Kasetsart J. (Nat. Sci.) 43 : 432 - 441 (2009)

Effects of Different Organic Amendments and Chemical Fertilizer on Plant Growth and Grain Yield of Soybean on Pakchong Soil Series

Thu Zar Myint[1,2], Isara Sooksathan[2]*, Rungsarid Kaveeta[2] and Sunanta Juntakool[2]

ABSTRACT

With increasing costs of chemical fertilizers, using organic amendments is an alternative method for the improvement of crop production and soil fertility maintenance. This study aimed to determine the effects of different organic amendments on soybean plant growth and grain yield. The eight treatments were arranged in an RCB design with three replications. Treatments were a combination of chemical fertilizer (16-20-0) 60 kg $ha^{-1}$and extracts of jatropha 20 cc, chitosan 60 cc and fish waste 40 cc in 20 l of water; chicken manure 3 ton ha^{-1}; jatropha cake 3 and 6 ton ha^{-1}; chemical fertilizer (16-20-0) 180 kg ha^{-1} and control (no application). The field experiment was conducted at the National Corn and Sorghum Research Center, on a site with Pakchong series soils during the dry season in 2007 (DS) and the wet season in 2008 (WS). In DS, soybean applied with chemical fertilizer produced the highest grain yield (1755 kg ha^{-1}). In WS, however, amendment with 3 ton of jatropha cake substantially increased grain yield (5410.83 kg ha^{-1}) over other treatments, followed by jatropha cake 6 ton (4331.67 kg ha^{-1}) and chemical fertilizer (4190.83 kg ha^{-1}). Other organic extract applications produced similar grain yield production as the control.

Key words: organic amendments, jatropha extracts and cake, chitosan extracts, fish waste extracts

INTRODUCTION

Soybean (*Glycine max* L. Merr) has the highest worldwide area and output among oilseeds as well as edible oils. Because of its nutritional value, demand for soybean is increasing at present. Therefore, suitable production technology as well as low cost production of soybean should be encouraged to improve soybean productivity. Due to the increasing price of chemical fertilizer, low-cost organic amendments are a convincing alternative for partial replacement.

Currently, worldwide demand for crude oil increases sharply year by year. Jatropha has exceptional potential to produce bio-diesel due to its adaptation to local environments, fast growth rate and potential for income generation. Increased production of bio-diesel contributes to increased production of bio-waste-seed cake, which is relatively high in total nitrogen, phosphorous, and potassium as well as organic matter content compared to chicken and cattle manure (Tigere *et al*., 2006). Accordingly, the use of jatropha cake is worth highlighting as a potential bio-fertilizer.

1 Oil Crops Development Project, Myanmar Agriculture Service, Ministry of Agriculture and Irrigation, Myanmar.

2 Department of Agronomy, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand.

* Corresponding author, e-mail: agrirs@ku.ac.th

Received date : 18/03/09 Accepted date : 13/05/09

Chitosan is extracted from chitin, which is the main structural component of the shells of shrimps, crabs and squid pens, by the deacetylation process and is easily bio-degradable. Chitosan is a bio-stimulant for plant growth and increases nodulation and nitrogen fixation in soybean (Boonkerd *et al*., 1996). Fish is a satisfactory alternative source to protein meal from animals and the waste from fish can be utilized as supplementary nutrients for plants (Tamaei, 2004). Therefore, the effects of jatropha extracts, chitosan extracts, fish waste extracts, chicken manure, jatropha cake and chemical fertilizer on soybean growth and grain yield as well as soil fertility improvement were evaluated.

MATERIALS AND METHODS

To examine the effect of soil amendments on soybean growth and grain yield, a trial was conducted on a site with Pakchong series soils (moderate, reddish-brown lateritic). The field experiment consisted of eight treatments arranged in an RCB design and replicated three times. The treatments consisted of: three treatments of a combination of chemical fertilizer (16:20:0) 60 kg ha^{-1} and foliar spray with jatropha extracts 20 cc, chitosan extracts 60 cc and fish waste extracts 40 cc in 20 l of water, and five other treatments of chicken manure 3 ton ha^{-1}, jatropha cake 3 and 6 ton ha^{-1}, chemical fertilizer (16-20-0) 180 kg ha^{-1}, and a control (no application) (Table 1). The chemical properties and nutrient content of the organic amendments are shown in Table 2.

