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Effects of Organic-Chemical Fertilizer on the Growth and Yield of Rice (Chai Nat 1)

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Abstract: A field experiment was undertaken to determine the effects of organic-chemical fertilizer and chemical fertilizer (NPK 16:16:8) on the growth and yield of rice Chai Nat 1 in Roi-Et province, Northeast Thailand. Organic-chemical fertilizer was developed from organic fertilizer 82+9.0 kg of NPK 46:0:0 + 4.5 kg of NPK 18:46:0 and 4.5 kg of NPK 0:0:60. Five treatments were compared consisting of: T_1 (control without fertilizer); T_2 (312.5 kg ha^{-1} organic-chemical fertilizer); T_3 (625 kg ha^{-1} organic-chemical fertilizer); T_4 (937.5 kg ha^{-1} organic-chemical fertilizer) and T_5 (chemical fertilizer; 312.5 kg ha^{-1} NPK 16:16:8). Yield of rice grains under all treatments increased between 2-4 times when compared to the control (1.37 t ha^{-1}). In terms of statistical data, growth and yield of rice Chai Nat 1 obtained from organic-chemical and chemical fertilizers were significantly different at a confidence level of 95% to the control. Application of organic-chemical fertilizer alone showed 2-2.5 times (2.66-3.43 t ha^{-1}) increased yield of grains over the control. However, maximum grain yield (5.57 t ha^{-1}) was obtained from T_5 (chemical fertilizer) which also gave the highest all yield parameters such as number of grain per panicle (108.20), total number panicle per hill (14.82), plant height (62.48 cm) and percentage of filled grain (82.17%). Excluding labor costs, even maximum grain yield obtained from chemical fertilizer was higher than those found from organic-chemical fertilizer but taking into account chemical fertilizer cost which is 3.4 times higher than organic-chemical fertilizer. Therefore, the soil amendment with organic-chemical fertilizer may be a practicable alternative for the farmers who are unable to afford the cost of chemical fertilizer. Moreover, organic-chemical fertilizer farming is more economically viable, beneficial for farmers livelihoods and environmentally friendly than those found in chemical fertilizer farming alone.

Key words: Organic-chemical fertilizer, chemical fertilizer, confidence level, Roi-Et province, Thailand

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important crop for the Thai people. Thailand is one of the world rice producer (approximately 31.65 million ton in 2009) and exporter (approximately 8.5 million ton in 2009) country (http://www.riceexporters.or.th/production.htm). Rice has been a major economic crop in Thailand and there is approximately 10 million hectares of land devoted to rice with giving an approximate grain yield of 2,600 kg h^{-1}. More than half of the total rice area is in the Northeast and approximately 25% of rice lands are irrigated while the rest is still rainfed. Rice Chai Nat 1 (CNTBR82075-43-2-1) originated from Phitsanulok Rice Research Center in Thailand. This rice was arose from the cross among the three varieties as following IR13146-158-1,IR15314-43-2-3-3andBKN6995-16-1-1-2.It is non-sensitive to photoperiod, contains high amylose, 119-130 days in maturity, 113 cm height, high nitrogen response, resistant to insect (*Nilaparvata lugents* and *Sogatella furcifera*), pests and diseases (*Pyricularia oryzae*). The extensive rice production and poor farm management systems have resulted in soil erosion, depletion of soil nutrients and soil exhaustion. A major constraint to crop production in Northeast Thailand is the low soil organic matter content and biological activity. Chemical fertilizers are significant to succor nutrients in soil. Heavy doses of chemical fertilizers and pesticides are commonly used in order to enhance rice yields. Approximately, 50% of crop yield increment has been promoted by chemical fertilizers (FAO, 1989; NFDC, 1989). Death and suffering from chemical fertilizers and pesticides of the farmers is a critical problem in Thailand. These problems arose from a general lack of knowledge of agro-chemical application and safety use procedures. Heavy and continuous use of pesticides may accelerate serious negative effects on farmers health, depletion of soil organic matter, nutrient deficiency in soil, crop yield reduction and increase cultivation cost (Higa, 1998). In addition, the over use of inappropriate inorganic nitrogen fertilizer has resulted in nitrous oxide production and denitrification activity near the soil surface (Yamauchi, 1995).

