Research article

Effect of Pre-Rice Mungbean and Cattle Manure Application on Growth and Yield of Organic Rice

ANAN POLTHANEE*
Khon Kaen University, Khon Kaen, Thailand
E-mail: panan@kku.ac.th

ARUNEE PROMKHAMBUT
Khon Kaen University, Khon Kaen, Thailand

VIDHAYA TRELO-GES
Khon Kaen University, KhonKaen, Thailand

Received 15 December 2011 Accepted 7 February 2012 (*: Corresponding Author)

Abstract The objective of this research was to investigate the effect of different rates of organic fertilizers with or without mungbean crop residues incorporated into the soil after harvesting, on growth and yield of transplanted rice as well as economic return of mungbean as pre-rice crop. An experiment was conducted in a farmer's field in Muang Yai Village, Khon Kaen Province, Thailand, in 2011. A split-plot arrangement of treatments in a RCBD (randomized completed block design) was used, with pre-rice mungbean or fallow with weeds incorporated into the soil in main plots, and cattle manure at four rates (0; 3,125; 6,250; 9,375 kg/ha) as subplots. Incorporation of mungbean residue into the soil provided 3.2 t of dry matter per ha containing 50.2 kg N, 9.8 kg P and 166.2 kg K per ha. Incorporation of weeds in the fallow treatment provided 1.7 t of dry matter per ha containing 11.3 kg N, 2.8 kg P and 90 kg K per ha. Mungbean residues incorporated into the soil significantly increased plant height and tiller number per hill but had no significant effect on top dry weight per hill of the succeeding rice crop at panicle initiation stage (PI). At harvest, pre-rice mungbean significantly increased top dry weight per hill of rice. Application of different rates of cattle manure significantly affected plant height at PI and harvest. Cattle manure applied at the highest rate (9,375 kg/ha) had the highest plant height. Grain yield of rice was not significantly affected by pre-rice management. However, incorporation of mungbean residues produced an increase in rice grain yield over fallow treatment of 416 kg/ha (or 17%). Incorporation of mungbean significantly increased panicle number per hill. Incorporation of mungbean residue and application of cattle manure at 6,250 kg/ha produced the maximum panicle number per hill. Cattle manure application at the rate of 9,375 kg/ha resulted in the maximum rice grain yield (2,920 kg/ha). No significant interaction between pre-rice residue management and cattle manure application was found on rice grain yield. Growing mungbean before rice provides the advantage of marketable grain of mungbean to 1.6 t/ha. The net economic return was found highest in growing mungbean alone with transplanted rice later (2,855US $/ha) or three times higher than the fallow treatment.

Keywords animal manure, mungbean residue, organic rice

INTRODUCTION

The development and popularity of organic farming in Thailand have arisen due to issues that have been building in the country for several years. These include poverty among small farmers, the problem of agricultural chemical residues, and the increasing consumer need for organic agricultural products in the foreign market (Thanwa, 2001; Vitoon, 1994; Saetang et al., 2003).

Organic rice production has played an important role in recent years in boosting the income of farmers in Northeast Thailand, due to expanding market demand in European countries since 2003

(Economic Research Center, 2003). One of its conditions at the production stage is that organic rice must be cultivated without chemical fertilizer and pesticides. With regard to soil fertility, compost, green manure and animal manure play an important role in improving the crop yield from organic rice farming. However, there is little information about the use of pre-rice mungbean as green manure after pod harvesting. The objectives of the study were to investigate the effect of pre-rice mungbean management and the application of different rates of cattle manure fertilizers on growth and yield of organic rice under rainfed conditions, as well as economic return of mungbean as pre-rice crop.

METHODOLOGY

The experiment was conducted in a farmer's field in Muang Yai village, Khon Kaen province in 2011. The soil physio-chemical characteristics before planting mungbean and rice are shown in Table 1. In general, the soil texture is sand. Before growing mungbean, soil is strongly acidic and has low OM, total N, available P and exchangeable K. However, after incorporation of weed and mungbean residue most soil characteristics improved, particularly in the mungbean residues incorporation treatment.

