AGPE THE ROYAL GONDWANA RESEARCH JOURNAL
OF HISTORY, SCIENCE, ECONOMIC, POLITICAL AND SOCIAL SCIENCE
ISSN (E): 2583-1348 | A Peer reviewed | An Open Access & Indexed
Volume 06 | Issue 06 | June 2025 | *www.agpegondwanajournal.co.in* | Page No. 04-13

ENHANCING YIELD AND SOIL QUALITY IN RICE THROUGH COMBINED USE OF INORGANIC FERTILIZERS AND COMPOST

Phyu Pya Lwin[1], Kyaw Ngwe[2], Swe Swe Mar[3] & Htay Htay Oo[4]

[1]Ph.D. candidate, Department of Soil and Water Science, YAU
[2]Professor and Head Department of Soil and Water Science, YAU
[3]Professor, Department of Soil and Water Science, YAU
[4]Professor and Head, Department of Agronomy, YAU

Abstract

Field experiments were conducted in 2024 during the summer and rainy seasons at the Regional Research Center in Myaungmya, Ayeyarwady Region, Myanmar, to assess the impact of integrated nutrient management on lowland rice cultivation. The study explored the combined effects of inorganic nitrogen fertilizer and compost derived from a blend of rice straw and cow dung on both yield performance and soil quality. Using a randomized complete block design with six treatments and four replications, the investigation evaluated different nitrogen levels (0, 26, 39, and 77 kg N ha^{-1}) applied either alone or in conjunction with 5 t ha^{-1} compost. Specifically, the treatments were as follows: T1 (control, no fertilizer), T2 (77 kg N ha^{-1} based on the Department of Agricultural Research recommendation), T3 (77 kg N ha^{-1} plus 5 t ha^{-1} compost), T4 (39 kg N ha^{-1} plus 5 t ha^{-1} compost), T5 (26 kg N ha^{-1} plus 5 t ha^{-1} compost), and T6 (5 t ha^{-1} compost only). Among the treatments, T3 recorded the highest grain yield at 6.2 t ha^{-1}, with an average of 14 tillers per plant and an 87.1% filled grain percentage. Moreover, treatments incorporating reduced nitrogen levels (T4 and T5) also performed well, indicating that compost can partially replace chemical fertilizers without compromising yield. In addition to yield benefits, compost application enhanced soil health by increasing organic matter and available potassium levels. Overall, these findings underscore that integrated nutrient management is a sustainable and effective approach to boosting rice productivity and maintaining soil fertility in Myanmar's lowland rice ecosystems.

Keywords: Integrated nutrient management, compost, nitrogen fertilizer, rice yield, soil quality

1. Introduction

Rice is the principal staple crop and a major economic driver in Myanmar, contributing significantly to national food security and rural livelihoods. The country possesses vast potential for rice production due to

CORRESPONDING AUTHOR:	REVIEW ARTICLE
Phyu Pya Lwin Ph.D. candidate, Department of Soil and Water Science, YAU E-mail: phyupyalwin@gmail.com	

its favorable agro-climatic conditions and abundant land resources. However, soil fertility decline, nutrient depletion, and unsustainable agricultural practices have become major challenges affecting rice yield stability in recent years (Tun et al., 2020). Traditional reliance on inorganic fertilizers, although initially effective in boosting yields, has led to long-term soil degradation, reduced organic matter content, and diminished microbial activity in many rice-growing regions (Win et al., 2019).

To address these challenges, integrated nutrient management (INM), such as the combined application of inorganic fertilizers and organic amendments using compost is important as a sustainable solution. Compost, derived from decomposed plant and animal residues, improves soil structure, enhances microbial biodiversity, and increases the nutrient-holding capacity of soils (Lal, 2020). When compost applied alongside inorganic fertilizers, compost can improve nutrient use efficiency, reduce environmental losses, and stabilize yields over time (Agegnehu et al., 2016).

In Myanmar, promoting the use of compost in rice-based systems aligns with national goals of sustainable agriculture, climate resilience, and improved rural livelihoods. By leveraging both the immediate nutrient availability from inorganic fertilizers and the long-term soil health benefits of compost, farmers can achieve more resilient and productive rice systems. In the context, where many rice farmers face resource constraints and degraded soils, integrating compost into existing fertilization practices offers a low-cost, sustainable solution to enhance yield stability and maintain soil quality over the long term. Therefore, this study aims to assess the effects of integrating compost with chemical fertilizers on yield and yield attributes in lowland rice farming systems.

