Optimizing Fertilizer Use: The Role of Organic and Inorganic Fertilizer in Enhancing Soil Physico-Chemical Properties and Rice Yield

.

ABSTRACT

|  |
| --- |
| Myanmar is an agricultural country, and rice is the major staple food for people. Today, many crop producers face higher fertilizer prices, which lead to increased input costs and unstable yields in the rice production system. A satisfactory fertilization approach is needed to achieve high production of rice yield. By discovering the proper ratio of organic and inorganic fertilizer combinations, farmers can have a beneficial effect on their rice production. The main objective of this research was to study the combined effect of organic and inorganic fertilizers on soil physico-chemical properties and yield of rice. The two season experiment was carried out in a field of the Regional Research Center (Myaungmya), Department of Agriculture Research (DAR), Myanmar from September to December 2023 and February to May 2024. The experimental design was a Randomized Complete Block with 5 replications. The treatments were: T1= control (without fertilizer), T2 = 77 kg N ha-1 (DAR recommended), T3 = 77 kg N ha-1 + 5 t ha-1 compost of rice straw with cow-dung, T4 = 36 kg N ha-1 + 5 t ha-1 compost of rice straw with cow-dung, T5 = 26 kg N ha + 5 t ha-1 compost of rice straw with cow-dung, and T6 = 5 ton ha-1 compost of rice straw with cow-dung only. The result indicates that the application of the recommended fertilizer plus 5 t ha-1 rice straw with cow-dung compost increased rice yield by 5.98 and 6.4 t ha-1 in both seasons of 2024. The physicochemical properties of soil were not significantly changed among the treatments except potassium. Therefore, the combined application of organic compost and recommended inorganic fertilizers could increase rice grain yield by increasing the tiller number, spikelet per panicle, and filled grain percentage. |

***Keywords: rice straw, cow-dung manure, chemical properties, compost***

1. INTRODUCTION

Rice is one of the three largest important food crops in the world (World Food and Agriculture – Statistical Yearbook, 2022), which plays a vital role in the social economy, and consistent rice production is required to confirm future food security (Alexandratos and Bruinsma, 2012). In Myanmar, the total sown area was 7.09 million hectares. Its production was 27.28 million tons. The average yield was 3.85 tons ha-1 (MOALI, 2022). Nitrogen (N) levels in soils are maintained by balancing N loss from crop harvest with N gain from various sources. However, using inorganic fertilizers can be expensive and contribute to environmental problems. Rice straw is a type of crop residues and it is useful for making compost. Improved management practices such as the incorporation of crop residue, animal manure, and chemical fertilizers application increase soil organic carbon and improve crop productivity ([Amanullah & Hidayatullah, 2016](https://www.frontiersin.org/articles/10.3389/fpls.2016.01440/full" \l "B7)). The potential for the use of farmyard manure has reduced total dependence on inorganic fertilizers (Motavalli et al., 1994). The effect of organic manure improves soil structure and water retention capacity (Bhagat & Verma, 1991). Organic manure increased infiltration rate and decreased bulk density (Khaleel et al., 1981). As per Fulhage (2000), manure contains the three major plant nutrients, nitrogen, phosphorus, and potassium (NPK), as well as many essential nutrients such as Ca, Mg, S, Zn, B, Cu, Mn, etc. In addition to supplying plant nutrients, manure generally improves soil tilth, aeration, and water-holding capacity of the soil and promotes the growth of beneficial soil organisms. Many reports indicated that when organic fertilizers are extended with inorganic fertilizers, they positively affect crop growth.

Composts were decomposed aerobically into carbon dioxide, water, minerals, and stabilized organic matter. It means putting compostable material together to support nutrients in the soil. Compost improves soil structure, provides a wide range of nutrients for plants, and adds beneficial microbes to the soil. The maximum benefits of compost on soil structure (better aggregation, pore spacing, and water storage) occur after several years of use. Composts commonly contain about 2 percent nitrogen, 0.5–1 percent phosphorus, and about 2 percent potassium. Organic manure can supply a good amount of plant nutrients. The use of farmyard manure, cow-dung manure, and compost minimizes nutrient losses in various pathways and ensures sustainable productivity (Satyanarayana et al., 2002). It is beneficial for maintaining soil nutrient balance, aggregation, moisture retention capacity, and fertility (Tadesse et al., 2013). It favored soil carbon accumulation, correction of secondary and micronutrient deficiency, and long-term enhancement of soil quality (Biswas et al., 2017).

