportive families (67.85%), strong personal conviction (64.29%), and organizational or LGU backing (60.71%). Technical and financial assistance from LGUs (57.14%) and favorable weather (57.14%) also supported LSA operations and knowledge transfer (Quizon et al., 2004). Conversely, the main constraint was unfavorable weather (64.29%), highlighting climate-related vulnerabilities (Lasco et al., 2011). Other barriers included limited agency support (25%), insufficient LGU aid (21.43%), and technical assistance gaps (17.86%). Few cited weak motivation (3.57%) or family support (10.71%) issues, reinforcing the operators' high intrinsic drive. Land access was not a concern, consistent with data in Table 1.

Capacity-building needs of RCEF-LSA owner-operators in Isabela

This section presents the capacity-building needs of RCEF-LSA owner-operators in Isabela.

Table 4. Capacity-building needs of RCEF-LSA owner-operators in Isabela

Particular	**Cluster**	**Frequency (n=28)**	**Percentage (%)**
Training or capacity-building programs received	Always	16	57.14
	Sometimes	12	42.86
Effectiveness	Highly effective	22	78.57
	Moderately effective	6	21.43
Specific areas of capacity-building are essential for improving extension service delivery	Technical skills in agriculture	23	82.14
	Communication and interpersonal skills	21	75.00
	Leadership and management skills	21	75.00
	Innovative farming techniques	24	85.71
	Data collection and analysis	17	60.71
	Workshops	25	89.29
	Online courses	5	17.86
	On-site mentoring	20	71.43
	Webinars	4	14.29
Prefer to receive training or capacity-building support	Printed materials/manuals	14	50.00
	Establish technodemo	1	3.57
	Access to funding/grants	20	71.43
	Access to technology and equipment	17	60.71
	Networking opportunities		
	Support from government agencies	11	39.29
Resources or support systems you feel are lacking in your current role as an extension service provider?	Collaboration with research institutions	15	53.57
	Other (Please specify)	8	28.57
	Grants on Machinery to LSA	1	3.57

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Table 4 reveals that 57.14% of respondents "always" received training, while 42.86% did so only "sometimes," indicating generally consistent—but improvable—exposure to capacity-building. Most found the training highly effective (78.57%), while others rated it moderately effective (21.43%). Training needs included innovative farming techniques (85.71%), technical skills (82.14%), communication (75%), and leadership (75%), indicating a demand for both technical and soft skills (Rivera & Sulaiman, 2009; Van den Ban & Hawkins, 1996).

Preferred modalities were workshops (89.29%), on-site mentoring (71.43%), and printed materials (50%), while online options such as webinars (14.29%) and online courses (17.86%) were less favored, likely due to rural connectivity challenges (Asian Development Bank [ADB], 2020). A few respondents (3.57%) suggested technology demonstration sites, underlining the value of experiential learning.

Critical support gaps were also noted: limited funding/grants (71.43%), inadequate technology/equipment (60.71%), and weak institutional collaboration (53.57%). Fewer cited weak networking (39.29%) or lack of partnerships with research institutions (28.57%), pointing to the need for broader institutional and resource support to sustain agricultural innovation and extension (Anderson & Feder, 2007; World Bank, 2012). In particular, machinery grants for LSAs are essential to enhance demonstration capacity.

Productivity and income from rice nutrient management technologies.

This section presents the effectiveness of seven nutrient management strategies in rice production.

Table 5. Productivity and income from different rice nutrient management technologies

TREATMENTS	MEANS									
	PLANT HEIGHT	Number of Productive Tillers per Hill	Number of Filled Grains per Panicle	Total Number of Spikelets per Panicle	Spikelet Fertility (%)	Weight of 1000-grains	Yield per hectare	Total cost of production	Net income	ROI
T_{1}- Farmer's Practice	126.08	153	153	198	77.33	22.06	6,329.61ab	69,985.88	37,617.54	53.75
T_{2}- Soil-Analysis Based Fertilizer Recommendation	120.83	141.67	141.67	182	78	23.81	6,585.57ab	77,357.78	34,597.00	44.72
T_3 – Rice Crop Manager (RCM)	122.17	126	126	177.33	71.33	22	5,323.52b	70,402.45	20,097.34	28.55
T_4 – Minus One Element Technique (MOET)	122.83	128.67	128.67	172	75	23.75	8,303.27b	84,877.03	56,278.52	66.31
T_5 - Soil Analysis with Leaf Color Chart	120.08	128.67	128.67	183.67	70.33	22.61	6,574.26ab	77,793.28	33,969.13	43.67
T_6 – Abonong Swak (7000-8000kg/ha)	119.92	120	120	179	67	22.83	6,650.70ab	77,258.98	35,802.89	46.34
T_7 – Abonong Swak (5000-6000kg/ha)	123.17	116.33	116.33	174.33	66.67	22.74	6,299.16ab	68,260.20	38,825.48	56.88
F- RESULTS	1.02 ns	0.79 ns	2.13 ns	0.34 ns	4.24 ns	2.37 ns	3.23 ns			
C. V. (%)	3.03	9.41	11.53	14.04	5.42	3.58	12.95			

Table 5 presents agronomic and economic data on rice nutrient management technologies. Plant height varied modestly (119.92–126.08 cm) without significant differences, suggesting it may not be a reliable nutrient management indicator (Tabile et al., 2021; Singh et al., 2019). Taller plants may also increase lodging risk (Buresh et al., 2010). Productive tillers ranged from 19.67 (Farmer's Practice) to 22.67 (Abonong Swak), with scientifically guided methods generally performing better, though not significantly, indicating site-specific approaches may confer agronomic benefits (Dobermann & Fairhurst, 2000; Cassman et al., 2002).

Spikelets per panicle ranged from 172 (MOET) to 198 (Farmer's Practice), with no significant differences, likely due to environmental or genetic variation. Despite higher spikelet numbers in T1, site-specific methods like Soil

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Analysis and LCC performed comparably (Peng et al., 1996; Dobermann & Fairhurst, 2000). Slightly lower counts in MOET and Abonong Swak may suggest nutrient balance issues (Fageria et al., 2011).

Significant variation was observed in spikelet fertility ($F = 4.24$, $p < 0.05$), with the highest rate under Soil Analysis (78.00%) and the lowest under Abonong Swak (66.67%). This highlights the value of site-specific nutrient application during reproductive stages (Dobermann & Fairhurst, 2000; Fageria et al., 2011). Thousand-grain weight varied slightly, from 22.00 g (RCM) to 23.81 g (Soil Analysis), with MOET also yielding well, suggesting balanced nutrient inputs promote grain filling (Fageria, 2007).

Grain yield varied significantly ($F = 3.23$, $p = 0.0397$), with MOET (T4) achieving the highest yield (8,303.27 kg/ha) and RCM (T3) the lowest (5,323.52 kg/ha). T6 and T2 also yielded over 6,500 kg/ha, reinforcing the advantages of tailored nutrient management (Dobermann & Cassman, 2004; Ladha et al., 2005).

Economic data revealed that while MOET had the highest input cost (₱84,877.03), it also produced the highest net income (₱56,278.52) and ROI (66.31%). In contrast, RCM had moderate costs (₱70,402.45) but yielded the lowest ROI (28.55%). Abonong Swak presented a viable, cost-effective alternative (ROI 56.88%), while Farmer's Practice remained competitive (ROI 53.75%), possibly due to local optimization. These findings reflect De Datta's (1981) emphasis on balancing input costs and returns, underscoring the need to integrate agronomic efficiency with economic viability in selecting nutrient management strategies.

Conclusion

The RCEF-LSAs in Isabela serve as crucial platforms for agricultural extension and the dissemination of innovative practices. They have made notable progress in infrastructure development, training delivery, and community outreach. Most operators are well-educated, experienced, and highly committed, supported by key stakeholders such as the Department of Agriculture, local government units (LGUs), and select private sector partners. However, systemic challenges persist, including inadequate financial resources, limited technical capacity, and underutilization of diversified farming practices. Addressing these issues is essential to fully realize the potential of LSAs in advancing rural transformation and sustaining farmer education.

The study further highlights the significant impact of nutrient management strategies on rice yield and farm profitability. Although high-input treatments like MOET (T4) delivered the highest yield and net returns, cost-effective options such as Abonong Swak (T7) achieved competitive returns on investment (ROI) with minimal capital. The Farmer's Practice (T1) also demonstrated viable outcomes, underscoring the practical value of traditional methods under resource-constrained conditions. Statistical analysis confirmed significant differences in yield across treatments ($p = 0.0397$), though not all pairwise comparisons were statistically distinct, as indicated by the HSD test.

Recommendations

To enhance the effectiveness of RCEF-LSAs, targeted financial support should be allocated for infrastructure development, acquisition of agricultural equipment, and the adoption of modern technologies. Capacity-building initiatives must be broadened to encompass technical, managerial, and communication skills, delivered through practical, community-based training programs that promote farmer-to-farmer learning.

Strengthening collaboration among LSAs, government agencies, state universities and colleges (SUCs), and private sector partners is essential to ensure sustained support, resource sharing, and continuous knowledge exchange.

For nutrient management, the Minus One Element Technique (MOET) is strongly recommended due to its superior performance in terms of both yield and return on investment (ROI) at 66.31%. Abonong Swak (T7) also presents a viable, cost-effective alternative with a competitive ROI of 56.88%, making it suitable for resource-constrained farmers. Conversely, the use of the Rice Crop Manager (RCM) warrants caution, as it underperformed in field trials. Its effectiveness may be improved when integrated with site-specific approaches such as MOET and soil analysis-based recommendations.

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Enhancing Eggplant Yield Through Fertilizer Application Supplemented with Micronutrients and Plant Growth Regulator

Camilyn A. Ligmayo*[1], Dr. Lucila V. Rocha[2]
[1] Isabela State University, Echague Isabela, Philippines
[2] Faculty of College of Agriculture, Isabela State University, Echague, Isabela, Philippines

Abstract
Aim: This study aimed to evaluate the effect of micronutrients and plant growth regulator, in combination with the recommended rate of Nitrogen (N), Phosphorous (P) , and Potassium (K), on the growth and yield of eggplant.
Methodology: The experiment was conducted in a farmer's field located at Barangay Guayabal, Cauayan City, Isabela, where the soil analysis had a pH of 6.15 (slightly acidic) 0.55% organic matter, 11.33 ppm Phosphorus and 210.15 ppm available Potassium and a fertilizer recommendation of 90-40-30 kg NPK ha^{-1}. Treatments included the application of micronutrients Zinc Sulfate ($ZnSO_4$), Borax, Ferrous Sulfate ($FeSO_4$), Black Soldier Fly (BSF) frass, a combination of Zinc Sulfate + Borax + Ferrous Sulfate and gibberellic acid (GA_3), all combined to the recommended NPK rate laid out in a Randomized Complete Block Design (RCBD) with three replications.
Results: Results of the study showed that treatments involving NPK + GA_3 (T7) and NPK + $ZnSO_4$ + Borax + $FeSO_4$ (T6) significantly enhanced plant height at 90 days after transplanting (DAT), number of branches, fruits per plant, fruit diameter, and fruit weight. Although fruit length was not significantly affected, these two above - mentioned treatments (T6 and T7), closely followed by BSF frass (T2), produced the highest yields per sampling area. Likewise, the marketable fruit yield per 1000 m^2 with increased by 59.23% (T6), 47.31% (T7) and 14.23% (T2) over the sole application of NPK. This emphasizes the effectiveness of micronutrient combinations and GA_3 in improving eggplant yield.
Conclusion: The supplementation of NPK with specific micronutrients significantly enhances both vegetative growth and yield in eggplant, particularly resulting in a return on investment of 65.69% with the application of 90-40-30 kg NPK ha^{-1} + Zinc sulfate + Borax + Ferrous sulfate).
Keywords: micronutrients, gibberellic acid, growth regulator, enzymes, black soldier fly frass

INTRODUCTION

A key crop globally, especially across tropical and subtropical areas, eggplant (*Solanum melongena L.*) is appreciated for its nutritional value and ability to thrive in varied agro-ecological conditions. This low-calorie vegetable boasts significant amounts of dietary fiber, vitamins C and K, potassium, magnesium, and beneficial antioxidants (Naeem & Ugur, 2019). Beyond its use in numerous dishes, eggplant serves as an important and stable source of income for farmers and small-scale entrepreneurs due to its consistent popularity.

