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Original Article

Effect of vermicompost-chemical mixed fertiliser on the growth and macronutrient use efficiency of upland rice cv. Sakonnakhon

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Abstract

This study focused on effects of vermicompost-chemical mixed fertiliser on the growth and macronutrient content of upland rice cv. Sakonnakhon in Khon Kaen province, Northeast Thailand. The experiment was carried out under greenhouse conditions. Five treatments were compared: T1 (control without fertiliser); T2 (chemical fertilisers, 156.25 kg ha^{-1} NPK 16-16-8 and 62.5 kg ha^{-1} NPK 46-0-0); T3 (vermicompost, 6,250 kg ha^{-1}); T4 (vermicompost, 6,250 kg ha^{-1} and chemical fertilisers, 78.125 kg ha^{-1} NPK 16-16-8 and 31.25 kg ha^{-1} NPK 46-0-0) and T5 (vermicompost, 6,250 kg ha^{-1} and chemical fertilisers, 156.25 kg ha^{-1} NPK 16-16-8 and 62.5 kg ha^{-1} NPK 46-0-0). The results showed significant effects on rice yield components from the application of T4 and T5. With regard to rice yield, the application of T3 (vermicompost, 6,250 kg ha^{-1}) had significant effects on spikelet number, average grain number and total grain weight.

Keywords: chemical fertiliser, growth, nutrient use efficiency, vermicompost, rice

1. Introduction

Agricultural areas in North-eastern Thailand with acidic sandy soil (low cation exchange capacity (CEC), low nutrient reserves, and low water holding capacity) are becoming depleted in availability (Leaungvutiviroj *et al.*, 2006). Furthermore, the average annual below 1,300 mm rainfall causes a severe dry season. The uplands often suffer from severe physical and/or chemical degradation, due to deforestation and the cultivation of cassava and sugar cane. Upland rice is grown in rain fed, naturally well-drained soils with bunded or unbunded fields without surface water accumulation. Upland rice varieties are mostly grown as a low-yield subsistence crop to give stable yields under the adverse environmental conditions of the uplands. Upland rice varieties are drought tolerant, but have poor yield potential and tend to lodge under high levels of external inputs, such as fertiliser and supplemental irrigation. The diversity of upland rice can be maintained while increasing levels of production using participatory varietal selection (PVS) techniques.

Application of chemical fertilisers at high levels can degrade soil and water resources in the long term, leading to loss of ecosystem services and worsened agricultural sustainability. The use of mixed organic and inorganic fertilisers increases the efficiency over only chemical fertilisers and promotes soil remediation (Rubber Research Institute of Thailand, 1997). Vermicomposts are products derived from the accelerated biological degradation of organic wastes by earthworms and microorganisms. Their microbial activity is ten to 20 times higher than that in the soil (Chaoui *et al.*, 2010). Vermicompost has high nutrient concentrations and is also believed to contain hormones and enzymes acquired during the passage of the organic matter through the earthworm gut. These hormones and enzymes are believed to stimulate plant growth and discourage plant pathogens (Gajalakshmi & Abbasi, 2004). The aim of this study was to investigate the effects of vermicomposton the growth and macronutrient use efficiency of upland rice cv. Sakonnakhon.

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2. Materials and Methods

2.1 Experimental design

The experiment was conducted using a completely randomised design (CRD) with four replications. The upland rice cv. Sakonnakhon experiments were conducted at Khon Kaen University, Khon Kaen province, Northeast Thailand under greenhouse conditions. Northeast Thailand is characterised by a tropical climate with acidic sandy soil. Vermicomposts are products derived from the accelerated biological degradation of organic wastes by earthworms and microorganisms. Vermicompost was applied at a rate of 6,250 kg ha^{-1} to upland rice. Chemical fertiliser (16-16-8 kg NPK) was applied at rates of 78.125 and 156.25 kg $ha^{-1}$and (46-0-0 kg NPK) was applied at rates of 31.25 and 62.5 kg ha^{-1} at20-25 days after sowing and panicle initiation, respectively. Five treatments were used: T1 (control without fertiliser); T2 (chemical fertilisers, 156.25 kg ha^{-1} NPK 16-16-8 and 62.5 kg ha^{-1} NPK 46-0-0); T3 (vermicompost, 6,250 kg ha^{-1}); T4 (vermicompost, 6,250 kg ha^{-1} and chemical fertilisers, 78.125 kg ha^{-1} NPK 16-16-8 and 31.25 kg ha^{-1} NPK 46-0-0) and T5 (vermicompost, 6,250 kg ha^{-1} and chemical fertilisers, 156.25 kg ha^{-1} NPK 16-16-8 and 62.5 kg ha^{-1} NPK 46-0-0) (Table 1).

