JUATIKA
JURNAL AGRONOMI TANAMAN TROPIKA
VOL. 8 No. 2 May 2026
DOI :https://doi.org/10.36378/juatika.v8i2.5940
eissn 2656-1727
pissn 2684-785X
pages : 626 – 633

REVIEW ARTICLE Open Access

Response of Rice (*Oryza sativa* L.) Growth and Productivity to the Combination of Cow Manure and Biofertilizer in Lebak Rice Fields

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Abstract

Lowland rice fields are suboptimal land with high acidity constraints and limited nutrient availability, thus requiring an appropriate and sustainable fertilization approach. These conditions make rice a commodity that requires special attention in nutrient management, considering that rice is the main food crop cultivated in lowland swamps but is sensitive to Fe and Al toxicity and nutrient deficiencies in acidic soil conditions. This study aims to examine the growth and productivity response of rice (*Oryza sativa* L.) to a combination of cow dung manure and biofertilizer in lowland rice fields. The study was conducted in Petar Village, Sungai Rotan District, Muara Enim Regency, South Sumatra Province, using a non-factorial Randomized Block Design (RBD) with five treatments and five replications, namely: no treatment, 100% recommended fertilizer dose, cow dung manure, cow dung manure + ½ recommended fertilizer dose, and biofertilizer + ½ recommended fertilizer dose. The parameters observed included plant height, total number of tillers, productive tillers, panicle length, number of full grains, full grain weight, root length, and productivity (tons/ha). Data were analyzed using ANOVA at the 5% level and continued with Tukey's test. The results showed that the treatment of cow dung manure + ½ dose of recommended fertilizer consistently produced the best values in all growth and productivity parameters, with the highest grain yield of 5.34 tons/ha, significantly different from all other treatments. The treatment of biofertilizer + ½ dose of recommended fertilizer produced a productivity of 4.88 tons/ha and ranked second best. The integration of organic materials and biofertilizers with reduced doses of inorganic fertilizers proved to be more efficient than the use of full doses of inorganic fertilizers alone in increasing rice growth and productivity in lowland rice fields.

Keywords: Dry Milled Grain, Fertilization Efficiency, Inorganic Dosage, Soil Acidity, Suboptimal Land

1. Introduction

Rice (*Oryza sativa* L.) is a strategic food commodity that serves as the primary source of carbohydrates for more than 90% of Indonesia's population. Rice plays a strategic role as a staple food source, but lowland rice productivity in various regions still faces various challenges that affect harvest yields and the sustainability of farming (Sulaminingsih et al., 2024). National rice production in 2023 decreased by 2.05% to 53.63 million tons of dry milled grain (GKG) compared to 2022, which reached 54.75 million tons of GKG (Laksmi & Nurdin, 2024). This condition requires serious efforts to optimize the utilization of various types of agricultural land, including lowland rice fields, which have not been optimally utilized.

Lowland swampland is a type of suboptimal land that has great potential for food agriculture development in Indonesia. Indonesia's lowland swampland covers 9.2 million hectares, spread primarily across Sumatra, Kalimantan, and Papua, and is part of the suboptimal land with great potential for agricultural development (Sulaiman et al., 2019). However, the utilization of this land is still limited due to various technical constraints. The main problem in lowland swampland rice fields is the high water levels during the rainy season, which cause rice plants to be

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submerged, while during the dry season the soil becomes dry and hard, posing challenges for farmers in managing the land (Datta et al., 2017). Furthermore, lowland rice fields are generally characterized by high levels of soil acidity, low to moderate organic matter content, and suboptimal nutrient availability for rice plant growth (Reis et al., 2019).

Quantitatively, these constraints lead to low cropping intensity and productivity in lowland swamps. Rice cropping intensity in lowland swamps generally occurs only once a year (IP 100), even though this cropping index has the potential to be increased to two plantings per year (IP 200) if hydrological constraints can be managed properly. However, implementing IP 200 in lowland swamps still faces various obstacles and has not been widely adopted by farmers, indicating that technical limitations in water management have not been fully overcome even though technology to increase the cropping index is available. This condition is in line with the characteristics of swamp agroecosystems in general, which are marginal with relatively low productivity levels compared to irrigated rice fields. As an illustration of the actual potential that can be achieved, superior varieties that have adapted to lowland swamp conditions, such as Inpara 3 which is tolerant to Fe and Al poisoning, can produce productivity of up to 5.6 tons/ha of dry milled grain, but this achievement is far from optimal when compared to technical irrigated rice fields, so that this yield gap is a measurable indicator of the magnitude of the impact of technical constraints on lowland land.

