International Journal of Multicultural and Multireligious Understanding

http://ijmmu.com
editor@ijmmu.com
ISSN 2364-5369
Volume 12, Issue 4
April, 2025
Pages: 206-213

Sustainable Fertilization Practices: Optimizing NPK Efficiency with Egg Shells and Organic Fertilizer for Rice Plant Growth and Yield

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http://dx.doi.org/10.18415/ijmmu.v12i4.6615

Abstract

The demand for rice continues to increase along with population growth. To address this challenge, the Indonesian government under the leadership of the President of the Republic of Indonesia Prabowo Subianto focuses on increasing rice production to achieve food security and restore food self-sufficiency. However, various obstacles are still faced in rice cultivation, one of which is the problem of soil fertility. The use of organic fertilizers derived from egg shells waste, Kirinyuh, and Tithonia has a crucial role in the agricultural system because of its ability to improve the physical, chemical, and biological properties of the soil. This study aims to study the interaction between organic fertilizers of egg shells + Kirinyuh + Tithonia and NPK fertilizers on rice production and to obtain the magnitude of the efficiency of the use of NPK chemical fertilizers in increasing rice production. The study was conducted in Kakaskasen Dua Tomohon, North Sulawesi, Indonesia for 8 months from March to October 2024. The study used a Completely Randomized Design (CRD) with a factorial pattern. The treatments consisted of, factor I (A) = dose of egg shells + organic fertilizer. A0 = without egg shells + organic fertilizer; A1 = 10 tons/ha of egg shells + organic fertilizer, A2 = 20 tons/ha of egg shells + organic fertilizer. Factor II (B) = NPK fertilizer dose B0 = 100 kg NPK / ha; NPK, B1 = 150 kg NPK / ha; B2 = 200 kg NPK / ha. Each treatment was repeated three times to obtain 27 experimental pots. Data were analyzed using analysis of variance and if there was a difference continued with the Least Significant Difference Test (LSD) at a test level of 5%. The results showed that the effect of interaction between organic fertilizer egg shells + Kirinyuh + Tithonia and NPK fertilizer was not significant on rice production so the amount of efficiency of NPK chemical fertilizer use in increasing rice production has not been obtained. The provision of egg shells + organic fertilizer increased the number of tillers and the weight of dry harvested grain. The dose of 10 tons/ha of egg shells + organic fertilizer was the best for the number of tillers and the weight of dry harvested grain.

Keywords: *Egg Shell; Kirinyuh; Rice; Tithonia*

Introduction

The President of the Republic of Indonesia, Prabowo Subianto, has set a target for Indonesia to achieve food self-sufficiency in the shortest possible time. In addition, he emphasized Indonesia's commitment to achieving food and energy self-sufficiency as a strategic step in facing increasingly complex global challenges. This statement was delivered in his first speech after being officially inaugurated as President of the Republic of Indonesia at the Nusantara Building of the MPR/DPR/DPD, Jakarta, on Sunday, October 20, 2024 (Public Relations of the Ministry of State Secretariat of the Republic of Indonesia, 2024). Soil fertility is one of the important factors that limit production, in addition to the availability of land, labor, and capital, in efforts to achieve food self-sufficiency. Rice farmers generally rely on chemical fertilizers such as compound NPK and urea to meet the nutrient needs of rice fields. The low use of organic fertilizers in rice fields affects the quality of the rice field soil, resulting in low nutrient content that is very much needed by plants, especially N, P, and K. Rice farmers generally do not use organic fertilizers so the resulting rice production is not as expected.

The provision of organic matter from bitter grass (*Thitonia diversifolia* L.) can be used to add organic matter and nutrients to rice field soil. *Thitonia* weeds contain quite high nutrients, namely 3.5–4.0% N; 0.35–0.38% P; 3.5–4.1% K; 0.59% Ca and 0.27% Mg. Therefore, this plant can be used as a source of nutrients, especially N and K (Jama et al., 2000). The provision of organic fertilizer affects the increase in the number of mustard leaves. The concentration of *Kirinyuh* Liquid Organic Fertilizer (LOF) 150 ml/liter of water is the best for increasing the number of mustard leaves (Likuayang et al., 2023). The results of laboratory analysis of the nitrogen content in *Kirinyuh* organic fertilizer are 3.55% (Jumini et al., 2012). The high calcium content of egg shells, which is around 36% of the total weight of egg shells, can also be used as a material to improve soil fertility. The combination of nutrients in egg shells + *Tithonia* + *Kirinyuh* complement each other to support growth and increase rice plant yields. These results are expected to make the use of NPK chemical fertilizers more efficient in lowland rice. The high calcium content of egg shells, which is around 36% of the total weight of egg shells, can also be used as a material to improve soil fertility. The composition of egg shells consists of 98.2% calcium carbonate, 0.9% magnesium, and 0.9% phosphorus. The shell membrane consists of 69.2% protein, 2.7% fat, 1.5% water, and 27.2% ash (King ori, 2011; Purwadi et al., 2011). This content helps increase the availability of nutrients in the soil, thus supporting optimal rice growth.