Based on the results of a preliminary test, the best level of organic extracts, chicken manure and chemical fertilizer treatments were selected from the different application rates (low, medium and high). All organic and chemical fertilizers were applied into the soil prior to planting. Jatropha, chitosan and fish waste extracts were sprayed six times in seven-day-intervals starting from 15 days after emergence (DAE). In both seasons, necessary irrigation was done. The same treatment was repeated in the same plot to evaluate the residual effect of organic and chemical fertilizer on plant

Table 1 Treatments and application rates of organic amendments and chemical fertilizer.

Treatment	Description	
	Foliar spray	Soil application
Control	-	-
Je+ F 60	Jatropha extract 20cc/ 20 l of water	60 kg ha^{-1} of 16-20-0
Ce + F 60	Chitosan extract 60cc/ 20 l of water	60 kg ha^{-1} of 16-20-0
Fe + F 60	Fish waste extract 40cc/ 20 l of water	60 kg ha^{-1} of 16-20-0
CM	Chicken manure 3 ton ha^{-1}	-
JC 3	Jatropha cake 3 ton ha^{-1}	-
JC 6	Jatropha cake 6 ton ha^{-1}	-
F 180	-	180 kg ha^{-1} of 16-20-0

Table 2 Chemical properties and nutrient content of organic amendments used in the study.

Name	N%	P_2O_5%	K_2O%
Jatropha extracts*	0.2	0.1	0.4
Fish waste extracts	5.0	2.0	2.0
Chicken manure*	2.0	4.0	2.0
Jatropha cake*	3.8	2.1	1.2

* Samples were analyzed in Department of soil science, Kasetsart University, Thailand.

growth and grain yield. Chiang Mai (CM-60) variety was planted in rows 50 cm apart with 20 cm between plants within rows and a population of 400 000 plants ha^{-1}. Soybean seed was inoculated with *Rhizobium japonicum* by mixing seeds with inoculum before planting to obtain better nodulation development. This experiment was conducted at the National Corn and Sorghum Research Center, Pakchong, Nakhon Ratchasima province during the dry season of 2007 (DS) and the wet season in 2008 (WS). Plant growth, yield and yield components data were collected and subjected to balanced analysis of Fisher's LSD, and a partition method was used to examine the differences among treatments. Surface soil samples from the experimental field were collected before fertilizer application and after plant harvesting. Soil texture, soil pH, organic matter percentage, phosphorous, potassium, calcium and magnesium content of soil were analyzed at the Department of Soil Science, Kasetsart University, Thailand.

RESULTS

Plant growth of soybean

The germination percentage of soybean seed was normal in all treatments in DS but in WS, the high rate of jatropha cake reduced the germination percentage. Soybean applied with the higher and lower rates of jatropha application (6 and 3 ton ha^{-1}) gave germination percentages of 38 and 74%, respectively. After the first germination-count, replanting was done three times to obtain 100% stocking (data not shown).

The influence of different organic and chemical fertilizers on plant height is shown in Table 3. There were no marked differences among treatments in plant height at 10 days after emergence (DAE) (data not shown) but significant differences were noted in the later stages. Throughout the growing period, plant height of soybean treated with a higher rate of chemical fertilizer (F180) was significantly taller at V5, R5 and harvest time (32.63, 37.23 and 35.77 cm in DS; 35.33, 77.03 and 77.57 cm in WS, respectively) than the control (29.85, 33.47 and 30.87 cm in DS; 26.37, 61.97 and 62.17 cm in WS, respectively). In DS, soybean applied with all of the extracts and jatropha cake showed no difference in height to the control in all stages, however, jatropha extract produced significantly taller (34.83cm) plants than those of other organic amendments and the control at harvest time. It was

Table 3 Plant height (cm) of soybean under different treatments in dry season (DS), 2007 and wet season (WS), 2008.