Representing about 28% of the total volume of the Philippines' primary vegetables, eggplant production achieves the highest market value. Grown across more than 1,875 hectares in farm sizes of 0.5 to 2.0 hectares, the average yield is 18.4 metric tons per hectare, which is roughly half the average yield in Asia and globally (DA, Region 02, 2017).

Achieving optimal eggplant yields and quality often faces hurdles, with soil fertility being a critical determinant of plant growth and productivity. This fertility is a product of the soil's physical, chemical, and biological characteristics. A significant concern in agriculture, is soil degradation—the deterioration of structure, porosity, and moisture retention—which diminishes crop yields and increases vulnerability to diseases. Furthermore, the quality of eggplant is paramount for consumer appeal, market price, and long-term sustainability. Micronutrients play a vital role in plant health, influencing growth, development, and the overall quality of horticultural crops. These essential elements support various physiological functions, ensuring plants achieve optimal productivity and resilience. Deficiencies in vital micronutrients like calcium, zinc, boron, and manganese are common in many areas, resulting in stunted growth and lower yields in eggplant.

Ensuring a balanced availability of micronutrients is paramount for the proper growth of eggplant, and deficiencies can lead to substantial declines in both yield and the quality of the fruit. Using sustainable practices to improve soil health and maintain long-term fertility is essential for boosting eggplant yields and ensuring high-quality crops. By fostering a balanced and nutrient-rich growing environment, farmers can achieve better productivity while promoting sustainability in agriculture.

This study highlights the use of plant growth regulators and micronutrients in combination with organic fertilizer, which might reduce the dependency on chemical fertilizers because the nutrient demands of eggplant may

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not be fully met by organic fertilizers alone. This management supports the Sustainable Development Goals of the nation. Additionally, micronutrient and foliar fertilizer applications not only enhance the nutritional quality of crops but also promote better human health. Moreover, sustainable nutrient management practices, such as micronutrient and plant growth regulator applications, also support improved plant efficiency and reduce the need for chemical inputs. SDG # 1 focuses on no poverty, ensuring that those in rural and vulnerable communities have access to basic services, economic resources, and opportunities to improve their livelihoods. SDG # 2 addresses zero hunger by aiming to achieve food security, improve nutrition, and promote sustainable agriculture. SDG # 3 concerns good health and well-being, and SDG # 13 focuses on decreasing the carbon footprint of agriculture, particularly through the adoption of climate-smart farming methods such as conservation tillage, crop rotation, and organic fertilizers.

While micronutrient deficiencies pose a challenge to increasing yield, addressing these deficiencies in soil is essential for boosting eggplant production. Micronutrients play vital roles in plant growth, flowering, fruit development, and disease resistance, making them crucial for healthy crop yields.

Objectives

This study aimed to determine the effect of growth regulator, micronutrients and organic fertilizer in enhancing the yield of eggplant.

Specifically, it aimed to:

1. determine the effects of growth regulator and micronutrients in combination to organic fertilizer on the on the growth, development, and fruit yield of eggplant;
2. identify the proper combinations of growth regulator, micronutrients, and organic fertilizer that increases the yield and quality of eggplant; and
3. Assess the most economical treatment using the simple cost and return analysis.

METHODS

Application of Micronutrients

Boron (B). Boron is required by direct-seeded or transplanted eggplant in the field. Boron was applied at one kilogram per hectare prior to transplanting.

Zinc (Zn). Zinc or zinc sulfate was applied prior to transplanting not to exceed 10 kilograms per hectare.

Iron (Fe). Iron or Iron sulfate was applied as foliar spray two weeks after transplanting at a rate of 1 kilogram per hectare.

Application of Plant Growth Promoter

Gibberellic acid was applied following manufacturer's recommendation of 6 grams per hectare.

Fertilization

Prior to transplanting, holes were constructed at a distance of 70 centimeters between rows and 50 centimeters between hills and the rate of inorganic fertilizer for T_1 was placed and covered with thin layer of soil. The application of foliar fertilizer was applied using the recommendation found in the label of the product. Plant growth promoter (Gibberellic acid) was applied following the manufacturer's recommendation.

Collection of Soil Sample and Analysis

Soil samples were randomly collected before land preparation within the experimental area with the use of a shovel. The soil sample were pulverized, air dried for 3 days, and inert matter were removed using sieve with 2 mm openings. One-kilogram composite soil sample was brought to the Department of Agriculture - Cagayan Valley Integrated Agricultural Laboratory (DA-CVIAL), San Felipe, Ilagan City. Based on the soil analysis, findings, the recommended fertilizer application rate was 90-40-30 kilograms of N, P, K per hectare.

Data Gathered

1. **Plant Height.** A total of ten sample plants were randomly selected from the central region of each experimental plot. Plant height measurements were conducted at 30-day intervals, specifically at 30, 60, and 90-days post-transplanting. Measurements were taken from the basal region of the plant to the apex of the primary stem to ensure consistency in data collection.
2. **Number of Branches per Plant.** The total number of branches from the ten selected plants was added together and then divided by ten to determine the average number of branches per plant.

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3. **Number of Marketable Fruits.** The total number of fruits harvested from the first to the last priming for each plant was added together and then divided by ten to calculate the average number of fruits per plant.
4. **Length of Marketable Fruits.** A random selection of ten fruits was made from ten sample plants in each treatment group to measure their length.
5. **Weight of Marketable Fruits per Plant.** During each harvest, the weight of marketable fruits was measured and documented. After the final collection, the cumulative recorded weight was calculated and then divided by ten sample plants to obtain the average fresh fruit weight per plant.
6. **Weight of Marketable Fruits per Plot.** The harvestable fruits from the central portion of each plot were measured and documented at every priming. Once the final harvest was completed, the total recorded weights were summed up to calculate the overall marketable fruit yield for the sampling area.
7. **Computed Fruit Yield Per 1000 Square Meters.** The predicted weight of marketable fruits per 1,000 square meters was derived using yield data from designated sampling areas. The calculation was based on the observed mean production within these reference plots to ensure accuracy and representativeness.
8. **Cost and Return Analysis.** The return on investment was analyzed using a basic financial evaluation. Production expenses were estimated based on the current market rates for agricultural inputs and labor within the region. Earnings were estimated by considering the market price of eggplant per kilo. To get the net income, the total earnings were reduced by the production expenses. Finally, the return on investment was worked out by dividing the net income by the production cost and then multiplying by 100.

Statistical Analysis

The collected data was analyzed using the ANOVA for Randomized Complete Block Design in the Statistical Tool for Agricultural Research (STAR) computer package. Any differences among treatment means were compared using Tukey's Honestly Significant Difference test (HSD).

RESULTS and DISCUSSION

The plant height at 30, 60, and 90 Days after transplanting is shown in table 1.

Table 1. Plant Height at 30, 60 and Days After Transplanting (cm). as Affected by Inorganic Fertilizer Supplemented with Micronutrients and Growth Regulator

TREATMENTS	30 DAT	60 DAT	90 DAT
T_1- 90-40-30 kg NPK ha^{-1} (Control)	32.13	64.50	89.93^{d}
T_2 - 90-40-30 kg NPK ha^{-1} + Black Soldier Fly Frass	36.67	69.47	112.30^{c}
T_3 - 90-40-30 kg NPK ha^{-1} + Zinc sulfate	30.83	63.40	108.47^{c}
T_4 - 90-40-30 kg NPK ha^{-1} + Borax	37.03	69.17	113.40^{bc}
T_5 90-40-30 kg NPK ha^{-1} + Ferrous sulfate	31.70	63.63	114.67^{bc}
T_6 - 90-40-30 kg NPK ha^{-1} + Zinc sulfate + Borax + Ferrous sulfate	40.33	72.53	120.80^{ab}
T_7 - 90-40-30 kg NPK ha^{-1} + Gibberellic Acid	35.67	72.13	125.70^{a}
F- RESULTS	ns	ns	**
C. V. (%)	9.45	6.04	2.46

Means with the same letter are not significantly different using HSD Test
ns-not significant
***- significant at 1% level*

Applying a combination of growth regulators and micronutrients, alongside the recommended inorganic fertilizer rate, led to relatively uniform plant growth across all treatments. At 30 days after transplanting (DAT),

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average plant height ranged from 31.70 cm to 40.33 cm, showing no significant variations. By 60 DAT, heights spanned from 63.40 cm to 72.53 cm, reflecting consistent development among treatments. These results suggest that integrating growth regulators and micronutrients with standard inorganic fertilization supports stable growth during early to mid-growth stages. Interestingly, these findings differ from those reported by Naga et al. (2013), who observed the highest plant height with micronutrient application alone. Likewise, Jakhar et al. (2018) noted that plants treated with gibberellic acid (GA3) exhibited superior growth across multiple parameters, including height.

The lack of significant differences in plant height across treatments was likely due to the consistent application of inorganic fertilizers across all plots. This uniform nutrient supply appeared sufficient to support early plant development. Similar trends were observed in plots receiving only the recommended inorganic fertilizer rate, suggesting that essential nutrients—particularly nitrogen, phosphorus, and potassium—ensured stable and comparable growth patterns.

At 90 days post-transplanting, plants supplemented with a combination of inorganic fertilizers, micronutrients, and growth regulators attained greater heights compared to those receiving only the recommended inorganic fertilizer rates. The tallest plants were recorded in the treatment that applied 90-40-30 kg NPK ha^{-1} along with gibberellic acid (T_7). This can be attributed to the rapid nutrient availability from inorganic fertilizers and the physiological effects of gibberellic acid, which enhances stem and root elongation, expands leaf area, and promotes flowering and seed germination, leading to increased plant height (Dhakar & Singh, 2015). Meanwhile, foliar application of zinc sulfate, borax, and ferrous sulfate (T_6) resulted in plant heights comparable to those observed in T_7, suggesting that these micronutrients are equally effective in stimulating plant growth.

Plants treated with ferrous sulfate and borax exhibited growth comparable to those receiving black soldier fly frass. Conversely, the control group (T_1), which was supplied solely with the recommended 90-40-30 kg NPK ha^{-1} without supplemental micronutrients or growth regulators, produced the shortest plants. This highlights the critical role of micronutrients in facilitating essential physiological functions, enhancing enzyme activity, promoting reproductive development, and improving plant resilience to stress.