A split-plot arrangement of treatments in a randomized completed block design with four replications was used. Pre-rice management (fallow with weeds incorporated into the soil and pre-rice mungbean in which residues were incorporated into the soil after pod harvesting) was the main-plot factor, while the application of different rates of cattle manure (0, 3,125, 6,250 and 9,375 kg/ha) were the sub-plot factors.

Table 1 Soil physio-chemical characteristics of the experimental field at 0-15 cm

Soil characteristics	Before growing mungbean	Before growing rice	
		Fallow	Mungbean residue incorporated
pH[a]	4.92	5.09	5.15
EC (mS/cm)[b]	0.03	0.015	0.024
Organic matter %)[c]	0.468	0.604	0.741
Total N (%)[d]	0.038	0.036	0.045
Available P (mg/kg)[e]	6.67	8.01	9.06
Exchangeable K(mg/kg)[f]	73.60	57.48	100.44
Soil texture[g]	Sand	-	-

[a]pH meter (1 : 1 H_2O); [b]EC meter (1 : 5 H_2O); [c]Walkley and Black method; [d]Kjeldahl method; [e]Bray II and molybdenum-blue method; [f]1N NH4OAc pH 7 and flame photometry method and [g]Hydrometer method

Table 2 Schedule of technical operations related to each treatment of the experiment in 2011

1st plowing	2nd plowing	Mungbean sowing	Mungbean harvest	Mungbean and weed incorporation	Application of cattle manure	Rice transplant-ing	Weed-ing	Flower -ing	Rice harvest
30 Apr.	7 May	11 May	11, 20 Jul.	23 Jul.	10 Aug.	12 Aug.	17 Sep.	23 Oct.	23 Nov.

Field managements of legume and succeeding rice crop are reported in Table 2. Before growing mungbean, soil was ploughed twice as in the farmers' usual cultivation practice from late April to the beginning of May. The main plots of each experiment were constructed by creating bunds surrounding areas of 4 x 17.5 m. Then cattle manure at the rate of 3,125 kg/ha were applied in the pre-rice mungbean treatment. The cattle manure application was done as the starter for the symbiotic fixation of N and favored the highest grain yield for mungbean. Mungbean was hand-seeded at a spacing of 20 × 50 cm. Pods of mungbean was harvested twice about 2 months after sowing. Before incorporation of weeds and mungbean residues into the soil, weeds and mungbean residues were randomly collected from 3 sites of 1 × 1 m to determine their dry weights (1,713 and 3,163 kg/ha, respectively). Total N, P and K contents of weeds and mungbean residues were also analyzed (1.59%, 0.3% and 5.25% for dry weight of mungbean residue and 0.66%, 0.16% and 5.25% for dry weight of weed, respectively). The amount of nutrients returned to the soil by incorporating weeds and mungbean residues into the soil was calculated as in Eq. (1)

$$\frac{\text{Dry weight (kg/ha) x nutrient content (\%)}}{100} \quad (1)$$

Cattle manure at different rates was applied about 18 days after the incorporation of weeds and mungbean residues. Total N, total P and total K of cattle manure were determined (1.3%, 0.3% and 1.95% of dry weight, respectively). The amount of nutrients in the cattle manure applied to the soil was calculated as in Eq. (2)

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

Rice seedlings were transplanted 1 day after the cattle manure application. Five seedlings per hill were transplanted in the pattern of 25 x 25 cm. Rice cv. KDML 105 was used in this study. Hand weeding was done once every 35 days after transplanting. No insecticide or fungicide was used in this experiment.

Five hills from each plot were measured to classify their height and tiller number per hill at panicle initiation (PI) growth stage and harvesting stage. Again, five hills from each plot outside the harvesting area were randomly selected and oven dried at 80 ℃ for 4 days to determine top dry weight at PI and harvest. The nitrogen, phosphorus and potassium contents of leaves were determined at 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 the percentage of filled grains per panicle was calculated. The grain yield was taken from the 6 m^2 harvesting area of each plot and calculated as kg/ha 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.