Efforts to increase rice productivity in lowland rice fields have relied heavily on the intensive use of inorganic fertilizers. While inorganic fertilizers can provide nutrients quickly and increase yields in the short term, excessive and continuous use has been shown to reduce soil quality and fertility in the long term (Yakup et al., 2024). Reliance on chemical fertilizers also leads to degradation of soil biological activity and increased production costs, burdening farmers. Therefore, a more sustainable fertilization approach is needed, integrating organic matter and biofertilizers into lowland rice cultivation systems.

Cow manure is a source of organic matter proven to improve the physical, chemical, and biological properties of soil while increasing plant productivity. Goldan et al. (2023) stated that adding manure aims to improve the physical, chemical, and biological properties of soil and increase nutrients, because manure can improve soil structure, increase porosity, aeration, drainage, and soil microorganism activity. Peng et al. (2023) reported that the use of cow manure in organic rice cultivation significantly increased plant growth and yield by increasing nutrient availability and improving soil structure. Furthermore, the combination of organic and inorganic fertilizers has been shown to optimize rice production by utilizing the advantages of each type of fertilizer and minimizing its weaknesses (Anisuzzaman et al., 2021).

Besides manure, biofertilizer is an innovative fertilizer technology that contains living microorganisms and can stimulate plant growth by increasing the availability of soil nutrients. (Setiawati et al., (2023). reported that biofertilizer based on growth-promoting bacteria was proven to be able to improve the nutrient content of acidic soil and increase the growth and production of both lowland rice and upland rice. Hazra and Santosa (2022) stated that the application of liquid biofertilizer in the field generally resulted in better growth and yield of lowland rice plants compared to the control treatment, with a combination of 0.75 doses of NPK and 1.00 doses of biofertilizer being the most agronomically effective treatment with an R/C value of 1.83. (Setiawati et al., 2026) also reported that the use of solid biofertilizer had a significant effect on plant N and P absorption and the yield components of lowland rice. Furthermore, Sun et al. (2020) stated that *Bacillus sp.* biofertilizer was able to reduce the use of N fertilizer by 25–50% without reducing lowland rice yields, so it has great potential to be applied in cultivation systems that prioritize input efficiency.

Research integrating cow manure and biofertilizer in combination in lowland rice fields is still very limited. Previous studies generally only examined one aspect separately: the combination of cow manure and inorganic fertilizers on rice in irrigated rice fields, the combination of cow manure and other organic sources (such as green manure or *Azolla*) for nutrient uptake in technically irrigated fields, or the application of biofertilizers in lowland rice fields but on soybeans, not rice. No research has been found that specifically combines cow manure and biofertilizers simultaneously on rice plants in lowland rice ecosystems. Therefore, this study offers a novelty in integrating these two organic nutrient sources, while also deepening information on the growth and productivity responses of rice to this combination in lowland rice fields.

2. Material and Methods

This research was conducted in Petar Village, Sungai Rotan District, Muara Enim Regency, South Sumatra Province, with coordinates 3°10'00.6"S 104°15'03.5"E, and the research location can be seen in Figure 1. The experimental design used was a single or non-factorial Completely Randomized Design (RAK) consisting of 5 treatment levels, namely: Control /without fertilizer (P1), using a recommended fertilizer dose of 100% (P2), Cow dung fertilizer (P3), Cow dung fertilizer + ½ recommended fertilizer dose (P4), Biofertilizer + ½ recommended fertilizer dose (P5) and repeated 5 times, so there were 25 experimental plots. In one experimental plot, five plant samples were planted using a bucket weighing 10 kg, so there were 125 rice plants. The research flow diagram is shown in Figure 2.

Figure 1. Research location of Lebak Swamp Land, Petar Dalam Village.