Table 2. Number of Branches, Number of Fruits, Length and Diameter of Fruits as Affected by Inorganic Fertilizer Supplemented with Micronutrients and Growth Regulator

TREATMENTS	Number of branches	Number of fruits	Length of fruits	Diameter of fruits
T_1- 90-40-30 kg NPK ha^{-1} (Control)	4.80c	11.77^{b}	21.72	3.03^{b}
T_2 - 90-40-30 kg NPK ha^{-1} + Black Soldier Fly Frass	5.33bc	13.17^{b}	22.90	3.19^{ab}
T_3 - 90-40-30 kg NPK ha^{-1} + Zinc sulfate	6.53a	11.87^{b}	21.23	3.07^{b}
T_4 - 90-40-30 kg NPK ha^{-1} + Borax	4.90c	12.07^{b}	21.86	3.15^{ab}
T_5 90-40-30 kg NPK ha^{-1} + Ferrous sulfate	5.97ab	13.47^{b}	22.09	3.06^{b}
T_6 - 90-40-30 kg NPK ha^{-1} + Zinc sulfate + Borax + Ferrous sulfate	5.27bc	17.90^{a}	21.98	3.28^{a}
T_7 - 90-40-30 kg NPK ha^{-1} + Gibberellic Acid	6.57a	17.27^{a}	21.91	3.28^{a}
F- RESULTS	**	**	ns	**
C. V. (%)	5.47	5.47	3.72	2.20

Means with the same letter are not significantly different using HSD Test
*** - significant at 1% level*

Number of branches. The data in Table 2 shows the effect of different treatments on the number of branches per plant and clearly indicates the significant effect of combining inorganic fertilizer and gibberellic acid as well as single application of zinc sulfate and ferrous sulfate resulted in the highest branch count (6.57, 6.53 and 5.97). These findings suggest that plant development can be enhanced through the application of GA_3 (which stimulates cell elongation and division) leading to taller plants; zinc sulfate (which is essential for synthesis of auxins

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responsible for elongation and growth of plant cells); and ferrous sulfate (which is critical for chlorophyll formation). These elements greatly improve different aspects of growth, such as height, leading to increased number of branches. Similarly, the application of ferrous sulfate yielded an average of 5.97 branches, which is comparable to the aforementioned treatments. On the other hand, the number of branches was higher in the plots treated with the combination of inorganic fertilizer and Black Soldier Fly Frass (T_2), as well as with Zinc sulfate + Borax + Ferrous sulfate (T_6), while the lowest number was observed in the plots treated with inorganic fertilizer plus Borax alone (T_4) and in the control treatment (T_1).

The positive impact observed in the eggplant trials suggests that the addition of growth regulators and micronutrients to the standard inorganic fertilizer application is highly beneficial. This is likely because these added elements play vital roles in plant growth and various physiological functions. This result supports the findings of Sathya et al. (2010), who highlighted that even in small quantities, micronutrients are very effective in regulating plant growth by influencing enzymatic activity, particularly when working in conjunction with inorganic fertilizers.

Number of fruits. Different treatments have a noticeable impact on fruit production per plant, as shown in Table 2. A significant increase in fruit count was observed when the recommended rate of inorganic NPK fertilizer was combined with zinc sulfate, borax, and ferrous sulfate (T_6), as well as gibberellic acid (T_7), resulting in 17.90 and 17.27 fruits per plant, respectively. The impressive results of these treatments indicate that gibberellic acid, when supplemented with the recommended fertilizer and micronutrients, leads to the highest fruit yield. Essential micronutrients such as boron, sulfur, zinc, and ferrous sulfate contribute greatly to plant health and the overall development of eggplant fruits, enhancing productivity.

The findings of Meena et al. (2006) support these results, emphasizing that zinc sulfate and ferrous sulfate enhance the synthesis of enzymes like indole acetic acid (IAA) and stimulate protein production, both of which contribute to stronger vegetative growth. Similarly, research by Suganiya and Harris (2015) indicates that boron application improves both the yield and quality of various crops, including eggplant. Additionally, their study highlights the effectiveness of micronutrients such as boron, zinc, and iron in enhancing fruit set, yield, and overall fruit quality. Beyond micronutrients, plant growth regulators like gibberellic acid (GA3) play a vital role in guiding plants from vegetative to reproductive phases, significantly influencing flower development, fertilization, and fruit formation, as observed by Plackett and Wilson (2016).

Length of Fruits (cm). The results for the length of eggplant fruits as shown in Table 2 indicates that combining inorganic fertilizer with a plant growth promoter and micronutrients had no significant effect on the fruit length of eggplant which ranged from 21.23 cm to 22.09 cm across treatments. Inasmuch as the study only employed one variety which restricts genetic diversity, it does not accurately reflect possible variation in fruit length. The non-significant difference on the varietal traits, particularly on fruit length, might be due the possibility that genetic factors, rather than environmental or experimental settings, primarily control this trait, similar to the claim of (Luo et al. 2024). These results clearly indicate that fruit length is a relatively stable trait that does not easily change in response to external factors and nutrient combinations.

Fruit Diameter (cm). There was a significant improvement on the fruit diameter of eggplant after the application of treatments (Table 2). The analysis on the fruit diameter of eggplant showed that those plots treated with 90-40-30 kg NPK ha^{-1} + Zinc sulfate + Borax + Ferrous sulfate (T_6) and Treatment 7 (90-40-30 kg NPK ha^{-1} + Gibberellic Acid) both had the biggest fruit diameter measuring 3.28 centimeters.

The critical roles of micronutrients in plant physiological systems are responsible for this improvement. As such, the synergistic effect of these elements likely improved nutrient uptake and hormonal balance, resulting in better fruit development and increased diameter. The consistent performance of this treatment across replications underscores its potential effectiveness in enhancing eggplant fruit quality. Moreover, the presence of a sufficient number of micronutrients enhances the photosynthetic capability of the plant that will be converted by plants for their growth and development (Sabijon & Sudaria, 2018).

Notably, Treatment 2 (90-40-30 kg NPK ha^{-1} + Black Soldier Fly Frass) and Treatment 4 (90-40-30 kg NPK ha^{-1} + Borax) had comparable fruit diameters, measuring 3.19 cm and 3.15 cm, respectively. This indicates that Black Soldier Fly Frass (BSFF) as a biofertilizer possesses beneficial biological properties proven to have a good effect on plants because there are groups of nitrogen-fixing bacteria and phosphate-solubilizing bacteria (Hernahadini, 2022). On the other hand, borax combined with inorganic fertilizer likewise has a potential in increasing fruit diameter, as it facilitates the transport of carbohydrates through cell membranes involved in the flowering and fruiting of the plant (Sharma, 2006).

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Plants treated with 90-40-30 kg NPK ha⁻¹ combined with zinc sulfate, NPK rate plus ferrous sulfate and the control plots recorded a slightly smaller fruit diameter of 3.07 cm, 3.06 and 3.03 centimeters, respectively indicating that supplementing NPK with micronutrients like zinc sulfate and ferrous sulfate may contribute to a marginal increase in fruit size.

Table 3. Weight of Fruits per Plant and per Sampling Area (kg/6 m^2) as Affected by Inorganic Fertilizer Supplemented with Micronutrients and Growth Regulator

TREATMENTS	Weight of Fruits per Plant (kg)	Weight of Fruits per Sampling Area (kg)
T_1- 90-40-30 kg NPK ha^{-1} (Control)	1116.80c	5.58^{d}
T_2 - 90-40-30 kg NPK ha^{-1} + Black Soldier Fly Frass	1275.93^{b}	6.38^{abc}
T_3 - 90-40-30 kg NPK ha^{-1} + Zinc sulfate	1162.93^{bc}	5.81^{cd}
T_4 - 90-40-30 kg NPK ha^{-1} + Borax	1182.53^{bc}	5.91^{bcd}
T_5 90-40-30 kg NPK ha^{-1} + Ferrous sulfate	1247.60^{bc}	6.24^{bcd}
T_6 - 90-40-30 kg NPK ha^{-1} + Zinc sulfate + Borax + Ferrous sulfate	1778.20^{a}	7.11^{a}
T_7 - 90-40-30 kg NPK ha^{-1} + Gibberellic Acid	1645.07^{a}	6.58^{a}
F- RESULTS	**	**
C. V. (%)	3.97	4.16

Means with the same letter are not significantly different using HSD Test
*** - significant at 1% level*

Weight of fruits per plant. As presented in Table 3, eggplant fruit weight varied significantly due to the influence of plant growth regulators and micronutrients. The supplementation of zinc sulfate, borax, ferrous sulfate, and gibberellic acid alongside the recommended NPK fertilizer rates notably increased the fruit weight per plant, yielding 1778.20 grams (T6) and 1645.07 grams (T7). These results indicate that both treatments enhanced plant growth and development, ultimately leading to higher fruit yields.

This yield improvement supports the findings of Roitsch et al. (2003), who explained that increased yield is associated with the efficient transport of photoassimilates from production sites (sources, such as leaves) to growth and storage sites (sinks, such as fruits, roots, or seeds). The enzyme responsible plays a vital role in sugar transport by breaking down sucrose outside the cells, facilitating sugar uptake into plant tissues where it is needed for growth and development, thereby promoting overall plant productivity.

On the other hand, lower fruit yield was recorded in plants applied with Black Soldier Fly Frass; however, it indicates a significant improvement over the control plots (T_1) and those plants treated with single-element micronutrients**.** Similarly, there were comparable and moderate yield improvements in Treatment 3 (1162.93 grams), Treatment 4 (1182.5 grams) and Treatment 5 (1247.60 grams). These yields were comparable to that of the control plots with a mean yield of 1116.80 grams. These results are in line with those of Dubey et al. (2013), who found that applying micronutrients along with NPK fertilizers significantly increased fruit weight compared to applying NPK alone. This demonstrates how micronutrients work in increasing fruit development and nutrient uptake efficiency, which in turn improves yield performance.

Weight of Fruits per Sampling Area (kg/6 m^2). The data on the weight of fruits per sampling area of eggplant in response to different micronutrients and plant growth regulators are shown in Table 3. The statistical results showed a highly significant variation in weight, with the highest total yields of 7.11 kg (17.92% increase in T_6) and 6.58 kg (27.41% increase in T_7). Additionally, the plants in T_2 – NPK + Black Soldier Fly Frass (14.33% increase) significantly attained heavier fruits compared to the control. However, the application of zinc sulfate, borax, and ferrous sulfate, although showing an improved yield over the control treatment, was only slightly effective compared with the other treatments (T_6, T_7, and T_2).

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This is in conformity with the claims of Afrin et al. (2024) that foliar application of GA_3 with micronutrients is an effective strategy for increasing crop yields of eggplant.

Table 4. Computed Marketable Fruit Per 1000 Square Meters (kg)

TREATMENTS	MEAN
T_1- 90-40-30 kg NPK ha^{-1} (Control)	29.78^{c}
T_2 - 90-40-30 kg NPK ha^{-1} + Black Soldier Fly Frass	34.02^{b}
T_3 - 90-40-30 kg NPK ha^{-1} + Zinc sulfate	31.01^{bc}
T_4 - 90-40-30 kg NPK ha^{-1} + Borax	31.53^{bc}
T_5 90-40-30 kg NPK ha^{-1} + Ferrous sulfate	33.27^{bc}
T_6 - 90-40-30 kg NPK ha^{-1} + Zinc sulfate + Borax + Ferrous sulfate	47.42^{a}
T_7 - 90-40-30 kg NPK ha^{-1} + Gibberellic Acid	43.87^{a}
F- RESULTS	**
C. V. (%)	3.97

Means with the same letter are not significantly different using HSD Test
*** - significant at 1% level*

The computed fruit yield per 1,000 square meters varied significantly between the treatment groups. Notably, a 59.23% yield improvement was noted over the control plots treated with a combination of recommended rates of NPK plus zinc sulfate, borax, and ferrous sulfate and the plots treated with GA_3, a 47.313% increase in yield was noted. The combined application of NPK and Black Soldier Fly Frass resulted in a yield advantage of 14.23% while yield increases ranging from 4.13% to 11.47% were observed in treatments that combined NPK with ferrous sulfate, borax and zinc sulfate.