This research aimed to evaluate the effect of organic manure and inorganic fertilizers on soil physio-chemical properties and rice yield.

2. material and methods

The two-season experiment was carried out in a field of the Regional Research Center (Myaungmya), Department of Agriculture Research (DAR), Ayeyarwady division, Myanmar from January to April 2024 and May to August 2024. The physico-chemical properties of the experimental soil are given in Table 1.

Before experimenting, we made four compost piles with different organic materials of cow-dung, chicken manure, composting rice straw with cow-dung and chicken manure. Compost was prepared in a heap (2 x 1.2 x 1 m) and composted for three months. Chemical properties of cow-dung, chicken manure, and composting rice straw with cow-dung and composting rice straw with chicken manure are presented in Table 1. According to analytical results, we chose one composting rice straw with cow-dung manure and applied it in field experiments.

**Table 1: Chemical properties of different compost samples**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Properties | Different kinds of material for compost | | | |
| Cow-dung manure | Chicken manure | Composting rice straw with cow-dung manure | Composting rice straw with chicken manure |
| pH | 7.44 | 9.33 | 8.39 | 8.98 |
| Total OC (%) | 17.26 | 6.70 | 15.54 | 10.16 |
| Total OM (%) | 29.63 | 11.46 | 26.74 | 17.46 |
| Total N (%) | 1.45 | 0.92 | 1.23 | 0.96 |
| Total P (%) | 0.19 | 1.3 | 0.32 | 1.15 |
| Total K (%) | 0.54 | 1.31 | 1.53 | 1.19 |
| C:N | 11.90 | 7.28 | 12.63 | 10.58 |

The field experimental design was a Randomized Complete Block (RCB) design with five replications. The tested rice variety was Yet-90, a popular rice variety in Myanmar. The treatments were: T1= control (without fertilizer), T2 = 77 kg N ha-1 (DAR recommended), T3 = 77 kg N ha + 5 t ha-1 compost of rice straw with cow-dung, T4 = 36 kg N ha + 5 t ha-1 compost of rice straw with cow-dung, T5 = 26 kg N ha + 5 t ha-1 compost of rice straw with cow-dung, and T6 = 5 t ha-1 compost of rice straw with cow-dung only. The physico-chemical properties of soil before conducting this experiment were analyzed. The results are shown in table 2.

**Table 2. Physico-chemical properties of the experimental soils before sowing at Regional Research Farm (RRC**), **Myaungmya**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameters | Analytical Result | Description | | Analytical Methods | |
| Texture class | Loamy sand | Sand 84.82%, Silt 7.43% and Clay 7.75% | Pipette method | |
| pH | 5.2 | Moderately acid | 1:5 (soil: water) pH meter | |
| Organic matter (%) | 1.78 | Low | Walkley-Black Method | |
| Total N (mg kg-1) | 0.10 | Low | Alkaline permanganate method | |
| Available P (mg kg-1) | 31.8 | High | 9C-Olsen’s P-Malachite green | |
| Available K (mg kg-1) | 48 | Low | 15AI-1N Ammonium acetate extraction | |

**2.1 Data collections**

Soil samples of each treatment were collected before sowing and after harvest and analyzed by physical and chemical properties at the Soil and Plant Analysis Laboratory (SPAL) in the Department of Agricultural Research. Each of the ten randomly selected plants' height was measured from the base of the plant to the tip of a spike of the mother shoot. The number of tillers of selected plants was counted at maturity in each replication and the average was calculated. The filled grains per panicle were threshed manually and the number of grains per panicle was counted for each treatment. The panicle length of ten selected hills was measured by centimeters from the base to the tip of the spike. The thousand-grain weight was counted randomly from each bulk and weighed by electric balance. The average grain yield was estimated using a one-square-meter plot yield in each replication and adjusted to14% moisture content.

**2.2 Analysis**

Statistical analysis of the data in this experiment was performed using Analysis of Variance (ANOVA) and the significance of variation between means was tested by Least Significant Difference (LSD) at a 5% probability level using the computerized Statistix-8 software (Version 8).