2. Materials and Methods

2.1 Experimental Location, Soil, and Climate

The experiment was conducted at the Regional Research Center (RRC) in Myaungmya, Ayeyarwady Region, Myanmar. The site is located at 16°36′ N latitude and 94°55′ E longitude, with an elevation of 5 meters above sea level. The field experiments were carried out during summer season (February to May 2024) and rainy season (June to September 2024).

Before the experiment, composite soil samples were randomly collected from the topsoil (0–15 cm) to determine physicochemical properties of soil. The soil was classified as loamy sand, comprising 84.82% sand, 7.43% silt, and 7.75% clay. Other characteristics included a pH of 5.2, organic matter content of 1.78%, total nitrogen of 0.10%, available phosphorus of 31.8 mg kg^{-1}, and available potassium of 48 mg kg^{-1}. Climatic data during the experimental period are presented in Figure 1.

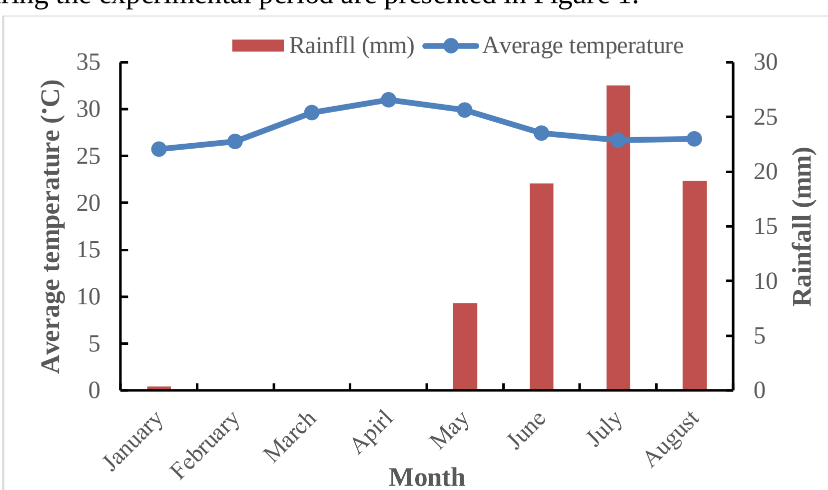

Figure 1. Monthly mean temperature and rainfall during the rice growing season in 2024

2.2 Rice variety

The rice variety used in this study was Yet-90, a high-yielding and short-duration cultivar recommended for both irrigated and rainfed ecosystems in Myanmar.

2.3 Seedbed Preparation and Transplanting

Seedlings were raised using the wet bed method. Rice seeds (5 kg ha^{-1}) were soaked in water for 24 hours and incubated for an additional 24 hours to promote germination. After 18 days, seedlings were uprooted and transplanted into the main field at a spacing of 20 × 20 cm, with two seedlings per hill. One week after transplanting, all plots were inspected for missing hills, and gaps were filled using extra seedlings as needed.

2.4 Land Preparation

The experimental field was initially plowed using a tractor-mounted seven-tooth plow, followed by saturation with irrigated water. The land was then harrowed twice with a rotary cultivator to achieve a fine tilth. Residual plant materials and debris were manually removed. Finally, the land was leveled, and the field was divided into unit plot according to the experimental design.

2.5 Experimental Design and Treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with five replications. The treatments consisted as follow

T1: Control (no fertilizer)

T2: 77 kg N ha^{-1} (Department of Agricultural Research recommendation)

T3: 77 kg N ha^{-1} + 5 t ha^{-1} compost (rice straw + cow dung)

T4: 39 kg N ha^{-1} + 5 t ha^{-1} compost (rice straw + cow dung)

T5: 26 kg N ha^{-1} + 5 t ha^{-1} compost (rice straw + cow dung)

T6: 5 t ha^{-1} compost (rice straw + cow dung) only.

Each plot size was 5 m × 5 m. The total number of plots were 24 plots. A buffer space of 0.5 m was maintained between plots and 1 m between blocks. The compost used in the experiment was prepared from rice straw and cow dung and had the following composition: 15.54% organic carbon, 1.23% total nitrogen, 0.32% total phosphorus, 1.53% total potassium, a C:N ratio of 12.63, and a pH of 8.39.