Table 5. Cost and Return Analysis for Eggplant Production in a 1000 m^2 Area

Particulars	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Total Cost of Production	16640.5	16990.53	17075.	17002.3	16990.53	17172.3	17074.5
Gross Income	17868	20412	18606	18918	19962	28452	26322
Net Income	1227.5	3421.47	1531	1915.7	2971.47	11279.7	9247.5
ROI (%)	**7.38**	**20.14**	**8.97**	**11.27**	**17.49**	**65.69**	**54.16**

Cost of eggplant at P60.00/kg

The cost and return analysis of the different treatments in table 5 showed that plants applied with 90-40-30 kg NPK ha^{-1} + zinc sulfate + borax + ferrous sulfate produced the highest return on investment (ROI) at 65.69 percent while the lowest ROI of 7.38 percent was recorded in 90-40-30 kg NPK ha^{-1} (Control). This indicates that the addition of zinc (Zn), boron (B), and iron (Fe) likely lead to an increase in productivity and profit.

Conclusions

Based on the results of the study, it has been found that the recommended rates of NPK in combination to micronutrients and PGRs have positive affect eggplant production. Among the micronutrients, the combination of NPK + zinc sulfate + borax + ferrous sulfate and NPK + gibberellic acid were found to enhance not only vegetative

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growth but also the overall crop productivity. However, economic analysis showed that the addition of 90-40-30 kg NPK ha^{-1} + zinc sulfate + borax + ferrous sulfate attained the highest return on investment.

Recommendations

Based on the results of this study, it is recommended that for increased yield and profits in eggplant, the application of the recommended rates of NPK fertilizer in combination with zinc sulfate + borax + ferrous sulfate greatly increases both productivity and economic returns. This combination has been shown to be effective in increasing the fruit yield of eggplant. Further studies exploring different levels of NPK and timing of application are also recommended to validate these results.

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Growth and Yield of Onion (*Allium cepa L.*) by the Application of Plant Growth-Promoting Rhizobacteria

Romel M. Ligmayo*[1], Dr. Lucila V. Rocha[2]
[1] Isabela State University, Echague Isabela, Philippines
[2] Faculty of College of Agriculture, Isabela State University, Echague, Isabela, Philippines

Abstract
Aim: This study assessed the effects of vermicompost, the plant growth-promoting rhizobacteria (PGPR) *Azospirillum*, and the entomopathogenic fungus *Beauveria bassiana* on the growth and development of onion (*Allium cepa L.*).
Methodology: The field experiment was conducted in a farmer's field located in Guayabal, Cauayan City, Isabela. This site has a flat surface and is suitable for planting upland crops. The soil texture is loamy with good drainage and is irrigated. The study evaluated combinations of vermicompost (ranging from 1.5 to 3 tons/ha), with or without *Azospirillum* and *Beauveria bassiana*, and compared these treatments to a control using the recommended rate of inorganic fertilizer. Treatments were arranged in a randomized complete block design (RCBD) with three replications.
Results: Findings indicated that the combination of 3 tons/ha vermicompost, *Azospirillum*, and 3 liters of *Beauveria bassiana* significantly enhanced plant height, leaf length, and bulb diameter, outperforming the recommended rate of inorganic fertilizer. No significant differences were observed in leaf number and neck diameter across all treatments. The improved bulb yields were attributed to increased nutrient availability and biological activity resulting from the organic amendments, suggesting that this integrated approach could serve as a superior alternative to conventional fertilization practices.
Conclusion: Based on the results, an integrated approach utilizing 3 tons/ha vermicompost, *Azospirillum*, and 3 liters of *Beauveria bassiana* offers a promising and potentially superior alternative to the recommended rate of inorganic fertilizer for enhancing key growth parameters and bulb yield in onion.
Keywords: *Azospirillum*, *Beauveria bassiana,* plant growth-promoting rhizobacteria, vermicompost

INTRODUCTION

A highly significant vegetable worldwide, onion *(Allium cepa L.*) plays a vital role in numerous cuisines due to its versatility and high demand. The onion bulb offers a wealth of essential nutrients such as carbohydrates, protein, vitamin C, phosphorus (P), and calcium, and is also known for its medicinal attributes (Ramesh et al., 2017). Frequently employed to enhance flavor or consumed as a vegetable in stews and salads, mature onions contain substantial quantities of starch, sugar, protein, and vitamins A, B, and C. The nutritional makeup of onions, as reported by the National Onion Association, is approximately 89% moisture, 4% sugar, 1% protein, 2% fiber, and 1% fat (Adeyeye et al., 2017).

Globally, onion cultivation is on the rise due to its high profitability per unit area and relatively simple production process (FAO, 2011). In the Philippines during the quarter, the MIMAROPA Region led onion production with 46.94 thousand metric tons (55.3% of the total). Central Luzon (23.66 thousand metric tons) and the Ilocos Region (12.54 thousand metric tons) followed, with these three regions collectively producing 97.9 percent of the nation's total onion output (PSA, 2023).

However, onion cultivation frequently faces challenges from various biotic stress factors, including soil-borne pathogens and insect pests, which can markedly decrease both crop yield and quality. While chemical pesticides are widely employed to address these issues, their prolonged use often results in environmental harm, pest resistance, and adverse health effects. This underscores the urgent need for sustainable and alternative pest management approaches. One promising strategy involves the use of plant-beneficial microorganisms, especially rhizobacteria and entomopathogenic fungi, which have shown potential in improving plant health, controlling pests, and enhancing crop productivity.

Rhizobacteria are recognized for promoting plant growth by increasing nutrient availability, synthesizing growth hormones, and triggering systemic resistance against pathogens. Meanwhile, entomopathogenic fungi like *Beauveria bassiana* and *Metarhizium anisopliae* have proven effective as biological control agents in managing insect pests. Although rhizobacteria and entomopathogenic fungi have typically been studied independently, their combined use holds promise for synergistic effects, potentially providing a more holistic and effective approach to onion cultivation.

Plant growth-promoting rhizobacteria (PGPR) enhance plant development by facilitating the uptake of vital nutrients such as nitrogen and phosphorus, as well as by regulating plant hormones. They also serve as biocontrol

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agents, helping to minimize the effects of pathogens on vegetable crops including potatoes, tomatoes, peppers, and onions. These beneficial soil bacteria, which belong to genera like *Pseudomonas*, *Bacillus, Azotobacter, Enterobacter, and Azospirillum*, colonize plant roots, improve soil fertility, break down organic matter, and increase the availability of nutrients like phosphorus and potassium. Furthermore, PGPR suppress harmful pathogens by outcompeting them or producing antimicrobial substances, thereby reducing disease incidence in crops.

While numerous studies highlight the beneficial impact of plant growth-promoting rhizobacteria (PGPRs) on onion (Thangasamy & Lawande, 2015), their effectiveness can vary depending on the specific location and growing season. This inconsistency may stem from the competition that introduced bacteria face with indigenous soil microorganisms, which are often better adapted to the local environment (Bishnoi, 2015). Nevertheless, the positive contributions of PGPRs to vegetable growth and yield are well-documented (Dey et al., 2004), involving a range of mechanisms that are species-specific. These mechanisms include modulating volatile organic compounds and hormone levels, enhancing nutrient availability, and improving tolerance to abiotic stresses (Choudhary et al., 2011).

This study contributes to addressing the urgent need for sustainable agricultural practices by reducing chemical inputs and enhancing plant resilience and productivity in onion farming systems, thereby supporting sustainable consumption and production patterns in line with Sustainable Development Goal (SDG) 12. Additionally, it aligns with SDG 8, which focuses on promoting sustained, inclusive, and sustainable economic growth, fostering progress, improving living standards, and creating decent work for all. By encouraging the development of decent jobs within communities, equipping young people with essential skills, investing in education and training, and providing vulnerable populations with access to social protection, this approach supports broader social and economic development goals.

Objectives

This study aimed to determine the effects of rhizobacteria in combination to organic fertilizer and entomopathogenic fungi as foliar spray on the growth, and yield of onion (*Allium cepa L.*).

Specifically, it aimed to:

1. evaluate the effect of rhizobacteria inoculation on the growth parameters (root length, shoot height) and yield of onion.
2. assess the effects of entomopathogenic fungi as foliar spray and pest control in onion; and
3. compare the effects of inoculation of rhizobacteria and entomopathogenic fungi with the control group in terms of growth, pest resistance, and yield of onion.

METHODS

Securing of Planting Material, PGPR and Entomopathogenic Fungi`

A red onion variety was used for the study. Seeds for planting were obtained from a reliable source in Nueva Vizcaya. The plant growth-promoting rhizobacteria (PGPR), vesicular arbuscular mycorrhiza (VAM), was secured from Biotech, Los Baños, Laguna, while the entomopathogenic fungi (Beauveria bassiana) was secured from the Department of Agriculture, Ilagan, Isabela.

Soil Sampling and Analysis

Soil samples were randomly collected from the experimental site using a shovel. The samples were then spread out on newspaper and air-dried for approximately one week. One-kilogram portions of the dried soil were thoroughly pulverized and cleaned to remove any foreign materials. These prepared samples were sent to the Cagayan Valley Integrated Laboratory Division, Soils Laboratory Research Center in San Felipe, City of Ilagan, for analysis. The soil's NPK content determined the fertilizer recommendation for the study, which was set at 90-40-75 kg NPK per hectare.

Production of Seedlings

Seeds were sown in a nursery on well-prepared seedling trays. When seedlings attained the proper stage for transplanting—at the 3- or 4-leaf stage, estimated around 12 to 15 cm in height—they were transplanted to the experimental field. Seedlings were planted on fine soil, which was prepared following the recommended tillage practice for the crop.

Land Preparation

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An area of 110 square meters was cleaned before plowing initially with animal-drawn plow. The area was left idle for two weeks for weeds to decay and weed seeds to germinate before the final plowing. Final harrowing was done before the construction of beds.

Application of Fertilizer

For the control treatment, urea (46% N), Triple Super Phosphate (TSP) (46% P_2O_5), and sulfur were the fertilizer sources. For the other treatments, organic fertilizer was applied before transplanting to supply nitrogen and phosphorus.

Planting and Replanting

Onion seedlings were planted in double rows. The spacing between rows was kept at 20 cm, and the spacing between hills was 20 centimeters. Replanting of missing hills was done to maintain the required plant population.

Experimental Design and Treatments

The treatments consisted of six levels of fertilizer supplemented with PGPR. The experiment was laid out as a Randomized Complete Block Design (RCBD) with three replications. Each treatment was assigned to the plots randomly as follows:

T_1 – 90-40-75 kg NPK ha^{-1}
T_2 – 3 Tons Vermicompost ha^{-1} + 3 liters *Beauveria bassiana*
T_3- 3 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*
T_4- 1.5 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*
T_5- 7.5 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*
T_6 - 3 Tons Vermicompost ha^{-1}

Data Gathered

Data on growth, yield, and yield components of onion were recorded from the central double rows of plants, which were randomly selected in each plot as specified for each plant character.