Presently, attraction in organic farming is increasing in Thailand and this interest has been promoted by the Thai government. Even organic agriculture can be

sustainable, economically viable, address farmers' livelihoods, environmentally friendly and the food produced should be safe to consumers (Sangakkara *et al*., 1995). However, organic fertilizer contains low amounts of essential plants nutrients and plants can not use the nutrients in organic material directly (Mamaril, 2004; Yamada *et al*., 1996). Moreover, soil organic matter can not increase significantly after applying organic fertilizer in 1 or 2 years. The conventional method of building up soil organic matter is through the application of manures such as farmyard manure, farm wastes and various compost preparations (Lopez-Real, 1990). Since, inorganic fertilizer can provide the main important nutrients (N, P, K) to plants directly.

In order to obtain high grain yield and improve soil quality, the proper amounts of chemical fertilizers may need to apply with organic fertilizer when growing rice. Therefore, this research was undertaken to examine the effect of organic-chemical fertilizer application on growth and yield of rice cultivation and its economic consequences. It is expected that the findings of this study will help to develop appropriate rice cultivation management techniques in the Northeast of Thailand.

MATERIALS AND METHODS

These field experiments were carried out at Huai Ang, Amphur Srisomded, Roi-Et province in Northeast Thailand.

Block preparation: Soil was ploughed one time each week for 2 weeks before Chai Nat 1 was cultivated. Chai Nat 1 was cultivated in a randomized complete block design of 15 blocks with three replications of each treatment. Each block size was 3×3 m and there were 225 plants in each block. Chai Nat 1 was grown with 20 and 20 cm row to row and line to line spacing, respectively.

Organic-Chemical fertilizer preparation: Organic fertilizer was prepared from cattle manure 1,000+5 kg of NPK 46:0:0+25 kg of NPK 0:3:0. This organic fertilizer was kept in the shade at room temperature in order to ferment for 7 days after mixing and ready to use after 14-21 days fermentation.

Organic-chemical fertilizer was prepared from organic fertilizer 82+9.0 kg of NPK 46:0:0+4.5 kg of NPK 18:46:0+ 4.5 kg of NPK 0:0:60.

Treatment design: Five treatments (each treatment has 3 blocks) were evaluated in this experiment as follows:

- Treatment 1; control (without fertilizer)
- Treatment 2; 312.5 kg ha^{-1} of organic-chemical fertilizer
- Treatment 3; 625 kg ha^{-1} of organic-chemical fertilizer
- Treatment 4; 937.5 kg ha^{-1} of organic-chemical fertilizer
- Treatment 5; 312.5 kg ha^{-1} of chemical fertilizer; NPK 16:16:8

Chai Nat 1 rice were grown in soil without fertilizer for 30 days before transplant. Two splits of chemical fertilizer and organic-chemical fertilizer were incorporated as following; 7 and 37 days after rice transplant. All treatments of Chai Nat 1 cultivation were harvested on day 130 after transplant.

Data analysis The Chai Nat 1 growth and yield data from each treatment was collected on the same day to determine the following parameters:

- Chai Nat 1 height (cm) and total number panicle per hill were measured every week after transplant
- Grain yield (kg), number of grain per panicle and percentage of filled grain from each treatment were determined on day 130 after transplant
- Statistical analysis; the data was analyzed using SPSS
- Nitrogen content was examined by Buurman *et al*. (1996)
- Potassium content was examined by Tan (1996) (Modified method)
- Phosphorus content was examined by Buurman *et al*. (1996)
- pH, Electrical Conductivity (EC), Carbon/Nitrogen ratio (C/N), moisture content, Cadmium (Cd), Chromium (Cr), Lead (Pb), Mercury (Hg), Arsenic (As) and Cupper (Cu) were examined by office of sciences for land; Thailand, 2004

RESULTS AND DISCUSSION

Soil, organic-chemical fertilizer and chemical fertilizer composition: Soil samples, organic-chemical and chemical fertilizer compositions were evaluated by Kasetvisai Agricultural Extension Office in Roi-Et province. The soil compositions were as following: pH 6.853, EC 7.98 dS m^{-1}, moisture content 0.184%, C/N ratio 2.243, sandy and low nutrient content (total nitrogen 0.05%, available phosphorus 1.321%, available potassium 1.242%). Chemical fertilizer showed the highest in nutrient content (Total nitrogen 13.045%, available phosphorus 14.006% and available potassium 7.505%) while the organic-chemical fertilizer contained 4.344% total nitrogen, 2.246% available phosphorus, 2.852% available potassium and pH 8.183. The compositions of soil sample, organic-chemical fertilizer and chemical fertilizer are shown in Table 1.