2.1. Work procedures

The study began with taking soil samples at 5 points using a soil drill, composited, and then analyzed in the laboratory to determine the soil fertility status, including texture, pH, total N, total P, and total K as the basis for determining fertilizer doses. The planting medium used 12-liter plastic buckets with holes at a height of 20 cm and filled with 10 kg of lowland rice field mineral soil per bucket. Seedlings were prepared in Experiment 1 to select the best varieties and treatments, which were then applied in Experiment 2. Fertilization was carried out before planting directly in the planting hole with a dose of Urea 300 kg/ha, TSP 100 kg/ha, and KCl 100 kg/ha, where TSP and KCl were given simultaneously at planting, while Urea was given twice, namely half the dose at planting and the rest at 30 HST. Maintenance included manual weeding three times and controlling rat pests using black plastic fences, bird pests with protective nets, and brown plant hopper pests with insecticides. Harvesting is carried out when the plants reach physiological maturity, with the criteria of grain moisture content of 21–26%, age 30–35 days after flowering, and 90–95% of the grain is yellow.

The parameters observed included initial soil chemical content, periodic plant growth at 2–8 WAP including plant height, total number of tillers, and productive tillers, as well as yield components in the form of panicle length, number of full and empty grains per panicle, productivity (tons/ha), and weight of full grains per clump at 14% moisture content. Root length was measured in the generative phase (8 WAP), and daily climate data in the form of rainfall, temperature, light intensity, and air humidity were obtained through the NASA Power DAV website.

2.2. Data analysis

The data obtained from the experimental results were then analyzed using *analysis of variance* (ANOVA) at a 5% level and continued with a further *Honestly Significant Difference* (HSD) test or Tukey test at a 5% level, to determine which treatments were statistically different. Data processing used SAS software version 9.0 and Microsoft Excel 2016. The *Pearson correlation test was* used with Minitab software version 22.

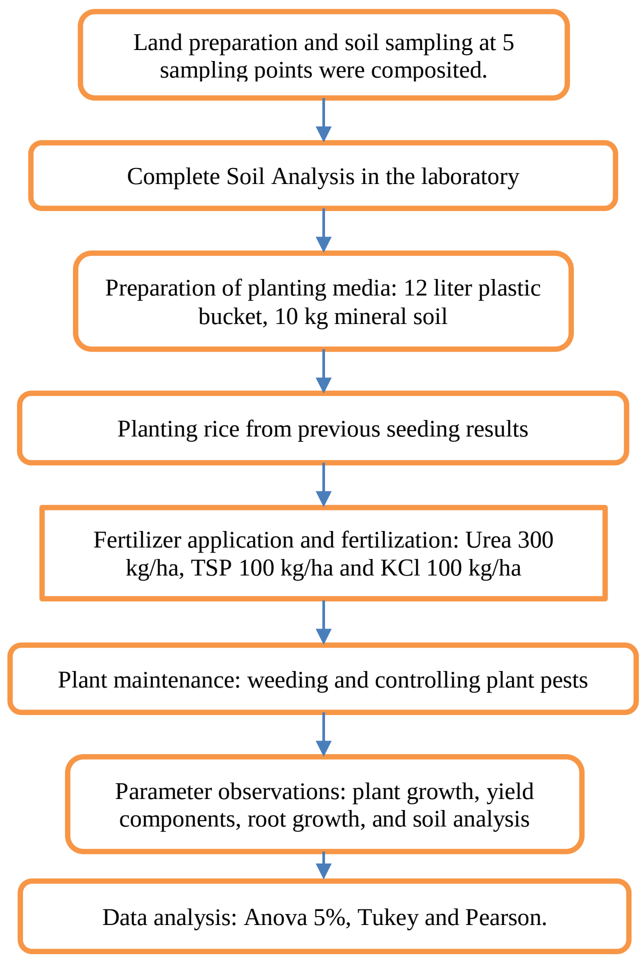

Figure 2. Research Flow Diagram.

3. Results and Discussion

3.1. Preliminary Soil Analysis Research

Initial soil analysis results showed that the soil had a very acidic reaction with a pH of 4.41 in H_2O and a pH of 3.76 KCl, which is typical of Ultisol soils in humid tropical regions. This acidic condition causes high levels of Al-dd (5.18 cmol(+)/kg), which is phytotoxic, and very high Fe content (373.02 ppm), which has the potential to poison plants. Although the CEC is relatively high (26.14 cmol(+)/kg), the base saturation of only 14.72% indicates that the adsorption complex is dominated by Al^{3+} and H^+, not productive base cations. The organic C content is very high (3.25%), but the C/N ratio of around 14.8 indicates slow mineralization of organic matter due to inhibition of microbial activity under acidic conditions, so that the total N is only in the moderate category of 0.22% (Jia et al., 2025).

Table 1. Chemical and Physical Properties of Initial Research Soil.

