International Journal of Sustainability and Advanced Integrated Research
Volume 2, Issue 2 (April-June 2026) | ISSN: 3107-7854
DOI: https://doi.org/10.65339/ijsair.V2.I2.297

Leveraging Rice Crop Manager through Application of Biofertilizers in Rice Production in Isabela

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Publication history: Received: April 7, 2026; Revised: April 20, 2026; Accepted: April 25, 2026
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Abstract

This study evaluated the combined effects of Rice Crop Manager (RCM) fertilizer recommendations and biofertilizers (EMAS and BioPrime) on rice growth, yield, soil fertility, profitability, and farmer adoption in Isabela, Philippines. Anchored on Site-Specific Nutrient Management (SSNM) and Integrated Nutrient Management (INM), the study employed a Randomized Complete Block Design with seven treatments and three replications, alongside a descriptive survey of 186 rice farmers. Agronomic data, soil properties, and economic indicators were measured, while a structured questionnaire assessed awareness, adoption, and constraints. Results showed that most growth parameters did not significantly differ among treatments, while root length and unfilled grains were significantly improved by biofertilizer application. Grain yield was highest under RCM-only treatments, particularly at 100% and 75% rates, while biofertilizer treatments showed moderate performance but did not surpass RCM alone. Economic analysis revealed that 75% RCM produced the highest return on investment, indicating cost efficiency without yield loss. Soil analysis showed improved phosphorus availability and stable soil fertility across treatments. Socioeconomic findings indicated high awareness but moderate adoption of RCM and low use of biofertilizers, constrained by cost, knowledge gaps, and accessibility issues. The study concludes that RCM remains the most effective and economically viable nutrient management strategy, while biofertilizers offer complementary benefits for root development and grain filling but require long-term evaluation. This study contributes to SDG 2 (Zero Hunger), SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action) by promoting efficient nutrient management and sustainable agricultural practices. Its sustainability impact lies in improving farmer profitability, enhancing soil health, and supporting environmentally responsible rice production systems.

Keywords: Biofertilizers; Grain yield; Rice Crop Manager; Soil fertility; Sustainable agriculture; Technology adoption

1. Introduction

Rice remains central to food security and agricultural livelihoods in the Philippines, yet increasing demand requires improved productivity, efficient fertilizer use, and sustainable soil management. The integration of precision tools such as the Rice Crop Manager (RCM) and biological inputs like biofertilizers offers a promising approach to optimize nutrient management, enhance yields, and sustain soil health. However, adoption challenges and limited empirical evidence on their combined effects under local conditions necessitate further investigation, particularly in major rice-producing regions such as Isabela.

1.1 Background of the Study on RCM and Biofertilizer Integration in Rice Production

Rice is a staple food for Filipinos and a major contributor to national food security and income. However, productivity is constrained by inefficient fertilizer use and declining soil fertility. Fertilizer mismanagement leads to reduced profitability and environmental degradation. The Rice Crop Manager (RCM), developed by IRRI and supported by the Department of Agriculture, provides site-specific nutrient recommendations to improve fertilizer efficiency and yields. Reported benefits include yield increases of 300–500 kg/ha and improved nutrient-use efficiency. Biofertilizers such as EMAS and BioPrime enhance soil biological activity, nutrient uptake, and plant vigor. Despite their potential, adoption remains limited due to knowledge gaps, inconsistent results, and cost concerns. Meanwhile, Region 02 faces declining soil fertility and minimal yield gains (0.04–0.29 mt/ha), partly due to poor nutrient management and reduced seed vigor, contributing to yield losses (Shenoy et al., 1988).

1.2 Themes and Insights from Related Literature on Nutrient Management, RCM, and Biofertilizers

Efficient nutrient management is critical for rice productivity and profitability (Singh et al. 2008; Marahatta et al. 2017). Site-specific nutrient management (SSNM), operationalized through tools like RCM, improves fertilizer efficiency, reduces environmental impact, and enhances yield (Bhandari et al., 2016; Yadvinder-Singh et al., 2017; Thakur et al., 2020;

Santiago et al., 2016). RCM provides tailored recommendations based on field conditions, resulting in increased yields and reduced fertilizer use (Bhandari et al., 2016). It also supports sustainable agriculture by minimizing nutrient losses and improving soil health (Lal, 2019). Biofertilizers improve nutrient availability through nitrogen fixation, phosphorus solubilization, and microbial activity (Mukherjee et al., 2020; Zhao et al., 2017; Ravi et al., 2019; Salwan et al., 2021). Their application enhances plant growth, yield components, and soil fertility (Kumar et al., 2018; Sharma et al., 2019; Ravi et al., 2020; Diedhiou et al., 2016). They also reduce reliance on chemical fertilizers and environmental impacts (Sharma et al., 2020; Suhag, 2016). Combined use of RCM and biofertilizers shows synergistic effects, improving nutrient efficiency, yield, and profitability (Ghosh et al., 2021; Kumar et al., 2021; Thakur et al., 2020). Additionally, biofertilizers enhance soil microbial activity, organic carbon, and resilience (Sivaprasad et al., 2016; Pandey et al., 2018).