Treatment	V5 stage		R5 stage		Harvest time	
	(DS) 2007	(WS) 2008	(DS) 2007	(WS) 2008	(DS) 2007	(WS) 2008
Control	29.85 b	26.37 b	33.47 b	61.97 b	30.87 b	62.17 b
Je+ F 60	31.07 ab	29.82 b	34.80 ab	66.80 ab	34.83 a	71.30 ab
Ce + F 60	32.47 ab	29.13 b	36.27 ab	64.50 b	33.87 ab	67.73 ab
Fe + F 60	30.62 ab	31.07 ab	35.67 ab	66.80 ab	34.10 ab	74.83 ab
CM	30.53 b	28.17 b	35.60 ab	65.50 b	33.63 ab	69.43 ab
JC 3	30.77 ab	30.77 ab	34.80 ab	65.40 b	33.30 ab	73.40 ab
JC 6	31.27 ab	29.00 b	35.77 ab	62.20 b	33.97 ab	72.83 ab
F 180	32.63 a	35.33 a	37.23 a	77.03 a	35.77 a	77.57 a
Mean	31.15	29.96	35.45	66.28	33.79	71.16
CV%	3.70	10.10	4.60	9.10	6.30	11.50
L.S.D. 0.05	2.03	5.32	2.83	10.51	3.72	14.28

In a column, means followed by the same letter are not significantly different at $p \leq 0.05$ by Fisher's LSD.

found that in WS, soybean applied with jatropha extracts, chitosan extracts, chicken manure and 6 ton of jatropha cake at V5; chitosan extracts, chicken manure and 3 and 6 ton of jatropha cake at R5; and all of the organic amended treatments at harvest time, had significantly lower plant heights than that of the chemical fertilizer, but these in turn tended to be higher than in the control plot. There was no significant difference in plant height between 3 and 6 ton of jatropha cake in all growth stages except under V5 in WS. Application of chicken manure produced no difference in height compared with the control plot under V5 in DS and V5 and R5 in WS. In general, growth of soybean in all treatments as represented by plant height showed the same trend in all stages. The mean height of soybean plants at the V5 stage in both DS and WS was not different (31.15 and 29.96 cm) but when the plant reached the R5 stage until harvest time, plant height in WS (66.28 and 71.16 cm) was nearly double or greater than the heights for the R5 stage and at harvest time in DS (35.45 and 33.79 cm). No application produced the lowest figures at all stages.

Table 4 shows no remarkable effects of treatments on soybean leaf size in DS. In WS, however, plots from the treatment of 3 ton of jatropha cake and the treatment of chemical fertilizer gave significantly greater leaf length (13.03 and 13.10 cm) and leaf width of soybean (9.07 and 8.98 cm), respectively. Other jatropha extracts, chitosan extracts, fish waste extracts, chicken manure and 6 ton of jatropha cake resulted in the same size but amendment with 6 ton of jatropha cake tended to give bigger leaf size than those of the others. The smallest leaf length and width in WS was observed from the control plots (10.52 and 7.11 cm). Considering the plant dry weight with respect to different treatments in DS, the application of chemical fertilizer and 6 ton of jatropha cake showed substantially greater weight (3086.67 and 3055.00 kg ha^{-1}) than any other treatment. Plant weight of jatropha extracts, chitosan extracts, fish waste extracts and chicken manure (2473.33, 2908.33, 2795 and 2475 kg ha^{-1}) tended to be higher than the plant weight of 3 ton of jatropha cake and the control (2336.67 and 2195 kg ha^{-1}) but they were not significantly different. In WS, soybean plants amended with 3 ton of jatropha cake gave higher plant dry weight (7214.17 kg ha^{-1}) than other treatments. The treatments of fish waste extacts, jatropha cake 6

Table 4 Soybean leaf growth at flowering stage and plant dry weight as affected by different treatments in dry season (DS), 2007 and wet season (WS), 2008.

