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The Effect of Different Fertilizers Management Strategies on Growth and Yield of Upland Black Glutinous Rice and Soil Property

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Abstract: The aim of this study was to investigate the effect of organic and inorganic fertilizers on growth and yield of five upland black glutinous rice varieties and soil property. Two experiments were conducted at Khon Kaen University, Thailand during the rainy seasons of 2007 and 2008. Experiments were laid out in a split-plot design with four replications. Four fertilizer treatments (control, farmyard manure (FYM) or cattle manure at a rate of 10 t ha^{-1}, NPK at the rate of 50-22-42 kg N-P-K ha^{-1}, the combination of the FYM and NPK were randomized in the main plots and five black glutinous rice varieties (KKU-GL-BL-05-002, KKU-GL-BL-05-003, KKU-GL-BL-05-004, KKU-GL-BL-05-009 and KKU-GL-BL-05-010) were randomized in the sub plots. Soil samples before fertilizer application and after harvesting were analyzed to determine chemical and physical properties. Leaf Area Index (LAI) and shoot dry matter were recorded at 40 days after planting, panicle initiation and flowering stages. Number of tillers and panicles per hill and grains per panicle, thousand grain weight, number of filled and unfilled grains and grain yield were recorded at harvest time. The results from both years indicated that using the combination of FYM and inorganic fertilizers increased shoot dry matter, LAI, tiller and panicle number per hill, grain number per panicle and grain yield. It was recorded that application of FYM together with inorganic fertilizers significantly increased soil organic matter, CEC, N, P and K. Comparing among the five varieties, KKU-GL-BL-05-002 had highest grain number per panicle and grain yield in both years.

Key words: Rice growth, yield, farm yard manure, cattle manure, soil property

INTRODUCTION

Black glutinous rice is a kind of glutinous rice variety that has purple or red color in pericarp and it has been recognized in many countries of Asia. In Thailand, black glutinous rice is grown under rainfed condition in both upland and lowland environments. Although, the black glutinous rice does not constitute a significant proportion of the total rice production, it is mostly grown throughout the North and Northeast Thailand. The farmers are growing this kind of rice in the small unit of their farm area. It can be used for making diverse products including sweet, health food and drink as well as cosmetic. Black glutinous rice varieties are reported to have higher protein, fat and crude fiber contents than the common white rice varieties as well as being rich in lysine, vitamin B_1, calcium, iron, zinc and phosphorus (Schiller *et al*., 2006). It is a crop thought to have herbal properties and has been used traditionally in Thai medical treatment for centuries. The purple pigment (anthocyanin: cyanidin-3-glucoside) in the husk (hull) and pericarp is a unique characteristic. In addition, gamma-oryzanol from rice bran oil comprises advantageous antioxidant (Dejian *et al*., 2002).

The farmers in Thailand, especially in the Northeast are growing black glutinous rice using local variety which has low yield productivity. Low average rice yields in Northeast Thailand would be to some extent associated with inadequate application of fertilizer despite the fact that most of soils in this region are sandy soils which have low organic matter, available nitrogen and phosphorus as well as cation exchange capacity (Jiraporncharoen, 1993). Even applying complete fertilizer at planting, followed by one or two nitrogen top dressings does not increase yield as would be expected because of low organic matter and clay content in the soil (Satyanarayana *et al*., 2002). Organic fertilizer such as farmyard manure (FYM) seems to be an alternative source of nutrients which appears to be more beneficial than inorganic fertilizer for crops grown on sandy soils. Nutrients from farmyard manure become available gradually and hence for a long time during growth.

The importance of fertilizers was also widely accepted by Thai farmers, as shown by their annual increase in

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fertilizer consumption (Jiraporncharoen, 1993). However, the long term use of chemical fertilizer may cause deterioration in the physical and chemical properties of soil (Fan *et al*., 2005). The experiments carried out in different countries have shown that crop yields are better when combinations of compost and inorganic fertilizers are used. The combination of FYM and inorganic fertilizers increased rainfed lowland rice yield in Northeast Thailand (Haefele *et al*., 2006). Therefore, this research focused to obtain information on the effect of organic and inorganic fertilizers on growth and yield of five upland black glutinous rice varieties and soil property.

