Research article

Growth and Yield of Organic Rice as Affected by Rice Straw and Organic Fertilizer

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Abstract The objectives of this research were to investigate the effect of rice straw management and the application of different types of organic fertilizer on the growth and yield of transplanted rice grown under rainfed conditions. The experiment was conducted in a farmer's field in Khon Kaen province in 2009. A Randomized Complete Block Design was used with four replications. The treatments consisted of (1) rice straw incorporation into the soil, (2) rice straw combined with cattle manure, (3) rice straw combined with bio-extracted fertilizer and (4) rice straw combined with cattle manure and bio-extracted fertilizer. In the present experiment, the rice straw remaining in the paddy field was incorporated into soil after the rice harvest in April. Then the rice was transplanted in August. The amount of rice straw and cattle manure incorporated into the soil were about 5.1 and 9.4 tons/ha respectively, which provided N 129 kg/ha, P 41 kg/ha and K 382 kg/ha. A liquid bio-extracted fertilizer was applied into the soil during the incorporation of rice straw at a rate of 30 liters per hectare which provided N 28 g/ha, P 5 g/ha and K 135 g/ha and foliar application at 60 days after rice transplanting which provided N 1.11 g/ha, P 0.18 g/ha and K 5.4 g/ha. It was found that the application of different types of organic fertilizer combined with rice straw had a significant effect on plant height, but did not show any significant effect on leaf area and aboveground dry weight at 30 days after transplanting and at panicle initiation growth stage. At harvest, total aboveground dry weight and panicle number were significantly affected by the application of different types of organic fertilizer. The treatment of rice straw combined with cattle manure and bio-extract fertilizer gave the maximum panicle number. The treatment of rice straw combined with cattle manure gave maximum grain yield, but did not show any significant difference from the treatment of rice straw combined with cattle manure and bio-extracted fertilizer.

Keywords organic rice, organic fertilizer, cattle manure, bio-extracted fertilizer

INTRODUCTION

Northeast Thailand has 5.27 million hectares of rainfed lowland rice growing area, which is about 57% of the rice growing area in the whole country (Office of Agricultural Economic [OAE], 2006). The average grain yield in this region is low (2.07 t ha^{-1}) (OAE, 2009), due to unstable water availability (Bell and Seng, 2004). With the current renewed focus on sustainable agricultural efficient resources (rice straw) recycling may be an alternative method of soil fertility management for Northeastern lowland rice producers. Straw management by incorporation into the soils is an alternative method to avoid straw burning before land preparation. Cattle manure is commonly an organic fertilizer available in the farms of the smallholder farmers. The bio-extracted fertilizers are also can be produced by farmers themselves using organic material wastes available in the farm.

Present studies were, therefore, undertaken to evaluate the effect of rice straw alone and in combination with various organic sources of nutrients on the growth and yield of organic rice.

METHODOLOGY

The experiment was conducted in a farmer's field in Muang Yai village, Khon Kaen province in 2009. The soil physio-chemical characteristics before planting are shown in Table 1. Randomized Completed Block Design with four replications was used. The treatments consisted of (1) rice straw incorporation into the soil, (2) rice straw combined with cattle manure, (3) rice straw combined with bio-extracted fertilizer and (4) rice straw combined with cattle manure and bio-extracted fertilizer. Rice straw was incorporated after the rice harvest. The amount of nutrients returned to the soil by incorporating rice straw into the soil was calculated as in Eq. (1).

$$\frac{\text{Rice straw dry weight (kg ha}^{-1}\text{) x nutrient content (\%)}}{100} \quad (1)$$

The amount of nutrients in the cattle manure applied to the soil before transplanting two weeks at the rate of 9,375 kg ha^{-1} was calculated as in Eq. 2.

$$\frac{\text{Rate of application (kg ha}^{-1}\text{) x nutrient content (\%)}}{100} \quad (2)$$

The amount of nutrients in the bio-extracted fertilizer applied to the soil was calculated as in Eq. 3.

$$\frac{\text{Rate of application (kg ha}^{-1}\text{) x nutrient content (\%)}}{100} \quad (3)$$

The bio-extracted fertilizer (vegetable wastes and molasses; by-product of the processing of sugar cane into sugar, fermented for 7 days) applied into the soil at the rate of 3,125 liter ha^{-1} two weeks before transplanting, and foliar application at rate of 1,250 ml ha^{-1} at 60 days after transplanting.