2.6 Statistical Analysis

All collected data were subjected to statistical analysis with Statistix 8.0 software. Treatment means were compared using the Least Significant Difference (LSD) test at a significane level 5% ($p \leq 0.05$).

2.7 Soil analysis

2.7.1 Soil pH determination

The 10 g air-dry soil (< 2 mm) was weighed into a 100-mL glass beaker, and added 50 mL Deionized water using a graduated cylinder, mixed well with a glass rod, and allowed to stand for 30 minutes. The suspension was stirred every 10 minutes during this period. After 1 hour, the suspension was measured with the pH meter.

2.7.2 Soil EC determination

The 10 g air-dry soil (< 2 mm) was weighed into a 100-mL glass beaker and 50 mL Deionized water was added using a graduated cylinder, mixed well with a glass rod, and allowed to stand for 30 minutes. The suspension was stirred every 10 minutes during this period. After 1 hour, stir the suspension was measured with the EC meter.

2.7.3 Soil Texture Analysis

Pipette method for soil texture

The air-dry soil 20 g was weighed into a beaker, added 10 ml of Tetrasodium pyrophosphate solution and 10 ml of distilled water and stirred for 5 minutes with gentle force at the time of stirring. The mixture was transferred into 1000 ml measuring cylinder and filled with 900 ml distilled water. The solution was shaken (up and down movement) with rubber pestle for 1 minute. Then the volume was made up to 1000 ml distilled water, kept 30 seconds before the sampling time for silt + clay. The solution of 25 ml was taken with pipette to the depth 10 cm from surface of suspension and was dried in an oven at 105°C for 5 hours. Then the dry sample was cooled in desiccator and weighed.

For second pipetting, the sample was taken after 5 hours for clay determination. The solution was taken with pipette 25 ml to depth 5 cm from surface of suspension and is dried in oven at 105°C for 5 hours. Then the sample was cooled in desiccator and weighed (Rowell, 2000).

2.7.4 Soil Organic Matter determination

Walkley-Black method for Organic Carbon

The air-dried soil 1.0 g was weighed into 500 ml conical flask and added 10 mL of 0.167 M $K_2Cr_2O_7$ and swirl the flask gently to disperse the soil in the solution. Then with care, 20 mL concentrated H_2SO_4 was rapidly added into the suspension. Immediately the flask was swirl ed gently until soil and reagents were mixed, then more vigorously for a total of 1 min. To minimize heat loss, the flask was allowed to stand on an insulated sheet for 30 min in a fume hood. The 200 mL of distilled water was added to the flask. The 10 mL of 85% H_3PO_4 was added. The three to four drops of o-phenanthroline indicator or barium diphenylamine sulfonate indicator was added and titrated the solution with 0.5 M $FeSO_4$ solution. (McLeod, 1973)

2.7.5 Total N determination in soil

Kjedahl Digestion method for Total Nitrogen

The 20 g of soil sample was weighed and placed it into Kjedahl's digestion tube. The 0.2 g of catalyst and 5 ml of acid mixture were added. The temperature was set at 400°C and digest for 1 hour. The Kjedahl's digestion tube was allowed to cool.The distilled water about 10 ml was added and set it at Kjedahl's distillation unit. At about 25 ml of 40% NaOH is automatically added to distillation tube with digested sample aliquot. Distillation time is set at 4 mins. In the conical flask, 10 ml of 3% H_3BO_3 and 3 drops of mix indicator were added. During the distillation time, about 100 ml of ammonium borate was collected in the conical flask. Finally, the amount of nitrogen in the aliquot was titrated with 0.02 N H_2SO_4.

2.7.6 Available P determination in soil

Olsen method for Available Phosphorus

The 5 g of dry soil was weighed into shaking bottle, added 40 ml of 0.5 M $NaHCO_3$, mechanically shaken for 30 min at end-over-end tumbler. The solution was filtered through a filter paper Whatman No. 42. The 3 mL of the solution was added by pipette and 1 ml of mixed reagent. The solutions was allowed to stand for at least 1 hour for the blue color to develop maximum. The solution was measured with spectrophotometer set at 630 nm wavelength. (Rayment & Higginson, 1992).