Table 1. Treatments studied under greenhouse conditions at Khon Kaen University, Khon Kaen province, Northeast Thailand.

Treatment of upland rice cv. Sakonnakhon	16-16-8 + 46-0-0 kg ha^{-1}NPK/plant	Vermicompost kg ha^{-1}/plant
TR1 Control	-	-
TR2	156.25 + 62.5	-
TR3	-	6,250
TR4	78.125 + 31.25	6,250
TR5	156.25 + 62.5	6,250

2.2 Upland rice cv. Sakonnakhon planting and sampling

The upland rice cv. Sakonnakhon plants were transferred to plastic pots with one plant per pot in order to control the application of organic and chemical fertilisers. The plants were grown under greenhouse conditions. Growth and development were measured at 45, 60 and 120–130 (harvest stage) days after sowing. Whole plant samples were harvested for assessment of tillering number, number of leaves, leaf area, plant height, leaf and stem biomass, rice yield and macronutrient content (N, P and K) in the leaves, stem and soil. All leaves and stems were placed into paper bags and oven-dried at 80 °C for 3–4 days before the weight of the leaves and stems was determined.

2.3 Nitrogen (N), phosphorus (P) and potassium (K) measurements

For each sample of above-ground biomass, N content was measured by the micro-Kjeldahl method using indophenol blue, P content was measured by wet oxidation and spectrophotometry and K content was assessed by wet oxidation and flame photometry.

2.4 Statistical analysis

An analysis of variance was performed on the data obtained for each parameter in each treatment. All analyses were carried out using Statistical analysis version 8.0. Least significant differences (LSD) were calculated at $p < 0.05$ and Duncan's multiple-range test was used to test for significant differences between treatments. Standard deviations were also calculated from the variances.

3. Results and Discussion

3.1 Growth and yield of upland rice cv. Sakonnakhon

This study examined the effects of vermicompost-chemical mixed fertiliser on the growth of upland rice cv. Sakonnakhon. The results showed that management using vermicompost-chemical mixed fertiliser had significant effects on the growth of upland rice. The application of vermicompost at 6,250 kg ha^{-1} combined with chemical fertilisers (156.25 kg ha^{-1} of NPK 16-16-8 for 20–25 days after planting and 62.5 kg ha^{-1} of NPK 46-0-0 from leaf bud formation to panicle initiation; T5) had a significant effect on the tillering number per plant (5.08 tiller/plant) at the tillering stage (60 days after planting) (Table 2). The leaf is the source of synthesised carbohydrate. The application of treatment T5 (vermicompost at 6,250 kg ha^{-1} combined with chemical fertilisers, 156.25 kg ha^{-1} of NPK 16-16-8 for 20-25 days after planting combined with 62.5 kg ha^{-1} of NPK 46-0-0 from leaf bud formation to panicle initiation) and treatment T4 (vermicompost at 6,250 kg ha^{-1} combined with chemical fertilisers, 78.125kg ha^{-1} of NPK 16-16-8 for 20-25 days after planting combined with 31.25 kg ha^{-1} of NPK 46-0-0 from leaf bud formation to panicle initiation) were significantly different in leaf number per plant (23 leaves and 20 leaves respectively) (Table 3) and leaf area per plant (55.59 cm^2/plant and 61.05 cm^2/plant respectively) (Table 4) at 60 days after planting. The chemical fertilisers, 156.25 kg ha^{-1} NPK 16-16-8 and 62.5 kg ha^{-1} NPK 46-0-0 (T2) and T3 (vermicompost, 6,250 kg ha^{-1}) gave the tallest plants at 60 days after planting (Table 5). This might be due to the vermicompost benefits to the ecosystem of root rhizosphere andthe increases in supply of available nutrients and in nutrient uptake by the rice (Thirunavukkarasu & Vinoth, 2013). Similar results were also observed by Roy and Singh (2006). Nitrogen element was the main nutrient affecting vegetative growth, contributing to the number of tillers (Fallah, 2012).