Table 1: The compositions of soil sample, organic-chemical fertilizer and chemical fertilizer

Parameters	Soil	Organic-chemical fertilizer	Chemical fertilizer
pH	6.853	8.183	5.740
EC (dS m^{-1})	7.980	17.550	39.500
Moisture content (%)	0.184	8.429	2.160
C/N ratio	2.243	0.297	0.010
Total nitrogen (%)	0.050	4.344	13.045
Total P_2O_5 (%)	1.321	2.246	14.006
Total K_2O (%)	1.242	2.852	7.505
Cd (mg kg^{-1})	<0.001	<0.001	<0.001
Cu (mg kg^{-1})	<0.001	<0.001	<0.001
Pb (mg kg^{-1})	<0.001	<0.001	<0.001
As (mg kg^{-1})	<0.001	<0.001	<0.001
Hg (mg kg^{-1})	<0.001	<0.001	<0.001
Pb (mg kg^{-1})	<0.001	<0.001	<0.001

Table 2: Effect of organic-chemical and chemical fertilizer on grain yield of rice Chai Nat 1

	Grain yield (ton ha^{-1})	
Treatments	Wet weight	Dried weight
T_1: Control (no fertilizer)	1.37±0.26^c	1.16±0.22^c
T_2: 312.5 kg ha^{-1} organic-chemical fertilizer	2.66±0.34^b	2.25±0.19^b
T_3: 625 kg ha^{-1} organic-chemical fertilizer	2.75±0.26^b	2.33±0.22^b
T_4: 937.5 kg ha^{-1} organic-chemical fertilizer	3.43±0.26^b	2.91±0.22^b
T_5: 312.5 kg ha^{-1} chemical fertilizer; NPK 16:16: 8	5.57±0.79^a	4.72±0.67^a

Means±SD in each column with different superscripts indicate statistical differences ($p<0.05$)

Table 3: Effect of organic-chemical and chemical fertilizer on percentage of filled grain and number of grain per panicle of rice Chai Nat 1

	Grain yield	
Treatments	Filled grain (%)	No. of grain per panicle
T_1: Control (no fertilizer)	50.48±15.17^b	87.67±6.46^b
T_2: 312.5 kg ha^{-1} organic-chemical fertilizer	69.05±2.520^{ab}	91.44±4.70^{ab}
T_3: 625 kg ha^{-1} organic-chemical fertilizer	77.29±0.530^a	100.82±1.07^{ab}
T_4: 937.5 kg ha^{-1} organic-chemical fertilizer	81.90±1.170^a	107.89±4.20^a
T_5: 312.5 kg ha^{-1} chemical fertilizer; NPK 16:16:8	82.17±1.740^a	108.20±7.25^a

Means±SD in each column with different superscripts indicate statistical differences ($p<0.05$)

Grain yield, percentage of filled grain, number of grain per panicle, average total number of panicle per hill (7-13 weeks) and height (7-13 weeks) of rice Chai Nat 1: Five treatments were evaluated in this research. Treatment 1: Control (with out fertilizer); treatment 2: 312.5 kg ha^{-1} organic-chemical fertilizer; treatment 3: 625 kg ha^{-1} organic-chemical fertilizer; treatment 4: 937.5 kg ha^{-1} organic-chemical fertilizer and treatment 5: chemical fertilizer 312.5 kg ha^{-1} NPK 16:16:8. Rice Chai Nat 1 grain yield, percentage of filled grain and number of grain per panicle were determined on the day of harvesting (130 days after transplant). However, average total number of panicle per hill (7-13 weeks) and height of rice Chai Nat 1 were measured every week after transplant (7-13 weeks). The results for each treatment are shown in Table 2-5.

From this experiment, it was found that yield of rice grains under all treatments increased between 2-4 times (5.57-2.66 t ha^{-1}) when compared to the control (1.37 t ha^{-1}). In terms of statistical data, growth and yield of rice Chai Nat 1 obtained from organic-chemical and chemical fertilizers were significant different at a confidence level of 95% to the control. Without fertilizer (control) grain yield, number of grain per panicle, total number panicle per hill, plant height and percentage of filled grain were 1.37 t ha^{-1}, 87.67 grains, 7.83 panicles, 36.72 cm and 50.48%, respectively. Even the application of organic-chemical fertilizer alone showed 2-2.5 times (2.66-3.43 t ha^{-1}) increased yield of grains over the control but maximum grain yield (5.57 t ha^{-1}) was obtained from T_5 (chemical fertilizer). T_5 gave the highest all yield parameters such as number of grain per panicle (108.20 grains), total number panicle per hill (14.82 panicles), plant height (62.48 cm) and percentage of filled grain (82.17%).