Growth Parameters

1. **Plant Height (cm)**. This was measured from the ground to the tip of the leaves from 10 randomly selected plants at maturity.
2. **Leaf Number per Plant**. The total number of leaves per plant was counted from 10 randomly selected plants at maturity.
3. **Leaf Length (cm).** This was measured at physiological maturity from the sheath to the tip of the **leaf** from the ten leaves of the representative plants that were used to count the number of leaves per plant, using a ruler.

Yield and Yield Components

1. **Bulb Diameter (cm).** The bulb diameter of ten sample bulbs was measured at the widest portion of matured bulbs using a caliper.
2. **Neck Diameter (cm).** The neck diameters of ten randomly selected mature bulbs were measured using a vernier caliper and expressed in centimeters after harvest.
3. **Average Bulb Weight (g)**. The fresh weight of ten randomly selected mature bulbs was measured using a sensitive weighing balance and then expressed in grams.
4. **Marketable Bulb Yield**. These bulbs were weighed using a weighing scale.

Statistical Analysis

The collected data were analyzed using ANOVA for a Randomized Complete Block Design with the Statistical Tool for Agricultural Research (STAR) software. Differences among treatment means were evaluated using Tukey's Honestly Significant Difference (HSD) test.

RESULTS and DISCUSSION

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Table 1 shows the growth parameters of onion such as plant height (cm), leaf length (cm) and number of leaves.

Table 1. Growth Parameters as Affected by the Application of Plant Growth-Promoting Rhizobacteria

TREATMENTS	Plant Height (cm)	Leaf Length (cm)	Number of Leaves
T_1 - 90-40-75 kg NPK ha^{-1}	57.30^{bc}	51.70^{c}	7.10
T_2 - 3 Tons Vermicompost ha^{-1} + 3 liters *Beauveria bassiana*	54.83^{c}	47.33^{d}	6.63
T_3 - 3 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	64.40^{a}	63.10^{a}	7.83
T_4 - 1.5 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	59.67^{b}	59.53^{a}	7.10
T_5 – 0.75 Ton Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	56.13^{bc}	55.67^{b}	7.13
T_6 - 3 Tons Vermicompost ha^{-1}	55.90^{bc}	55.47^{bc}	7.20
F- RESULTS	**	**	ns
C. V. (%)	2.55	2.44	5.35

Means with the same letter are not significantly different using HSD Test
ns-not significant
***- significant at 1% level*

Plant Height (cm). The effect of combining vermicompost, *Azospirillum*, and *Beauveria bassiana* effectively enhanced onion plant height as shown in Table 1. The application of 3 Tons Vermicompost ha[1] combined with *Azospirillum* and 3 liters *Beauveria bassiana* were the tallest plants among all treatments with 64.40 centimeters. Lowering the levels of vermicompost into 1.5 tons vermicompost ha^{-1} + *Azospirillum* + 3 liters *B. bassiana* registered an average height of 59.67 cm. Treatments that included the recommended fertilizer rate (90-40-75 kg NPK ha^{-1}), in combination with 3 tons vermicompost ha^{-1} or 0.75 ton vermicompost ha^{-1} + *Azospirillum* + 3 liters *B. bassiana*, showed comparable plant heights to T_4. The treatment comprising 3 tons vermicompost ha^{-1} + 3 liters *B. bassiana* without Azospirillum recorded a lower average height of 54.83 cm. It shows that the combination of vermicompost), Azospirillum), and Beauveria bassiana as biocontrol agent had a t positive effect on the height of onion plants.

The observed increase in plant height resulting from the combined treatments is consistent with the findings of Wani and Khan (2010), who reported that Bacillus strains improved nutrient uptake, leading to taller tomato plants and greater fresh weight in both nutrient-deficient soils and those supplemented with nitrogen fertilizer. This suggests that the synergistic effect of the treatment combination can be attributed to the plant growth-promoting properties of the organic fertilizer, *Azospirillum*, and *Beauveria bassiana*, which collectively enhance nutrient absorption and overall plant vigor.

Furthermore, as noted by Ardakani and Mafakheri (2011), while the nitrogen-fixing ability of *Azospirillum* is its most widely recognized benefit, a growing number of studies highlight additional growth-promoting properties. These include the production of phytohormones that significantly stimulate root development, thereby improving the plant's capacity to absorb water and nutrients.

Leaf Length (cm). Leaf length was measured from the base of the pseudo-stem to the tip of the leaf. The ANOVA results indicated significant variation across all treatments. The longest leaves were recorded in treatments with 3 tons and 1.5 tons of vermicompost per hectare combined with *Azospirillum* and a constant rate of *Beauveria bassiana*, measuring 63.10 cm and 59.53 cm, respectively (T_3 and T_4). This suggests a synergistic effect among vermicompost, *Azospirillum*, and *Beauveria bassiana*, where even a reduced organic input (T_4), when paired with appropriate microbial support, can effectively promote vertical growth in onion plants.

On the same manner, the plants treated with 0.75 tons of vermicompost in combination with *Azospirillum* and *Beauveria bassiana* exhibited a mean leaf length of 55.67 cm, comparable to those treated with vermicompost

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alone (55.47 cm). The leaf length in T_1 (51.70 cm) and T_6 (55.47) both resulted in similar lengths despite of the variation in nutrient sources. In contrast, the shortest leaf length was observed in the treatment applied with 3 tons of vermicompost per hectare combined with 3 liters of *Beauveria bassiana* with 47.33 centimeters.

Number of Leaves. Results listed in Table 1 revealed that the number of leaves of onion was not affected by the tested treatments. This shows that regardless of treatment employed did not increase leaf number (6.63 to 7.83) which might be attributed to onion plant that has a specific potential in producing number of leaves mostly governed by genetics factor. In addition, although environmental and nutrient management factors influence the growth of the plants, they have minimal effect on surpassing the genetic limit of the plant in terms of the total number of leaves.

Table 2 shows the yield parameters of onion such as neck diameter (cm), bulb diameter (mm), bulb weight per plant (g), and bulb weight per sampling area (kg/6m^2).

Table 2. Yield Parameters as Affected by the Application of Plant Growth-Promoting Rhizobacteria

TREATMENTS	Neck diameter (cm)	Bulb diameter (mm)	Bulb weight per plant (g)	Bulb weight per sampling area (kg)
T_1 - 90-40-75 kg NPK ha^{-1}	1.19	68.43^{c}	68.43c	13.06^{c}
T_2 - 3 Tons Vermicompost ha^{-1} + 3 liters *Beauveria bassiana*	1.03	72.37^{c}	72.37c	14.03^{c}
T_3 - 3 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	1.12	90.27^{a}	90.27a	18.20^{a}
T_4 - 1.5 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	1.10	86.83^{ab}	86.83ab	16.99^{ab}
T_5 – 0.75 Ton Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	1.18	84.00^{b}	84.00b	16.87^{b}
T_6 - 3 Tons Vermicompost ha^{-1}	0.99	83.07^{b}	83.07b	15.38^{b}
F- RESULTS	ns	**	**	**
C. V. (%)	10.14	6.61	2.46	2.38

Means with the same letter are not significantly different using HSD Test
*** - significant at 1% level*
Ns - not significant

Neck Diameter (cm). Table 2 shows the average neck diameter of onion at harvest. Results revealed that all treated plants, regardless of fertilizer sources (either organic or inorganic) and irrespective of the application of *Azospirillum* and *Beauveria bassiana*, recorded comparable neck diameters, with mean values ranging from 0.99 cm to 1.19 centimeters. This shows that the treatments did not influence the neck diameter of the onion due to the inherent genetic characteristics and the stability of the variety used in the study.

Bulb Diameter (mm). Average bulb diameters of onion plants as affected by fertilization and bacterial inoculation are also presented in Table 2. The results indicate that mineral fertilization, bio-fertilization, and inoculation had a significant impact on bulb diameter. The treatments that produced the largest bulb diameters were T3 (86.83 mm) and T4 (86.83 mm), which showed similar results, followed by T6 and T5 with diameters of 93.07 mm and 84.00 mm, respectively. The smallest bulb diameters were observed in plants under T2 (72.37 mm) and T1 (68.43 mm).

This clearly demonstrates the role of biofertilization in increasing average bulb diameter, which may be attributed to the application of the recommended rate of vermicompost enhancing mineralization. As stated by Arisha et al. (2003), the increase is likely due to the organic matter in vermicompost, which contains many species of living

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organisms that release phytohormones, stimulating plant growth and improving nutrient absorption. Similarly, these results align with the findings of (Nagaraju et al., 2000), who reported that onion bulb diameter significantly increased with the application of vesicular-arbuscular mycorrhizae (VAM) - a beneficial fungus that forms a symbiotic relationship with plant roots-especially when combined with 50% to 100% inorganic fertilizer. Their observation that treatments without inoculation also performed well is consistent with the results of this study.

Bulb Weight per Plant (g). The data recorded on bulb yield per plant by different treatments are presented in Table 2. The results showed that combined application of vermicompost, *Azospirillum* and *Beauveria bassiana* significantly influences bulb yield per plant. The heaviest onions was recorded in the plants applied with 3 tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana* (T_3) and lower level of vermicompost (T_4) with constant application of *Azospirillum* *Beauveria bassiana* indicating better results than the application of chemical fertilizer. This was followed by the plants treated with 0.75 tons vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana* and the plot without beneficial microbes (T_6) which were less effective in increasing bulb weight with mean values of 84.00 and 83.07 grams. The significant difference in bulb yield per plant under the combined application of vermicompost, *Azospirillum*, and *Beauveria bassiana* suggests that the treatment combinations are potentially beneficial in enhancing bulb yield.

Table 3. Bulb Weight per 1000 Square Meters (tons) as affected by the Application of Plant Growth-Promoting Rhizobacteria

TREATMENTS	Bulb weight per 1000 square meters (tons)
T_1 - 90-40-75 kg NPK ha^{-1}	2.18^{c}
T_2 - 3 Tons Vermicompost ha^{-1} + 3 liters *Beauveria bassiana*	2.34^{c}
T_3 - 3 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	3.04^{a}
T_4 - 1.5 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	2.83^{b}
T_5 – 0.75 Ton Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	2.81^{b}
T_6 - 3 Tons Vermicompost ha^{-1}	2.56^{b}
F- RESULTS	**
C. V. (%)	2.39

Means with the same letter are not significantly different using HSD Test
*** - significant at 1% level*

Bulb Weight per 1000 Square Meters (tons). Calculating the yield per 1000 square meters, a similar trend of significant differences was observed. Effect of different treatments showed that the application of vermicompost *Azospirillum* and *Beauveria bassiana* (T_3) led to increase blub yield of onion compared to other treatments. Followed by T4, T5 and T6, while the least was noted in the plots fertilized with 90-40-75 kg NPK ha^{-1} and 3 Tons Vermicompost ha^{-1} + 3 liters *Beauveria bassiana.*

Table 4. Number of Infected Bulb per Plot as affected by the Application of Plant Growth-Promoting Rhizobacteria

TREATMENTS	Number of Infected Bulb per Plot
T_1 - 90-40-75 kg NPK ha^{-1}	11.33^{a}
T_2 - 3 Tons Vermicompost ha^{-1} + 3 liters *Beauveria bassiana*	8.00^{b}
T_3 - 3 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	2.00^{d}

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T_4 - 1.5 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	7.33^{b}
T_5 – 0.75 Ton Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	2.67^{c}
T_6 - 3 Tons Vermicompost ha^{-1}	3.33^{c}
F- RESULTS	**
C. V. (%)	2.39

Means with the same letter are not significantly different using HSD Test
*** - significant at 1% level*

The number of infected bulbs per plot due to insect infestation is shown in Table 4. This reflects that the plants treated with the recommended rate of inorganic fertilizer produced the highest number of infected bulbs (11.33). The plants in both T2 and T4, which included Beauveria bassiana, had a moderate number of infected bulbs (8.00 and 7.33, respectively), followed by the plants in T6 and T5 (vermicompost only or with a reduced rate of vermicompost and microbes), which showed lower values (3.33 and 2.67). It is interesting to note that the plants treated with 3 tons vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana* (T3), despite receiving the full rate of vermicompost and bio-agents, had the lowest number of infected bulbs (2.00). This suggests that this combination is the most effective in minimizing bulb losses due to insect pests.