Table 2. Tillering number of *Oryzasativa* cv. Sakonnakhon with various fertiliser application schemes

Treatment	Tillering Number/plant	
	45 days	60 days
TR1	1.50^{b}	1.50^{c}
TR2	3.08^{a}	3.75^{b}
TR3	3.08^{a}	3.58^{b}
TR4	3.50^{a}	3.92^{b}
TR5	3.67^{a}	5.08^{a}

Means in the same column with different superscripts are significantly different at p<0.05, and at 0.01 by LSD

Table 3. Leaf number of *Oryzasativa* cv. Sakonnakhon with various fertiliser application schemes

Treatment	Leaf number/plant	
	60 days	Harvest stage (120–130 days)
TR1	5.42[c]	4.33[b]
TR2	5.42[c]	18.00[a]
TR3	15.83[b]	17.90[a]
TR4	20.00[a]	25.83[a]
TR5	23.00[a]	19.63[a]

Means in the same column with different superscripts are significantly different at $p<0.05$, and at 0.01 by LSD.

Table 4. Leaf area of *Oryzasativa* cv. Sakonnakhon with various fertiliser application schemes

Treatment	Leaf area/plant (cm^2)		
	45 days	60 days	Harvest stage (120–130 days)
TR1	31.31[d]	29.53[c]	13.37[c]
TR2	41.78[c]	65.93[a]	58.64[b]
TR3	44.30[bc]	53.42[b]	56.47[b]
TR4	51.09[a]	61.05[ab]	82.53[a]
TR5	46.51[b]	55.59[b]	63.89[b]

Means in the same column with different superscripts are significantly different at $p<0.05$ and at 0.01 by LSD.

Table 5. Plant height of *Oryzasativa* cv. Sakonnakhon with various fertiliser application schemes

Treatment	Plant height (cm)	
	60 days	Harvest stage (120-130 days)
TR1	62.41[d]	62.56[b]
TR2	102.12[a]	118.75[a]
TR3	104.01[a]	115.94[a]
TR4	98.00[b]	126.25[a]
TR5	89.76[c]	116.38[a]

Means in the same column with different superscripts are significantly different at $p<0.05$ and at 0.01 by LSD.

With regard to the rice yield, treatment T3 (vermicompost, 6,250 kg ha^{-1}) and treatment T5 (156.25 kg ha^{-1} of NPK 16-16-8 for 20–25 days after planting and 62.5 kg ha^{-1} of NPK 46-0-0 from leaf bud formation to panicle initiation) were significantly different in total grain weight (2.96 g/plant and 2.83 g/plant respectively) (Table 6). This might be because vermicompost combined with chemical fertilisers (156.25 kg ha^{-1} NPK 16-16-8 and 62.5 kg ha^{-1} NPK 46-0-0) helped maintain nutrient availability and absorption by the plant.

Table 6. Yield of *Oryzasativa* cv. Sakonnakhon with various fertiliser application schemes

Treatment	Rice yield /plant		
	Spike No.	Average Grain No./spike	Total grain weight/plant (g)
TR1	1.42[b]	40.00[c]	0.63[b]
TR2	3.42[a]	82.75[a]	2.74[a]
TR3	4.00[a]	78.50[ab]	2.96[a]
TR4	2.58[a]	49.00[c]	1.41[b]
TR5	5.25[a]	53.75[bc]	2.83[a]

Means in the same column with different superscripts are significantly different at $p<0.05$ and at 0.01 by LSD.

However, the harvest index (HI) may decrease when the plant height increases. This is because increased plant height with lack of trunk strength causes lodging, which can easily damage productivity. The damage can be considered an indirect impact of nitrogen fertiliser or planting date, especially in light sensitive local varieties. The application of high nitrogen fertilisers is suitable for increasing productivity in high harvest index varieties (Sampet, 1999).