RESULTS

Grain yield of mungbean and nutrient recycling to the soil

Grain yield of mungbean averaged 1,635 kg/ha. Incorporation of mungbean residues into the soil provided about 4 times higher N, P and K contribution than by weeds, 50.2 kg N, 9.8 kg P and 166.2 kg K per ha, respectively (Table 3). The amount of nutrients returned to the soil was further increased when cattle manure was applied and was higher in pre-rice mungbean treatment than fallow treatment. Application of the highest rate of cattle manure, 9,375 kg/ha, resulted in the highest N, P and K returned to the soil, 133.4 kg N, 71.1 kg P and 273.1 kg K per ha, respectively under fallow treatment and 172.3 kg N, 78.1 kg P and 349.3 kg K per ha, respectively under pre-rice mungbean. However, the ratio of increase of nutrients among cattle manure application rates was small in pre-rice mungbean treatment, i.e. N returned to the soil was only 3, 4 and 6 times higher than no cattle manure application when cattle manure was applied at the rates of 3,125, 6,250 and 9,375 kg/ha, respectively. In contrast to fallow treatment, N returned to the soil was 8, 15, and 22 times higher than no cattle application when cattle manure was applied at the rates of 3,125, 6,250 and 9,375 kg/ha, respectively (Table 3).

Growth of following rice

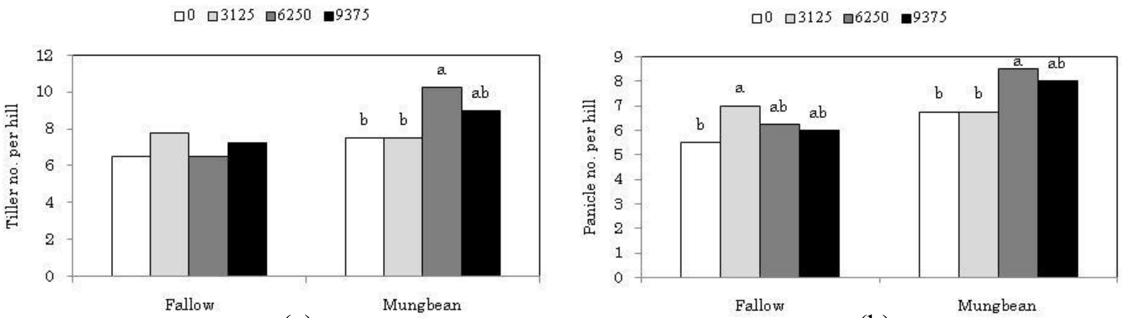
Incorporation of mungbean residues significantly increased plant height and tiller number per hill of succeeding rice but had no significant effect on top dry weight at PI growth stage (Table 4).

Application of different rates of cattle manure affected plant height at PI but not tiller number per hill and top dry weight. The maximum plant height was obtained at the highest rate of cattle manure application (9,375 kg/ha), but was not significantly different from the rates of 3,125 and 6,250 kg/ha. No interaction between pre-rice mungbean management and cattle manure application rate on plant growth at PI was observed (Table 4).

Table 3 Total N, P and K (kg/ha) returned to the soil by weed and mungbean residue at different cattle manure application rates before growing rice

Cattle manure application rate (kg/ha)	Nutrients returned to the soil (kg/ha)					
	Weed incorporation			Mungbean residue incorporation		
	N	P	K	N	P	K
0	11.3	2.8	90.0	50.2	9.8	166.2
3,125	52.0	25.6	151.0	90.9	32.6	227.2
6,250	92.7	48.3	212.1	131.6	55.3	288.3
9,375	133.4	71.1	273.1	172.3	78.1	349.3

N, P and K contents in plant tissues were analyzed by micro-kjeldahl method and indophenol blue method, wet oxidation method and yellow molybdovanadophosphoric acid method and wet oxidation method and flame photometry method, respectively.