Treatment	Leaf length (cm)		Leaf width (cm)		Plant dry weight (kg ha^{-1})	
	(DS) 2007	(WS) 2008	(DS) 2007	(WS) 2008	(DS) 2007	(WS) 2008
Control	7.27	10.52 c	6.40	7.11 c	2195.00 b	3862.50 b
Je+ F 60	8.93	11.63 b	5.57	7.70 bc	2473.33 ab	3387.50 b
Ce + F 60	8.50	11.73 b	6.69	8.13 b	2908.33 ab	3490.83 b
Fe + F 60	7.83	11.87 b	5.97	8.25 b	2795.00 ab	4740.83 ab
CM	7.97	11.87 b	6.30	8.13 b	2475.00 ab	4034.17 b
JC 3	7.33	13.03 a	6.13	9.07 a	2336.67 b	7214.17 a
JC 6	7.83	12.40 ab	6.13	8.61 ab	3055.00 a	6617.50 ab
F 180	7.73	13.10 a	6.30	8.98 a	3086.67 a	5173.33 ab
Mean	7.92	12.02	6.19	8.25	2665.63	4815.10
CV%	12.50	4.20	11.70	4.40	14.80	32.20
L.S.D. 0.05	1.73	0.88	1.27	0.63	691.84	2713.29

In a column, means followed by the same letter are not significantly different at $p \leq 0.05$ by Fisher's LSD.

ton and chemical fertilizer (4740.83, 6617.5 and 5173.33 kg ha^{-1}) seemed to produce greater weight than that of the control, but those three treatments were not significantly different to the control, jatropha extracts, chitosan extracts and chicken manure (3862.50, 3387.50, 3490.83 and 4034.17 kg ha^{-1}, respectively). Average plant dry weight in WS (4815.10 kg ha^{-1}) increased to nearly double the weight in DS (2665.63 kg ha^{-1}). The control plot showed the lowest plant dry weight in both seasons (Table 4).

Grain yield and yield components of soybean

Considering the soybean seed yield in DS, crops applied with chemical fertilizer resulted in a significantly greater yield (1755.00 kg ha^{-1}) than for any other treatment. Application of chitosan and fish waste extracts (1533.33 and 1436.67 kg ha^{-1}) tended to be higher than those of the other treatments of the control, jatropha extracts, chicken manure and 3 and 6 ton of jatropha cake (1133.33, 1251.67, 1356.67, 1313.33 and 1245 kg ha^{-1}, respectively), however, there were no significant differences among those treatments. In WS, soybean grain yield amended with 3 ton of jatropha cake gave the highest yield (5410.83 kg ha^{-1}). The seed yield of soybean applied with 6 ton of jatropha cake (4331.67 kg ha^{-1}) and chemical fertilizer (4190.83 kg ha^{-1}) seemed to be higher than the yields of the control (3280 kg ha^{-1}), jatropha, chitosan and fish waste extracts (3600, 3444.17 and 3850.83 kg ha^{-1}) and chicken manure (3757.50 kg ha^{-1}) plots, however, there were no significant differences among those treatments. Average seed yield of all treatments in WS (3983.23 kg ha^{-1}) was nearly triple the yield in DS (1378.13 kg ha^{-1}) (Table 6).

Table 5 indicates that the application of different treatments in DS did not increase the number of soybean nodes and branches per plant, though, in WS, soybean amended with 6 ton of jatropha cake had a significantly higher node number (15.80) than any other treatment. Other organic extracts and chemical fertilizer plots also gave higher node numbers, whereas the chitosan-treated plot produced the fewest nodes. The average soybean branch number, however, increased from 1.33 in DS to 3.13 in WS, but no differences were detected among treatments in either year (data not shown).

The results showed that different treatments affected the numbers of pods and seeds

Table 5 Some yield components of soybean under different treatments in dry season (DS), 2007 and wet season (WS), 2008.