MATERIALS AND METHODS

The experiment was conducted in the rainy seasons of 2007 and in the rainy seasons of 2008. The experimental field in 2007 was carried out 10 m far from the experimental field in 2008 at an upland farm of Agronomy Experimental Station, Agronomy section, Faculty of Agriculture, Khon Kaen University, Thailand at latitude of 16° 28' N and longitude of 102° 48' E and at an elevation of 176 m from mean sea level.

Both experiments were laid out in a split-plot design with four replications. Four fertilizer treatments (Table 1) were randomized in the main plots. The rates of fertilizer used in this study were managed following the procedure described in the research carried out in Northeast Thailand (Haefele *et al*., 2006). A rate of 50-22-42 kg N-P-K ha^{-1} was above the regional recommendation (40-12-10 kg N-P-K ha^{-1}) and the average farmers' practice (e.g., 35-14-13 kg N-P-K ha^{-1}) to achieve high yields and avoid soil nutrient depletion. Farmyard manure (FYM) at a rate of 10 t ha^{-1} was used to guarantee an effect, but was at least three to four times above the farmers' practice (Haefele *et al*., 2006).

The five different black glutinous rice varieties (KKU-GL-BL-05-002,KKU-GL-BL-05-003,KKU-GL-BL-05-004, KKU-GL-BL-05-009 and KKU-GL-BL-05-010) were randomized in the sub-plots and these varieties are elite black glutinous rice varieties for plant breeding program of Agriculture Faculty, Khon Kaen University.

Soil samples were collected at the depth of 0-15 cm before fertilizer application and after harvesting by using soil auger. The soils were analyzed to determine soil texture, pH, Cation Exchange Capacity (CEC), percentage of total nitrogen, extractable phosphorus, exchangeable potassium and percentage of organic matter. The results for soil analysis before fertilizer application are shown in Table 2.

The organic fertilizer used in this experiment was FYM from the animal farm, Khon Kaen University. This FYM was analyzed to determine pH, percentage of total nitrogen, percentage of total phosphorus, percentage of total potassium and percentage of organic matter. The results are shown in Table 3.

Land preparation was started at the onset of the rainy season of 2007 and 2008. FYM at a rate of 10 t ha^{-1} was applied to the plot corresponding to the designated fertilizer at two weeks before planting. Five different black glutinous rice varieties were sown on 27th July 2007 and 28th July 2008. Five dry rice seeds were dibbled into planting holes at a spacing of 25 cm×25 cm. After complete emergence (20 days after planting), the plants were thinned down to three plants per hill. Hand weeding was used as necessary. For the experimental plots which were imposed with the chemical fertilizer, the urea fertilizer (at a rate of 25 kg N ha^{-1}), triple superphosphate (at a rate of 22 kg P ha^{-1}) and murate of potash (at a rate of 42 kg K ha^{-1}) were applied as basal. Urea fertilizer (at a rate of 25 kg N ha^{-1}) was also applied at panicle initiation stage. The controls of pest and disease were conducted

Table 1: Fertilizer management practices for the years 2007 and 2008

Treatment	Description
Control	No fertilizer applied
FYM	Farmyard manure or cattle manure at a rate of 10 t ha^{-1} (fresh weight)
NPK[a]	NPK at a rate of 50-22-42 kg N-P-K ha^{-1}
FYM+NPK	Combined applications as in the treatments FYM and NPK

[a]NPK used were urea, triple superphosphate and muriate of potash

Table 2: Soil surface (0-15 cm) property before fertilizer application in the rainy seasons of 2007 and 2008

	Value		
Description	2007	2008	Method used
Soil Texture	Loamy sand	Loamy sand	Hydrometer
Sand (%)	89.700	87.200	
Silt (%)	8.900	11.400	
Clay (%)	1.400	1.400	
pH (1:2.5)	6.410	6.600	pH meter
Cation Exchange Capacity (CEC)	5.860	3.600	1 N ammonium acetate and distillation method
Total Nitrogen (%)	0.028	0.047	Kjeldahl method
Extractable phosphorus (ppm)	29.000	43.000	Bray II and Molybdenum-blue method
Exchangeable potassium (ppm)	91.000	41.000	1 N ammonium acetate and Flame photometry method
Organic mtter (%)	0.590	0.560	Walkley and black method

Table 3: Chemical analysis of farmyard manure (FYM) used in the experiment in the rainy seasons of 2007 and 2008

Description	Value 2007	Value 2008	Method used
pH (1:2.5)	6.580	7.50	pH meter
Total nitrogen (%)	0.997	1.32	Kjeldahl method
Total phosphorus (%)	0.721	0.57	Wet digestion (HNO_3: $HClO_4$) Vanado-molybdate method
Total potassium (%)	6.750	0.93	Wet digestion (HNO_3: $HClO_4$) Flame photometry method
Organic matter (%)	16.050	23.72	Walkley and black method

by following the standard recommendation for rice production in Thailand. Supplementary irrigation was applied using the mini-sprinkler system during dry period.