2.7.7 Available K determination in soil

1N Ammonium acetate extraction method for Available K

The 2 g of dry soil was weighed into a shaking bottle, added 40 ml of 1 N ammonium acetate solution, shaken for 1 hour using a shaker and centrifuged for 5 min at 3000 rpm. The solution 2 ml was pipetted for Ca, Mg and 18 ml for K & Na and measured with Atomic Absorption Spectrophotometer (AAS) (Rayment & Lyons, 2011).

3. Results and Discussion

3.1 Growth Attributes of Rice

The integration of compost with inorganic fertilizer significantly influenced the vegetative growth parameters of lowland rice across both summer and rainy seasons. As shown in Table 2, **plant height** exhibited noticeable variation among treatments. The highest average plant height (90.9 cm) was observed in treatment T3 (77 kg N ha^{-1} + 5 t ha^{-1} compost), followed by T4 (39 kg N ha^{-1} + 5 t ha^{-1} compost) with 89.4 cm. These results suggest that compost not only supplements essential nutrients but also improves soil structure, aeration, and water retention, which positively influence plant height (Chen et al., 2018; Lal, 2020).

The improved plant height under integrated nutrient management aligns with the findings of Agegnehu et al. (2016), who reported that organic amendments enhance root development and nutrient uptake. Conversely, the control treatment (T1) showed the lowest plant height, which indicates the importance of exogenous nutrient supply in achieving optimal vegetative growth.

The number of tillers per hill, a key determinant of yield potential, also responded significantly to the treatments. T3 recorded the highest mean number of tillers (14.0), statistically outperforming the control (T1) and compost-only (T6) treatments, which produced 7 and 8 tillers, respectively. These findings demonstrate that while compost improves soil fertility, its nutrient release is too gradual to support early tiller development when used alone. When combined with nitrogen fertilizer, however, the synergy enhances both immediate nutrient availability and sustained nutrient release throughout the growing season (Zhao et al., 2019).

3.2 Yield Components

Yield components such as **filled grain percentage**, **the number of spikeletsper panicle**, and **1000-grain weight** were all positively influenced by the combined application of inorganic fertilizer and compost (Table 3). The filled grain percentage, in particular, showed substantial improvement under integrated treatments. T3 and T4 achieved 87.1% and 85.5%, respectively, significantly higher than the control (74.4%). These results suggest improved pollination success and grain development, potentially due to better nutrient synchronization and soil biological activity (Duan et al., 2021).

In terms of **the number of spikelets per panicle**, T4 (36 kg N ha^{-1} + 5 t ha^{-1} compost) produced the highest number of spikelets (108.0), closely followed by T5 and T3. These results reinforce the potential of reduced nitrogen rates when used in conjunction with compost. The addition of organic matter contributes to increase microbial activity and better nutrient retention, which supports panicle development and grain setting (Khan et al., 2018). Notably, panicle length and 1000-grain weight did not differ significantly across treatments, suggesting these traits may be more genetically controlled and less influenced by moderate changes in nutrient management (Chen et al., 2018).

3.3 Grain Yield Performance

Grain yield showed a clear and statistically significant response to the integrated application of inorganic fertilizer and compost (Table 4). The highest grain yield (6.2 t ha^{-1}) was recorded in T3, followed closely by T2 (6.0 t ha^{-1}) and T4 (5.9 t ha^{-1}). The yield advantage of T3 highlights the effectiveness of applying both readily available (inorganic) and slow-releasing (organic) nutrient sources.

The control treatment (T1) yielded only 3.3 t ha^{-1}, which was significantly lower than all fertilized treatments. Even the compost-only treatment (T6) produced a yield of 4.8 t ha^{1}, which was 29.4% higher than the control. These findings align with the work of Agegnehu et al. (2016), who demonstrated that compost improves yield by enhancing soil structure, microbial activity, and water retention, even without inorganic nutrient inputs.

Interestingly, treatments with reduced nitrogen rates (T4 and T5) also maintained high yields (5.9 and 5.4 t ha^{-1}, respectively), suggesting that partial substitution of inorganic fertilizer with compost is a viable strategy for sustainable intensification. This finding is particularly relevant for Myanmar's smallholder farmers, who face rising costs of synthetic fertilizers. Similar outcomes were reported by Zhang et al. (2022), who found that a 50% reduction in nitrogen fertilizer could be offset by compost without significant yield loss in rice.