Parameter	Results	Criteria
pH_{H2O}	4.41	Very Sour
pH of KCl	3.76	Very Sour
C-Organic (%)	3.25	Very high
N-Total (%)	0.22	Currently
P_2O_5 Bray I (ppm)	27.06	Very high
K (cmol(+) kg^{-1})	0.29	Low
CEC (cmol(+) kg^{-1})	26.14	Tall
Saturated base (%)	14.72	Low
Al-dd (cmol(+) kg^{-1})	5.18	Tall
Fe (ppm)	373.02	Very high
Cu	1.36	Low
Zn	1.32	Low
M N	5.28	Low
Soil Texture:		
a. Sand (%)	25.17	-
b. Clay (%)	42.25	-
c. Clay (%)	19.13	Silty Clay

Description: Based on Balittanah Criteria (2005).

The very high availability of P_2O_5 (27.06 ppm) does not reflect the actual availability of P for plants, because at acidic pH phosphate tends to be fixed by Al^{3+} and Fe^{3+}. The low K content (0.29 cmol(+)/kg) and the low levels of the analyzed micronutrients Cu (1.36 ppm), Zn (1.32 ppm), and Mn (5.28 ppm) are suspected to be due to intensive leaching and sorption competition with Al^{3+}. The texture of silty clay soil with a composition of 25.17% sand, 42.25% clay, and 19.13% clay is actually quite good for agriculture, but all the chemical constraints above make liming using dolomite a top priority for soil improvement to suppress Al-dd, increase pH to the range of 5.5–6.0, and optimize nutrient availability for plants, combined with K, Zn fertilization, and mature compost application (Cinta et al., 2024).

3.2. Weather conditions at the research location

Weather conditions during the study period (November 2025 – February 2026) indicated a relatively stable humid tropical climate. Maximum temperatures ranged from 31.0–31.8°C and minimum temperatures between 23.1–23.6°C, with a consistent monthly average temperature of 27.2–27.7°C. This temperature range is considered optimal for the growth of most tropical cultivated plants, given that the ideal temperature for photosynthesis and plant metabolism is generally 25–30°C (Dusenge et al., 2019). High and stable relative humidity ranging from 85.3–88.1% indicates a water vapor-saturated atmosphere, which has implications for increasing the risk of fungal and bacterial plant diseases, while also suppressing the rate of evapotranspiration.

Monthly rainfall during the study period ranged from 172.8–218.5 mm/month with a daily intensity of 6.17–7.05 mm/day, which is classified as a wet month based on the Schmidt-Ferguson classification (rainfall > 100 mm/month). The highest rainfall occurred in December (218.5 mm) and the lowest in February (172.8 mm), but overall water availability during the study period was considered sufficient for plant water needs without significant deficits. However, the relatively high rainfall intensity on silty clay soil with acidic conditions has the potential to accelerate the leaching of base cations and worsen soil acidity if not managed properly.

3.3. Rice Plant Growth Parameters

The statistical analysis results showed that all fertilization treatments significantly affected plant height, total tillers, and the number of productive tillers compared to no treatment ($p < 0.05$). The combination treatment of cow dung manure with half the recommended fertilizer dose resulted in the highest plant height (101 cm) and the highest total tillers (21.2 tillers), significantly different from all other treatments. Similar results were shown by the biofertilizer treatment with half the recommended fertilizer dose (99 cm; 20.2 tillers), which was not significantly different from the manure combination, but both consistently outperformed the 100% recommended fertilizer dose treatment alone (89 cm; 15.2 tillers) or no treatment (79 cm; 12.2 tillers). This result indicates that integrating organic matter or biofertilizer with low-dose inorganic fertilizer can optimize plant vegetative growth more efficiently than using full-dose inorganic fertilizer alone, which is in line with the concept of balanced fertilization to increase nutrient uptake efficiency (Barłóg et al., 2022).

Table 2. Weather conditions at the research location in November 2025 – February 2026.

Weather parameters	November	December	January	February
T Max (°C)	31.8	31.2	31.0	31.5
T Min (°C)	23.6	23.2	23.1	23.4
Average Temperature (°C)	27.7	27.2	27.5	27.4
Relative Humidity (%)	85.3	87.6	88.1	86.4
Rainfall (mm/month)	189.2	218.5	203.7	172.8
Rainfall (mm/day)	6.31	7.05	6.57	6.17

Source: NASA Power (2026).