Five adjacent hills bordered by guard plants were harvested from each experimental plot at 40 days after planting, panicle initiation and flowering stages. Plant samples were cleaned and three leaves per hill were then randomly selected to measure leaf area by using an automatic leaf area meter (Model AAC-400). The samples leaves and the remaining leaves were dried at 80°C for 48 h by hot air oven to measure dry weights which were then used to calculate Leaf Area Index (LAI). Shoot dry matter was also measured for those three growth stage and for harvest maturity date.

At harvest time, grain yield was recorded from the sampling area (2.25 m^2) of each experimental plot. Yield components were also measured as number of tillers per hill, number of panicles per hill, number of grains per panicle, thousand grain weight, number of filled grains and number of unfilled grains. The number of tillers per hill and panicles per hill were counted from randomly selected ten hills of harvested area. From randomly selected ten panicles of harvested area, the grains were threshed and bulked, the number of filled grains and unfilled grains were counted and thousand grain weight was measured.

The data collected were analyzed statistically using analysis of variance technique. Treatment means were compared by Least Significant Different (LSD) method at 95% confidence level. All statistical analyses were done using Statistix 8.0 software by followed by Gomez and Gomez (1984).

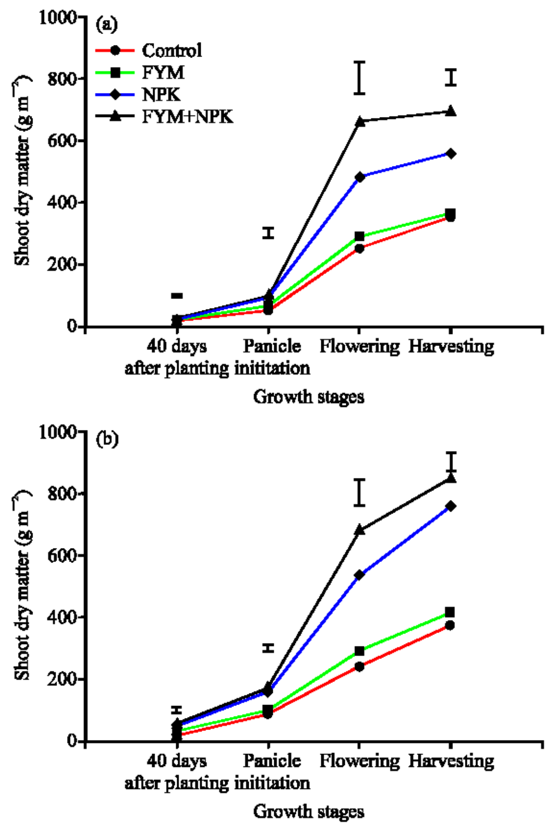

Fig. 1: Means of shoot dry matter (g m^{-2}) for four different fertilizer applications at different growth stages in the rainy season of (a) 2007 and (b) 2008 (Bars indicate LSD at $p \leq 0.05$)

RESULTS

Dry matter accumulation and Leaf Area Index (LAI): Shoot dry matter accumulation for four different fertilizer applications at four different growth stages is shown in Fig. 1a and b. The data from the experiment in 2007 and 2008 revealed that FYM in combination with inorganic fertilizers significantly produced maximum shoot dry matter at all growth stages and it was followed by the result of inorganic fertilizers application. FYM alone and no fertilizer application treatments gave very poor value of shoot dry matter at all growth stages.

Leaf area indices were significantly different among the four different fertilizer applications at three different growth stages for the experiment in 2007 and 2008 (Fig. 2a, b). The combination of FYM and inorganic fertilizers treatment resulted in the highest LAI for all growth stages which was followed by the inorganic fertilizers treatment. The highest average values of LAI for both 2007 and 2008 experiments were 0.95 cm^2 cm^{-2} for 40 days after planting, 1.33 cm^2 cm^{-2} for panicle initiation stage and 2.12 cm^2 cm^{-2} for flowering stage. FYM alone and no fertilizer application treatments gave very poor value of LAI.