3. results and discussion

The plant height of rice was not affected significantly by various combinations of fertilizers in both seasons (Tables 3 and 4). The tiller number was affected significantly by various combinations of fertilizer and compost. The data showed that the recommended rate of fertilizer + 5 tons per hectare of compost gave the highest number of effective tillers than the other treatments. The lowest number of tillers was found in T1 (control) and T6 (compost 5 t ha-1) in both seasons.

**Table 3. Yield and Yield components as affected by organic and inorganic fertilizer (Summer season, 2024)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | Plant height  (cm) | Tiller number | Spikelet panicle-1 | Filled grain  (%) | Panicle length  (cm) | 1000 seed weight (gm) | Grain yield  (t ha-1) |
| T1 | 68.5±5.36 | 8±1.22c | 81±1.22e | 78.7±2.76c | 19.4±0.88 | 27.2±0.76 | 3.18±1.73f |
| T2 | 80.8±7.08 | 11±1.64b | 100±1.12c | 83.2±1.27ab | 20.9±1.26 | 26.8±1.03 | 5.80±0.07b |
| T3 | 80.8±6.26 | 18±1.12a | 101±3.11bc | 84.7±0.87a | 20.4±2.82 | 27.4±1.16 | 5.98±0.25a |
| T4 | 78.0±5.87 | 12±2.28b | 105±0.43a | 82.7±0.75ab | 20.7±0.68 | 27.1±0.71 | 5.70±0.12c |
| T5 | 72.8±4.76 | 12±1.12b | 104±1.50ab | 83.8±0.97ab | 19.5±0.84 | 27.1±0.64 | 5.20±0.37d |
| T6 | 70.8±6.50 | 8±1.12c | 94±1.48d | 81.6±1.21b | 20.3±1.37 | 27.1±0.89 | 4.30±0.07e |
| Pr>F | ns | \*\* | \*\* | \*\* | ns | ns | \*\* |
| CV% | 9.23 | 15.14 | 1.69 | 2.04 | 9.23 | 3.57 | 0.84 |
| LSD0.05 | 2.81 | 2.59 | 2.48 | 2.53 | 2.81 | 1.45 | 0.06 |

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

T1= control (without fertilizer), T2 = 77 kg N ha-1 (DAR recommended), T3 = 77 kg N ha-1 + 5 t ha-1 compost,

T4 = 36 kg N ha-1 + 5 t ha-1 compost, T5 = 26 kg N ha-1 + 5 t ha-1, T6 = 5 t ha-1 compost only.

The number of spikelets per panicle was highly significant among the treatments. Data indicated that combined application of compost with inorganic fertilizer positively affected the number of spikelets per panicle. The highest number of spikelets per panicle were found in T2, T3, T4, and T5. The lowest number of spikelets per panicle was found in T1 and T6 in both seasons. The filled grain percentage was increased with the application of compost manure. The highest filled grain percentage was found in the application of 36 kg N ha-1 + 5 t ha-1 compost in both seasons. The highest grain yield was found in the combined applications of organic and inorganic fertilizers in the summer and rainy seasons. However, the maximum grain yield was observed in the application of 36 kg N ha-1 + 5 t ha-1 compost. And, applying compost of only 5 t ha-1 produced a proper grain yield of 4.3 t ha-1 and 5.2 t ha-1 in the summer and the rainy season, respectively. The grain yield was significantly different by the various application treatments. The grain yield of T3 (36 kg N ha-1 + 5 t ha-1 compost ) was obtained at 5.9 tons per hectare in the 2023 summer season and 6.4 tons per hectare in the 2024 rainy season.

**Table 4. Yield and Yield components as affected by organic and inorganic fertilizer (Rainy season, 2024)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | Plant height  (cm) | Tiller number | Number of Spikelets panicle-1 | Filled grain % | Panicle length  (cm) | 1000 seed weight  (gm) | Grain yield  (t ha-1) |
| T1 | 94.8±2.86 | 6.3±1.22b | 72±1.22b | 70.1±7.82b | 20.7±1.02 | 24.1±0.22c | 3.5±0.70d |
| T2 | 95.8±3.70 | 9.0±1.64ab | 110±1.12a | 84.85±2.86a | 22.2±2.34 | 24.8±0.25a | 6.2±0.04ab |
| T3 | 101.0±2.35 | 10.0±1.12a | 109±3.11a | 89.4±1.13a | 22.6±0.69 | 24.6±0.41ab | 6.4±0.10a |
| T4 | 100.8±4.02 | 10.3±2.28a | 111±0.43a | 88.3±0.73a | 21.8±0.78 | 24.4±0.41bc | 6.0±0.25ab |
| T5 | 98.3±2.95 | 10.8±1.12a | 109±1.50a | 86.1±1.74a | 21.5±0.88 | 24.6±0.22ab | 5.6±0.37bc |
| T6 | 97.3±4.02 | 7.0±1.12b | 94±0.71b | 84.2±2.80a | 22.3±2.34 | 24.9±0.22a | 5.2±0.62c |
| Pr>F | ns | \* | \*\* | \*\* | ns | \*\* | \*\* |
| CV% | 4.07 | 21.40 | 3.43 | 4.82 | 6.20 | 0.90 | 8.11 |
| LSD0.05 | 6.01 | 2.86 | 5.21 | 6.09 | 2.04 | 0.33 | 0.67 |