(a) (b)

Fig. 1 Interactions between pre-rice management and cattle manure application rates on tiller number per hill (a) and panicle number per hill (b) of KDML 105 at harvest

Table 4 Plant growth of KDML 105 as affected by pre-rice managements and cattle manure application rates at panicle initiation stage and harvest

Treatment	PI			Harvest		
	Height (cm)	Tiller no. per hill	Top dry weight per hill (g)	Height (cm)	Tiller no. per hill	Top dry weight per hill (g)
Pre-rice management						
Fallow	78.8b	10b	11.13	121.8	7	31.65b
Mungbean	90.1a	12a	14.88	128.5	9	42.67a
F-test	*	**	ns	ns	ns	*
Cattle manure application rate						
0 (kg/ha)	80.4b	10	12.57	118.7c	7	30.99
3,125 (kg/ha)	83.5ab	11	11.69	123.3bc	8	36.45
6,500 (kg/ha)	85.8a	11	14.15	128.2ab	8	40.37
9,375(kg/ha)	88.0a	12	13.60	130.4a	8	40.81
F-test	*	ns	ns	*	ns	ns
Interaction						
F-test	ns	ns	ns	ns	*	ns
CV a (%)	8.44	8.60	28.59	7.05	19.76	16.77
CV b (%)	6.04	18.21	26.57	5.28	14.86	20.87

Means followed by the same letter in the same column had no significant difference by LSD.
, indicate significance at 5% and 1% levels of probability, respectively. ns= not significant*

At the harvest stage, incorporation of mungbean residues significantly increased top dry weight of rice but had no significant effect on plant height and tiller number per hill (Table 4). Cattle manure application rates significantly affected plant height at harvest. Application of the highest rate of cattle manure gave the maximum plant height but it was not significantly different from the rate of 6,250 kg/ha. Cattle manure application rates had no effect on tiller number per hill and top dry weight of rice. An interaction between pre-rice mungbean management and cattle manure application rate was found in tiller number per hill at harvest (Table 4). Under pre-rice mungbean treatment, application of cattle manure at the rate of 6,250 kg/ha resulted in the maximum tiller number per hill (10 tillers per hill) and was lowest in no cattle application treatment and at the rate of 3,125 kg /ha (7 tillers per hill). Under fallow treatment, application of different rates of cattle manure had no significant effect on tiller number per hill at harvest (Fig. 1(a)).

Table 5 Yield and yield components of KDML 105 as affected by pre-rice managements and cattle manure application rates at harvest

Treatment	Grain yield (kg/ha)	Panicle (no. per hill)	Grain (no. per panicle)	Filled grain (%)	1,000 grain weight (g)
Pre-rice management					
Fallow	2,433.5	6.19b	109.69	90.50	29.06
Mungbean	2,849.9	7.50a	106.81	90.13	29.14
F-test	ns	*	ns	ns	ns
Cattle manure application rate					
0 (kg/ha)	2,358.6b	6.13b	98.50	90.38a	28.90
3125 (kg/ha)	2,578.9ab	6.88a	111.13	88.63b	28.92
6250 (kg/ha)	2,709.3ab	7.38a	112.87	91.00a	28.94
9375 (kg/ha)	2,919.9a	7.00a	110.50	1.25a	29.63
F-test	**	*	ns	*	ns
Interaction					
F-test	ns	*	ns	ns	ns
CV a (%)	18.57	11.46	10.35	3.22	3.90
CV b (%)	10.32	10.37	15.34	1.78	3.13

Means followed by the same letter in the same column had no significant difference by LSD
, indicate significance at 5% and 1% levels of probability, respectively. ns= not significant*

Grain yield and yield components of succeeding rice

Grain yield of rice was not significantly affected by pre-rice management. However, incorporation of mungbean residues tended to increase rice yield up to 17% over the fallow treatment (Table 5). Cattle manure application rates significantly affected rice grain yield. The maximum grain yield was obtained at the highest cattle manure application rate (2.9 t/ha) but it was not significantly different from other two rates. There was no interaction between pre-rice mungbean management and cattle manure application rate in grain yield of rice (Table 5).

Growing mungbean before rice significantly increased panicle number per hill but had no significant effect on grain number per panicle, filled grain percentage and 1,000 grain weight. Cattle manure application rate significantly affected panicle number per hill and filled grain percentage. Cattle manure application at the rate of 6,250 kg/ha provided the maximum panicle number per hill but it was not significantly different from the other two application rates. Maximum filled grain percentage was obtained when cattle manure was applied at the highest rate (Table 5). Interaction between pre-rice mungbean management and cattle manure application rate was found. When mungbean residue was incorporated into the soil, application of cattle manure at the rate of 6,250 kg/ha gave the maximum panicle number per hill. However, when the field was left fallow, application of cattle manure at the rate of 3,125kg/ha resulted in the maximum panicle number per hill. No cattle manure application treatment provided the lowest panicle number per hill in both pre-rice managements with lowest in fallow treatment (Fig. 1b).

