Effect of Rice Straw Incorporation on Soil Properties and Rice Yield

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Abstract

Effect of rice straw management on soil properties in rice soil was conducted in this study. The Pathumthani 1 rice variety was planted in pot experiment by using Kamphaeng Saen soil series (Typic Haplustalfs). The experiment was designed by Completely Randomized Design (CRD) with three treatments of soil preparation which included 1) soil without rice straw or rice straw ash application (control) 2) soil with rice straw incorporation and, 3) soil with rice straw ash incorporation. The rate of rice straw used in treatment 1 and 2 were 13.15 kg m^{-2}. Soil properties such as soil pH, %OM, %OC, available P, extractable K, bulk density, Total N, Total C and C/N ratio were determined after growing season and compared with its properties before growing period. Control treatment presented less %OM, %OC and K than soil with rice straw and soil with rice straw ash. Rice cultivation in soil with rice straw incorporation presented highest %OM, %OC compared with other. Phosphorus and potassium contents in rice straw treatment were higher than that control treatment. In addition, lowest bulk density has been observed in soil with rice straw applied. These results implied that rice straw induces soil fertility which is useful for plant growth.

Keywords: straw management, soil chemical properties, Pathumthani 1 rice variety

Introduction

Thailand is an agricultural country; rice cultivation area occupied about 26,063,292 acres in the year 2012. After harvesting, particularly rice straw was burned in the cultivated area and some was left as rice straw and stuff before incorporated into soil. Rice straw compost incorporation plays an importance role on soil nutrients fertility by adding soil nutrient. The composition of fresh rice straw included nitrogen (14.26 kg ha^{-1}), phosphorus (1.86 kg ha^{-1}), and potassium (35.34 kg ha^{-1}). These components are retained and accumulated in the soil. The nutrients and soil abundance has increased when rice straw was incorporated into soil for several years (Pomnamperuma, 1984). Therefore, this study was interested in finding out effects of soil management using rice straw, rice straw burned on rice growth, rice yield, and soil properties from rice cultivation.

Materials and Methods

Pot Experiment

The pot experiment was conducted during November 18, 2009-March 30, 2010 at Kasetsart University Kamphaeng Saen Campus, Nakhon Pathom province in central of Thailand. The soil was Kamphaeng Saen (Ks) soil series (Typic Haplustalfs). This soil contained of total carbon 1.13%, total nitrogen 0.06%, soil organic matter 0.91%, soil organic carbon 0.53%, phosphorus

0.065 g kg^{-1} and potassium 0.169 g kg^{-1} content under an initial soil pH of 7.68 (Table 1). Soil texture was classified as clay with a percentage composition of sand: silt: clay of 22: 24: 54.

The photoperiod insensitive jasmine rice cultivar Pathumthani 1 was used. Rice plant 30 days was transplanted in pot with 22 cm diameter and 24.5 cm height. Three treatments were investigated; 1) planted control pot (soil without rice straw and rice straw ash), 2) planted in soil with rice straw incorporation (13.15 kg m^{-2}), and 3) planted in soil with rice straw ash incorporation (13.15 kg m^{-2} of rice straw was burn to a charcoal before incorporation into soil). Nutrient contents in the rice straw are shown in Table 2. The experimental design by Completely Randomized Design (CRD) with fifteen replications was applied. The pots were flooded for 7 days after planting and the water level in each pot was controlled (5-10 cm) throughout the growing period. The rice was planted in growing season of 120 days long and the final drainage was applied for all treatment for 15 days before harvesting. Rice cultivation in this experiment was not applied for chemical fertilizer but the pesticide was used once for worn eradication during vegetation period.

Soil Properties Analysis and Rice Plant Monitoring

Initial soil properties and after growing season was analyzed for soil pH, organic matter, organic carbon, phosphorus, potassium, bulk density, total nitrogen, and total carbon (Table 3). Rice growth including plant height, tiller numbers were recorded at 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15 weeks after transplanting by sampling from 15 pots in each treatment. Yield per pot and yield components, i.e., number of panicles per pot, number of filled seed per panicle, and filled seed weight were also measured at the harvesting period. In addition, the rice plant biomass was dry and weight in order to record aboveground and below ground biomass.

Data Analysis

Data was analyzed by the statistical package for the social sciences (SPSS) routine of completely randomized design (CRD). Treatment effects were compared using F-tests, while multiple comparisons of means were assessed using Duncan's New Multiple Range Test (DMRT).

Table1 Soil properties before growing period.

Soil properties	
pH	7.68
Organic matter (%)	0.91
Organic carbon (%)	0.53
Phosphorus (g kg^{-1})	0.065
Potassium (g kg^{-1})	0.169
Bulk density (g cm^{-3})	1.51
Total carbon (%)	1.13
Total nitrogen (%)	0.06
C/N ratio	17.67

Table 2 Nutrient contents in the rice straw.

Rice straw	Nutrient contents
Total carbon (g kg^{-1})	383.0
Total nitrogen (g kg^{-1})	6.2
C/N ratio	61.7
Phosphorus (g kg^{-1})	1.4
Potassium (g kg^{-1})	19.4

Source: Ruensuk. et al., 2008

Table 3 Soil properties analysis.