Treatment	Node number plant^{-1}		Pod number plant^{-1}		Seed number plant^{-1}	
	(DS) 2007	(WS) 2008	(DS) 2007	(WS) 2008	(DS) 2007	(WS) 2008
Control	7.43	13.67 ab	31.40 ab	60.73 b	51.87 b	107.76 bc
Je+ F 60	7.97	14.30 ab	34.87 ab	58.47 b	61.27 ab	111.30 bc
Ce + F 60	7.67	13.60 b	31.37 ab	65.50 b	58.30 ab	92.77 c
Fe + F 60	7.60	15.43 ab	31.53 ab	62.93 b	53.90 ab	121.70 bc
CM	7.53	14.70 ab	30.03 b	57.53 b	49.30 b	118.10 bc
JC 3	7.03	15.40 ab	31.70 ab	84.67 ab	58.17 ab	163.80 a
JC 6	7.50	15.80 a	34.60 ab	97.23 a	58.90 ab	180.27 a
F 180	7.43	15.17 ab	37.63 a	60.23 b	64.40 a	126.43 b
Mean	7.52	14.76	32.89	68.41	57.01	127.77
CV%	16.40	8.30	12.60	19.40	11.20	13.10
L.S.D. 0.05	2.16	2.14	7.25	23.19	11.22	29.68

In a column, means followed by the same letter are not significantly different at $p \leq 0.05$ by Fisher's LSD.

per plant (Table 5). In DS, the soybean crop applied with chemical fertilizer produced a higher pod number (37.63). In WS, however, crops applied with 6 ton of jatropha cake significantly increased pods per plant (97.23) over other treatments. It was found that there were no significant differences in pod number between other organic-treated plots and the control in both DS and WS. The plot applied with chicken manure obtained significantly lower pod numbers (30.03) in DS and also minimum pods (57.53) in WS. Although there was a similarity in the number of soybean pods, in DS, applying chemical fertilizer resulted in a greater seed number per plant (64.60). Although soybean seeds of jatropha, chitosan and fish waste extracts, 3 and 6 ton of jatropha cake-treated plots were not significantly different to the number of seeds from the control and chicken manure plots, the number of seeds from the former treatments seemed to be higher than the latter. In WS, however, amendment with 6 and 3 ton of jatropha cake showed increased seed numbers (180.26 and 163.80) over the other treatments. Soybean seeds from the chemical fertilizer-treated plot tended to be greater than the control, jatropha, chitosan and fish waste extracts, and chicken manure-treated plots; however, those treatments were not statistically different in number of seeds per plant, whereas the chitosan extract-treated plot produced the lowest seed number (92.77). The average number of soybean seeds produced under different treatments in WS (127.77) was progressively higher than those in DS (57.01). In DS, the chemical fertilizer-treated plot produced significantly higher soybean seed weight than other treatments but there was no increase in seed weight over all treatments in WS. Average seed weight, however, in WS (20.09 gm) was more than in DS (18.60 gm).

DISCUSSION

Plant growth of soybean

The jatropha cake used in this experiment was fresh (undecompost) and the high application rate reduced seed germination. Heller (1996) reported similar results on tomato seed germination by the application of 5 ton ha^{-1} of jatropha. Therefore, jatropha cake should be applied in the soil for at least three weeks to be well decomposed and only applied at less than 3 ton ha^{-1}.

Table 6 Grain yield and some yield components of soybean under different treatments in dry season (DS), 2007 and wet season (WS), 2008.

Treatment	100 seed weight (gm)		Seed yield (kg ha^{-1})	
	(DS) 2007	(WS) 2008	(DS) 2007	(WS) 2008
Control	18.13 b	19.77	1133.33 b	3280.00 b
Je+ F 60	18.93 ab	19.63	1251.67 b	3600.00 b
Ce + F 60	17.77 b	19.63	1533.33 ab	3444.17 b
Fe + F 60	17.97 b	20.33	1436.67 ab	3850.83 b
CM	19.33 ab	19.53	1356.67 b	3757.50 b
JC 3	18.67 ab	20.80	1313.33 b	5410.83 a
JC 6	18.83 ab	20.13	1245.00 b	4331.67 ab
F 180	19.27 a	20.90	1755.00 a	4190.83 ab
Mean	18.60	20.09	1378.13	3983.23
CV%	3.40	6.30	16.20	21.10
L.S.D. 0.05	1.11	2.22	391.76	1468.59

In a column, means followed by the same letter are not significantly different at $p \leq 0.05$ by Fisher's LSD.