Organic fertilizers have many benefits for plants, including encouraging and increasing the formation of leaf chlorophyll, increasing the photosynthesis ability of plants, and absorbing nitrogen from the air so that it can increase production and good results in plants. The use of organic fertilizers can help modify plant microclimates, can increase the cation exchange capacity of the soil, which in turn can optimally increase production. *Thitonia* weeds (*Tithonia diversifolia*) are plants that grow wild and grow a lot in critical plains. *Thitonia* can be used as green manure and compost that can provide nutrient availability for plants. *Thitonia* in fresh form has a nutrient content of 2.7-3.59% (N); 0.14-0.47% (P); and 0.25-4.10% (K) (Jumini et al., 2012; Hartatik et al., 2015; Peniwiratri & Afany, 2022).

The N nutrient content in *Thitonia* compost functions to form assimilates, especially carbohydrates and proteins, and as a component of chlorophyll needed in the process of photosynthesis. Sufficient N elements in plants will facilitate the process of cell division because nitrogen has a major role in stimulating overall growth, especially stem growth, so it affects the growth of plant height (Riyawati, 2012; Pangestuti & Zahrah, 2021). The main benefit of providing organic fertilizer in rice fields is to provide nutrients for rice plants because organic fertilizers contain macro and micronutrients needed by plants, as well as minerals and growth hormones. Based on research results, it is known that 90% of agricultural products in Indonesia are produced using inorganic materials, such as chemical fertilizers and pesticides (Seufert et al., 2012; Hartatik et al., 2015). It is expected that the provision of egg shells + organic fertilizer can make the use of NPK chemical fertilizers more efficient because several research results have shown that *Tithonia* can reduce the use of N and K inorganic fertilizers from

various horticultural plants, plantations, and food crops by 25-100% so that the addition of egg shells to *Tithonia* and *Kirinyuh* can reduce the use of N, P, and K in compound chemical fertilizers and can reduce the number of empty grains (not filled). Egg shells are organic waste that is no longer used and has the potential to be used as organic fertilizer. The use of organic fertilizers is expected to replace the role of chemical fertilizers. Based on this background, this study aims to analyze the interaction between egg shells + organic fertilizers and NPK fertilizers on rice production and to obtain the amount of efficiency of the use of NPK chemical fertilizers in increasing rice production.

Method

The research was conducted in Kakaskasen Dua Tomohon, North Sulawesi, Indonesia for 8 months from March to October 2024. The materials and tools used were: rice seeds, egg shells, *Kirinyuh* weeds, *Tithonia* weeds, local microorganisms, sugar, NPK chemical fertilizer, urea fertilizer, pots, rice field soil media, meters, scales, ovens, stationery, other materials and tools used. The research used a Completely Randomized Design (CRD) with a factorial pattern. The treatments consisted of, factor I (A) = dose of egg shells + organic fertilizer. A0 = without egg shells + organic fertilizer; A1 = 10 tons/ha of egg shells + organic fertilizer, A2 = 20 tons/ha of egg shells + organic fertilizer. Factor II (B) = dose of NPK fertilizer B0 = 100 kg NPK/ha; NPK, B1 = 150 kg NPK/ha; B2 = 200 kg NPK/ha. Each treatment was repeated three times to obtain 27 experimental pots. The data were analyzed using analysis of variance and if there were differences, continued with the Least Significant Difference Test (LSD) at a test level of 5%.

Results and Discussion

The results of the analysis of variance showed that the interaction between NPK fertilizer and egg shells + organic fertilizer had no significant effect on seeds per plant. However, the interaction also did not show a significant effect on the number of tillers, the number of panicles, and the weight of dry grain harvested per plant. Meanwhile, the use of egg shells + organic fertilizer affected the number of tillers and the weight of dry grain per plant (Table 1). The results of this study are not different from Hasibuan et al., (2021); Munira et al., (2024); Sajar, (2022) who stated that the application of organic fertilizers based on household waste such as egg shells increases plant productivity. The increase in the number of tillers and the weight of dry grain harvested shows that the input of organic material from egg shells can have a positive effect on the vegetative and generative growth of rice.