Nutrient concentration of rice at PI

Fallow and incorporation of mungbean residue into the soil had no significant effect on N and K concentrations of KDML 105 rice leaves at PI but had significant effect on P content (Table 6). Phosphorus concentration in rice leaves was higher in fallow treatment than mungbean residue incorporation. Cattle manure application rates significantly affected N and P content in rice leaves but not K content. In terms of N concentration, application of the highest rate of cattle manure provided the highest leaf N concentration. Nevertheless, the highest P concentration was obtained when cattle manure was applied at the rate of 6,250 kg/ha (Table 6). There were interactions between pre-rice mungbean management and cattle manure application rate. When mungbean residues were incorporated into the soil, application of the highest rate of cattle manure provided the highest leaf N concentration. Under fallow treatment, application of different cattle manure rates had no significant effect on leaf N concentration (Table 7).

Table 6 Nutrient concentration (%) in leaf of KDML 105 as affected by pre-rice managements and cattle manure application rates at panicle initiation stage

Treatment	N (%)	P (%)	K (%)
Pre-rice management			
Fallow	1.977	0.229a	2.225
Mungbean	1.948	0.209b	2.323
F-test	ns	**	ns
Cattle manure application rate			
0 (kg/ha)	1.958b	0.212b	2.230
3,125 (kg/ha)	1.905b	0.222ab	2.222
6,250 (kg/ha)	1.946b	0.235a	2.333
9,375 (kg/ha)	2.041a	0.206b	2.310
F-test	*	*	ns
Interaction			
F-test	**	ns	ns
CV a (%)	8.27	1.12	5.72
CV b (%)	3.90	8.78	5.28

Means followed by the same letter in the same column had no significant difference by LSD
**, ** indicate significance at 5% and 1% levels of probability, respectively. ns= not significant*

Table 7 Interactions between pre-rice management and cattle manure application rates on nitrogen concentration in leaf of KDML 105 at panicle initiation stage

Cattle application rate	N concentration in leaves of rice at PI	
	Fallow	Mungbean
0 kg/ha	2.019	1.896bc
3,125 kg/ha	1.973	1.836c
6,250 kg/ha	1.938	1.954b
9,375 kg/ha	1.976	2.1045a

Means followed by the same letter in the same column had no significant difference by LSD

Table 8 Yield, production cost, gross income and net income

Treatment	Yield (kg/ha)		Production cost (US $/ha)	Gross income (US $/ha)	Net income (US $/ha)
	Mungbean	Rice			
Fallow	0	1,995	26	966	940
Fallow+3125 kg CM per ha	0	2,502	176	1,211	1,035
Fallow+6250 kg CM per ha	0	2,427	327	1,175	848
Fallow+9375 kg CM per ha	0	2,810	477	1,360	883
Mungbean	1,635	2,722	297	3,152	2,855
Mungbean+3125 kg CM per ha	1,635	2,656	448	3,120	2,672
Mungbean+6250 kg CM per ha	1,635	2,992	598	3,282	2,684
Mungbean+9375 kg CM per ha	1,635	3,030	748	3,301	2,553

Note: CM = cattle manure; Planting material = mungbean seed 35 baht/kg, KDML 105 rice seed 26 baht/kg and cattle manure price 1.5 baht/kg; Market price of crop: mungbean seed 35 baht/kg and KDML 105 rice 15.1 baht/kg; 1 US$ =31.2 Thai baht
Production cost = Material cost + Land preparation for mungbean growing; Household labor is considered as farming labor

Economic return of growing mungbean before rice

All mungbean growing treatments provided higher net income than all fallow treatments. This is due to the additional income from selling mungbean grains. The net income of growing mungbean before rice without cattle manure application, however, yielded the highest net income because of low production cost. The net income was similar when growing mungbean as a pre-rice crop and application of different rates of cattle manure (Table 8).