1.3 Local, National, and Global Context of Rice Productivity and Soil Fertility

Globally, rice provides nearly half of caloric intake for a significant portion of the population, and the Philippines contributes about 3% of global production. Nationally, rice consumption exceeds 110 kg per capita annually, emphasizing its importance. In Region 02, a major rice-producing area with 345,874.53 hectares, declining soil fertility and limited yield improvements highlight the need for improved nutrient management strategies. National initiatives such as the National Soil Health Program aim to restore soil productivity and promote sustainable agriculture.

1.4 Theoretical or Conceptual Basis of Integrated Nutrient Management Using RCM and Biofertilizers

This study is grounded in Site-Specific Nutrient Management (SSNM), which optimizes fertilizer application based on crop needs and field conditions. RCM operationalizes SSNM by delivering precise nutrient recommendations through digital tools. Biofertilizers complement this approach by enhancing biological nutrient cycling, improving root development, and increasing nutrient uptake efficiency. Their integration supports Integrated Nutrient Management (INM), combining chemical and biological inputs to sustain soil fertility and productivity (Lal, 2019).

1.5 Research Gaps and Rationale for Studying RCM and Biofertilizer Integration in Isabela

Despite evidence supporting RCM and biofertilizers individually, their combined agronomic and economic effects remain underexplored under local field conditions in Isabela. Adoption barriers, including limited knowledge, inconsistent results, and lack of access to technologies, further highlight the need for empirical validation. This study addresses these gaps by evaluating the combined effects of RCM and biofertilizers on rice growth, yield, soil properties, and economic returns, while also identifying adoption constraints among farmers.

1.6 Alignment with Relevant Sustainable Development Goals (SDGs)

This study aligns with multiple Sustainable Development Goals by promoting efficient and sustainable rice production systems. It contributes to SDG 2 – Zero Hunger by improving rice yield and ensuring food security through optimized nutrient management. It supports SDG 8 – Decent Work and Economic Growth by enhancing farmer profitability through reduced input costs and increased returns. The study also addresses SDG 12 – Responsible Consumption and Production by encouraging efficient fertilizer use and minimizing waste and environmental degradation. Furthermore, it contributes to SDG 13 – Climate Action by reducing greenhouse gas emissions and nutrient losses associated with excessive fertilizer application (Bhandari et al., 2016; Sharma et al., 2020). These alignments highlight the role of integrating RCM and biofertilizers in advancing sustainable, climate-resilient, and economically viable agricultural practices.

1.7 Importance of the Study to Multidisciplinary Sustainability

The study contributes to socio-economic sustainability by improving farmer income and reducing production costs. It supports environmental sustainability by minimizing chemical fertilizer use, enhancing soil health, and reducing pollution. It advances agricultural and technological sustainability through the use of digital decision-support tools like RCM and biologically based inputs such as biofertilizers. Additionally, it promotes community and institutional sustainability by providing evidence for extension programs, policy development, and sustainable farming practices. Overall, the integration of RCM and biofertilizers supports resilient, productive, and sustainable rice farming systems in the Philippines.

2. Material and methods

2.1 Research Design

The study utilized an experimental design for the agronomic component and a descriptive survey design for the adoption assessment. A Randomized Complete Block Design (RCBD) was applied in the field experiment with seven treatments and three replications to evaluate the effects of different combinations of RCM fertilizer recommendations and biofertilizers on rice growth, yield, and soil properties. The second component employed a structured survey to assess farmers' awareness, adoption, and challenges related to RCM and biofertilizers.

2.2 Locale of the Study

The field experiment was conducted in Barangay Minagbag, Quezon, Isabela during the 2024–2025 dry season, an area representative of irrigated lowland rice production. Soil samples were analyzed at the Ilagan Soils Laboratory in San Felipe, City of Ilagan, Isabela. The survey component was carried out in Roxas, Isabela, particularly among farmers affiliated with the Learning Site for Agriculture (LSA) of the Agricultural Training Institute.