Table 1. The Effect of Egg Shells + Organic Fertilizer on the Numbers of Tillers and Weight of Dry Grain Harvested by Planting

Treatment	Numbers Tillers per Plant	Weight of Dry Grain
A0 (0 tons/ha egg shells + organic fertilizer)	19,56a	62,84a
A1 (10 tons/ha egg shells + organic fertilizer)	21,78ab	75,38b
A2 (20 tons/ha egg shells + organic fertilizer)	26,00b	82,39b
BNT 5%	4,36	12,38

Note: Numbers followed by the same letter are not significantly different based on the Least Significant Difference Test (LSD) 5%

The number of rice panicles was not affected by the application of NPK fertilizer and egg shells + organic fertilizer. This shows that the application of both types of fertilizers has a similar effect on the number of rice panicles. This condition indicates that the nutrients available in the soil are sufficient for the panicle formation process. The average number of rice observed in the study was 34 to 42 panicles per plant (Figure 1). It is suspected that the lack of diversity in the number of panicles due to the application of NPK fertilizer and the combination of egg shells with organic fertilizer indicates that other factors,

such as environmental conditions, rice varieties, or growth phases, may have a more dominant influence on panicle formation. According to Rachmawati & Retnaningrum, (2013); Subiksa, (2020), panicle formation in rice is greatly influenced by the optimal vegetative growth phase and water availability, in addition to the availability of nutrients.

The provision of egg shells + organic fertilizer has been proven to increase the number of tillers and the weight of dry grain harvested in rice. Egg shells contain 98.2% calcium carbonate (CaCO3), 0.9% magnesium (Mg), and 0.9% phosphorus (P). The shell membrane consists of 69.2% protein, 2.7% fat, 1.5% water, and 27.2% ash (Nakano et al., 2003; King ori, 2011; Bimasri et al., 2017). The availability of calcium is very important for rice growth. Calcium plays a role in strengthening cell walls, stimulating root hair growth, and activating various enzymes in plant metabolism processes. Chadijah & Rustiah, (2016) and Hasibuan et al., (2021), the increase in the number of tillers and the weight of dry grain harvested due to the provision of egg shells and organic fertilizers is due to the role of calcium as a secondary nutrient that supports the structure and strength of plant cells. Calcium helps maintain the integrity of cell membranes and increases meristematic activity, which is important in the process of cell division and elongation, thereby promoting the growth of rice seedlings.

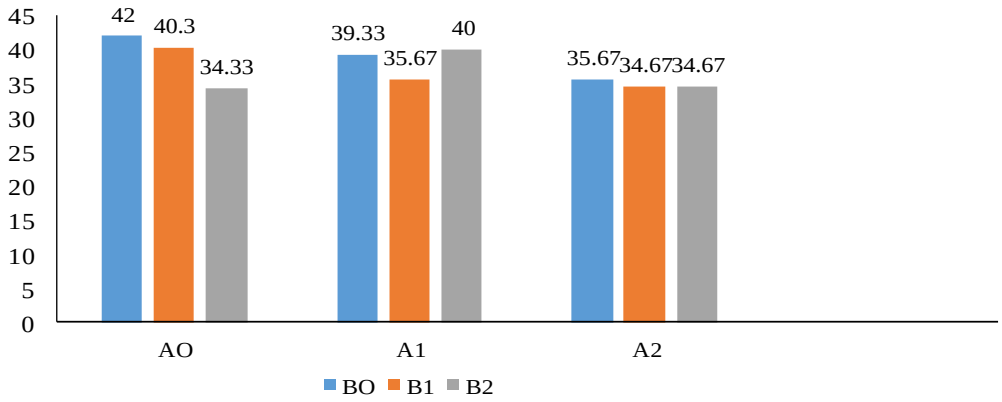

Figure 1. Rice Panicle Numbers

Discussion

The interaction of chemical fertilizers with organic materials requires the right balance to show optimal results because the content of macro and micronutrients must be to plant needs (Suryana et al 2020). The use of egg shells combined with organic fertilizers separately showed a significant effect on the number of tillers and dry grain weight per plant. This shows that egg shells as a source of calcium carbonate ($CaCO_3$) can improve soil structure, increase soil pH, and improve the availability of nutrients for plants. In addition, organic fertilizers contribute to improving soil fertility by increasing the activity of microorganisms and cation exchange capacity. Calcium from egg shells plays a role in strengthening cell walls and supporting root growth and affects the number of rice tillers (Machado et al., 2008; Ardi et al., 2023).