DISCUSSION

The incorporation of mungbean residues into the soil did not significantly increase the grain yield of KDML 105 rice over the fallow treatment. However, pre-rice mungbean increased rice grain yield over fallow treatment by 416 kg/ha (or 17%). Suriyakup et al. (2007a) reported that grain yield of direct-seeded RD 6 rice variety was not significantly different when mungbean was incorporated into the soil at the flowering stage. However, grain yield of transplanted RD 6 rice with mungbean residues incorporated into the soil was increased by 355-1,399 kg/ha over the fallow treatment with weeds incorporated into the soil (Suriyakup et al., 2007b). In India, sown summer mungbean increased rice grain yields by 05-0.9 t/ha (Sharma et al., 2000) or 0.3 t/ha (Sharma et al., 1995). In the present experiment, the mungbean residue provided 3,163 kg/ha dry weight containing 50 kg N per ha, 10 kg P per ha and 166 kg K per ha. A similar amount of mungbean residue contributed to the soil of 2,810-4,170 kg/ha dry weight and 53-57 kg N per ha (Suriyakup et al., 2007b), 2.2-3.2 t/ha dry matter and 56.8- 70.2 kg N per ha (Sharma et al., 1995) have been reported. Bhuiyan et al. (2009) reported that mungbean residue accumulated 1.14-1.76 t of dry matter per ha which amounted to 14.6-43.1 kg N per ha, 1.26-3.66 kg P per ha and16.3-35.9 kg K per ha. Poomthaisong (2002) reported that the amount of nitrogen fixed by mungbean was 35-51 kg N per ha. However, in this study, the amount of nitrogen returned to the soil did not include nitrogen from fixation process.

Increase in the application rates of cattle manure significantly improved rice grain yield. Application of cattle manure at the highest rate (9,375 kg/ha) resulted in the maximum grain yield but did not make significant difference from other application rates. Polthanee et al. (2011) reported that application of cattle manure at 9,375 kg/ha with rice straw incorporated into the soil provided the maximum transplanted KDML 105 rice grain yield (3,820 kg/ha) (increased 717 kg/ha over no fertilizer plot). Grain yield of direct-seeded KDML 105 rice with cattle manure at the same rate was increased by 258 kg/ha over no fertilizer (Polthanee et al., 2008). Application of farmyard manure at 7 t/ha did not affect yield of rice and wheat in Bhutan but it increased organic carbon in the soil (Chettri et al., 2003). The maximum cattle manure rate in the study provided additional N, P and K to rice at122 kg, 68 kg and 183 kg, respectively. In the present study, calculated nutrients returned to the soil did not include nutrients from cattle manure being used as starter and nitrogen fixation process. Abe et al (1995) reported that cattle manure applied to the rice crop supported root growth at deeper soil layers by increasing root density and enhanced root growth.

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 study, the N in leaves at the PI stage was 1.905-2.041% of dry weight for all treatments. This indicates that the N in soil was not adequate for plant growth at PI. Dobermann and Fairhurst (2000) indicated that the N deficiency at the PI stage caused a reduction of grain numbers per panicle and filled grain percentage. The significant differences in tiller and panicle number per hill and filled grain percentage in this study may indicate that N is the limiting factor for rice crop production in sandy soils. Applied N may be lost by leaching, denitrification or remobilisation by microbiorganisms.

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 the PI stage was 0.206-0.235% of dry weight for all treatments. This indicates that P in soil provided an adequate amount for rice growth at PI. Similarly, in the 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 the

PI stage was 2.222-2.333% of dry weight for all treatments. This indicates that K in the soil was sufficient for rice growth at PI.

In the present experiment, even though rice grain yield from the mungbean-rice cropping system was not significantly different from fallow treatment, growing mungbean before rice provides the advantage of marketable grain of mungbean to 1.6 t/ha. Net income of all growing mungbean before rice treatments was 2.6-3.0 times higher than fallow treatment. Introduction of summer mungbean in the rice-wheat cropping system yielded 0.4-1.3 t/ha protein-rich grain in India (Sharma et al., 2000). Nevertheless, in terms of economic return for the whole cropping system, application of cattle manure at 3,125kg /ha at sowing date of mungbean may be sufficient to support mungbean growth and reduce the production cost of rice growing.