3.4 Post-Harvest Soil Properties

Soil **pH**, **total nitrogen**, and **available phosphorus** remained statistically unchanged across all treatments. This suggests that short-term application may not be sufficient to significantly alter these parameters. However, trends in organic matter buildup and potassium retention suggest that long-term compost use could positively impact overall soil fertility. (Ref)

The integration of compost with chemical fertilizer not only enhanced crop performance but also led to improvements in soil chemical properties after harvest (Table 4). Notably, **available potassium (K)** was significantly higher in compost-inclusive treatments, with T4 and T6 showing the highest values (50.75 and 53.25 mg kg^{-1}, respectively). This is consistent with the known benefit of compost in enhancing the retention and slow release of potassium, a critical nutrient for grain filling and disease resistance (Khan et al., 2018).

Organic matter content increased across all compost-treated plots, with T6 and T3 reaching 2.08% and 2.02%, respectively, compared to 1.78% in the initial soil and 1.98% in the fertilizer-only treatment (T2). These results confirm the long-term benefit of compost in enriching soil organic carbon pools, which is vital for improving soil structure, microbial diversity, and nutrient cycling (Lal, 2020; Zhao et al., 2019).

3.5 Sustainability Implications

The integration of compost and chemical fertilizers presents a promising approach to sustainable rice intensification in Myanmar. It enhances crop yields, improves soil health, and reduces reliance on costly synthetic inputs. This strategy aligns well with Myanmar's national agricultural policy, which emphasizes ecological intensification and farmer resilience (MOALI, 2020).

Moreover, composting agricultural residues such as rice straw and integrating them into cropping systems can help to address waste management and greenhouse gas emission challenges, thereby contributing to climate-smart agriculture. As noted by Lal (2020), organic amendments are key to build resilient agroecosystems, especially under conditions of resource scarcity and climate variability.

Table 1. Chemical composition of experimental soil before sowing

Properties	Initial soil properties	Rating	Method
Texture class	Loamy sand		
pH	5.2	Moderately acid	**4A1 -**1:5 soil: water suspension
Total OM (%)	1.78	Low	Walkley-Black Method
Total N (mg kg^{-1})	0.10	Low	Kjaldehl distillation method
Available P (mg kg^{-1})	31.8	High	**9C**-Olsen's P-Malachite green
Available K (mg kg^{-1})	48	Low	**15A1**_1N Ammonium acetate extraction

Table 2. Plant height, tiller number and filled grain % as affected by different doses of inorganic fertilizer and compost in summer and rainy season, 2024

Treatment	Plant height (cm)		Mean	Tiller number (cm)		Mean	Filled grain %		Mean
	Summer	Rainy		Summer	Rainy		Summer	Rainy	
T1	68.5	94.8	**81.7**	8 c	6.3 b	**7.2**	78.7 c	70.1 b	**74.4**
T2	80.8	95.8	**88.3**	11 b	9.0 ab	**10.0**	83.2 ab	84.8 a	**84.0**
T3	80.8	101.0	**90.9**	18 a	10.0 a	**14.0**	84.7 a	89.4 a	**87.1**
T4	78.0	100.8	**89.4**	12 b	10.3 a	**11.2**	82.7 ab	88.3 a	**85.5**
T5	72.8	98.3	**85.6**	12 b	10.8 a	**11.4**	83.8 ab	86.1 a	**85.0**
T6	70.8	97.3	**84.1**	8 c	7.0 b	**7.5**	81.6 b	84.2 a	**82.9**
Mean	**75.3**	**98.0**		**11.5**	**8.9**		**82.5**	**83.9**	
F-test	ns	ns		**	*		**	**	
$LSD_{0.05}$	2.81	6.01		2.59	2.86		2.53	6.09	
CV%	9.23	4.07		15.14	21.40		2.04	4.82	

Means followed by the same letters in each column are not statistically different at 5% level.

T_1= control (without fertilizer), T_2 = 77 kg N ha^{-1} (DAR recommended), T_3 = 77 kg N ha^{-1} + 5 t ha^{-1} compost, T_4 = 36 kg N ha^{-1} + 5 t ha^{-1} compost, T_5 = 26 kg N ha^{-1} + 5 t ha^{-1}, T_6 = 5 t ha^{-1} compost only.