In the early growth stage, plant nutrients from different treatments could not be fully absorbed to support the plant growth but at later stages, different treatments showed different soybean plant height. In DS, chemical fertilizer application provided better plant growth due to its higher nutrient availability and rapid nitrogen mineralization power. Other organic amendments also tended to accumulate the nutrient availability to support the plant growth in both DS and WS but jatropha extract-treated plots responded significantly with height growth as did the chemical fertilizer at harvest time in DS. This result was supported by Suppadit (2004), who considered that organic sewage sludge could be used as a replacement for fertilizer. At later growth stages, soybean plant height in WS was double or more than in DS. This was most likely the effect of sufficient water supply from the rainy season and some additional accumulation of soil nutrition in those treatments. Moreover, effective soil microorganisms provided higher nitrogen fixation and stimulation of plant growth in succeeding crops. This was supported by Vangnai *et al*. (1982), who revealed that higher nitrogen fixation activity occurred under sufficient soil moisture content. The same plant height at 3 and 6 ton of jatropha cake applications seemed to suggest the same nutrient ability and chicken manure application alone was slow to release nutrients to promote soybean plant growth.

In terms of DS, the readily available nutrient form of chemical fertilizer application was supported by the production of the highest soybean plant dry weight. However, application of 6 ton of jatropha cake in DS provided the same nutrient availability to the plant as chemical fertilizer and the application of 3 ton of jatropha cake substantially increased plant weight in WS. Therefore, it is suggested that the application of jatropha cake enhanced soybean plant weight due to its better activity of nutrient uptake in WS as well as a residual carryover effect of nutrients from DS. Applications of organic extracts led to a greater increase in plant weight in DS than in WS due to more nutrient absorption under limited moisture conditions. Application of different treatments also improved soybean leaf size.

Grain yield and yield components of soybean

In DS, soybean plants treated with chemical fertilizer gave the highest grain yield due to the fertilizer's high nutrient solubility that supported improved seed formation but in WS, soybean treated with 3 ton of jatropha cake obtained the highest grain yield and 6 ton of jatropha cake also showed a similar outcome to chemical fertilizer. This result confirmed that the application of jatropha cakes stimulated plant growth and enhanced seed setting to a similar extent as chemical fertilizer. The similar effect of jatropha cake and chemical fertilizer was reported by Tasosa *et al*. (2001), who stated that there was no significant difference in tomato yield with applications of press cakes compared to inorganic fertilizer. In WS, moreover, the application of 3 ton of jatropha cake tended to give higher soybean yield than the application of 6 ton of cake. This result was supported by Ghosh *et al*. (2007), who revealed that the application of jatropha cake at a rate of 3 ton ha^{-1} produced a higher yield of soybean than applying either 0 or 6 ton ha^{-1}, using a spacing of either 4 × 3 m or 3 × 2 m. The application of organic extracts produced greater yield results in DS due to the greater efficacy of a foliar application under limited soil moisture conditions. The relatively higher mean grain yield of soybean in WS than in DS was due mainly to the combined effect of efficient soil moisture and effective nodulation development in WS inducing more nutrient accumulation in the soil for the succeeding crop with better plant growth as well as higher seed yield.

Applying 6 ton of jatropha cake and other treatments except chitosan extracts in WS produced a high concentration of nutrients in those

treatments, which increased the number of nodes. This result was in agreement with Suppadit (2004), who stated that the highest number of nodes per plant (15 nodes) was obtained from organic sewage sludge that was not different from fertilizer treatment. However, the application of different treatments did not support the increase in the number of soybean branches.