CONCLUSION

The incorporation of mungbean residue into the soil did not significantly increase the grain yield of KDML 105 rice over the fallow treatment. However, pre-rice mungbean increased rice grain yield over fallow treatment by 416 kg/ha (or 17%). In addition, the net economic return was found higher in all growing mungbean before rice cropping system than the fallow treatment. Application of cattle manure at 9,375 kg/ha resulted in the maximum grain yield (2,920 kg/ha) due to the effect on panicle number per hill and filled grain percentage. Incorporation of mungbean residue and cattle manure application at 9,375 kg/ha could not provide sufficient N to the rice crop in this experiment. Improvement of residue incorporation method, increase in cattle manure application rate or another rich N organic fertilizer source, as well as water management in the field need to be further studied to improve rice grain yield in sandy soil.

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.

Bhuiyan, M.A.H., Mian, M H., Islam, M.S., Islam, M.R. and Alam, F. (2009) The contribution of mungbean residue and cowdung in supplying nutrients. Bull. Inst. Trop. Agr., Kyushu Univ., 32, 35-42.

Chettri, G.B., Ghimiray, M. and Floyd, C.N. 2003. Effects of farmyard manure, fertilizers and green manuring in rice-wheat systems in Bhutan: Results from a long-term experiment. Expl. Agric., 39, 129-144.

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

Economic Research Center. 2003. Study on developing Hom Mali organic rice for export to Europe and United States of America (in Thai). Faculty of Economics, Kasetsart Univ. 286.

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

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.

Mikkelsen, D.S., Hunziker, R.G. 1971. A plant analysis survey of California rice. Agri. Chem., 14, 18-22.

Polthanee A. and Treloges, V. 2008. Effect of rice straw management and organic fertilizer application on growth and yield of dry direct-seeded rice. Paddy Water Environ., 6, 237-241.

Polthanee, A. Promkhambut, A. and Kaewrahan, S. 2011. Growth and yield of organic rice as affected by rice straw and organic fertilizer. IJERD, 2, 93-98.

Poomthaison, J. 2002. Growth and nitrogen fixation of some mungbean cultivars and subsequent effect of mungbean residues on maize. Master of Science Thesis in Agronomy. Graduate School, Khon Kaen University, Thailand.

Saetang, C., Igata, M., Niinuma, K., Goto, K., Matsuda, T. and Pitipunya, R. 2003. Present condition of the organic agricultural products authentication system in Thailand. J. ISSAAS, 9, 179-195.

Sharma, S.N., Prasad, R. and Singh, S. 1995. The role of mungbean residues and *Sesbania aculeata* green manure in the nitrogen economy of rice-wheat cropping system. Plant Soil, 172, 123-129.

Sharma, S.N., Prasad, R., Singh, S. and Singh, P. 2000. On-farm trials of the effect of introducing a summer green manure of mungbean on the productivity of a rice-wheat cropping system. J. Agr. Sci., Cambridge, 134, 169-172.

Suriyakup, P., Polthanee, A., Pannangpethch, K., Katawatin, R. and Clermont-Dauphin, C. 2007a. Mungbean (Vigna radiate L.) residue and nitrogen rate affected growth and yield of direct-seeded rice (Oryza sativa L.) in rainfed riceland. Asian J. Plant Sci., 6, 1158-1165.
Suriyakup, P., Polthanee, A., Pannangpethch, K., Katawatin, R. Mouret, J. C. and Clermont-Dauphin, C. 2007b. Introducing mungbean as a preceding crop to enhance nitrogen uptake and yield of rainfed rice in northeast Thailand. Aust. J. Agric. Res., 58, 1059-1067.
Thawa, J. 2001. The policy of sustainable agriculture development. Kasetsart Univ. 2.1-2.15, Thailand.
Vitoon, P. 1994. Asian type organic farming. National Organic Agric. Res., Japan. 115-119.