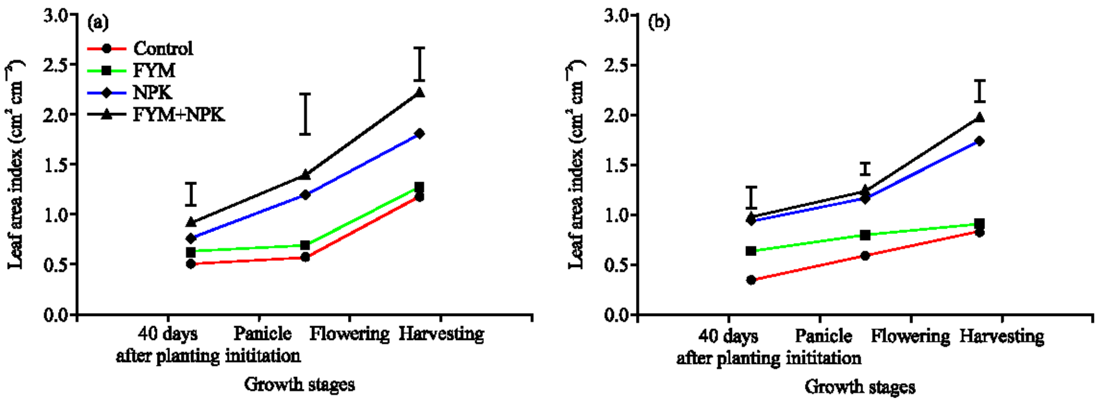

Fig. 2: Means of leaf area index for four different fertilizer applications at different growth stages in the rainy season of (a) 2007 and (b) 2008 (Bars indicate LSD at $p \le 0.05$)

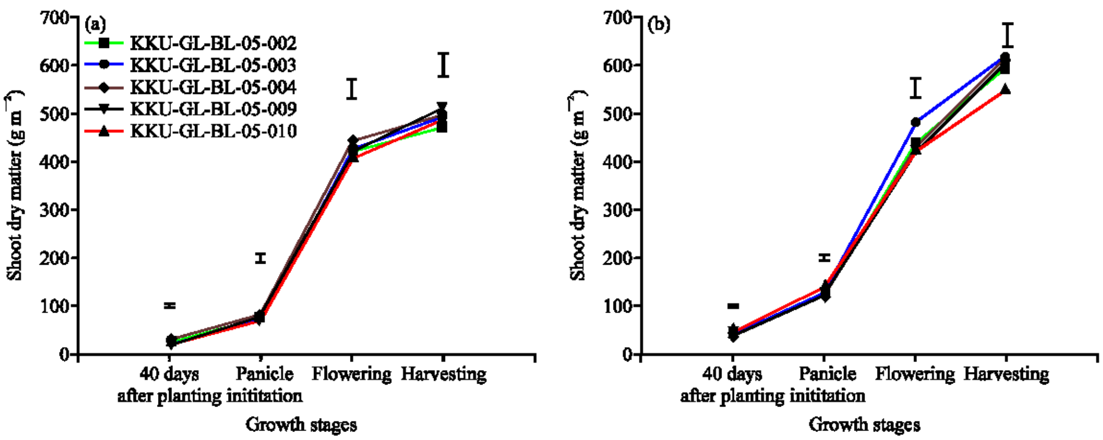

Fig. 3: Means of shoot dry matter (g m^{-2}) for the five black glutinous rice varieties at different growth stages in the rainy season of (a) 2007 (b) and 2008 (Bars indicate LSD at $p \le 0.05$)