Two to three seedlings per hill were transplanted in the first week of July in the pattern of 25 x 25 cm hills. Rice cv. KDML 105 was used in this study. Hand weeding was done one at 60 days after transplanting. No insecticide and fungicide were used in this experiment.

Five hills from each plot were measured to classify their height at 30 days after transplanting (DAT) and at panicle initiation (PI) growth stage. Five hills from each plot outside the harvesting area were randomly selected to determine leaf area at 30 DAT and PI. The leaf area was measured using leaf area meter. Again, five hills from each plot outside the harvesting area were randomly selected and oven dried at 80 ^{0}Celsius for 4 days to determine total aboveground dry weight at 30 DAT and PI. The numbers of panicles per hill in the harvesting areas were measured at harvest time. For the same samples, ten panicles from each plot were randomly selected to determine the number of filled and unfilled grains and calculated the percentage of filled grain per panicle. The grain yield was taken from the 2 x 3 m harvesting area of each plot and calculated as kg ha^{-1} at 14% moisture content. The filled grains were randomly selected from the grain yield sample to determine the weight of 1,000 grains. The data were analyzed using analysis of variance procedures and LSD was used to compare treatment methods when the F-test was significant.

Rainfall, maximum and minimum temperature were recorded at the Khon Kaen Meteorological Station 5 kilometers from the site. Weekly rainfall, as well as the maximum and minimum temperature during the growing season is shown in Fig. 1.

Table 1 Soil physio-chemical characteristics before planting of the experimental field

Soil characteristics	Values
Physical properties[1]	
-Sand (%)	83.09
-Silt (%)	7.60
-Clay (%)	9.25
Texture class	Loamy sand
Chemical properties	
-pH[2]	5.24
-EC (ms/cm at 25 ºC)[3]	0.070
-Organic Matter (%)[4]	0.352
-Total N (%)[5]	0.0213
-Available P (ppm) [6]	9.20
-Exchangeable K (ppm) [7]	54.65
-Exchangeable Ca (ppm) [7]	485.00

[1]Texture: Hydrometer method, [2]pH: pH meter (1:1 H_2O), [3] EC (1:5 H_2O),[4]O.M.: Walkley and Black method, [5]Total N: Kjeldahl method, [6]Extractable P: Bray II and Molybdenum-blue method, [7]Exchangeble K and Ca: 1N NH4OAc pH7 and Flame photometry method.

RESULTS

Plant height

The plant height is not a yield component in grain crops but it indicates the influence of various nutrients on plant metabolism. It was found that incorporation of rice straw into the soil combined with application of cattle manure gave the maximum plant height at 30 DAT and PI stage. The plant height, however, did not show any significant difference from the incorporation of rice straw into the soil combined with the application of cattle manure and bio-extracted fertilizer treatment (Table 2).

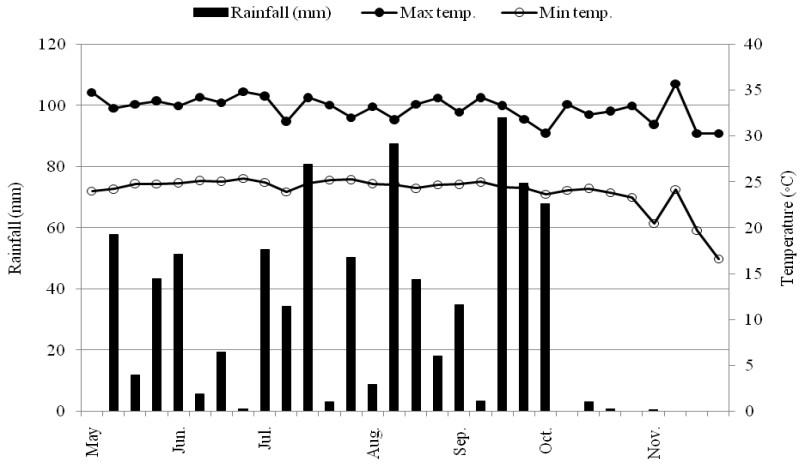

Fig. 1 Weekly rainfall (mm), maximum and minimum temperature (ºC) in the field during growing season in 2009