In terms of productive tillers, the combination treatment of cow manure and half the recommended dose of fertilizer again produced the highest value (11.8 tillers) and was significantly different from the untreated treatment (9.2 tillers), but not significantly different from the single manure treatment (10.6 tillers) or the biofertilizer treatment with half the recommended dose of fertilizer (10.8 tillers). Interestingly, although the total tillers in the single manure treatment were lower than in the two combination treatments, the conversion of total tillers to productive tillers was relatively insignificant, indicating that the availability of soil organic matter more influences the quality of tiller growth than quantity alone. The role of organic matter in improving the chemical properties of acidic soils, increasing nutrient availability, and supporting soil biological activity are key factor explaining the superiority of organic-based treatments in this study (Almendros et al., 2025).

Table 3. Parameters of Plant Height, Total Tillers and Productive Tillers

Treatment	Plant Height	Total Offspring	Number of Productive Offspring
No Treatment	79±3.21d	12.2±0.35d	9.2±0.32c
100% Recommended Fertilizer Dosage	89±2.34c	15.2±0.52c	10.0±0.17bc
Cow Manure Fertilizer	96±3.15b	18.2±0.12b	10.6±0.23ab
Cow Manure Fertilizer + 1/2 Recommended Fertilizer Dose	101± 2.61a	21.2±0.46a	11.8±0.37a
Biofertilizer + 1/2 Recommended Fertilizer Dose	99±2.53a	20.2±0.13a	10.8±0.14ab

Note: Numbers followed by the same letter in the same column are not significantly different based on Tukey's test at α= 5%. 6 sample plants represent each experimental unit, and the mean value is followed by the standard error (SE).

3.4. Rice Plant Production Parameters

The results of the analysis of rice yield components showed that all fertilizer treatments significantly affected panicle length, number of full grains, full grain weight, and root length compared to no treatment ($p < 0.05$). The combination treatment of cow dung manure with half the recommended fertilizer dose resulted in the highest panicle length (28.2 cm), the highest number of full grains (142.2 grains), and the highest full grain weight (33.38 g), significantly different from all other treatments except for the parameter of full grains number which was not significantly different from the treatment of biofertilizer + ½ recommended fertilizer dose (141.4 grains). The treatment of biofertilizer + ½ recommended fertilizer dose was the second best in all yield component parameters, and consistently outperformed the treatment of 100% of the recommended fertilizer dose alone or without treatment. The superiority of this organic-based treatment is in line with the role of organic matter in continuously improving nutrient availability during the flowering and grain-filling phases, so that assimilate translocation to the panicle takes place more optimally (Irawan et al., 2024).

Root length as an indicator of nutrient exploration capacity by plants showed a significant gradation across all treatments, with values ranging from 39.40 cm in the untreated treatment to 64.46 cm in the combination treatment of manure + ½ recommended fertilizer dose, followed by biofertilizer + ½ recommended fertilizer dose (59.38 cm), single manure (52.34 cm), and 100% recommended fertilizer dose (42.50 cm). The development of a better root system in the organic and biofertilizer-based treatments is thought to result from improved physical and biological soil properties, including increased porosity, aeration, and rhizosphere microorganism activity that directly stimulates root elongation and branching (Rocha et al., 2024). The deeper and more extensive root system in the best treatment allows plants to explore a larger volume of soil to absorb water and nutrients, which ultimately contributes significantly to increasing yield components and rice productivity in lowland rice fields.

Table 4. Parameters: Panicle length, full grain, grain weight, root length.

Treatment	Panicle Length	Amount of Grainy Rice	Weight of Grain (g)	Root Length (cm)
No Treatment	22.2±2.41d	97.6±12.48d	18.56±2.57e	39.40±5.78e
100% Recommended Fertilizer Dosage	24.2±3.36c	117.6±11.56c	24.50±2.12d	42.50±8.19d
Cow Manure Fertilizer	26.2±2.19b	132.2±9.13b	28.50±3.46c	52.34±7.54c
Cow Manure Fertilizer + 1/2 Recommended Fertilizer Dose	28.2±1.56a	142.2±12.42a	33.38±2.12a	64.46±8.18a
Biofertilizer + 1/2 Recommended Fertilizer Dose	27.2±2.17ab	141.4±14.55a	30.50±2.07b	59.38±9.12b

Note: Numbers followed by the same letter in the same column are not significantly different based on Tukey's test at α= 5%. 6 sample plants represent each experimental unit, and the mean value is followed by the standard error (SE).

