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Effect of organic fertilizer rates on grain yield and seed qualities of rice

Kaewtaphan, P.[1], Maniin, P.[2*], Nilkong, P.[2], Aninbon, C.[1] and Teamkao, P.[1]

[1]Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand; [2]Faculty of Agricultural Innovation, College of Agricultural Innovation and Food, Rangsit University, Phthumthani, Thailand.

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Abstract The effect of organic fertilizer quantity on the yield and seed qualities of Pathumthani 1 rice revealed that the highest grain yield, 3,893 kg/ha, was attained with the application of 2.24 kg N/ha of organic fertilizer, whereas rice without fertilizer exhibited the lowest yield. However, the application of 1.6 kg N/ha of organic fertilizer resulted in the highest seed germination rate, germination index, and pure seed percentage, with values of 98.00%, 32.43, and 99.71%, respectively. Conversely, applying 2.24 kg N/ha of organic fertilizer yielded the lowest seed germination rate, germination index, and pure seed percentage at 87.50%, 28.74, and 98.11%, respectively. Moreover, the 1.6 kg N/ha rate demonstrated the least inert matter and the lowest number of dead seeds. Consequently, the findings suggested that organic fertilizer should be applied at a rate of 2.24 kg N/ha to achieve high grain yields, while it is still maintained seed germination percentage of over 80%.

Keywords: *Oryza sativa*, Organic, Yield, Seed quality

Introduction

Rice (*Oryza sativa* L.) has been essential for human livelihoods from ancient times to the present day. Besides serving as a staple food, rice is utilized as a raw material for cooking and processing into various food products. Additionally, rice plays a vital role in Thailand's economy as a significant export crop. Over the years, Thai rice has undergone continuous development, resulting in various strains with improved quality. Its recognized quality has made Thai rice a preferred choice both domestically and internationally (Rice Department, 2015). Fertilizer application is crucial for enhancing agricultural productivity. While increasing fertilizer usage generally leads to higher plant yields, the application of an appropriate nitrogen rate significantly enhances nitrogen use efficiency, grain yield, milling quality, and nutritional quality of rice, resulting

[*] **Corresponding Author**: Maniin, P.; **Email:** phissanu.ka@kmitl.ac.th

in moderate eating quality (Mahmood *et al*., 2022; Liang *et al*., 2021). However, long-term use of large quantities of chemical fertilizers may harden the soil and disrupt nutrient balance. Relying solely on chemical fertilizers can also degrade soil properties (Faculty of Soil Science Department, 2001).

In modern agriculture, organic fertilizers are increasingly favored for producing high-quality, toxin-free rice while conserving natural resources and promoting sustainable development. Organic rice production emphasizes natural processes. Studies have shown that rice growth and yield, such as with "RD43", are higher when organic fertilizers are applied compared to chemical fertilizers (Rajaboonmee *et al*., 2020). For instance, application of cow manure at 9,375 kg/ha for three consecutive years has promoted maximum growth of "KDML 105", enhancing yield components and grain quality more effectively than pig and chicken manures (Sriwichan and Srisa-ard, 2020). However, application of cow dung and poultry manure reduced rice yield but had no effect on seed quality in terms of germination, viability, and vigor compared to urea and urea combined with manure application (Khatun *et al*., 2015).

Seed quality is critical for successful plant production, and seed testing is necessary to assess quality levels, categorizing them as meeting standards or not (Boonnarithi, 1999). One current challenge is the absence of organically labeled seeds in the market, with commercially available seeds typically containing chemicals. International organic standards mandate the use of organic seeds in agriculture since 2003. In Europe, a six-fold increase in organic seed production is needed within the next decade to achieve 100% organic seed use in organic farming (IFOAM Organics Europe, 2023). While there are preparation processes in place, no organization currently produces organic seeds. Authorities allow seed production in the GAP system for now. Consequently, there is urgently needed to prepare organic seeds free from chemicals. The situation is led to a research gap and prompted to study of organic fertilizer rates to enhance seed yield and quality of Pathumthani 1. The study aimed to investigate the organic fertilizer quantity affected to the yield and seed qualities of rice.