2.3 Respondents of the Study

The respondents for the survey component consisted of 186 rice farmers selected from the Learning Site for Agriculture in Roxas, Isabela. These farmers were actively engaged in rice production and had exposure to RCM deployment and biofertilizer demonstration projects, making them suitable for assessing adoption behavior and constraints.

2.4 Sample and Sampling Procedure

The experimental component covered a total area of 918 square meters, divided into plots measuring 4 m × 5 m with appropriate spacing between plots and blocks to prevent treatment interference. Seven treatments were randomly assigned and replicated three times under RCBD. These treatments included different levels of RCM fertilizer recommendations (100% and 75%) combined with biofertilizers (EMAS and BioPrime), as well as a soil laboratory-based recommendation as control. For the survey, respondents were selected using a random sampling method from the LSA farmer population. This ensured representation of farmers who had varying levels of exposure to RCM and biofertilizer technologies.

2.5 Research Instrument

The study used both field measurements and a structured questionnaire as research instruments. For the experimental component, agronomic and soil parameters were measured, including plant height, root length, productive tillers, filled and unfilled grains per panicle, 1000-grain weight, and grain yield. Soil properties such as pH, organic matter, and nutrient content were analyzed before and after the experiment. Economic performance was evaluated through cost and return analysis, including net income and return on investment. For the survey component, a structured questionnaire was developed to collect data on socio-demographic characteristics, awareness and adoption of RCM and biofertilizers, perceived benefits, challenges, and sources of information. The instrument was reviewed by experts and approved by the Institutional Research Ethics Board to ensure validity and ethical compliance.

2.6 Data Gathering Procedure

In the experimental component, seeds of NSIC Rc222 were procured from an accredited seed producer, while biofertilizers were obtained directly from manufacturers to ensure viability. Soil samples were collected from multiple points within the experimental area, air-dried, and analyzed in the laboratory. RCM recommendations were generated through farmer interviews using the RCM Advisory Service, producing site-specific fertilizer guidelines. Field preparation involved land clearing, plowing, harrowing, and leveling. Seeds were soaked, incubated, and sown using the wet bed method, followed by transplanting at recommended spacing. Fertilizers were applied according to RCM recommendations, while biofertilizers were applied at planting and mid-growth stages. Standard crop management practices, including irrigation, weed control, and pest management, were implemented throughout the growing period. Harvesting was conducted at physiological maturity, and yield data were recorded per plot. For the survey component, data were collected through face-to-face interviews using pre-tested questionnaires administered by trained enumerators. Participants were informed of the study objectives, provided consent, and were assured of confidentiality. Interviews lasted approximately 15 minutes, with clarifications provided when necessary.

2.7 Data Analysis Techniques

The experimental data were analyzed using Analysis of Variance (ANOVA) under RCBD through the Statistical Tool for Agricultural Research (STAR). Treatment means were compared using Tukey's Honestly Significant Difference (HSD) test. Economic analysis included computation of net income, return on investment, and marginal benefit-cost ratio (MBCR). Survey data were processed through coding and encoding in spreadsheet format, and analyzed using descriptive statistics such as frequencies and percentages to summarize farmers' responses regarding adoption and challenges of RCM and biofertilizer technologies.

3. Results and Discussion

3.1 Agronomic and Yield Performance under RCM and Biofertilizer Integration

3.1.1 Plant Height

Plant height across treatments ranged from 103.1 cm to 107.67 cm, with the highest value observed in the 100% RCM treatment and the lowest in the reduced RCM with EMAS treatment. Other treatments showed comparable values, and statistical analysis indicated no significant differences among treatments. The uniformity in plant height suggests that all treatments supplied sufficient nutrients to support normal vegetative growth. Plant height is largely influenced by genetic factors, and nutrient effects stabilize once optimal levels are reached (Fageria, 2007; Singh et al., 2011). The lack of response to biofertilizers indicates that these inputs primarily affect root development and nutrient efficiency rather than aboveground growth when soil fertility is adequate (Vessey, 2003; Banayo et al., 2012; Khan et al., 2018).

3.1.2 Root Length

Root length varied significantly among treatments, with the longest roots recorded under 100% RCM combined with EMAS, while the shortest roots were observed in RCM-only and soil-based recommendations. Biofertilizer treatments generally produced longer roots compared to non-biofertilizer treatments. This result indicates that biofertilizers enhanced root development through microbial activity that improves nutrient uptake and root growth. The findings support previous studies showing that microbial inoculants stimulate root elongation and nutrient absorption (Banayo et al., 2012; Khan et al., 2018; Corales, 2006). Biofertilizers are known to promote plant-growth processes through beneficial microorganisms, resulting in improved belowground development even when nutrient supply is adequate.