Comparing between five black glutinous rice varieties, the result for the experiment in 2007 showed that there were no significant differences in shoot dry matter for all four growth stages except at an early growth stage (Fig. 3a, b). For the result in 2008 experiment, there were significant differences in the shoot dry matter of five black glutinous rice varieties for all four growth stages. It was found that there were no interactions between fertilizer and variety on shoot dry matter for all growth stages in both years except at 40 days after planting of 2008 experiment. This indicates that the effect of fertilizers on shoot dry matter of all tested varieties was similar for almost all growth stages in both 2007 and 2008 experiments. It was also found that there were highly significant differences in LAI at every growth stages for 2007 experiment (Fig. 4a and b). KKU-GL-BL-05-004 variety gave the highest values of LAI at different growth stages (0.97 cm^2 cm^{-2} for 40 days after planting, 1.23 cm^2 cm^{-2} for panicle initiation stage and 1.86 cm^2 cm^{-2} for flowering stage) whereas KKU-GL-BL-05-010 had the lowest values (0.47 cm^2 cm^{-2} for 40 days after planting, 0.76 cm^2 cm^{-2} for panicle initiation stage and 1.50 cm^2 cm^{-2} for flowering stage). KKU-GL-BL-05-003 variety was the second highest values of LAI at different growth stages. For 2008 experiment, there were no significant differences in LAI at 40 days after planting and panicle initiation stage whereas highly significant difference at flowering stage was observed. KKU-GL-BL-05-003 and KKU-GL-BL-05-004 varieties gave the highest values of LAI at flowering stage (1.62 and 1.55 cm^2 cm^{-2}, respectively) whereas, KKU-GL-BL-05-010 produced the lowest value (0.77 cm^2 cm^{-2}). It was also observed that there were no interactions for LAI between fertilizer and variety at all different growth stages in both 2007 and

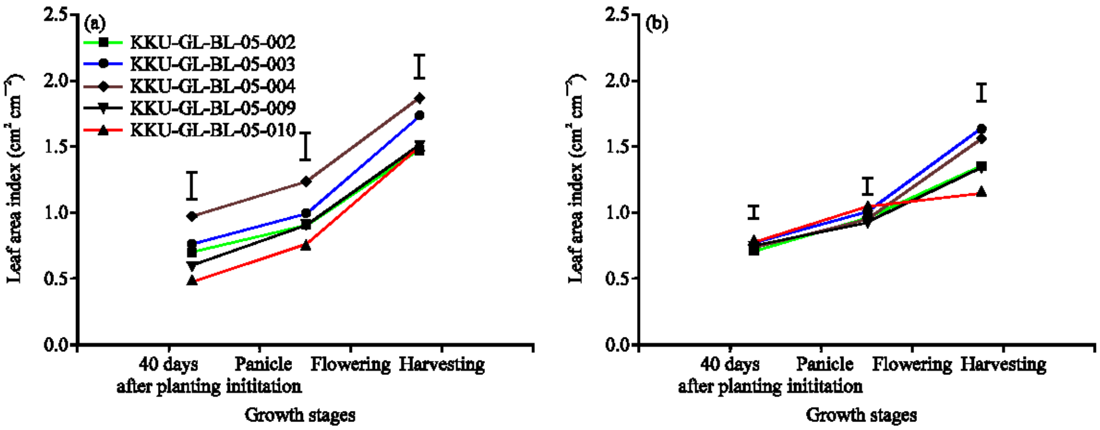

Fig. 4: Means of leaf area index for the five black glutinous rice varieties at different growth stages in the rainy season of (a) 2007 and (b) 2008 (Bars indicate LSD at $p \leq 0.05$)

Table 4: Effect of FYM and inorganic fertilizers on yield and yield components of five black glutinous rice varieties grown in upland condition in the rainy season of 2007 and 2008

	Tiller No. per hill		Panicle No. per hill		Grain No. per panicle		% of filled grains		1000-grain weight (g)		Grain yield (kg ha^{-1})	
Treatments	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Fertilizer (F)												
Control	6.4b	6.4b	5.5b	5.7c	111b	86c	85.2	87.9	23.8	23.7b	810b	897b
FYM	6.9b	6.7b	5.6b	6.3b	113b	96b	87.2	87.6	24.0	24.8a	865b	1011b
NPK	10.7a	10.7a	7.3a	9.2a	129a	119a	84.1	86.0	24.8	25.2a	1551a	1709a
FYM+NPK	11.1a	11.4a	7.7a	9.6a	134a	121a	83.9	87.0	24.4	25.2a	1578a	1834a
Statistical analysis												
F-test	**	**	**	**	**	**	ns	ns	ns	**	**	**
C.V %	19.1	17.4	15.6	8.1	13.4	6.8	4.7	5.1	6.5	4.9	21.2	27.2
Variety (V)												
KKU-GL-BL-05-002	8.0c	8.4b	5.9b	7.7ab	137a	113a	84.5a	86.8	22.4c	23.8b	1229	1493a
KKU-GL-BL-05-003	9.8ab	9.4a	6.6ab	7.9a	108b	103bc	87.6a	86.7	24.5b	25.2a	1205	1413ab
KKU-GL-BL-05-004	9.9a	9.3a	7.1a	8.0a	100b	99c	87.0a	87.9	25.9a	25.0a	1143	1340b
KKU-GL-BL-05-009	8.4bc	8.7b	6.5ab	7.8a	129a	106b	81.3b	87.8	24.0b	24.8a	1206	1444ab
KKU-GL-BL-05-010	7.6c	8.3b	6.5ab	7.3b	133a	107b	85.1a	86.5	24.7b	24.8a	1223	1123c
Statistical analysis												
F-test	**	**	*	**	**	**	**	ns	**	**	ns	**
F×V	ns	*	ns	ns	ns	ns	ns	**	ns	**	ns	*
C.V %	24.6	6.2	14.3	7.0	14.6	7.3	5.3	3.2	5.9	4.2	25.9	13.7