Materials and methods

The experiment was conducted during September 2019 - March 2020. It was carried out in three laboratories; Rangsit University, located in Nong Sarai Sub-district, Phanom Thuan District, Kanchanaburi Province, Chemical laboratory of Rangsit University, and seed laboratory, Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang. The rice variety used in this study was Pathumthani 1.

The experimental plan was employed using the Randomized Complete Block Design (RCBD) with four repetitions. The treatments consisted of four rates of organic fertilizer: 1) no fertilizer, 2) organic fertilizer at a rate of 1.6 kgN/ha, 3) organic fertilizer at a rate of 1.92 kgN/ha, and 4) organic fertilizer at a rate of 2.24 kgN/ha. The organic fertilizer used was produced from the fermentation of agricultural waste. The properties of organic fertilizers used were as follows: total nitrogen content of 2.00%, total P_2O_5 content of 2.28%, total K_2O content of 3.04%, organic matter content of 23.38%, C/N ratio of 10.76, electrical conductivity of 11.02 dS/m, and pH of 7.89.

The agricultural plots were divided into four plots, with each sub-plot measuring 8 x12 m. Each fertilizer treatment was applied three times; when the rice was 15 days old after planting (first time), during the tillering period (second time), and pre-heading stage (third time). The samples were monitored to ensure sufficient water levels for rice growth. The water level was adjusted according to the rice plant's stage until maturity at 120 days. Data were recorded on seed quality, including yield per hectare, seed moisture content, 100 seeds weight, number of seeds per panicle, germination percentage (following ISTA, 1996 guidelines), germination index (following Association of Official Seed Analysts, 2009 guidelines), seedling root length, seedling shoot length, and purity analysis (following ISTA, 1996 guidelines) including, contamination by red rice and assessment of normal and abnormal seedling. Data were analysed based on the Randomized Complete Block Design (RCBD), and Least Significant Difference was used to compare means.

Results

Effect of organic fertilizers on yield, yield components and seed moisture content

Different rates of organic fertilizers affected the number of seeds per panicle, grain yield, and seed moisture content of rice, but it was not affected on 100 seed weight (Table 1). The number of seeds per panicle was highest when applying organic fertilizer at 2.24 kg N/ha, with a value of 150.75 seeds per panicle, followed by application rates of 1.92 kg N/ha, 1.6 kg N/ha and no fertilizer, respectively. Moreover, apply organic fertilizer at the rate of 2.24 kg N/ha produced the highest grain yield (3,893 kg/ha), followed by application rate of 1.92 kg N/ha, 1.6 kg N/ha and no fertilizer, with values of 2,877, 2,200 and 1,626 kg/ha, respectively. Seed moisture content was significantly different among organic fertilizer rates, with on organic fertilization resulting in the lowest seed moisture content.

Effect of organic fertilizers rates on seed quality traits

The varying rates of organic fertilizers resulted in different seed germination percentages of Pathumthani 1 rice variety (Table 2). Applying organic fertilizer at a rate of 1.60 kg N/ha produced the highest seed germination percentage (98.00%), whereas application of the organic fertilizer at a rate of 2.24 kg N/ha resulted in the lowest seed germination percentage (87.50%). The germination index was highest when applying 1.60 kg N/ha of organic fertilizer but did not differ significantly from no fertilizer application or applying organic fertilizer at a rate of 1.92 kg N/ha. Additionally, the root length of rice seedling did not show significant difference among organic fertilizer rates. However, seedling shoot length was significantly highest in rice that received 2.24 kg N/ha of organic fertilizer, with a value was 2.97 cm.