3.5. Productivity (Ton/Ha)

Rice productivity as an integrative parameter of the entire growth and yield process showed significant differences among all treatments ($p < 0.05$). The combination treatment of cow dung manure with half the recommended dose of fertilizer resulted in the highest productivity of 5.34 tons/ha, significantly different from all other treatments, followed sequentially by the treatment of biofertilizer + ½ the recommended dose of fertilizer (4.88 tons/ha), single cow dung manure (4.56 tons/ha), 100% recommended dose of fertilizer (3.92 tons/ha), and the lowest was without treatment (2.96 tons/ha). The increase in productivity in the best treatment reached 80.4% compared to no treatment and 36.2% compared to the use of 100% of the single inorganic fertilizer dose, indicating significant agronomic efficiency of the organic-based balanced fertilization approach. These results are in line with the findings of Iqbal et al. (2024), which confirm that the combination of organic and inorganic fertilizers consistently produces higher rice productivity compared to the use of either type of fertilizer alone, because the two types of fertilizer complement each other in providing short-term and long-term nutrients.

Table 5. Productivity parameters (Ton/Ha)

Treatment	Productivity (Ton/Ha)
No Treatment	2.96±0.12d
100% Recommended Fertilizer Dosage	3.92±0.26c
Cow Manure Fertilizer	4.56±0.45bc
Cow Manure Fertilizer + 1/2 Recommended Fertilizer Dose	5.34±0.19a
Biofertilizer + 1/2 Recommended Fertilizer Dose	4.88±0.32b

Note: Numbers followed by the same letter in the same column are not significantly different based on Tukey's test at α= 5%. 6 sample plants represent each experimental unit, and the mean value is followed by the standard error (SE).

A noteworthy aspect is the biofertilizer treatment plus ½ the recommended fertilizer dose, which resulted in a productivity of 4.88 tons/ha, exceeding the 100% single inorganic fertilizer dose (3.92 tons/ha) treatment despite using a lower inorganic dose. This result confirms that biofertilizers can compensate for reduced inorganic inputs through mechanisms such as increased nutrient uptake efficiency, biological nitrogen fixation, and phosphate solubilization by the microorganisms they contain (Xin et al., 2026). Furthermore, the single manure treatment (4.56 tons/ha), which was not significantly different from the biofertilizer treatment plus ½ the recommended fertilizer dose, indicates that the contribution of organic matter to improving soil properties and nutrient availability is quite substantial even without inorganic fertilizer supplementation. Overall, the results of this study demonstrate that a balanced fertilization strategy that integrates organic matter or biological agents with a reduction in inorganic fertilizer doses of up to 50% is a more efficient, economical, and sustainable approach to increasing rice productivity in lowland rice fields.

3.6. Pearson Correlation Analysis

The results of Pearson correlation analysis of eight agronomic parameters of rice plants showed that all pairs of observed variables had a positive and statistically significant relationship ($p < 0.05$), with correlation coefficient (r) values ranging from 0.9286 to 1.0000. This result indicates that an increase in one agronomic parameter is consistently followed by an increase in other parameters, reflecting an integrated plant response to the fertilizer treatment given.

Full grain weight (FW) was recorded to have a perfect correlation with productivity ($r = 1.0000$; $p < 0.01$), which confirms that grain weight is the most determinant yield component in determining the final production level. Panicle length (PL) also showed a very strong correlation with productivity ($r = 0.9964$; $p < 0.01$) and with total tillers ($r = 0.9984$; $p < 0.01$), indicating its strategic role as a link between the vegetative growth phase and the formation of yield components. The number of full grains (FG) was also very closely correlated with plant height ($r = 0.9974$; $p < 0.01$), which indicates that taller plants tend to have greater photosynthetic capacity, thus supporting more optimal grain filling.

Vegetative growth parameters, including plant height (PH), total tillers (TT), and productive tillers (PT), all correlated significantly with productivity (r 0.9930, 0.9925, and 0.9766, respectively; $p < 0.01$), indicating that vegetative vigor is the agronomic foundation that determines crop yield potential. Meanwhile, root length (RL) recorded the lowest correlation value with productivity ($r = 0.9570$; $p < 0.05$), but remained statistically significant. This condition indicates that root system development contributes indirectly to crop yield by increasing the efficiency of water and nutrient absorption from the soil.