Table 3. Panicle length, 1000-grain weight and spikelet $panicle^{-1}$ as affected by different dose of inorganic fertilizer and compost in summer and rainy season, 2024

Treatment	Panicle length (cm)		Mean	1000-grain weight (gm)		Mean	Spikelet $panicle^{-1}$		Mean
	Summer	Rainy		Summer	Rainy		Summer	Rainy	
T1	19.4	20.7	20.1	27.2	24.1 c	25.7	81 e	72 b	76.5
T2	20.9	22.2	21.6	26.8	24.8 a	25.8	100 c	110 a	105.0
T3	20.4	22.6	21.5	27.4	24.6 ab	26.0	101 bc	109 a	105.0
T4	20.7	21.8	21.3	27.1	24.4 bc	25.8	105 a	111 a	108.0
T5	19.5	21.5	20.5	27.1	24.6 ab	25.9	104 ab	109 a	106.5

T6	20.3	22.3	21.3	27.1	24.9 a	26.0	94 d	94 b	94.0
Mean	20.2	21.85		27.12	24.57		97.5	100.8	
F-test	ns	ns		ns	**		**	**	
$LSD_{0.05}$	2.81	2.04		1.45	0.33		2.48	5.21	
CV%	9.23	6.20		3.57	0.90		1.69	3.43	

Means followed by the same letters in each column are not statistically different at 5% level.
T_1= control (without fertilizer), T_2 = 77 kg N ha^{-1} (DAR recommended), T_3 = 77 kg N ha^{-1} + 5 t ha^{-1} compost, T_4 = 36 kg N ha^{-1} + 5 t ha^{-1} compost, T_5 = 26 kg N ha^{-1} + 5 t ha^{-1}, T_6 = 5 t ha^{-1} compost only.

Table 4. Grain yield and yield increased % as affected by different dose of inorganic fertilizer and compost in summer and rainy season, 2024

Treatment	Grain yield ($t\ ha^{-1}$)		Mean	Yield increased (%)		Mean
	Summer	Rainy		Summer	Rainy	
T1	3.2 f	3.5 d	**3.3**	-	-	-
T2	5.8 b	6.2 ab	**6.0**	43.5	45.2	**44.4**
T3	6.0 a	6.4 a	**6.2**	45.3	46.8	**46.1**
T4	5.7 c	6.0 ab	**5.9**	41.7	44.2	**42.9**
T5	5.2 d	5.6 bc	**5.4**	37.5	38.8	**38.2**
T6	4.3 e	5.2 c	**4.8**	32.7	26.0	**29.4**
Mean	**5.03**	**5.48**				
F-test	**	**				
CV%	0.84	8.11				
$LSD_{0.05}$	0.06	0.67				

Means followed by the same letters in each column are not statistically different at 5% level.
T_1= control (without fertilizer), T_2 = 77 kg N ha^{-1} (DAR recommended), T_3 = 77 kg N ha^{-1} + 5 t ha^{-1} compost, T_4 = 36 kg N ha^{-1} + 5 t ha^{-1} compost, T_5 = 26 kg N ha^{-1} + 5 t ha^{-1}, T_6 = 5 t ha^{-1} compost only.

Table 4. Chemical properties of soil after harvest

Treatments	pH	Electrical conductivity ($dS\ m^{-1}$)	Total N (%)	Available P ($mg\ kg^{-1}$)	Available K ($mg\ kg^{-1}$)	Organic matter (%)
Initial soil (before sowing)	5.20	-	0.10	31.80	48.00	1.78
T_1	5.28	0.033	0.11	22.25	40.25 b	2.09
T_2	5.20	0.040	0.11	22.03	40.00 b	1.98
T_3	5.28	0.035	0.12	21.03	45.50 ab	2.02
T_4	5.23	0.040	0.12	22.30	50.75 a	2.04
T_5	5.20	0.043	0.11	21.80	44.00 ab	1.98
T_6	5.08	0.043	0.12	22.45	53.25 a	2.08
Pr>F	ns	ns	ns	ns	*	ns

CV%	2.94	18.6	12.5	7.38	14.24	10.35
$LSD_{0.05}$	0.23	0.12	0.02	2.44	9.79	0.34

4. Conclusion

The present study demonstrates that integrating compost with inorganic nitrogen fertilizer significantly improves rice yield, yield components, and soil fertility in lowland rice cultivation systems in Myanmar. Among all treatments, the combination of the full recommended nitrogen dose (77 kg N ha^{-1}) with 5 t ha^{-1} of compost (T3) produced the highest grain yield, tiller number, and filled grain percentage, confirming the synergistic effects of organic and inorganic nutrient sources.