Table 1. Effects of organic fertilizer rates on number of seeds per panicle, 100 seed weight (g), grain yield (kg/ha) and seed moisture content (%) of Pathumthani 1 rice

Organic fertilizer rates	Seed / panicle	100 seed weight (g)	Grain yield (kg/ha)	Moisture content (%)
No fertilizer	102.00 c	2.75	1,626 c	10.01 b
1.60 kg N/ha	114.00 bc	3.00	2,200 bc	10.07 a
1.92 kg N/ha	119.50 b	2.75	2,877 b	10.06 a
2.24 kg N/ha	150.75 a	3.00	3,893 a	10.04 a
F-test	*	ns	*	*
C.V. (%)	6.35	10.04	18.62	0.20

Difference letters in the same column indicate significant differences by LSD (P≤0.05).
ns = not significantly different (P>0.05)

Table 2. Effects of organic fertilizer rates on seed germination percentage (%), germination index, root length (cm) and shoot length (cm) of rice seedling

Organic fertilizer rates	Seed Germination (%)	Germination index	Root length (cm)	Shoot length (cm)
No fertilizer	95.75 ab	31.21 a	3.37	1.67 b
1.60 kg N/ha	98.00 a	32.43 a	3.99	1.70 b
1.92 kg N/ha	92.75 b	30.60 ab	3.25	2.21 ab
2.24 kg N/ha	87.50 c	28.74 b	3.71	2.97 a
F-test	*	*	ns	*
C.V. (%)	3.29	3.92	16.86	34.56

Difference letters in the same column indicate significant differences by LSD (P≤0.05).
ns = not significantly different (P>0.05).

Effect of organic fertilizers rates on seed purity traits

Different rates of organic fertilization significantly influenced the seed purity percentage and the percentage of inert matter in rice (Table 3). The percentage of pure seeds was highest in rice fertilized with 1.60 kg N/ha (99.71%), and at this rate, the organic fertilizer had the lowest percentage of inert matter (0.24%) compared to other fertilization rates. There were no significant differences observed in the presence of other seeds and red seeds among the treatments.

Table 3. Effects of organic fertilizer rates on seed purity traits of rice seed

Organic fertilizer rate	Pure seeds (%)	Inert matter (%)	Other seeds (%)	Red rice (seeds)
No fertilizer	98.16 b	1.78 a	3.50	2.50
1.60 kg N/ha	99.71 a	0.24 b	1.50	2.75
1.92 kg N/ha	98.13 b	1.83 a	6.75	3.00
2.24 kg N/ha	98.11 b	1.84 a	2.25	2.50
F-test	*	*	ns	ns
C.V. (%)	0.31	21.13	25.82	46.51

Difference letters in the same column indicate significant differences (P≤0.05).
ns = not significantly different (P>0.05).

Effect of organic fertilizer rates on seedlings traits

The different levels of organic fertilization were significantly influenced the percentage of normal seedlings and the percentage of dead seeds but did not affect abnormal seedling traits (Table 4). Rice samples treated with no fertilizers and organic fertilization at a rate of 1.60 kg N/ha resulted in the highest percentage of normal seedlings (95.75% and 98.00%, respectively). Moreover, fertilization with organic fertilizer at a rate of 2.24 kg N/ha resulted in the highest percentage of dead seeds (12.25%).

Table 4. Effects of organic fertilizer rates on seed germination tests of rice seedlings

Organic Fertilizer rates	Normal seedlings (%)	Abnormal seedlings (%)	Dead seed (%)
No fertilizer	95.75 a	0.75	3.5 bc
1.60 kg N/ha	98.00 a	0.50	1.50 c
1.92 kg N/ha	92.75 b	0.50	6.75 b
2.24 kg N/ha	87.50 c	0.25	12.25 a
F-test	*	ns	*
C.V. (%)	3.29	14.14	53.00

Difference letters in the same column indicate significant differences by LSD (P≤0.05).
ns = not significantly different (P>0.05).

Discussion

Effect of organic fertilizer rates on yield and yield components

This study observed an increase in grain yield of Pathumthani 1 rice with the application of increasing amount of organic fertilizer. Fertilizing with 2.24 kg N/ha of organic fertilizer produced the highest grain yield (3,893 kg/ha). The number of seeds per panicle ranged from 102.00-150.75 seeds, a result consistent with Kongpolprom *et al*. (2015), which found and average of 150.03 seeds per panicle. The growth of Pathumthani 1 rice appeared to be influenced by the nitrogen content of organic fertilizers. Nutrients, particularly nitrogen, play a crucial role in plant growth, affecting overall crop development. Mahmood *et al*. (2022) observed significant increases in net photosynthetic rate, stomatal conductance, chlorophyll content, and activities of metabolic enzymes with higher nitrogen levels. Application of an appropriate nitrogen rate notably enhanced nitrogen use efficiency in rice plants, leading to improvements in grain yield, rice milling quality, and nutritional quality (Liang *et al*., 2021). Nitrogen deficiency can severely limit crop growth and development, resulting in premature senescence and reduced yields (Lee, 2021).