3.1.3 Productive Tillers per Hill

The number of productive tillers ranged from 15.63 to 17.47, with the highest values observed in the 75% RCM treatment and soil laboratory-based recommendations. Biofertilizer treatments showed slightly lower tiller numbers, and differences were not statistically significant. The results suggest that moderate fertilizer levels can optimize tillering, consistent with findings that excessive nitrogen may reduce efficiency (Witt et al., 2007). The lower tiller counts in biofertilizer treatments may be due to the gradual nutrient release of microbial inputs, which influence root development more than early vegetative growth (Vessey, 2003; Singh et al., 2016). This supports earlier findings that biofertilizers may not significantly increase tiller production when nutrients are already sufficient (Banayo et al., 2012).

3.1.4 Panicle Length

Panicle length ranged from 25.86 cm to 27.25 cm, with the longest panicles observed under full RCM and soil laboratory recommendations. Biofertilizer treatments produced slightly shorter panicles, and no significant differences were detected. This indicates that panicle length is primarily influenced by adequate macronutrient supply rather than microbial inputs. Balanced NPK nutrition plays a key role in reproductive development (Fageria et al., 2011), while biofertilizers mainly support long-term nutrient cycling (Vessey, 2003; Singh et al., 2016). The results confirm that panicle development stabilizes once nutrient requirements are met (Dobermann and Fairhurst, 2000).

3.1.5 Filled Grains per Panicle

The number of filled grains ranged from 102.30 to 135.20, with the highest values observed in treatments combining 100% RCM with biofertilizers, particularly BioPrime. However, differences among treatments were not statistically significant. The trend suggests that biofertilizers enhance grain filling by improving nutrient uptake and microbial activity. This supports findings that integrated nutrient management increases grain formation through improved nitrogen and phosphorus availability (Mahato et al., 2017; Verma et al., 2019). The superior performance of BioPrime may be linked to plant growth-promoting rhizobacteria that enhance physiological processes during grain formation (Dobbelaere et al., 2003; Singh et al., 2020).

3.1.6 Unfilled Grains per Panicle

The number of unfilled grains differed significantly among treatments, with biofertilizer treatments generally showing lower values compared to RCM-only treatments. This indicates that biofertilizers improved spikelet fertility by enhancing nutrient uptake, particularly nitrogen and phosphorus, which are critical for grain filling (Mahanty et al., 2017; Shukla et al., 2020). Higher unfilled grain counts in non-biofertilizer treatments may be attributed to nutrient deficiencies during reproductive stages (Fageria, 2014). These findings confirm that biofertilizers can reduce grain sterility and improve yield components (Vessey, 2003; Egamberdieva et al., 2017).

3.1.7 Thousand-Grain Weight

Thousand-grain weight ranged from 30 g to 34 g, with minimal variation among treatments and no significant differences observed. This suggests that grain weight is a stable trait largely determined by genetics and environmental conditions rather than nutrient management. Previous studies confirm that grain weight is less responsive to fertilizer inputs compared to other yield components (Buresh et al., 2019; Banayo et al., 2012; Khan et al., 2018; Sahoo et al., 2014).

3.1.8 Grain Yield

Grain yield ranged from 8,820 to 10,466.67 kg/ha, with the highest yield recorded under 100% RCM and the lowest under reduced RCM with EMAS. Significant differences were observed among treatments. The results demonstrate that full RCM recommendations maximize yield due to balanced and site-specific nutrient supply. Biofertilizers did not significantly increase yield beyond RCM alone, indicating limited additional effects under optimal fertilization. These findings align with studies showing that RCM improves yield efficiency (Buresh et al., 2019), while biofertilizers provide greater benefits under nutrient-limited conditions (Banayo et al., 2012; Khan et al., 2018; Sahoo et al., 2014).