Conclusion

The study's results demonstrated that the combined application of 3 tons of vermicompost, *Azospirillum* , and 3 liters of *Beauveria bassiana* significantly enhanced growth parameters and yield in onions, outperforming traditional chemical fertilizer treatments.

Recommendations

Based on the results of the study, to enhance the growth and yield of onions, it is recommended to apply 3 tons of vermicompost, Azospirillum, and 3 liters of *Beauveria bassiana* per hectare. The combined benefits of organic nutrients from vermicompost, nitrogen fixation by *Azospirillum*, and biological pest control provided by *Beauveria bassiana* offer a sustainable and eco-friendly alternative to conventional inorganic fertilizers. Therefore, this integrated approach is strongly recommended for improved onion production.

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Growth and Yield Performance of Mung Bean Applied with Vermichar as Nutrient Supplement

Romel A. Ramos*[1], Lucila V. Rocha, PhD[2]
[1, 2] Isabela State University, Echague Campus, Echague, Isabela, Philippines

Abstract
Aim: This study aimed to evaluate the effect of vermichar integration in mung bean production on the growth and yield, changes in the characteristics of soil, and economic returns.
Methodology: The experiment was conducted at Angadanan Isabela, Philippines, using Randomized Complete Block Design (RCBD) with three (3) replications and a total of 18 plots. The treatments were; T1 – Control (No application), T2 –30-10-20 NPK ha-1, T3 – 30-10-20 NPK ha-1 plus 0.5 Vermichar, T4 – 30-10-20 NPK ha-1 plus 1.0 Vermichar, T5 – 30-10-20 NPK ha-1 plus 1.5 Vermichar and T6 – Vermi-char (100%).
Results The Vermichar application showed significant results on the plant height fifteen, thirty, and forty-five days after planting. Significant results were obtained regarding the number of pods, seeds per pod, and total weight of seeds of the experimental plants in the study. The computed yield per sampling area of the experimental plants showed significant results. In terms of income over farm inputs and labor cost, T_1 – Control (No application of Recommended Rate of Inorganic Fretilizer plus Vermichar) had the highest return, 618.56%, and the lowest was in T_3 – 30-10-20 NPK ha-1 plus 0.5 Vermichar had a return of 525.61%. The soil analysis before and after the conduct of the study showed changes in pH level, organic matter, phosphorus and potassium content.
Conclusion: The addition of 30-10-20 NPK ha-1 plus 1.5 Vermichar had been proven to produce taller plants, a greater quantity of nodules per plant, the number of developed pods, and higher number of seeds, hence the heaviest seed per sampling area. Therefore, this attribute practice in mung bean production is an ideal and potential practice for farmers.
Keywords: *Biochar, Vermicompost, Soil Fertility, Sustainable Agriculture, and Yield Improvement*

INTRODUCTION

Mung beans are a powerhouse of nutrition they are rich in protein, dietary fiber, vitamins, and minerals, making them a valuable addition to a healthy diet. Studies have shown that mung beans contain bioactive compounds such as polyphenols, polysaccharides, and peptides, which contribute to their health benefits, including antioxidant, anti-inflammatory, and antihypertensive properties (Hou et al., 2019). Additionally, they are widely used in various cuisines, from soups and salads to desserts, due to their versatility and nutritional value (Wang et al., 2021).

Over the past years, farmers have optimized synthetic fertilizers to promote yield. The essential nutrients in fertilizer inputs are crucial for crop production, but they also account for a significant portion of the total crop input cost, making it challenging for many farmers to fund agricultural inputs. Yield is the most essential constituent that is profitable in crop production. A significant portion of the overall cost of crop inputs is the management of inputs used in agriculture, such as fertilizers. The soil supply is used for sufficient availability and plant absorption of vital nutrients used in the harvest of mung beans.

Synthetic fertilizers play a crucial role in boosting agricultural productivity, but their excessive use can lead to significant environmental concerns. Studies highlight that synthetic nitrogen fertilizers contribute to soil acidification, disrupt microbial diversity, and lead to groundwater contamination (Sabina et al., 2025). The soil has become excessively depleted as a result of the overuse of synthetic fertilizers becomes increasingly stressed and unproductive, leading to higher pH levels and affecting crop growth and yield. Due to this significant problem and the disadvantages of synthetic fertilizer use, several researchers have developed a solution, focusing on the application of organic fertilizer to restore soil fertility and productivity by lowering the expense of agricultural inputs and lessening the long-term consequences of synthetic fertilizer.

Integrating vermicompost and biochar in soil is valuable for enhancing soil fertility. Vermicompost is a natural fertilizer derived from worm waste, adding essential nutrients, improving soil structure, boosting water retention, and enhancing microbial activity, which makes the soil healthier and more fertile. Vermicompost is a fantastic organic amendment that enhances plant growth and soil health research has shown that vermicompost significantly improves root development, boosts plant yield and quality, and strengthens disease resistance (Rehman et al., 2023). Biochar is a powerful soil amendment with multiple benefits research has shown that biochar improves soil structure, enhances water retention, and boosts nutrient-holding capacity, making it an excellent tool for

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sustainable agriculture (Kabir & Kwon, 2023). Together, they significantly improve soil health and crop productivity, fostering sustainable agricultural practices.

Adding organic additions to agricultural soils generally conserves natural resources and lessens the need for artificial inorganic fertilizers. After applying organic amendments, soil structure, nutrient composition, and microbiological activity typically improve. Research has shown that organic amendments, including carbohydrates and amino acids, contribute to soil fertility and microbiological activity. These amendments enhance microbial communities and enzyme production, improving soil health and nutrient cycling (Liu et al., 2023). Organic fertilizers supply the macro-nutrients required for crop growth and enhance soil microbial activity. A combination of inorganic and organic fertilizer applications has been suggested to increase and maintain soil fertility, crop yields, and agronomic nutrient use efficiency (Debele, 2021).

Because most organic resources have conflicting uses, like fuel and livestock feed on the farm, most farmers do not apply organic fertilizers despite their crucial role in restoring natural fertility. Research indicates that inadequate cultural techniques can lead to sub-optimal plant stands and lower yields, ultimately affecting overall production. Factors such as improper crop rotation, incorrect sowing dates, and insufficient fertilizer application have been identified as contributors to yield reduction (Uoyang et al., 2022). Low soil fertility is another factor contributing to low plant output. Adding organic amendments to mung bean production is one way to enhance soil fertility and yield, which can be further improved through specific farming techniques. Vermicompost has been shown to enhance soil health by improving nutrient availability, boosting microbial activity, and increasing water retention, all of which contribute to healthier plant growth. Research highlights its role in enriching soil with essential nutrients, humic acids, and beneficial microorganisms, leading to better crop productivity and sustainability (Oyege & Balagi, 2023).

Vermicompost plays a crucial role in improving soil health supports its benefits, including enriching soil with essential nutrients, enhancing microbial activity, improving water retention, and promoting healthy plant growth. Studies highlight its effectiveness in sustainable agriculture and pest management (Oyege & Balagi, 2023). Vermicompost is rich in essential nutrients like nitrogen, phosphorus, and potassium, which are vital for plant growth and development. Studies highlight its ability to enhance soil fertility and improve crop yield by providing these nutrients in an organic form (Rehman et al., 2023). Vermicompost enhances plant health and productivity, making it a valuable addition to gardening and farming. Research highlights its ability to improve soil quality, increase nutrient availability, boost crop productivity, and enhance pest and disease tolerance (Oyege & Balagi, 2023). Other organic compounds, such as biochar plays a crucial role in enhancing soil conditions and nutrient availability, leading to healthier, more resilient plant growth. Research highlights its ability to improve soil fertility, increase nutrient retention, boost microbial activity, and enhance water-holding capacity (Oyege & Balagi, 2023). Biochar promotes healthier, more robust plant growth by improving soil conditions and enhancing nutrient availability, resulting in more productive and resilient plants. This study will assess the influence of vermichar application on mung bean production.

In this research, mung bean cultivation can contribute to the Sustainable Development Goals (SDGs) and could focus on its role in enhancing food security, reducing poverty, and promoting sustainable agricultural practices. Mung beans are an inexpensive, readily available, protein-rich legume, especially in areas with limited access to various nutrient-dense meals. Addressing malnutrition, fostering improved health, and enhancing overall food security, their inclusion in diets can support SDGs 2 (Zero Hunger) and 3 (Good Health and Well-Being). Additionally, its adaptability to different cropping systems and climates, such as cover crops or intercropping, promotes sustainable agriculture and advances SDGs 13 (Climate Action) and 15 (Life on Land).

Objectives

This study aims to evaluate the effect of vermichar integration on the growth and yield of mung bean as well as changes in the soil characteristics.

Specifically, the study aims to:

1. evaluate the changes in soil pH, organic matter, phosphorus and potassium content resulting from the application of vermichar;
2. determine the effect of vermichar on the development and yield of mung bean; and
3. determine the economic return of using vermichar that was feasible for crop raisers.

METHODS

Procurement of Mung Bean Seeds and Other Materials

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An authorized agricultural supply store in Cabatuan, Isabela, at Maharlika Agricultural Supply was the source of mung bean seeds ("Kusapo" PSBMg2 (VC3876), the most widely planted variety in the region, which was utilized. Additional field supplies needed for this study was acquired from other suppliers in the province of Isabela. The vermi-char was acquired from Isabela State University's Center for Organic Agriculture Research, Extension, and Training (COARET) in Echague, Isabela, Philippines.

Soil Sampling and Analysis

Prior to preparing the land, soil samples were collected. This was done using a shovel to reach the proper depth and follow a zigzag pattern with enough sub-samples. In addition it was also collected after the conduct of the study to determine the changes on soil pH, organic matter, phosphorus and potassium content, it was pulverized and air-dried, the soil's inactive substance was eliminated. One kilogram of composite soil samples was brought to the Cagayan Valley Research Center (CVRC) for analysis.

Land Preparation

The 430 square meter experimental space was meticulously prepared for consistent seedling emergence and healthy root development. A Four-wheel drive tractor was used for the plowing, and a week later, the area was harrowed using an animal-drawn plow tool to break up the soil clods and effectively control weeds.