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

T1= control (without fertilizer), T2 = 77 kg N ha-1 (DAR recommended), T3 = 77 kg N ha-1 + 5 t ha-1 compost,

T4 = 36 kg N ha-1 + 5 t ha-1 compost, T5 = 26 kg N ha-1 + 5 t ha-1, T6 = 5 t ha-1 compost only.

**Table 5. Chemical properties of soil after harvest**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatment | pH | Electrical conductivity  (dS m-1) | Total  N  (%) | Available  P  (mg kg-1) | Available  K  (mg kg-1) | Organic matter (%) |
| T1 | 5.28±0.15 | 0.033±0.01 | 0.11±0.01 | 22.25±1.27 | 40.25±7.95 b | 2.09±0.18 |
| T2 | 5.20±0.16 | 0.040±0.01 | 0.11±0.01 | 22.03±1.26 | 40.00±7.76b | 1.98±0.18 |
| T3 | 5.28±0.13 | 0.035±0.01 | 0.12±0.01 | 21.03±1.31 | 45.50±7.35ab | 2.02±0.19 |
| T4 | 5.23±0.13 | 0.040±0.01 | 0.12±0.01 | 22.30±1.36 | 50.75±7.48a | 2.04±0.17 |
| T5 | 5.20±0.13 | 0.043±0.01 | 0.11±0.01 | 21.80±1.54 | 44.00±7.46ab | 1.98±0.17 |
| T6 | 5.08±0.13 | 0.043±0.01 | 0.12±0.01 | 22.45±1.47 | 53.25±6.88a | 2.08±0.17 |
| Pr>F | ns | ns | ns | ns | \* | ns |
| CV% | 2.94 | 18.6 | 12.5 | 7.38 | 14.24 | 10.35 |
| LSD0.05 | 0.23 | 0.12 | 0.02 | 2.44 | 9.79 | 0.34 |

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

T1= control (without fertilizer), T2 = 77 kg N ha-1 (DAR recommended), T3 = 77 kg N ha-1 + 5 t ha-1 compost,

T4 = 36 kg N ha-1 + 5 t ha-1 compost, T5 = 26 kg N ha-1 + 5 t ha-1, T6 = 5 t ha-1 compost only.

**Table 6. Physical properties of soil after harvest**

|  |  |  |  |
| --- | --- | --- | --- |
| Treatment | Bulk density  (g cm-3) | Porosity | Water holding capacity |
| T1 | 1.28±0.10 | 50.0±4.92 | 61.0±3.74 |
| T2 | 1.21±0.09 | 49.8±4.57 | 61.0±3.74 |
| T3 | 1.18±0.09 | 50.3±4.98 | 58.5±5.88 |
| T4 | 1.20±0.09 | 47.0±5.21 | 64.5±5.44 |
| T5 | 1.27±0.09 | 47.0±4.93 | 62.0±5.4 |
| T6 | 1.17±0.09 | 46.3±5.19 | 63.0±5.63 |
| Pr>F | ns | ns | ns |
| CV% | 6.61 | 13.2 | 9.42 |
| LSD0.05 | 0.12 | 9.63 | 8.75 |

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

T1= control (without fertilizer), T2 = 77 kg N ha-1 (DAR recommended), T3 = 77 kg N ha-1 + 5 t ha-1 compost,

T4 = 36 kg N ha-1 + 5 t ha-1 compost, T5 = 26 kg N ha-1 + 5 t ha-1, T6 = 5 t ha-1 compost only.