The results also indicated that the application of chemical fertilizer produced higher pod numbers in DS. However, applying jatropha cake accumulated more plant nutrients in the soil during the first season (DS) and supported greater pod numbers in the second season (WS). This result was supported by Board and Tang (1995), who revealed that source strength influenced pod number and pods per reproductive node on the whole plant. Applications of organic extracts showed no significance difference to the control. This might have been due to the fact that the same quantities of nutrient supported pod formation under sufficient soil moisture conditions and chicken manure had low nitrogen-releasing ability. In a similar manner as for the number of pods, the application of organic amendments and chemical fertilizer possibly accumulated more nutrients during the critical plant growth period and higher available P contributed to the developing seed numbers. While applications of jatropha cake did not produce the highest plant height at R5 stage, they did produce the highest seed number in WS as a result of faster nutrient mineralization in the second season. This result was in contrast to Vega *et al*. (2001), who observed that seed number per plant and plant growth rate during the critical period for seed set had a linear relationship. However, it did agree with Board (2002), who stated that neither plant height nor seed filling-period (SFP) directly resulted in greater plot yield. There seemed to be less nutrient ability in the chitosan extract plots resulting in low seed numbers. Soil micro-organisms in different treatments in DS acted in different ways and resulted in different seed weights, but in WS the developed microbial communities released more uniform nutrients resulting in identical seed formation. This result was supported by Manalo *et al*. (1998), who considered that nitrogen fertilizer increased seed weight in a non-nodulation cultivar but did not affect the nodulation soybean lines.

Soil analysis

After two seasons of planting, soil pH was classified as closely neutral from moderate acid (pH 5.2 to 6-6.4), therefore, it would be better for soybean growth. No detectable difference in nutrient level was observed between different treatments, except for the soil K result. Although the level of organic matter after two seasons was in the medium range, the trend was decreasing (2.9 to 2.1-2.4%). This was possibly due to temporary nitrogen fixation during the period of organic matter decomposition. This result closely agreed with Eriksen *et al*. (1999), who stated that immobilization of soil N was found in the first season when municipal solid waste compost (MSWC) was applied to maize plants and this deficiency did not persist through the season and did not affect crop productivity. After two seasons of planting, the soil P level seemed to increase to more than at pre-planting time (77 to 74-134 ppm), however, the level of soil P content was at the same high level before and after the two-season experiment. After two seasons, no K fertilizer application showed decreased uptake efficiency from a high to low level range (270 to 50-90 ppm) but the soil K content of organic amendment-treated plots tended to be higher than that of the chemical fertilizer-treated one (data not shown). This result was in close agreement with Yu *et al*. (2008), who stated that a decrease in the yield of soybean and corn were found in the absence of K application, and it was suggested to apply fertilizer according to the nutrient requirements of the plant.

Table 7 Range of soil analysis data of different treatments in Pakchaung series soils.

Soil properties[1]	Pre-planting time	After DS harvest time	After WS harvest time
Soil texture	Clay	Clay	Clay
Sand (%)	27	29	23 - 25
Silt (%)	14	10	10 - 14
Clay (%)	59	60	60 - 65
pH	5.2	5.4 - 6.3	6 - 6.4
Organic matter (%)	2.9 (M)*	2.3 - 2.5(M)	2.1 - 2.4 (M)
Extractable P_2O_5 (mg kg^{-1})	77 (H)	71 - 104 (H)	74 - 134 (H)
Extractable K_2O (mg kg^{-1})	270 (H)	130 - 200 (H)	50 - 90 (L)
Extractable Ca (mg kg^{-1})	874 (H)	1040 - 1360(H)	1280 - 1480 (H)
Extractable Mg (mg kg^{-1})	109 (H)	100 - 140 (H)	100 - 120(H)

[1] Analyzed by Deptartment of Soil Science, Kasetsart University, Bangkok.

* L= low, M = medium, H = high.

CONCLUSION

The highest soybean plant growth and grain yield was obtained from a chemical fertilizer application in DS. In contrast, the application of jatropha cake led to higher growth and yield than other treatments as did chemical fertilizer in the second season (WS). Therefore, from this experiment, it could be suggested that the application of jatropha cake accumulated more nutrients to support better grain yield in the succeeding crop, though, the jatropha cake 6 ton treatment could reduce soybean seed germination in the second season. Other kinds of organic extract applications also tended to produce higher plant growth and grain yield than the control plot but their performances were noticeably increased in the dry season. Therefore, it might be recommended to apply jatropha cake or a combination of organic extracts and chemical fertilizer to improve soybean yield, but further detailed experiments will be needed to understand fully the interaction between organic amendments and soybean production.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support given by the Oil Crops Development Project (OFID Fund), the Myanmar Agriculture Service, Ministry of Agriculture and Irrigation, Myanmar. The first author also expresses her most sincere thanks and gratitude to her advisor, Dr Isara Sooksathan and the advisory committee for all their invaluable guidance, and the Department of Agronomy, Kasetsart University and the Corn and Sorghum Research Centre for kindly supporting the completion of this research.