Leaf area per hill

The leaf area (cm^2 $hill^{-1}$) was taken at the 30 DAT and PI stage. It did not show any significant difference among the treatments. The leaf area per hill, however, obtained the highest in the treatment of the incorporation of rice straw into the soil combined with the application of cattle manure at 30 DAT and the treatment of incorporation of rice straw into the soil combined with cattle manure and bio-extracted fertilizer (Table 2).

Table 2 Plant height, leaf area and total aboveground dry weight of KDML 105 as affected by application of rice straw, cattle manure and bio-extracted fertilizer at 30 days after planting (DAP) and at panicle initiation (PI) in 2009

Treatments	Plant height (cm)		Leaf area (cm^2/hill)		Total aboveground dry weight (g/hill)	
	30 DAP	PI	30 DAP	PI	30 DAP	PI
Rice straw	59.00 b	100.75 ab	525.18	1358.70	3.63	19.35
Rice straw + cattle manure	65.75 a	110.35 a	869.25	1642.00	5.05	22.16
Rice straw + bio-extracted fertilizer	57.65 b	96.55 b	520.35	1367.80	2.87	15.68
Rice straw + cattle manure+ bio-extracted fertilizer	61.55 ab	105.95 ab	754.63	1767.00	4.41	20.27
F-test	*	**	NS	NS	NS	NS
CV (%)	5.05	4.17	40.00	4.17	29.68	19.64

Means followed by the same letter at the same column were not significantly different by LSD
, significant at P<0.05 and 0.01, respectively and NS not significant*

Total aboveground dry weight

The total aboveground dry weight (g $hill^{-1}$) was taken at the 30 DAT and PI stage. It did not show any significant difference among the treatments. The maximum total aboveground dry weight, however, was obtained in the treatment of incorporation of rice straw into the soil combined with the application of cattle manure at 30 DAT and PI stage (Table 2).

Number of panicle per hill

The number of panicle per hill or per unit area is the most important component of yield. The larger the number of panicles, the more the yield will be. In the present experiment, incorporation of rice straw into the soil combined with the application of cattle manure and bio-extracted fertilizer produced the maximum number of panicle per hill (9.00), but did not show a significant difference from the incorporation of rice straw into the soil combined with the application of cattle manure (Table 3).

Table 3 Grain yield and yield components of KDML 105 as affected by application of rice straw, cattle manure and bio-extracted fertilizer in 2009

Treatments	Panicle no./hill	Filled grains (%)	1000 grain weight (g)	Grain yield (kg/ha)
Rice straw	7.50 b	96.90	25.24	3103.13 b
Rice straw + cattle manure	8.50 a	96.65	26.42	3820.31 a
Rice straw + bio-extracted fertilizer	7.50 b	97.10	25.10	3239.38 b
Rice straw + cattle manure+ bio-extracted fertilizer	9.00 a	95.78	25.34	3796.88 a
F-test	*	NS	NS	*
CV (%)	6.60	1.58	4.12	11.78

Means followed by the same letter at the same column were not significantly different by LSD
** significant at P< 0.05 and NS not significant*

Fill grain percentage and 1000- grain weight

In the present experiment, rice straw incorporation into the soil alone and combined with various organic fertilizers did not show any significant difference in filled grain percentage and 1000-grain weight (Table 3).