Organic fertilizers contribute to soil structure improvement, creating a favorable environment for plant growth. The balanced chemical composition of soil applied with organic fertilizer enhanced nutrients availability compared to denser soils (Ruamsiri, 2011). Soil organic content increased by 20% with organic fertilizer compared to chemical fertilizer applications (Rajaboonmee *et al*., 2020). Furthermore, the seed moisture content ranged from 10.04 - 10.07 % in this study is consistent with finding by Prasertsak *et al*. (2014) who reported a range of 10.87% to 12.93%.

Effect of organic fertilisers rates on seed quality, seedling and seed purity

The application of 2.24 kg N/ha organic fertilizer resulted in the lowest seed germination percentage (87.50%) compared to other organic fertilizer rates. However, this study observed a high germination index under low levels of nitrogen application. The germination index serves as an indicator of seed vigor, with higher values indicating quicker germination. This finding aligns with Kongpolprom *et al*. (2015), who found that sample treated with organic fertilizers at 1.6 kgN/ha exhibited the highest germination index (32.43). Notably, this was not statistically different from the unfertilized samples and those treated with organic fertilizers at 1.92 kg nitrogen per ha, which had germination indices of

31.21 and 30.60, respectively. Mansuriwong and Chumthong (2013) also reported germination indices ranging from 19.68 to 19.86 in rice seeds.

This study also observed that the shoot length of seedling was highest when applying 2.24 kgN/ha of organic fertilizer. This phenomenon can be attributed to the high levels of nitrogen, which prompts seeds to accumulate more protein. Increased protein content often results in heavier seedlings. Wen *et al.* (2018) found a significant correlation between protein content in wheat seeds and plant dry weight (r = 0.892**). Similarly, Torres and Paulsen (2018) discovered that enhancing the protein content of seeds occasionally resulted in heightened seedling emergence rates, though this effect wasn't consistent, and frequently led to an increase in seedling dry weight.

The samples treated with no fertilizers and organic fertilizers at 1.60 kg N/ha resulted in the highest percentage of normal seedlings (95.75% and 98.00%, respectively) compared to those treated with high levels of organic fertilizer. The dead seed percentages were higher in treatment with highest level of nitrogen (2.24 kg N/ha). However, even when applied at a rate of 2.24 kg N/ha, the germination percentage remained above 80% (87.50%), meeting the standard criteria for seed quality. This indicates that rice can effectively utilize organic fertilizer at a rate of 2.24 kg N/ha, ensuring both high yields and good seed quality.

According to the Bureau of Plant Breeding and Agricultural Materials, the acceptable seed purity rate should not be less than 98%, with impurity rate remaining under 2%. The results of this study found seed purity percentage ranging from 98.11 to 99.71%. These findings suggest that proper management practices, including the use of pure organic fertilizers (without weed seed contamination), indirectly reduce weed content in the field. Ultimately, this leads to a harvesting process that yields high-quality rice seeds. Also, Prasertsak *et al*. (2014) reported a seed purity percentage of 99.47%, with impurity percentages related to other kernels and red rice at 1%.

In conclusion, highest grain yield was attained with the application of 2.24 kg N/ha of organic fertilizer, whereas rice without fertilizer exhibited the lowest yield. Application of 1.6 kg N/ha of organic fertilizer resulted in the highest seed germination rate, germination index, and pure seed percentage, with values of 98.00%, 32.43, and 99.71%, respectively. Moreover, the 1.6 kg N/ha rate demonstrated the least inert matter and the lowest number of dead seeds.

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