Values in column followed by the same letter are not significantly different at 5% level. **Significantly different at $p \leq 0.01$, *Significantly different at $p \leq 0.05$, ns: Not significant

2008 experiments, indicating that the varietal difference on LAI was not significantly affected by different fertilizer applications.

Yield components and grain yield: Yield components and grain yield of five black glutinous rice varieties grown in 2007 and 2008 are presented in Table 4. From the results of yield components affected by fertilizers, the application of inorganic fertilizers alone and using the combination of FYM and inorganic fertilizers significantly increased tiller number per hill, panicle number per hill and grain number per panicle when compared to the treatments of without fertilizer application and using FYM alone. It was found that means for grain yield of black glutinous rice varieties recorded from the experimental plots with inorganic fertilizers alone (1511 kg ha^{-1} for 2007 and 1709 kg ha^{-1} for 2008) and with a combination of FYM and inorganic fertilizers (1578 kg ha^{-1} for 2007 and 1834 kg ha^{-1} for 2008) were significantly higher than means grain yield from the experimental plots with application of FYM alone (865 kg ha^{-1} for 2007 and 1011 kg ha^{-1} for 2008) and with no fertilizer application (810 kg ha^{-1} for 2007 and 897 kg ha^{-1} for 2008).

Comparing among the five black glutinous rice varieties, the result indicated that there was no significant difference in mean grain yield for 2007 experiment, but there was highly significant difference for 2008 experiment. It was also found that mean grain yield of KKU-GL-BL-05-002 variety was the highest for both 2007 and 2008 experiments (1229 kg ha^{-1} for 2007 and 1493 kg ha^{-1} for 2008). Based on the results for yield component in both experimental years, there were significant differences in all yield components among the five varieties except percentage of filled grains in 2008 experiment. There were no interactions for grain yield and all yield components between fertilizer and variety in 2007 experiment, indicating that the varietal differences on grain yield and yield components were not significantly affected by different fertilizer applications. For 2008 experiment, however, there were interactions for grain yield, tiller number per hill, percentage of filled grains and thousand grain weight between fertilizer and variety, indicating that the varietals difference on those yield components was significantly affected by different fertilizer applications. No interactions between fertilizer and variety for panicle number per hill and grain number per panicle in 2008 experiment indicates that the response of the five black glutinous rice varieties based on these characteristics to different fertilizer applications were similar.

Physical and chemical properties of soil (0-15 cm) at harvest stage: The data on soil properties as affected by FYM and inorganic fertilizers are presented in Table 5. The results on soil physical and chemical properties in both 2007 and 2008 experiments revealed that soil organic matter content was significantly higher in combined use of FYM and inorganic fertilizers applications (0.723% for 2007 and 0.690% for 2008). It was noticed that FYM application increased more organic matter accumulation in the soil when compared with inorganic sources and no fertilizer input. Soil pH values among the different fertilizer treatments for both experiments were not statistically significant difference (varied from 6.22-6.81). In both years, CEC was significantly higher in the plots where the combination of FYM and inorganic fertilizers was added (3.05 c mol kg^{-1} for 2007 and 5.05 c mol kg^{-1} for 2008). Significantly lowest CEC was obtained from the plots with no fertilizer application (2.52 c mol kg^{-1} for 2007 and 3.60 c mol kg^{-1} for 2008).