Field cost (US$) cultivation of rice Chai Nat 1: The most important cost for cultivation of rice for Thai farmers is the cost of fertilizer. In Thailand, chemical fertilizer (NPK 16:16:8) costs \$0.61 kg^{-1} which is equivalent to 3.4 times higher than organic-chemical fertilizer (\$0.18 kg^{-1}). The percent net return for farmers is dependant not only on cost of fertilizer but also on yield of rice grains and the unit price of un-milled grains (dried weight; \$0.30 kg^{-1}). Excluding labor costs, economic analysis of yield data shown in Table 6 that the maximum net return increase over control (252%) was achieved in treatment with 312.5 kg ha^{-1} chemical fertilizer; NPK 16:16:8 (T_5) while 78-102 % increase in the treatment with application of organic-chemical fertilizer (T_2-T_4). Without control even treatment of 312.5 kg ha^{-1} organic-chemical fertilizer (T_2) contributed the lowest yield of grains (2.25 ton ha^{-1}) but the farmer net return (\$618.75) and percentage of net return increase over control (78%) were higher than those found in T_3 (625 kg ha^{-1} organic-chemical fertilizer).

Yield of rice grains under all treatments increased between 2-4 times (5.57-2.66 t ha^{-1}) when compared to the control (1.37 t ha^{-1}). Control did not show significant effects in promoting grain yield might be a result of the soil properties which are dry and a low nutrient content. Such soils are inappropriate for rice growth. Maximum total yield of rice grains (5.57 t ha^{-1}) was obtained in T_5 (312.5 kg ha^{-1} chemical fertilizer; NPK 16:16:8) and this rice grain yield was significant difference to those found in other treatments (without and organic-chemical fertilizer). Even application of organic-chemical fertilizer

Table 4: Effect of organic-chemical and chemical fertilizer on average total number of panicle per hill (7-13 weeks) of rice Chai Nat 1

	Average total number of panicle per hill of rice Chai Nat 1						
Treatments	7 weeks	8 weeks	9 weeks	10 weeks	11 weeks	12 weeks	13 weeks
T_1	3.11±0.29^{NS}	3.69±0.71^{NS}	5.33±0.58^{b}	7.33±1.53^{NS}	7.37±0.33^{d}	7.27±0.12^{c}	7.83±0.06^{c}
T_2	3.67±1.00	4.00±1.00	6.85±0.75^{b}	9.84±0.49	10.38±0.49^{c}	10.52±0.43^{b}	10.92±0.73^{d}
T_3	3.78±0.11	5.40±1.97	7.14±0.48^{b}	11.06±2.03	11.20±0.68^{bc}	11.78±1.08^{b}	12.52±1.32^{ab}
T_4	3.00±0.39	6.80±0.95	10.71±0.86^{a}	12.06±1.33	12.97±1.19^{ab}	12.67±0.62^{ab}	13.42±0.80^{ab}
T_5	3.67±0.19	7.66±0.88	11.72±1.24^{a}	13.45±1.19	14.00±0.58^{a}	14.62±1.13^{a}	14.82±0.44^{a}

Means±SD in each column with different superscripts indicate statistical differences ($p<0.05$); NS = Not Significantly different

Table 5: Effect of organic-chemical and chemical fertilizer on rice Chai Nat 1height (7-13 weeks)