Grain yield (kg ha^{-1})

The results showed that grain yield was significantly different among the incorporation of rice straw into the soil and rice straw combined with various organic fertilizers treatments. The rice straw incorporated into the soil combined with the application of cattle manure produced maximum grain yield (3820 kg ha^{-1}) which did not make a significant difference from the treatment of rice straw incorporated into the soil combined with cattle manure and bio-extracted fertilizer (3797 kg ha^{-1}) (Table 3).

Nutrient concentration in leaf

The incorporation of rice straw into the soil alone and incorporation with various organic fertilizers had no significant effect on N and K, but it did significantly affect the P concentration of the leaves. The incorporation of rice straw into the soil combined with cattle manure gave the maximum P (0.219%) concentration (Table 4).

Nutrient concentration in stem

The incorporation of rice straw into the soil alone and combined with various organic fertilizers had a significant effect on the N, P and K concentration of stem. The incorporation of rice straw into the soil combined with the application of cattle manure and bio-extracted fertilizer gave maximum N (0.535%) concentration of the stem. The incorporation of rice straw into the soil combined with application of cattle manure obtained the maximum P (0.267%) and K (2.938%) concentration of the stem (Table 4).

Table 4 Nitrogen, phosphorus and potassium content in leaves and stems of KDML 105 as affected by application of rice straw, cattle manure and bio-extracted fertilizer at panicle initiation in 2009

Treatments	Leaf			Stem		
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
Rice straw	1.614	0.165 b	2.381	0.430 b	0.193 b	2.510 b
Rice straw + cattle manure	1.580	0.219 a	2.514	0.484 a	0.267 a	2.938 a
Rice straw + bio-extracted fertilizer	1.603	0.176 b	2.389	0.500 a	0.208 b	2.756 ab
Rice straw + cattle manure+ bio-extracted fertilizer	1.645	0.212 a	2.548	0.535 a	0.259 a	2.859 a
F-test	NS	**	NS	**	**	**
CV (%)	2.92	2.92	3.56	3.72	9.41	4.73

Means followed by the same letter at the same column were not significantly different by LSD
*** significant at P< 0.01 and NS not significant*

DISCUSSION

The rice straw incorporated into the soil after the rice harvest combined with the application of cattle manure significantly increased the grain yield over the yields from incorporation of the rice straw alone. But it did not show any significant increase in the grain yield over the treatment of incorporation of rice straw into the soil combined with application of cattle manure and bio-extracted fertilizer. In general, rice straw provided a higher supply of K, but a lower supply of N and P than the other organic fertilizers (Javier et al., 2002). At crop maturity, the rice straw has about 40% of N, 30-35% of P and 80-85% of K (Dobermann and Fairhurst, 2002). In the present experiment, rice straw provided N, P and K in the soil at 25.7, 6.2 and 47.4 kg ha^{-1}, respectively. Rice straw improves the soil's physical, chemical and biological properties (Mandal et al., 2004).

In the treatment of incorporation of rice straw into the soil combined with the application of cattle manure, the rice crop received additional N, P and K from the cattle manure. In the present experiment, cattle manure provided N, P and K at 103.7, 35.1 and 335.6 kg ha^{-1}, respectively.

Cattle manure applied to the rice crop increased root density and enhanced root growth to deeper soil layers (Abe et al., 1995). Cattle manure-P is relatively more mobile than inorganic fertilizer-P and promotes microbiological activities and P cycling (Parham et al., 2002).

In the present experiment, however, bio-extracted fertilizer combined with cattle manure application did not show any significant effect on grain yield in comparison with cattle manure application. This is probably due to the small quantity of N, P and K that bio-extracted fertilizer provided to the rice crop. The concentration value of N, P and K was about 0.089, 0.014 and 0.433%, respectively. This means that the bio-extracted fertilizer provided an additional small quantity of the nutrients to the rice crop. Kaewtubtim (2008) reported that quantity of macro-nutrients in soluble bio-extracted fertilizer depends on the sources of materials fermented. He found an N concentration range of 0.24-0.64%, a P concentration range from 0.2 to 0.62% and a K range from 0.54 to 2.09% in soluble bio-extracted fertilizer fermented from 6 native fruits.