LITERATURE CITED

Board, J.E. 2002. A regression model to predict soybean cultivar yield performance at late planting dates. **Agron. J.** 94: 483-492.

_____ and Q. Tang. 1995. Assimilatory capacity effects on soybean yield components and pod number. **Crop Sci.** 35: 846-851.

Boonkerd, N., S. Chandrkrachang and W.F. Stevens. 1996. Effects of chitin on nodulation and N_2 fixation in rhizobia-soybean symbiosis. Chitin and Chitosan, pp. 183-187. *In* F.S. Willem, M.S. Rao and S. Chandrkrachang (eds). **Proc. the Second Asia Pacific Symposium, 21 to 23 November, 1996, AIT, Bangkok, Thailand.**

Eriksen, G.N, F.J. Coale and G.A. Boller. 1999. Soil nitrogen dynamics and maize production in municipal solid waste amended soil. **Agron. J.** 91: 1009–1016.

Ghosh, A., J.S. Patolia, D.R. Chaudhary, J. Chikara, S.N. Rao, D. Kumar, G.N. Boricha and A. Zala. 2007. **Response of *Jatropha curcus* under Spacing to Jatropha De-oiled Cake.** Expert seminar on *jatropha curcus*. L. Agronomy and genetics. 26-28 March, 2007. Wageningen, the Netherlands, Published by the FACT foundation.

Heller, J. 1996. **Physic nut-*Jatropha curcas*. L**. International Plant Genetic Resource Institute, Germany. 1-66.p

Manalo, D.D, S. Sawada, H. Miura and K. Kato. 1998. Seed weight of nodulation and non-nodulation soybeans at different nitrogen level and years. **Plant Prod. Sci.** 1(4): 264-268.

Suppadit, T. 2004. **Sewage Sludge as Fertilizer in Soybean Production.** The Graduate Program in Environmental Management, School of Social Development and Environment, National Institute of Development, Thailand. *Available source*: http://www.bloggang.com/viewdiary.php?id=inthedark&month=06-2007&date=30&group=14& gblog=23

Tamaei, S. 2004. Study of gray mangrove afforestation for greening of gray mangroves combined with aquaculture waste water for ecosystem. **Japanese. J. Ecol.** 54(1): 35-46.

Tasosa, J, C. Chiduza, I. Robertson and N. Manyowa. 2001. A comparative evaluation of the fertilizer value of castor and jatropha presscakes on the yield of tomato. **Crop Res.** 21 (1): 66-71.

Tigere, T. A., T.C. Gatsi., I.I. Mudita., T.J. Chikuvire., S. Thamangani and Z. Mavunganidze. 2006. **Potential of Jatropha Curcas in Improving Smallholder Farmers' Livelihoods in Zimbabwe: An Exploratory Study of Makosa Ward, Mutoko District.** *Available Source:* http://www.jsd-africa.com/Jsda/Fall2006/PDF/Arc_Potential%20of%20JC%20in%20 Improving%20Smallholder%20Farmers's%20livlihoods%20in%20Zimbabwe.pdf

Vangnai, S, W. Sirivatpaitoon and V. Verasan. 1982. Effects of soil moisture on nodulation and nitrogen fixation. **Kasetsart J. (Nat. Sci.)** 16 (1): 12-17.

Vega, C. R. C, F. H. Andrade, V. O. Sadras, S.A. Uhart and O. R. Valentinuz. 2001. Seed number as a function of growth. A comparative study in soybean, sunflower, and maize. **Crop Sci.** 41: 748-754.

Yu, W-T, Z.S. Jiang, H. Zhou and Q. Ma. 2008. Effects of nutrient cycling on grain yields and potassium balance. **Nutrient Cycling in Agroecosys.** 1-11.