Total amount of N content in soil was significantly higher in the combination of FYM and inorganic fertilizers (0.0318% for 2007 and 0.0323% for 2008) whereas significantly lowest total amount of N content resulted in the treatment of without fertilizer application (0.0275% for 2007 and 0.0225% for 2008). It was found that using the

Table 5: Effect of FYM and inorganic fertilizers on some chemical properties of soil at final harvest in the rainy season of 2007 and 2008

	pH (1:2.5)		CEC (c mol kg^{-1})		Total N (%)		Extr. P (ppm)		Exch. K (ppm)		OM (%)	
Treatments	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Control	6.22	6.55	2.52b	3.60c	0.0275b	0.0225b	36.50	34.00b	22.50b	19.25	0.625b	0.535b
FYM	6.40	6.72	2.78ab	4.45b	0.0298ab	0.0318a	45.00	40.00b	27.50a	18.75	0.660b	0.578b
NPK	6.32	6.81	2.80ab	4.10bc	0.0315a	0.0255ab	45.75	40.75b	30.50a	23.75	0.658b	0.588 b
FYM+NPK	6.25	6.73	3.05a	5.05a	0.0318a	0.0323a	47.25	52.75a	31.00a	28.50	0.723a	0.690a
Statistical analysis												
F-test	ns	ns	*	**	*	*	ns	*	*	ns	**	**
C.V %	2.9	2.3	6.3	8.2	5.5	16.1	16.2	15.7	10.7	41.4	4.0	7.0

Values in column followed by the same letter are not significantly different at 5% level. **Significantly different at $p\leq0.01$, *Significantly different at $p\leq0.05$, ns: Not significant

Table 6: Estimated net income for four different fertilizer managements

	Gross income (US$ ha^{-1})		Production cost[a] (US$ ha^{-1})		Net income (US$ ha^{-1})	
Treatments	2007	2008	2007	2008	2007	2008
Over material cost						
Control	476	528	88	88	389	440
FYM	509	594	205	205	304	389
NPK	912	1005	291	291	622	715
FYM+NPK	928	1079	408	408	520	671
	Gross income (US$ ha^{-1})		Production cost[b] (US$ ha^{-1})		Net income (US$ ha^{-1})	
Treatments	2007	2008	2007	2008	2007	2008
Over material and labor cost						
Control	476	528	266	266	210	261
FYM	509	594	393	393	115	201
NPK	912	1005	479	479	434	527
FYM+NPK	928	1079	606	606	322	473
	Gross income (US$ ha^{-1})		Production cost[c] (US$ ha^{-1})		Net income (US$ ha^{-1})	
Treatments	2007	2008	2007	2008	2007	2008
Over material cost without paying labor and FYM cost						
Control	476	528	88	88	389	440
FYM	509	594	88	88	421	507
NPK	912	1005	291	291	622	715
FYM+NPK	928	1079	291	291	638	788

[a]Cost of Fertilizers, seed and gasoline; [b]Cost of Fertilizers, seed, gasoline and labor; [c]Cost of Fertilizers, seed and gasoline

combination of FYM and inorganic fertilizers gave the highest soil extractable P among the different fertilizer treatments (47.25 ppm for 2007 and 52.75 ppm for 2008). In addition, the highest values of exchangeable K in soil were recorded in the plots with the combination of FYM and inorganic fertilizers (31.00 ppm for 2007 and 28.50 ppm for 2008).

Estimated net income among the four fertilizer applications: The result for an analysis of estimated net income over material cost for four different fertilizer applications is shown in Table 6 indicated that application of inorganic fertilizers alone gave the highest profit for both 2007 and 2008 experiments (622 US$ ha^{-1} for 2007 and 715 US$ ha^{-1} for 2008) it was followed by the application of FYM together with inorganic fertilizers (520 US$ ha^{-1} for 2007 and 671 US$ ha^{-1} for 2008). Similar result was also observed for an analysis of estimated net income over material and labor costs for the years 2007 and 2008 (Table 6). Even though estimated net income for inorganic fertilizers application alone was higher than estimated net income for the application of FYM together with inorganic fertilizers, the farmers might consider that long term use of inorganic fertilizers would causes deterioration of soil physical and chemical properties. Whereas the use of FYM together with inorganic fertilizers would improve both rice production and soil fertility. In case of the farmers who have FYM in their own farm and use their family labor, they would be able to receive high profit from the application of FYM together with inorganic fertilizers (638 US$ ha^{-1} for 2007 and 788 US$ ha^{-1} for 2008) (Table 6).