Overall, the very strong and even positive correlation pattern among all observed variables confirms that the agronomic response of rice plants to various fertilizer treatments is comprehensive and coordinated. Therefore, treatments that simultaneously optimize vegetative growth, particularly by increasing plant height, tiller number, and panicle length, will have a proportionally positive impact on increasing yield components and overall crop productivity.

Figure 3. Pearson correlation analysis. PH= Plant height, TT= Total Tillers, PT= Productive Tillers, PL=Panicle Length, FG= Filled Grains, GW= Grain Weight, RL=Root Length, PRD= Productivity.

Figure 4. The appearance of rice plants for each treatment from left to right is as follows: control or without fertilizer application (P1), use of 100% of the recommended fertilizer dose (P2), cow dung fertilizer (P3), cow dung fertilizer along with ½ the recommended fertilizer dose (P4), and biofertilizer along with ½ the recommended fertilizer dose (P5).

4. Conclusion

All fertilization treatments significantly affected rice growth and productivity in lowland rice fields compared to no treatment. The combination of cow manure and ½ the recommended fertilizer dose was the best treatment, producing the highest values for all growth parameters and yield components, with a productivity of 5.34 tons/ha. The combination of biofertilizer and ½ the recommended fertilizer dose was also competitive, producing 4.88 tons/ha, surpassing the 100% single inorganic fertilizer treatment (3.92 tons/ha). This result proves that integrating organic matter with a reduction in the inorganic fertilizer dose by up to 50% is more efficient and sustainable than full-dose inorganic fertilization. The combination of cow manure and ½ the recommended fertilizer dose is recommended as the main fertilization strategy for farmers in lowland rice fields, with biofertilizer as an alternative if manure is difficult to obtain.

References

Almendros, G., & González-Pérez, J. A. (2025). Soil organic carbon sequestration mechanisms and the chemical nature of soil organic matter: A review. *Sustainability, 17*(15), 6689. https://doi.org/10.3390/su17156689

Anisuzzaman, M., Rafii, M. Y., Jaafar, N. M., Izan Ramlee, S., Ikbal, M. F., & Haque, M. A. (2021). Effect of organic and inorganic fertilizer on the growth and yield components of traditional and improved rice (*Oryza sativa* L.) genotypes in Malaysia. *Agronomy, 11*(9), 1830. https://doi.org/10.3390/agronomy11091830

Barłóg, P., Grzebisz, W., & Łukowiak, R. (2022). Fertilizers and fertilization strategies mitigating soil factors constraining efficiency of nitrogen in plant production. *Plants, 11*(14), 1855. https://doi.org/10.3390/plants11141855

Cinta, M., & Mulatsih, S. (2024). Pengaruh dosis kapur terhadap pertumbuhan dan hasil tiga varietas kacang hijau (*Vigna radiata* L.). *Jurnal Agroqua: Media Informasi Agronomi dan Budidaya Perairan, 22*(2), 134–140. https://doi.org/10.32663/ja.v22i2.4354

Datta, A., Ullah, H., & Ferdous, Z. (2017). Water management in rice. In T. Sasaki (Ed.), *Rice production worldwide* (pp. 255–277). Springer International Publishing. https://doi.org/10.1007/978-3-319-47516-5_11

Dusenge, M. E., Duarte, A. G., & Way, D. A. (2019). Plant carbon metabolism and climate change: Elevated CO_2 and temperature impacts on photosynthesis, photorespiration and respiration. *New Phytologist, 221*(1), 32–49. https://doi.org/10.1111/nph.15283

Goldan, E., Nedeff, V., Barsan, N., Culea, M., Panainte-Lehadus, M., Mosnegutu, E., & Irimia, O. (2023). Assessment of manure compost used as soil amendment: A review. *Processes, 11*(4), 1167. https://doi.org/10.3390/pr11041167

Hazra, F., & Santosa, D. A. (2022). Efektivitas pupuk hayati cair pada tanaman padi sawah (*Oryza sativa*) serta analisis usaha taninya. *Jurnal Ilmu Tanah dan Lingkungan, 24*(2), 39–46. https://doi.org/10.29244/jitl.24.2.39-46

Iqbal, A., He, L., Khan, A., Wei, S., Akhtar, K., Ali, I., & Jiang, L. (2019). Organic manure coupled with inorganic fertilizer: An approach for the sustainable production of rice by improving soil properties and nitrogen use efficiency. *Agronomy, 9*(10), 651. https://doi.org/10.3390/agronomy9100651