The chemical properties of soil after harvest are shown in Table 5. The chemical properties were not significant differences among the treatments except available K. The amount of available potassium increased in the soil by applying compost. Although there was no statistical difference, the application of compost only resulted in a decreased pH value in treated soil. Smieiklas et al., (2002), Pattanayak et al., (2001), and Yaduvanshi (2001) observed that the use of organic materials could lead to a decrease in soil pH. This reduction is attributed to the production of organic acids, such as amino acids, glycine, cysteine, and humic acid, during the mineralization processes (ammonification and ammoniation) carried out by heterotrophs, as well as nitrification by autotrophs. The physical properties of soil after harvest are also shown in Table 6, which are the indicators of soil health and structure. The treatments did not result in statistically significant differences in bulk density, porosity, and water-holding capacity. However, the application of chemical fertilizer 36 kg N ha-1 + 5 t ha-1 compost stands out with the highest water-holding capacity (64.3%), which could be beneficial in a water-limited environment. The compost only (5 t ha-1) has the lowest bulk density (1.17 g cm-3) and porosity (46.3%) because the combination of low bulk density with low porosity in rice fields is often a result of soil texture, puddling practices, water management, and organic matter dynamics.

4. Conclusion

Our results showed that among the different organic and inorganic applications, 77 kg N ha-1 + 5 t ha-1 compost produced the optimal yield for rice cultivation without altering chemical and physical properties of the soil. Soil chemical properties did not change significantly, highlighting that organic materials support increased grain yield while chemical fertilizer alone is not sufficient to achieve stable rice yields. Therefore, to increase the tiller number, number of spikelets per panicle, and filled grain percentage, applying organic materials (compost) during cultivation can be considered to enhance the grain yield.

References

1. Alexandratos, N., & Bruinsma, J. (2012). World agriculture towards 2030/2050: the 2012 revision.
2. Amanullah, H. (2016). Influence of organic and inorganic nitrogen on grain yield and yield components of hybrid rice in Northwestern Pakistan. *Rice Science*, *23*(6), 326.
3. Bhagat, R. M., & Verma, T. S. (1991). Impact of rice straw management on soil physical properties and wheat yield. *Soil Science*, *152*(2), 108-115.
4. Biswas S, Hazra GC, Purakayastha TJ, Saha N, Mitran T, Roy SS and Mandal B. 2017. Establishment of critical limits of indicators and indices of soil quality in rice-rice cropping systems under different soil orders. Geoderma, 292: 34-48.
5. FAO. (2022). *World Food and Agriculture Statistical Yearbook 2022*. FAO.
6. Fulhage, C. D. (2000). Reduce environmental problems with proper land application of animal manure (2000).
7. Khaleel, R., Reddy, K. R., & Overcash, M. R. (1981). Changes in soil physical properties due to organic waste applications: a review. *Journal of environmental quality*, *10*(2), 133-141.
8. MOALI, (2022). Myanmar Agriculture Sector in Brief.
9. Motavalli, P. P., Singh, R. P., & Anders, M. M. (1994). Perception and management of farmyard manure in the semi-arid tropics of India. *Agricultural systems*, *46*(2), 189-204.
10. Pattanayak, S.K., K.N. Mishra, M.K. Jena and R.K. Nayak. 2001. Evaluation of green manure crops fertilized with various phosphorus sources and their effect on subsequent rice crop. J. Indian Soc. Soil Sci., 49(2): 285-291.
11. Satyanarayana V, Vara Prasad PV, Murthy VRK and Boote KJ. 2002. Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice. J. of Plant Nutrition, 25(10): 2081-2090.
12. Smiciklas, K.D., P.M. Walker and T.R. Kelley. 2002. Utilization of Compost (Food, Paper, Landscape and Manure) in Row Crop Production. Department of Agriculture and Health Sciences, Illinois State University, USA.
13. Tadesse T, Dechassa N, Bayu W and Gebeyehu S. 2013. Effects of farmyard manure and inorganic fertilizer application on soil physico-chemical properties and nutrient balance in rain-fed lowland rice ecosystem.
14. Yaduvanshi, N.P.S. 2001. Effect of five years of rice-wheat cropping and NPK fertilizer use with and without organic and green manures on soil properties and crop yields in a reclaimed sodic soil. J. Indian Soc. Soil Sci., 49(4): 714-719.