Experimental Layout and Design

The prepared area was divided into three equal blocks; each block has a dimension of 6 meters x 20 meters. Each block was subdivided into six equal plots measuring 6 meters x 3 meters and with a spacing of 0.5 meters between plots. The experimental treatments were randomly allocated following the randomization procedure for Randomized Complete Block Design (RCBD).

Experimental Treatments

The treatments for the study using vermichar were the following:

T_1 – Control (No Application of Fertilizer)
T_2 –30-10-20 NPK ha^{-1}
T_3 – 30-10-20 NPK ha^{-1} plus 0.5 Vermichar
T_4 – 30-10-20 NPK ha^{-1} plus 1.0 Vermichar
T_5 – 30-10-20 NPK ha^{-1} plus 1.5 Vermichar
T_6 – Vermi-char Alone

Construction of Furrows and Application of Fertilizer

Prior to applying fertilizer, furrows were set at a standard distance of 45 centimeters based on soil examination. This spacing served as the fertilizer benchmark. The research involved six different approaches: T1 - acting as a control with no fertilizer added, T2 - applying the suggested amount of synthetic fertilizer according to soil analysis, T3, T4, and T5 - blending the recommended synthetic fertilizer rate with vermi-char for basal application, T6 - applying vermichar alone before planting. To safeguard against harm from microorganisms, the seeds were shielded by covering them with topsoil.

Planting and Replanting

Three seeds were planted per hill in a furrow with a distance of 15 centimeters between hills and 45 centimeters between rows using a jabber for uniform germination. A straight bamboo pole was prepared, marked at every 15 cm distance, and used as a planting guide. This was done to ensure that seed placement was equidistant and in a proper manner to avoid sources of variation during planting. The missing seeds were replanted five days after they were planted. Thinning was done 10 days after planting to maintain two healthy plants per hill.

Care and Management

Cultivating and Weeding. Hilling-up was done 10 days after planting. Cultivation was practiced to loosen the root zone of the plants, provide aeration and entry of oxygen in the roots, and control weed growth.

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Crop Protection. Diseases, weeds, and insect pests that may arise throughout the study were controlled appropriately. To control sucking and chewing insect pests, pesticides were applied as needed using a 10 ml/ 16 L knapsack sprayer.

Irrigation. Depending on the field, soil, and weather, provide irrigation. Adequate moisture was maintained to promote germination and healthy seedling emergence. To supplement the plants' water needs, the plot can be manually watered using furrow irrigation.

Harvesting

When the pods dry out and become light brown to black, mung bean seeds are ready to be collected. The mung beans were harvested by hand and then individually stored in sacks with the appropriate treatment labels to prevent the samples from being mixed. Following the conventional procedure, the samples were taken into the sorting room, manually threshed, and the seeds were separated from the pods. At one-week intervals, preliminary data on harvested pods and other yield component metrics were recorded for each priming.

Data Gathered

Growth and Yield Parameters

1. Plant height (cm). Ten randomly chosen representative plants were selected, and their height was measured from the base to the top using a meter stick. This was taken at 15, 30, and 45 DAP.
2. Number of pods per plant. The quantity of pods harvested from each priming was counted and recorded. A total quantity of pods per plant was generated by adding all pod counts obtained from the first to the last.
3. Seeds per pod (count). The number of seeds from 10 randomly selected pods was manually opened, and the number of whole, undamaged seeds per plot was counted and recorded. This was taken during the R6 stage, also known as the first harvest.
4. Total weight of seeds per plant (g). The weight of seeds per plant from 6 inner rows x 3 meters (approximately 7.2 m^2) was weighed after each harvest. The weight of harvested seed samples from all priming treatments was combined to determine the final seed yield per plant, using 10 randomly selected plants.
5. Computed yield per Hectare (kgs/ha). The yield per Hectare was computed based on the total weight of seeds from the sampling area, and the formula used was as follows

$$\text{Yield per Hectare} = \frac{\text{Yield per Sampling Area X 10,000}}{\text{Sampling Area } (m^2)}$$

Statistical Analysis

All the data was gathered and examined using Analysis of Variance for the Randomized Complete Block Design. The Statistical Tool for Agricultural Research (STAR) was utilized for data analysis. Duncan's Multiple Range Test (DMRT) was employed to compare averages when there were significant findings.

Cost and Return Analysis

The fundamental economic analysis was used to calculate the return on investment. The production cost determined the current cost of labor and agricultural inputs in the neighborhood. The market price per kilogram of mung bean was used to calculate the gross income. The return on investment is calculated by dividing the net income by the cost of production, which is multiplied by 100. Net income is equal to gross income minus the cost of production.

RESULTS and DISCUSSION

Growth and Yield Parameters

Plant height at maturity. The height of the plants at 15, 30, and 45 days after planting with the application of Vermichar is shown in Table 1. At 15 days after planting, a significant outcome was observed where the application of Vermichar Alone (T_6), the 30-10-20 NPK ha^{-1} (T_2), the 30-10-20 NPK ha^{-1} plus 0.5 Vermichar (T_3), the 30-10-20 NPK ha^{-1}plus 1. 0 Vermichar (T_4), and the 30-10-20 NPK ha^{-1} plus 1.5 Vermichar (T_5) resulted

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in comparable heights with mean values ranging from 12.45 to 13.88 centimeters. The shortest plants were noted in the group with no fertilization (T_1-Control), which achieved a mean value of 12.13 centimeters.

Similarly, a notable variation was observed concerning the heights of the plants at 30 days after planting. The use of the 30-10-20 NPK ha^{-1} plus 0.5 Vermichar (T_3), 30-10-20 NPK ha^{-1} with 1.0 Vermichar (T_4), and the 30-10-20 NPK ha^{-1} mixed with 1. 5 Vermichar (T_5) resulted in the tallest plants, with average measurements between 28.43 and 30. 48 centimeters. Next were the plants treated with Vermichar Alone (T_6) and the 30-10-20 NPK ha^{-1} (T_2), which measured between 26. 55 and 27.94 centimeters. The plants that received no fertilizer (T_1-Control) reached the shortest height, averaging 25. 19 centimeters.

Additionally, the tallest plants showed significant outcomes among treatment means 45 days after planting. The tallest plants were noted with the application of 30-10-20 NPK ha^{-1}plus 1. 5 Vermichar (T_5), 30-10-20 NPK ha^{-1} plus 1. 0 Vermichar (T_4), the 30-10-20 NPK ha^{-1} plus 0. 5 Vermichar (T_3), the 30-10-20 NPK ha^{-1} (T_2), and Vermichar Alone (T_6) with mean values ranging from 53. 10 to 57. 35 centimeters. The plants without fertilizer (T_1-Control) showed the shortest height with a mean value 52. 79 centimeters.

These findings demonstrate that Vermichar, particularly when combined with NPK fertilizer, enhances plant height across different growth stages. The consistent increase in height indicates that the addition of Vermichar improves nutrient availability and soil conditions, promoting better plant development. Furthermore, the progressive growth differences observed between treatments showed that higher Vermichar concentrations lead to better results, emphasizing its role in boosting plant productivity.

The outcome of the study is consistent with the results of Bezabeh et al., (2022), who found that employing vermicompost boosts root and plant development, resulting in enhanced water and nutrient absorption. According to a study conducted by Ding et al., (2016), field experiments demonstrated that the use of biochar improved soil health, increased yields, and stimulated plant growth.

Number of pods per plant. The application of Vermichar significantly influenced the quantity of development pods per plant, as shown in Table 1. Among the different treatments, the highest number of development pods was observed in plants treated with 30-10-20 NPK ha^{-1} combined with 1.5 Vermichar (T_5), yielding a mean value of 85.50 pods. This was closely followed by 30-10-20 NPK ha^{-1} with 1.0 Vermichar (T^4) and 0.5 Vermichar (T_3), which produced mean values of 81.77 and 78.40 pods, respectively. Comparatively, plants treated with only 30-10-20 NPK ha^{-1} (T_2) and Vermichar alone (T_6) exhibited slightly lower pod counts, averaging 75.77 and 70.55, respectively. Meanwhile, the untreated control group (T_1) had the least number of development pods, with a mean of 67.77.

These findings suggest that the integration of Vermichar with a balanced NPK fertilizer enhances pod formation, potentially due to its ability to improve soil nutrient availability, water retention, and microbial activity. Vermichar, a combination of vermicompost and biochar, has been recognized for its role in enriching soil organic matter, promoting plant growth, and enhancing nutrient uptake. The gradual release of nutrients from Vermichar likely contributes to sustained plant development, leading to better pod formation. Additionally, biochar in Vermichar aids in improving soil aeration, which supports root expansion and nutrient absorption. These factors collectively demonstrate that Vermichar, when combined with an appropriate fertilizer mix, can optimize pod production, making it a promising soil amendment for increased crop yields (Rab et al., 2021).

Another findings were consistent with previous studies that have found using biochar to increase mung bean pod formation. For instance, applying 30 t ha¹ of biochar resulted in the highest number of pods per plant (27.3) and improved grain yield (Jalal *et al.*, 2024). Biochar enhances soil organic matter, retains moisture, and boosts microbial activity, contributing to better pod development. Another finding from (Arsalan et al., 2016) stated that using Vermicompost improves soil structure, increases nutrient uptake, and enhances root development, leading to better pod formation. Additionally, phosphorus application alongside Vermicompost has been found to improve nodulation and nutrient absorption.

Seed per pod (count). The number of seeds per pod applied with Vermichar is shown in Table 1. A significant result was observed in the number of seeds, which was higher in plants treated with 30-10-20 NPK ha^{-1} plus 1.5 Vermichar (T_5) compared to the untreated plant control (T_1), with a mean value of 417.67, versus 350.93. Seed treated showed significant effect on the number of seed plant treated with 30-10-20 NPK ha^{-1} plus 1.5 Vermichar (T_5) with a value of 417.67 and 30-10-20 NPK ha^{-1} plus 1.0 Vermi-char (T_4) with a value of 408.33 produced the greater number of seed per plant compared to the seed treated with 30-10-20 NPK ha^{-1} plus 0.5 Vermichar (T_3) with a mean value of 393.87, 30-10-20 NPK ha^{-1} (T_2), with a mean value of 379.40, Vermichar Alone

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(T_6) with a mean value of 351.63 and the least of them is those plants untreated in (T_1-Control) with a mean value of 350.93.