Irawan, J., Allamah, A., & Wahyudi, E. (2024). Respons fisiologi dan hasil tanaman padi (*Oryza sativa* L.) terhadap aplikasi pupuk organik dan pupuk NPK dengan penambahan mikrob pada media gambut. *Innovative: Journal of Social Science Research, 4*(4), 6752–6765. https://doi.org/10.31004/innovative.v4i4.13609

Jia, P., Huang, Y., Wang, X., Zhu, Z., Dou, Y., Huang, Q., & Wang, A. (2025). Mechanisms of chemical polymers and microbial residues in affecting organic matter stabilization under varying carbon/nitrogen ratios during composting. *Chemical Engineering Journal, 513*, 162879. https://doi.org/10.1016/j.cej.2025.162879

Laksmi, A. N., & Nurdin, N. (2024). Public goods policy analysis: Case study of rice import policy by Perum BULOG in 2023. *Jurnal Ad'ministrare, 11*(1), 100–107. https://doi.org/10.71309/administrare.v11i1.2858

NASA Power Project. (2025). *NASA POWER data access viewer*. https://power.larc.nasa.gov/data-access-viewer/ (Accessed April 21, 2026).

Peng, G., Zhang, T., Huang, J., Zhang, Z. H., & Zhang, H. M. (2023). Improvement of soil fertility and rice yield after long-term application of cow manure combined with inorganic fertilizers. *Journal of Integrative Agriculture, 22*(7), 2221–2232. https://doi.org/10.1016/j.jia.2023.02.037

Reis, A. F. B., Nascente, A. S., Almeida, R. E. M., & Chagas Júnior, A. F. (2018). Growth and nutrient contents in lowland rice due to phosphorus and potassium fertilization. *Pesquisa Agropecuária Tropical, 48*, 98–108. https://doi.org/10.1590/1983-40632018v4850666

Rocha, T. M., Marcelino, P. R. F., da Costa, R. A. M., Rubio-Ribeaux, D., Barbosa, F. G., & da Silva, S. S. (2024). Agricultural bioinputs obtained by solid-state fermentation: From production in biorefineries to sustainable agriculture. *Sustainability, 16*(3), 1076. https://doi.org/10.3390/su16031076

Setiawati, M. R., Herdiyantoro, D., & Suryatmana, P. (2023). Aplikasi pupuk organik *Azolla* dan pupuk hayati terhadap kandungan N tanaman, serapan N tanaman, dan hasil tanaman padi sawah organik pada Inceptisols Jatinangor. *Soilrens, 21*(1), 34–43. https://doi.org/10.24198/soilrens.v21i1.49320

Setiawati, M. R., Sofyan, E. T., & Mutaqin, Z. (2016). Pengaruh pupuk hayati padat terhadap serapan N dan P tanaman, komponen hasil, dan hasil padi sawah (*Oryza sativa* L.). *Jurnal Agroekoteknologi, 8*(2). http://dx.doi.org/10.33512/j.agrtek.v8i2.1485

Sulaiman, A. A., Sulaeman, Y., & Minasny, B. (2019). A framework for the development of wetlands for agricultural use in Indonesia. *Resources, 8*(1), 34. https://doi.org/10.3390/resources8010034

Sun, B., Bai, Z., Bao, L., Xue, L., Zhang, S., Wei, Y., & Zhuang, X. (2020). *Bacillus subtilis* biofertilizer mitigating agricultural ammonia emission and shifting soil nitrogen cycling microbiomes. *Environment International, 144*, 105989. https://doi.org/10.1016/j.envint.2020.105989

Xin, Y., Yue, B., Zhao, X., Li, S., Li, T., Ren, J., & Liang, X. (2026). Long-term effects of the combined application of organic and inorganic fertilizers on soil fertility, structural stability, and rice productivity in cool rice-growing regions of Northeast China. *Plants, 15*(7), 993. https://doi.org/10.3390/plants15070993

Yakup, Y., Simamora, M. W. K., Jenyca, Z. Z. A., Sholehah, N., Hunafa, G. Z., & Laoli, J. (2024, December). Efikasi pupuk organik dan pupuk anorganik terhadap pertumbuhan dan produksi tanaman padi di lahan kering. In *Prosiding Seminar Nasional Lahan Suboptimal* (Vol. 12, No. 1, pp. 461–476).