Moreover, treatments with reduced nitrogen levels (T4 and T5) in combination with compost also achieved comparable yields, suggesting that chemical fertilizer inputs can be partially replaced with compost without compromising productivity. This finding has important implications for promoting cost-effective, sustainable, and environmentally friendly rice production practices among smallholder farmers in Myanmar.

Post-harvest soil analysis further revealed that compost application improved key soil properties, particularly organic matter content and available potassium, indicating long-term benefits for soil health and fertility. While short-term changes in total nitrogen and phosphorus were not significant, trends suggest potential for cumulative improvement with continued organic input use.

In conclusion, the combined application of compost and inorganic fertilizer offers a viable strategy for enhancing yield stability and maintaining soil quality in rice-based systems. It aligns with national agricultural sustainability goals and provides a practical pathway for reducing dependency on synthetic fertilizers while improving farm-level resilience and productivity.

References

1. Agegnehu, G., Bass, A. M., Nelson, P. N., & Bird, M. I. (2016). Benefits of biochar, compost and biochar–compost for soil quality, maize yield and greenhouse gas emissions in a tropical agricultural soil. *Science of the Total Environment, 543*, 295–306.
2. Chen, J., Liu, X., Zheng, J., Zhang, B., Lu, H., Chi, Z., & Li, L. (2018). Effects of compost and inorganic fertilizer on soil nutrients, enzyme activity, and crop yield in a wheat–maize rotation system. *Sustainability, 10*(2), 475.
3. Duan, Y., Zhang, X., Zhang, L., Wang, H., Yang, B., Wang, Y., & Zhang, M. (2021). Effects of integrated fertilizer application on rice yield and nitrogen use efficiency. *Agriculture, Ecosystems & Environment, 310*, 107302.
4. Khan, M. A., Khan, S., & Waqas, M. (2018). The effect of organic and inorganic fertilizers on soil health and crop productivity: A review. *Environmental Science and Pollution Research, 25*(4), 3219–3231.
5. Lal, R. (2020). Sustainable soil management and food security. *Soil Science and Plant Nutrition, 66*(1), 1–9. https://doi.org/10.1080/00380768.2020.1718548
6. MCLEOD, R. A., & BEABOUT, J. W. (1973). The roentgenographic features of chondroblastoma. *American Journal of Roentgenology, 118*(2), 464-471.
7. MOALI (Ministry of Agriculture, Livestock and Irrigation). (2020). *Myanmar Agriculture at a Glance*. Department of Planning, Nay Pyi Taw, Myanmar.

8. Rayment, G. E., & Higginson, F. R. (1992). *Australian laboratory handbook of soil and water chemical methods* (pp. xvii+-330pp).
9. Rayment, G. E., & Lyons, D. J. (2011). *Soil chemical methods: Australasia* (Vol. 3). CSIRO publishing.
10. Rowell, D. L. (1996). Soil Science, Methods and Applications. UK: University of Reading. *British Library Catalogue in Publication data*.
11. Tun, N. N., Myint, M. M., & Oo, A. Z. (2020). *Soil fertility status and nutrient management practices in rice-based cropping systems of Myanmar*. Myanmar Journal of Agricultural Research, 8(1), 45–57.
12. Win, S. S., Htwe, A. Z. Z., & Aung, T. T. (2019). *Impact of long-term chemical fertilizer application on soil health and rice productivity in central Myanmar*. Journal of Soil Science and Plant Nutrition, 19(3), 624–633.
13. Zhang, Y., Li, Y., Lin, F., & Liu, Q. (2022). Effect of nitrogen reduction and organic substitution on yield and nitrogen efficiency in rice–wheat rotation. *Field Crops Research*, *281*, 108519. https://doi.org/10.1016/j.fcr.2022.108519
14. Zhao, Y., Wang, P., Li, J., Chen, Y., Ying, X., & Liu, S. (2019). The effects of organic amendments on the abundance of nitrifiers and denitrifiers and nitrogen transformation in soils. *Applied Soil Ecology*, *138*, 111–120.

■ ■ ■