3.2 Economic and Soil Fertility Outcomes

Economic analysis revealed that the 75% RCM treatment produced the highest return on investment, followed by the 100% RCM treatment, indicating that reduced fertilizer rates can maintain profitability while lowering costs. Biofertilizer treatments incurred additional expenses that reduced overall economic returns, and marginal benefit-cost analysis showed that no treatment exceeded the economic efficiency of RCM alone. Soil analysis showed that initial conditions were moderately acidic with moderate organic matter, low phosphorus, and sufficient potassium. After the experiment, soil pH remained stable, organic matter slightly increased, phosphorus availability improved significantly, and potassium levels remained adequate. These changes indicate that nutrient management practices maintained or enhanced soil fertility without degradation. These findings support the role of balanced nutrient management in sustaining soil health and productivity (Dobermann & Fairhurst, 2000; Fageria, 2007; Buresh et al., 2019). Biofertilizers contributed to improvements in organic matter and nutrient cycling through enhanced microbial activity (Vessey, 2003; Sahoo et al., 2014).

3.3 Socioeconomic Characteristics and Technology Adoption

The respondents were predominantly older farmers with an average age of 56, moderate education levels, and small farm sizes averaging 1.63 hectares. Awareness of RCM was relatively high at 64%, but adoption was lower at 47%, while biofertilizer use was very low at 16%. The gap between awareness and adoption reflects common barriers such as risk perception, limited knowledge, and access constraints (Feder and Umali, 1993). Older farmers and smaller landholdings may reduce willingness to adopt new technologies (Tabbal and Lamban, 2019; Doye et al., 2017; Liu et al., 2018). Limited education also affects the ability to utilize digital tools and evaluate innovations (Rogers, 2003; Mwalupaso et al., 2021). Farmers who adopted biofertilizers reported benefits such as improved crop quality, cost savings, and increased resistance to pests and diseases, consistent with findings on improved nutrient uptake and soil health (Vessey, 2003; Wu et al., 2005). However, adoption remained constrained by high costs, lack of knowledge, limited availability, and insufficient government support (Marenya and Barrett, 2007; Ndlovu et al., 2021). Information was primarily obtained through extension programs, and farmers showed strong reliance on peer influence and institutional trust, highlighting the importance of extension services in technology dissemination (Anderson and Feder, 2007; Rogers, 2003). Future adoption intentions remained mixed, indicating that sustained support, affordability, and consistent results are necessary to improve long-term adoption (Buresh et al., 2019).

4. Conclusion and Recommendations

The study demonstrated that integrating Rice Crop Manager (RCM) recommendations with biofertilizers improved certain physiological traits of rice, particularly root development and reduction of unfilled grains, indicating enhanced nutrient uptake and reproductive efficiency; however, most growth parameters showed no significant differences among treatments. Grain yield was highest under RCM-only treatments, confirming that both 100% and 75% RCM rates effectively optimized nutrient supply and crop performance. Economic analysis further revealed that the 75% RCM treatment was the most cost-efficient, providing the highest return on investment while maintaining yield levels. Although biofertilizers contributed to improved root growth and grain filling, these benefits did not translate into higher yield or profitability within a single cropping season. Additionally, farmer adoption of RCM and biofertilizers remained moderate to low due to constraints related to cost, knowledge, and accessibility, despite awareness of their potential benefits.

It is recommended that farmers adopt 100% or 75% RCM as primary fertilizer strategies to maximize yield and profitability while using biofertilizers as complementary inputs to improve root vigor and reduce unfilled grains, particularly in areas with declining soil fertility. Proper and consistent application of biofertilizers should be emphasized to achieve long-term benefits. Extension workers and local government units should strengthen training programs, promote RCM as a standard nutrient management tool, and improve access to biofertilizers through partnerships and demonstration farms. Policymakers should consider developing support programs to reduce cost barriers, enhance availability, and integrate biofertilizers into broader soil health initiatives. Further research is encouraged to evaluate long-term impacts, optimize combinations of RCM and biofertilizers, and assess additional grain quality parameters.

The study was limited to a single cropping season and one experimental location, which may restrict the generalizability of the findings across varying environmental conditions, soil types, and management systems. The short duration also limited the ability to capture the long-term cumulative effects of biofertilizers on soil fertility, yield stability, and economic returns. Additionally, the study focused on selected agronomic and economic parameters and did not include postharvest grain quality assessment or interactions with other agronomic practices such as pest and water management, which may influence overall crop performance.

Compliance with ethical standards

The authors declare no conflict of interest, and no external funding was received for this study. The research was conducted with voluntary participation of rice farmers, with informed consent obtained prior to data collection, and with approval from the Institutional Research Ethics Board. Data were gathered using non-invasive methods, including field measurements and structured interviews, and all information was treated with strict confidentiality, ensuring that no identifying details of participants were disclosed. The authors acknowledge the cooperation of the farmer respondents and the support of the Agricultural Training Institute and related institutions involved in the study.

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