Significant results were consistent with previous studies, which showed that the application of vermicompost and biochar in mung beans can significantly enhance seed yield. Biochar improves soil fertility and nutrient retention, producing better plant growth and yield (Jalal *et al.*, 2024; Rab *et al.*, 2021). Vermicompost, rich in organic matter and beneficial microbes, enhances soil structure and nutrient availability, further boosting mung bean productivity. Similarly, Vermicompost contributes to higher pod and seed production, making it a valuable organic amendment (Bankoti et al., 2021)

Table 1. Growth Performance of Mungbean as Affected by Various Combination of NPK and Vermi-char

TREATMENTS	Mean Height-15	Mean Height-30	Mean Height-45	Mean No. of Pods	Mean Seed Per Pods (count)
T_1- Control	12.13^{c}	25.19^{c}	52.79^{c}	67.75^{c}	350.93^{b}
T_2- 30-10-20 NPK ha^{-1}	13.07^{abc}	27.94^{ab}	55.03^{abc}	75.07^{bc}	379.40^{ab}
T_3- 30-10-20 NPK ha^{-1} plus 0.5 Vermi-char	13.21^{ab}	28.43^{ab}	55.51^{abc}	78.40^{ab}	393.87^{ab}
T_4- 30-10-20 NPK ha^{-1} plus 1.0 Vermi-char	13.43^{ab}	29.77^{a}	56.11^{ab}	81.77^{ab}	408.33^{a}
T_5- 30-10-20 NPK ha^{-1}plus 1.5 Vermi-char	13.88^{a}	30.48^{a}	57.35^{a}	85.50^{a}	417.67^{a}
T_6-Vermi-char Alone	12.45^{bc}	26.55^{bc}	53.10^{bc}	70.55^{c}	351.63^{b}
F-RESULTS	**	**	**	**	**
C.V. (%)	2.70	3.25	1.98	3.49	2.52

Note: Means with common letters are not significantly different with each Honest Significant Different (HSD)
**-significant at 1% level

Total weight of seeds per plant (g). The seed weight per plant was a significant result when applied with Vermichar, as presented in Table 2. The heaviest seeds were produced in the plants treated with 30-10-20 NPK ha^{-1} plus 1.5 Vermichar (T_5), 30-10-20 NPK ha^{-1} plus 1.0 Vermichar (T_4), and 30-10-20 NPK ha^{-1} plus 0.5 Vermichar (T_3), which had mean values of 7.04, 6.52, and 6.00 grams, respectively. Similarly, comparable seed weights were recorded with the application of 30-10-20 NPK ha^{-1} (T_2) and Vermichar Alone (T_6), which had mean values 5.73 and 5.58 grams. The lightest seeds were found in the untreated plots (T_1), measuring 5.26 grams.

These results suggest that Vermichar contributes significantly to improving seed development and overall grain quality. Vermichar, composed of vermicompost and biochar, enhances soil structure and fertility, creating optimal growing conditions for crops. Its ability to increase nutrient retention and improve microbial activity likely leads to more efficient nutrient uptake by plants, which in turn supports larger seed formation. Biochar and Vermicompost helps improve soil aeration and moisture retention, ensuring that plants receive adequate water and nutrients throughout their growth cycle. Additionally, the gradual release of nutrients from vermicompost sustains plant development, allowing seeds to reach their full potential in size and weight. These benefits highlight Vermichar as a valuable soil amendment for maximizing crop productivity, particularly when integrated with appropriate NPK fertilizer applications(Jalal et al., 2024; Rab et al., 2021).

Vermicompost provides various benefits compared to uncomposed organic waste and mineral fertilizers, leading to enhanced crop growth, biomass, and yield. The gradual release of nutrients in vermicompost, aided by humic and fulvic acids, boosts the accessibility of soil nutrients to plants, fostering root development. This, in turn, improves water and nutrient absorption by plants, as mentioned in (Bezabeh et al., 2022). Studies by Mistry (2015) have shown that vermicompost can significantly impact the germination, growth, blooming, fruiting, and overall yields of crops.

Studies suggest that biochar application increases nodulation, yield components, and overall plant health in mung beans. For instance, applying 30 t ha¹ of biochar resulted in the highest number of pods per plant (27.3) and improved grain yield (Jalal et al., 2024). Research suggests that biochar and Vermicompost can significantly enhance seed yield in mung beans. Biochar improves soil fertility and nutrient retention, producing better plant growth and yield (Jalal et al., 2024; Rab et al., 2021). Research suggests that Vermicompost and biochar can positively impact mung bean growth and yield (Rab et al., 2021).

The computed yield per hectare of mung bean production clearly illustrates the positive effect of Vermichar application, as shown in Table 2. Treatment 5 (T_5), which combined 30-10-20 NPK ha^{-1} with 1.5 Vermichar, achieved the highest yield of 312.96 kg/ha (3.10 tons), followed closely by Treatment 4 (T_4) with 304.43

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kg/ha (3.00 tons). Treatment 3 (T_3) also showed strong productivity at 288.16 kg/ha (2.90 tons), indicating that increasing Vermichar levels enhances yield. Treatment 2 (T_2) with only fertilizer yielded 275.20 kg/ha (2.80 tons), while Treatment 6 (T_6), which applied Vermichar alone, produced 268.00 kg/ha (2.70 tons). The lowest yield was observed in the control group (T_1), which lacked both Vermichar and fertilizer, producing only 252.21 kg/ha (2.50 tons). These results emphasize the crucial role of Vermichar in boosting mung bean production, particularly when combined with NPK fertilizer. The gradual increase in yield across treatments suggests that proper soil amendments, nutrient management, and organic inputs can significantly enhance productivity, ultimately leading to better agricultural efficiency and profitability.

Table 2. Yield Performance of Mungbean as Affected by Various Combination of NPK and Vermi-char

TREATMENTS	Mean	Mean
	Total weight of seeds per plant (g)	Computed yield per hectare (kg/ha)
T_1- Control	5.26^{c}	252.21^{c}
T_2- 30-10-20 NPK ha^{-1}	5.73^{bc}	275.20^{b}
T_3- 30-10-20 NPK ha^{-1} plus 0.5 Vermi-char	6.00^{b}	288.16^{ab}
T_4- 30-10-20 NPK ha^{-1} plus 1.0 Vermi-char	6.52^{ab}	304.43^{a}
T_5- 30-10-20 NPK ha^{-1}plus 1.5 Vermi-char	7.04^{a}	312.96^{a}
T_6-Vermi-char Alone	5.58^{bc}	268.00^{bc}
F-RESULTS	**	**
C.V. (%)	3.59	3.59

Note: Means with common letters are not significantly different with each Honest Significant Different (HSD)
**-significant at 1% level

The cost and return analysis of mung bean production reveals significant variations in profitability among different treatments. Treatment 1 demonstrated the highest return on investment (ROI) at 618.56%, indicating an optimal balance between cost efficiency and yield maximization. Treatment 2 closely followed at 617.41%, suggesting similar effectiveness with slight differences in resource utilization. Treatments 6, 5, and 4 maintained strong profitability, with ROI ranging from 562.05% to 538.45%, likely reflecting variations in production costs, soil conditions, or input efficiency. Meanwhile, Treatment 3 exhibited the lowest ROI at 525.61%, which, while still a considerable return, suggests higher production expenses or lower yield efficiency compared to the other treatments. These results highlight the importance of identifying key factors influencing yield and cost-effectiveness, such as input usage, soil management, pest control, and market prices, to optimize profitability. Refining less effective treatments and further analyzing the methodologies behind the most successful ones can help improve overall mung bean production efficiency and financial returns.

Table 3. Economic Return Analysis of Mungbean as Affected by Various Combination of NPK and Vermi-char

TREATMENTS	Cost of Production	Gross Income	Net Income	ROI%
T_1	10100.00	72574.72	62474.72	618.56
T_2	12489.37	89600.00	77110.63	617.41
T_3	14862.37	92800.00	78117.63	525.61
T_4	15036.37	96000.00	80963.63	538.45
T_5	15297.37	99200.00	83902.63	548.48
T_6	11840.00	78383.36	66546.36	562.05

Cost of Mung Bean-P37.00/kg

Soil Analysis Before the Conduct of the Study

Soil pH and NPK Content before Conduct of the Study. The soil analysis before the execution of the study is shown in Table 4. The soil analysis pH, ranging from 7.23, is slightly alkaline but still within the ideal range for mung bean production. Mung bean thrives best in soils with a pH between 6.0 and 7.5, meaning a pH of 7.23 is well-suited for its growth. The soil organic matter examination ranged from 2.41, indicating a moderate soil organic matter level of 2.41%. This level is considered beneficial for mung bean growth, although its suitability depends on

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other soil properties, such as texture, pH, and nutrient content. A soil organic matter of 2.41% suggests decent organic matter content, which can support root development, nitrogen fixation (since mung beans are legumes), and water retention. Phosphorus availability 17.37, phosphorus availability at 17.37 ppm seems to be in the moderate to sufficient range for mung bean production, depending on soil type and environmental conditions. Mung bean requires adequate phosphorus for root development, flowering, and pod formation. Generally, a phosphorus level between 15-30 ppm is suitable for legume crops, including mung bean. Potassium analysis ranged from 288.94 ppm, which is crucial in mung bean production, influencing plant growth, yield, and overall health. A potassium level of 288.94 mg/kg in the soil generally falls within a reasonable range for supporting mung bean development. For mung bean production, potassium enhances seed quality, improves disease resistance, and supports better yield. Studies on integrated nutrient management suggest that combining organic and inorganic fertilizers, including potassium sources, can significantly boost soil health and mung bean productivity (Choudhary et al., 2025).

Table 4. Soil Analysis Before Conduct of the Study

REPORT OF ANALYSIS			
pH	Organic Matter %	Available Phosphorus, P ppm	Available Potassium, K ppm
7.23	2.41	17.37	288.94

Soil Analysis

Soil Analysis after the Conduct of the Study

pH and NPK levels were measured after the study was conducted. Table 5. Represents the soil analysis per treatment for mung bean production. Soil properties' ability to retain water and minerals determines the success of plant growth. Therefore, it is essential to understand various methods for conserving soil, particularly topsoil, which contains the vital nutrients for plant growth. Treatments showed the soil properties and analysis of the sequence after the study for Treatment 1 with the pH level of 7.58, Organic Matter-2.86, Phosphorus-16.45 and Potassium-213.16, Treatment 2 with the pH level of 7.39, Organic Matter-1.83, Phosphorus-22.36 and Potassium-224.98, Treatment 3 with the pH level of 7.20, Organic Matter-2.88, Phosphorus-44.31 and Potassium-287.95, Treatment 4 with the pH level of 7.39, Organic Matter-2.41, Phosphorus-62.83 and Potassium-367.24, Treatment 5 with the pH level of 6.86, Organic Matter-4.90, Phosphorus-105.87 and Potassium-739.35, Treatment 6 with the pH level of 6.82, Organic Matter-3.38, Phosphorus-67.70 and Potassium-341.02 respectively.

Understanding variations in nutrient content after a study is essential for conducting soil analysis because it helps determine the effectiveness of treatments, environmental influences, and soil health over time. By analyzing these variations, researchers and farmers can make informed decisions on fertilization, crop selection, and land management. It ensures that nutrients are optimized for plant growth while preventing deficiencies or excesses that could harm the environment.

Table 5. Soil Analysis After Conduct of the Study

	REPORT ANALYSIS			
TREATMENT	pH	Organic Matter%	Available Phosphorus P ppm	Available Potassium K ppm
T1	7.58	2.86	16.45	213.16
T2	7.39	1.83	22.36	224.98
T3	7.20	2.88	44.31	287.95
T4	7.39	2.41	62.83	367.24
T5	6.86	4.90	105.87	739.35
T6	6.82	3.38	65.70	341.02

Soil Analysis

Conclusion

The addition of 30-10-20 NPK ha^{-1} plus 1.5 Vermichar had been proven to produce taller plants, a greater quantity of nodules per plant, the number of developed pods, and the longest pods with a higher number of seeds, hence the heaviest seed per sampling area. Therefore, this attribute practice in mung bean production is an ideal and potential practice for farmers.

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Recommendations

Based on the study's results, the application of 30-10-20 NPK at 1 $ha^{-1,}$ plus 1.5 Vermi-char, is recommended for the dry season of planting. Likewise, treatments using 30-10-20 NPK ha^{-1} plus 1.5 Vermi-char are recommended due to their potential for the highest yield per hectare.

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