The sufficient N concentration in leaves at the PI stage was about 2.6-3.2% of dry weight (Mikkelsen and Hunziker, 1971). In this experiment, the N in leaves at PI stage was 1.580-1.645% of dry weight of all treatments. This indicates that the N in soil was not adequate for plant growth at PI. The N deficiency at PI stage caused a reduction of grain numbers per panicle and filled grain percentage (Dobermann and Fairhurst, 2000).

The sufficient P concentration value in leaves at the PI stage was about 0.17% of dry weight (Fageria et al., 1988). In the present experiment, P in leaves at PI stage was 0.165-0.219% of dry weight of all treatments. This indicates that P in soil provided an adequate amount for rice growth at PI. Similarly, in case of K, the sufficient K concentration value in leaves at the PI stage was about 1.0-2.2% of dry weight (Jones et al., 1991). In the present study, K in leaves at PI stage was 2.381-2.548% and 1.770-2.017% of dry weight of all treatments. This indicates that K in soil provided adequate amount for rice growth at PI.

In this study of the growth and yield of organic rice as affected by rice straw and organic fertilizer it was found that rice straw incorporated into the soil after rice harvest combined with application of cattle manure produced maximum grain yield (3820 kg ha^{-1}). It produced an 18.77% higher yield over the treatment of incorporation of rice straw into the soil alone. However, it did not show any significant difference from the treatment of incorporation of rice straw into the soil combined with application of cattle manure and bio-extracted fertilizer. In the present experiment, number of panicle per hill is the most important component of yield.

REFERENCES

Abe, J., Songmuang, P. and Harada, J. (1995) Root growth of paddy rice with application of organic materials as fertilizers in Thailand. JARO, 29, 77-82.

Bell, R.W. and Seng, V. (2004) Rainfed lowland rice-growing soils of Cambodia, Laos, and Northeast Thailand. ACIAR Proceedings, 116, 161-173.

Dobermann, A. and Fairhurst, T.H. (2002) Rice straw management. Better Crop International, 16, 7-11.

Dobermann, A. and Fairhurst, T.H. (2000) Rice: Nutrient disorders and nutrient management. International Rice Research Institute, Philippines.

Fageria, N.K., Wright, R.T. and Buligar, V.C. (1988) Rice cultivar evaluation for phosphorus use efficiency. Plant and Soil, 111, 105-109.

Javier, E.F., Marguez, J.M., Gnospe, F.S., Manucod, H.F. and Tabien, R.E. (2002) Three year effect of organic fertilizer use on paddy rice. Journal of Crop Sci., 27, 11-15.

Jones, J.B., Wolf, B. and Mills, H.A. (1991) Plant Analysis Handbook: A practical sampling, preparation, analysis and interpretation guide. Micro-Macro Inc., USA.

Kaewtubtim, M. (2008) Quantity of plant nutrients in soluble organic fertilizer from fermented native fruits. Agricultural Sci. J., 39, 31-34.

Mandal, K.G., Misra, A.K., Hati, K.M. and Kali, K. (2004) Rice residue management options and effects on soil properties and crop productivity. Food, Agriculture and Environment, 2, 224-231.

Mikkelsen, D.S. and Hunziker, R.G. (1971) A plant analysis survey of California rice. Agrichem., 14, 18-22.

OAE (Office of Agricultural Economics) (2009) The survey's report of major rice crop year 2007/08. Agricultural Statistics. Ministry of Agriculture and Cooperatives, Thailand.

OAE (2006) The survey's report of major rice crop year 2007/08. Agricultural Statistics. Ministry of Agriculture and Cooperatives, Thailand.

Parham, J.A., Deng, S.P., Roun, W.R and Johnson, G.V. (2002) Long-term cattle manure application in soil. I. Effect on soil phosphorus levels, microbial biomass C and dehydrogenase and phosphatase activities. Bio Fertile Soils, 35, 328-337.