DISCUSSION

According to the results from both 2007 and 2008, significantly highest shoot dry matter and LAI in the combination of FYM along with inorganic fertilizers would be attributed to better physiological growth of plants as an addition of organic matter from FYM increased the soil water holding capacity and CEC, improved availability of macronutrients as well as micronutrients and improved soil physical properties under upland conditions (Dobermann and Fairhurst, 2000). In both experimental years, increases in CEC, total N, soil extractable P, soil exchangeable K and organic matter were also observed in the plots where addition of FYM along with inorganic fertilizers was used (Table 5).

The reason for maximum tillering occurred for an application of inorganic fertilizers alone and a combination of FYM and inorganic fertilizers would be attributed to the more availability of nitrogen which played a vital role in plant growth and the more solubility of phosphorus (Dobermann and Fairhurst, 2000) which promoted root development and tillering. Fageria (2009) reported that rice tillering was minimized in the pot that did not receive P fertilization compared to the pot that received N and P fertilization in upland rice.

The result pattern for panicle number per hill was similar to that of tiller number per hill in both years. Therefore, increase tiller number per hill contributed to more panicle number per hill for an application of inorganic fertilizers alone and for a combination of FYM and inorganic fertilizers application. This result is in accordance with Fageria *et al.* (2003) who reported that the number of panicles per unit area is determined by either stand density or tiller development during vegetative growth of rice. In addition, Chang and De Datta (1975) reported that tiller number and panicle number were also positively and closely correlated.

The highest total grain number per panicle for a combination of FYM and inorganic fertilizers was due to high available N at the panicle initiation stage may increase spikelet number per panicle (De Datta, 1981; Nachimuthu *et al.*, 2007) and K increases the number of spikelets per panicle, percentage of filled grains and thousand grain weight (Dobermann and Fairhurst, 2000; Bahmaniar *et al.*, 2007). The potential number of grains per panicle is determined at panicle initiation and it is influenced by the plants' nutritional status during vegetative growth (Fageria *et al.*, 2003). The result of a high grain yield under inorganic sources of nutrient might be due to immediate release and availability of nutrients. Organic fertilizer with inorganic fertilizer increased the fertilizer use efficiency and improved the physical and chemical properties of soil and it would be a reason towards increased yield (Banik *et al.*, 2006).

For the results of soil property after harvesting, the greatest amount of soil organic matter in treatment receiving a combination of FYM and inorganic fertilizers was due to the fact that the application of FYM could increase organic matter content of the soil. Soil organic matter is not only a pool of plant nutrient but also affects soil physical, chemical and biological properties and it plays a key role in establishing and maintaining the level of soil fertility (Haefele *et al.*, 2004; Fageria, 2009). No significant different for soil pH value among different fertilizer treatments could be explained by the high buffering capacity of the soils. A noticeable increase CEC in combined use of FYM with inorganic fertilizers might be mainly attributed to the increase of organic matter (Kumazawa, 1984; Gupta and O'Toole, 1986; Dobermann and Fairhurst, 2000).

CONCLUSION

This study investigated the fertilizer management practice for increasing rainfed upland black glutinous rice productivity. The results from both experimental years indicated that using the combination of FYM and inorganic fertilizers slightly increased shoot dry matter, LAI, tiller number per hill, panicle number per hill, grain number per panicle and grain yield when compared to using inorganic fertilizer alone, but it significantly increased those agronomic traits when compared to the treatments of no fertilizer application and FYM alone. The results indicated the beneficial effect of FYM application together with inorganic fertilizers in increasing the growth and grain yield of black glutinous rice. Therefore, organic and inorganic fertilizers would be complementary in meeting the nutrients requirements of rice plants.

This study also investigated the effect of organic and inorganic fertilizers on soil quality under upland condition. According to the results of soil analysis in two years, it was evident that application of FYM together with inorganic fertilizers significantly increased soil organic matter, CEC and soil nutrients content such as N, P and K. Therefore, organic fertilizers can be a source of essential nutrients for plants as well as for the improvement of soil properties. The use of organic fertilizer combined with inorganic fertilizers is likely to be helpful for both crop production and soil fertility improvement particularly on upland soil. Therefore, the application of organic and inorganic fertilizers used in the right practice need to be done in order to increase sustainable agriculture and fertility of soil.

In addition, comparing between the varieties, the results indicated that KKU-GL-BL-05-003 and KKU-GL-BL-05-004 had good performance in term of plant growth characteristics, e.g., shoot dry matter, LAI and tiller number per hill. KKU-GL-BL-05-002 had the highest grain number per panicle and grain yield in both years. Therefore, this variety performance would be valuable information for black glutinous rice breeding program in Thailand.

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