Macronutrients such as nitrogen, phosphorus, and potassium play a role in rice growth, especially in the tillering and panicle formation phase. However, if these nutrients are already available in sufficient quantities in the soil, adding fertilizer will not significantly increase. Wijanarko & Taufiq, (2012); Subiksa, (2020) stated that the plant response to fertilization will decrease when the soil already has an adequate level of fertility or if the plant has reached its optimal physiological limit. In addition, calcium from egg shells plays a role in improving soil structure and strengthening plant cell walls but does not directly affect panicle formation. Organic fertilizers contribute to improving soil fertility and increasing microorganism activity, but their significant effect on the number of panicles takes longer (Roidah, 2013).

Ardi et al., (2023) stated that calcium can increase root and shoot growth. If the calcium needs of plants are not met, it can cause stunting and flower loss in plants due to inhibited plant growth. Fitriana et al., (2022) sufficient P elements will increase the efficiency of the function of N use. Nitrogen is an integral part of chlorophyll which plays a role in photosynthesis and most of the results of photosynthesis are stored in grain (grain). In addition to N and P, K also plays an important role for plants, namely to increase the photosynthesis process, save water use, maintain turgor, form strong stems, as an activator of various enzyme systems, and strengthen roots. The results of Jufri et al., (2017) research showed that the provision of 20 tons/ha of *Tithonia* compost can replace the need for N (urea) and K (KCl) fertilizers by 50% of the need for corn and soybeans with a total corn production of 6.68 tons/ha and 1.80 tons/ha of soybean seeds. The results of the study by Montolalu et al., (2023), a dose of 200 kg Phonska/ha + 200 kg Urea/ha at a concentration of 200 ml of liquid organic fertilizer/liter of water increased the weight of dry milled rice. A dose of 10 tons/ha of *Kirinyuh* organic fertilizer increased the number of productive rice tillers (Tumewu et al., 2018).

Furthermore, it was stated that the administration of *Kirinyuh* organic fertilizer could reduce the use of urea fertilizer by 50% for plant height and the number of rice tillers. The results of laboratory analysis of *Kirinyuh* organic fertilizer were 3.55% using the Kjeldahl-titrimetric analysis method (Palm Plant Instrument Standard Testing Center Testing Laboratory, 2019). The value of 3.35% according to the criteria for assessing soil chemical properties is categorized as very high (Staf Peneliti Pusat Penelitian Tanah, 1983; Subardja et al., 2014). The results of laboratory analysis of nutrient content in organic fertilizer were total N (%) 0.59, P (ppm) 1.65, K (%) 1.21), and organic C (%) 35.44.

The high calcium content in egg shells, about 36% of its total weight, can be used as a material to improve soil fertility. The nutrient content in organic fertilizer + egg shells complements each other to meet the nutrient needs of rice plants. Calcium nutrients play an important role in stimulating the formation of root hairs, hardening plant stems, and stimulating seed formation. Calcium is absorbed by plants in the form of Ca^{2+} ions, the role of calcium for plants is to stimulate the formation of root hairs, form cell walls needed in the process of forming new cells, and harden plant stems. In addition, calcium also plays a role in stimulating the formation of perfect fruits and seeds and neutralizing organic acids produced during the metabolic process (Supriyadi, 2009; Putra & Maizar, 2023).

Conclusion

The interaction between organic fertilizers of egg shells + *Kirinyuh* + *Tithonia* with NPK fertilizers did not show a significant effect on rice production, so the efficiency of the use of chemical fertilizers NPK in increasing yields has not been determined. However, the application of a combination of egg shells + organic fertilizers has been proven to increase the number of tillers and the weight of dry grain harvested. The best dose for the combination of eggs + organic fertilizers is 10 tons/ha, which provides an optimal increase in the number of tillers and the weight of dry grain harvested. To increase rice productivity sustainably, it is recommended that farmers start considering the use of organic fertilizers made from egg shells as an alternative or complement to chemical fertilizers. The use of a dose of 10 tons/ha of egg shells + organic fertilizers can be an environmentally friendly solution to increase yields, reduce dependence on chemical fertilizers, and improve soil structure and fertility.

Acknowledgments

We would like to thank the Institute for Research and Community Service of Sam Ratulangi University for financial support for this research. This project was funded through the 2024 PNBP research grant, under contract number 239/UN12.27/LT/2024

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