	Average rice Chai Nat 1 height (cm)						
Treatments	7 weeks	8 weeks	9 weeks	10 weeks	11 weeks	12 weeks	13 weeks
T_1	33.19±1.50^{c}	35.76±0.88^{c}	36.90±2.35^{b}	36.48±3.21^{c}	36.61±0.70^{d}	36.54±1.63^{c}	36.72±0.37^{c}
T_2	34.13±1.34^{bc}	36.47±4.33^{c}	37.20±5.02^{b}	38.33±3.22^{c}	43.51±3.84^{c}	46.90±4.83^{b}	46.86±4.88^{b}
T_3	34.56±2.51^{abc}	39.80±1.03^{ab}	40.07±2.75^{b}	41.60±3.40^{bc}	44.56±0.32^{c}	47.90±1.58^{b}	47.89±0.85^{b}
T_4	38.90±1.55^{ab}	39.87±1.41^{ab}	45.50±2.39^{ab}	48.43±3.66^{ab}	52.42±1.69^{b}	55.99±1.24^{a}	56.05±0.48^{a}
T_5	39.62±0.16^{a}	44.43±0.84^{a}	54.37±1.17^{a}	56.55±0.89^{a}	58.88±1.17^{a}	62.00±0.62^{a}	62.48±1.76^{a}

Means±SD in each column with different superscripts indicate statistical differences ($p<0.05$)

Table 6: Comparative economic analysis among various treatments

Treatments	Grain yield ton ha^{-1}(dried weight)	Total cost of fertilizer per ha (US$)	Farmer income per ha (US$)	Net return (US$)	Percentage of net return increase over control
T_1	1.16±0.22	-	348	348.00	-
T_2	2.25±0.19	56.25	675	618.75	78
T_3	2.33±0.22	112.50	699	586.50	69
T_4	2.91±0.22	168.75	873	704.25	102
T_5	4.72±0.67	190.63	1416	1225.37	252

T_1: Control (no fertilizer); T_2: 312.5 kg ha^{-1} organic-chemical fertilizer; T_3: 625 kg ha^{-1} organic-chemical fertilizer; T_4: 937.5 kg ha^{-1} organic-chemical fertilizer; T_5: 312.5 kg ha^{-1} chemical fertilizer; NPK 16:16:8; PS: Economic analysis was calculated base on the cost of fertilizer

alone (T_2-T_4) showed 2-2.5 times increased rice grain yield over control but increasing organic-chemical fertilizer concentration had no significant effect on rice growth and yield. Moreover, in terms of statistical data, the total rice grain yield obtained from three different concentration of organic-chemical fertilizer (312.5, 625 and 937.5) was similar. Since, the organic-chemical fertilizer consists of organic material plus inorganic fertilizer therefore this organic-chemical fertilizer did not show significant effects in promoting rice grain yield. Supplementing 937.5 kg ha^{-1} organic-chemical fertilizer (T_4) was inadequate to make a difference in rice growth and grain yield when compared with application of 312.5 kg ha^{-1} organic-chemical fertilizer (T_2). It may have been caused by a slow degraded material property of organic matter which may have caused the minerals and availability of plant nutrients to only gradually be released into the soil via the fermentation process, rice may not directly use the nutrients contained in organic fertilizer, low essential nutrients in organic fertilizer and soil organic matter can not be improved significantly after applying organic fertilizer (Parr and Hornic, 1995; Mamaril, 2004; Karim *et al*., 1992).

Even maximum total yield of rice grains (5.57 t ha^{-1}) and percentage of net return increase over control (252%) were obtained from T_5 (312.5 kg ha^{-1} chemical fertilizer; NPK 16:16:8) but chemical fertilizer has been mostly considered a bane in farming. Since heavy use of chemical fertilizer may deteriorate the nutrient base, biological activity, depletion of the soil's natural fertility, decline soil productivity and deleterious effect of groundwater and environment (Yamauchi, 1995; Mamaril, 2004).

CONCLUSION

Presently, Thailand is concerned about promoting more organic farming systems since they are free of chemical fertilizers and pesticides, organic material can improve the physical properties of soil under aerobic condition, environmentally friendly, address farmers' livelihoods and emphasize utilization of on-farm resources by recycling waste into useful organic matter. However, many researches have been shown that organic fertilizer alone may not altogether be the best option for rice farming (Dahal, 1993). Mamaril (2004) has been suggested that a greater chance to sustain fairly high yields and improve soil productivity for rice farming can be achieved by applying farm wastes (crop residues and farm manure). Combination with proper amount of inorganic fertilizer. In addition, the present cost of chemical fertilizer (NPK 16:16:8) is 3.4 times higher than organic-chemical fertilizer. Hence, under the potential constraint of chemical fertilizer cost and in order to obtain fairly high grain yield therefore farmers who own degraded farmlands may

consider using organic-chemical fertilizer in their rice farming rather than using inorganic or organic fertilizer alone.

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