3.2 Nutrient uptakeofupland rice cv. Sakonnakhon

Growth and development under fertiliser management has consequences up to the post-harvest period. The applications of vermicompost at 6,250 kg ha^{-1} combined with chemical fertilisers (T4 and T5) were significantly different in leaf and stem biomass (Table 7). This may be linked to the macronutrient contents in leaves, stem and soil (Table 8 and 9). The increased N uptake with vermicompost combined with chemical fertilisers gave the highest N content, by mineralization of N from organic matter and mineralization of native nitrogen (Sims, 1987). Higher nitrogen uptake with the application of nitrogen fertilizer might be facilitated by higher nutrient concentration along with higher biomass production. The P uptake by leaves and stem were highest with vermicompost along with N fertilizers, possibly due to solubilisation of native phosphorous in soil by the vermicompost. Moreover, the synergistic effects of N and P may have promoted P content in stem. However, the split fertilizer applications provide steady availability of N that promotes the translocation of P from the vegetative organs to the grain (Thirunavukkarasu & Vinoth, 2013). The data indicate that K uptake by stem was highest with vermicompost along with N fertilizers. This could be attributed to high K content and improved availability of K ions caused by the vermicompost, and also the available nutrient content of vermicompost itself, as well as the rates of release that were much higher than with other treatments (Goswami, 1996). The increasing trend of K in stem may be due to the applied N releasing more $NH^+{}_4$-N and $NO^-{}_3$-N from the soil, which may occupy selective exchange sites in the 2:1 layer clay minerals and replace the K^+ from exchange sites, so that the increased available K concentration in soil increased its absorption by rice (Thirunavukkarasu & Vinoth, 2013).

Table 7. Leaf and stem biomass of *Oryzasativa* cv. Sakonnakhon with various fertiliser application schemes

Treatment	Leaf and stem biomass (g.) /plant	
	Leaf biomass	Stem biomass
TR1	2.05[c]	2.43[c]
TR2	12.94[b]	17.63[b]
TR3	8.17[b]	22.89[a]
TR4	18.22[a]	23.80[a]
TR5	19.03[a]	20.57[ab]

Means in the same column with different superscripts are significantly different at p<0.05 and at 0.01 by LSD.

Table 8. Macronutrient content in leaves and stems of *Oryza-sativa* cv. Sakonnakhon with various fertiliser application schemes

Treatment	Macronutrient content (%) /plant		
	N Leaves/stem	P Leaves/stem	K Leaves/stem
TR1	0.42[d]/0.29[d]	0.21[d]/0.27[c]	2.30[bc]/3.20[d]
TR2	1.30[a]/1.19[a]	0.25[c]/0.27[c]	2.28[bc]/2.44[e]
TR3	0.68[c]/0.64[c]	0.18[c]/0.37[b]	2.84[a]/3.39[c]
TR4	0.78[c]/0.69[c]	0.30[b]/0.37[b]	2.38[b]/3.54[b]
TR5	0.91[b]/0.99[b]	0.35[a]/0.52[a]	2.23[c]/3.69[a]

Means in the same column with different superscripts are significantly different at p<0.05 and 0.01 by LSD.

Table 9. Macronutrients in the soil after *Oryzasativa* cv. *Sakon-nakhon* planting with various fertiliser application schemes

Treatment	Macronutrients in the soil		
	N (%)	Available P (mg/kg)	Exchangeable K (mg/kg)
TR1	0.03[c]	68.82[b]	79.27[ab]
TR2	0.02[d]	71.43[b]	61.69[c]
TR3	0.10[a]	186.89[a]	84.24[a]
TR4	0.08[b]	159.49[a]	75.62[abc]
TR5	0.07[b]	150.35[a]	68.66[bc]

Means in the same column with different superscripts are significantly different at p<0.05 and at 0.01 by LSD.

4. Conclusions

The application of vermicompost with chemical fertiliser seems to have interesting effects on the growth and yield of *Oryzasativa* cv. Sakonnakhon. Applying vermi-compost at 6,250 kg ha^{-1} after planting for 20-25 days and from leaf bud formation to panicle initiation (T3) or vermi-compost at 6,250 kg ha^{-1} combined with chemical fertilisers, 78.125 kg ha^{-1} of NPK 16-16-8 after planting for 20-25 days combined with 31.25 kg ha^{-1} of NPK 46-0-0 from leaf bud formation to panicle initiation (T4), are useful schemes that decrease the consumption of chemical fertilisers but improve quality of the rice. This work provides an assessment of using vermicompost as a bio-fertiliser for improving upland rice quality and nutrient uptake, soil fertility, and sustainable crop production.

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