Parameter	Measurer	References
pH	pH meter	Thomas, 1996
Organic matter and Organic carbon	Walkley and Black	Walkley and Black, 1934
Phosphorus (P)	Spectrophotometer	Abbott, 1985: Bartlett et. al., 1994
Potassium (K)	Atomic absorption spectroscopy	Thorpe, 1973
Bulk density	Clod method	Bartlett et al., 1994
Total N and Total C	CNS Analyzer	Leco Corporation, 1996 CNS-2000

Results and Discussion

Effects of Rice Straw Incorporation on Soil Properties

Table 4 shows soil properties after growing season. The lowest %OM content (1.80%) was observed from rice cultivation in control treatment, the second low obtained from rice straw ash treatment (1.97%), and the highest %OM content (2.02%) was observed from rice straw treatment (Figure 1). Amount of %OM and %OC contents from all treatments were not significantly different ($p \leq 0.01$) but %OM and %OC of control and rice straw treatments were significantly different ($p \leq 0.01$). Rice straw has been reported as materials improving soil fertility by promoting soil organic matter (SOM) and soil moisture contents (Ruensuk et al., 2008). In addition, rice straw incorporation into soil result high soil nutrient, induce living organism activities, and soil fertility (Department of Soil Science, Faculty of Agriculture, Kasetsart University, 1987, 1998). The highest total C content was observed from rice straw treatment (1.63), then rice straw ash treatment (1.57) and control (1.50), in descends order. Total C contents were significantly different ($p \leq 0.01$) among three treatments. Comparison of total N contents from three treatments revealed the rice straw treatment stored high total N than that control, and show significant difference ($p \leq 0.05$) when compared to control.

Rice straw ash improves soil phosphorus (P) contents but there was no significant difference among three treatments ($p \leq 0.05$) and potassium (K) contents were significantly different among three treatments ($p \leq 0.01$) (Table 4). Phosphorus content in rice straw ash treatment (105.08 mg kg^{-1}) was higher than that rice straw treatment (101.21 mg kg^{-1}) and rice straw treatments raised up 3-7% of soil phosphorus contents in comparison to control (97.71 mg kg^{-1}). The potassium content in soil with rice straw ash, soil with rice straw, and control was 98.12, 88.02, and 61.70 mg kg^{-1}, respectively. Potassium contents in control increased about 37% when added rice straw ash. Bulk density from soil with rice straw, control and soil with rice straw ash treatments were 1.24 g cm^{-3}, 1.31 g cm^{-3}, and 1.32 g cm^{-3}, respectively. There was no significant difference among three treatments ($p \leq 0.05$). Normally bulk density condition in fine textured soil was 1.00-1.60 g cm^{-3} and suitable soil bulk density for planting is 1.30 g cm^{-3} (Nakhon Sawan Rajabhat University, 2005). Therefore, bulk density from all three treatments was suitable for planting. However, lowest bulk density in soil with rice straw treatment was lowest, which is helpful for soil preparation, reduce tillage and enhance air circulation in soil (Nie et al., 2007).

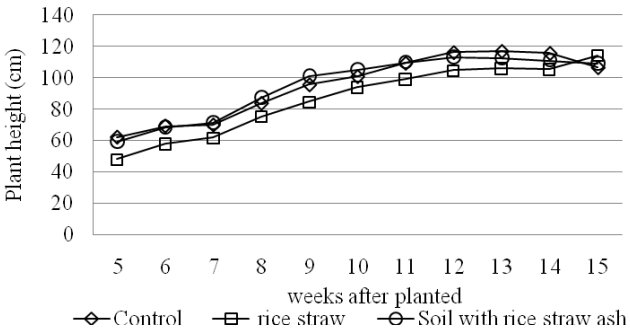

Figure 1 Average plant height throughout growing period from control, rice straw treatment, and rice straw ash treatment.

Table 4 soil properties after harvested.

Treatment	Total C	Total N	C/N ratio	pH	Soil Carbon		Available P	Available K	Bulk density
					OM (%)	OC (%)	(mg kg^{-1})	(mg kg^{-1})	(g cm^{-3})
Control	1.50c	0.058b	23.49a	7.06a	1.80b	1.04b	97.71a	61.70c	1.31a
Soil with rice straw	1.63a	0.088a	19.44b	7.18a	2.02a	1.17a	101.21a	88.02b	1.24a
Soil with rice straw ash	1.57b	0.079a	18.66c	7.17a	1.97a	1.14a	105.08a	98.12a	1.32a
F-test	**	*	**	ns	**	**	ns	**	ns
CV. (%)	2.02	13.33	1.93	1.25	2.83	2.82	5.92	4.03	7.35

Values in a column followed by a common letter are not significantly different at the 5% level by DMRT.
**: significantly different *($p \leq 0.01$)*, ns: not significantly different.

Effects of Rice Straw Incorporation on Rice Growth and Yield

The result revealed rice cultivation in soil with rice straw ash presented lower rice growth rate compared to control (Table 5). But the quality of rice seed including seed number and seed weight per 1,000 seeds cultivated soil with rice straw treatment and rice straw ash treatment was 34% and 29% higher than that in control (Table 6). Rice plant height was significantly different ($p \leq 0.01$) among three treatments. Tiller number and panicle number per pot was significantly different ($p \leq 0.01$) between control and rice straw treatments (both rice straw and rice straw ash) but both properties were not significantly different ($p \leq 0.05$) between rice straw and rice straw ash treatment. Plant wet weight and plant dry weight was significantly different ($p \leq 0.01$) among three treatments (Table 5). Average plant height throughout growing period from control, rice straw treatment, and rice straw ash treatment is shown (Figure 1).

Rice yields were not significantly different among three treatments ($p \leq 0.01$) as shown in Table 6. Rice straw incorporated into soil was then slowly decomposed and induced reduction rate of nitrogen immobilization result in low nitrogen content in soil. Directly affect occurred to rice plant which was presented as yellow leafs, dark roots, low nutrient uptake efficiency and low rice grain yield (Broadbent, 1979).

The numbers of filled seeds per panicles among three treatments were significantly different ($p \leq 0.01$). Average filled seeds from rice straw treatment were 86.90 seeds and rice straw ash was 86.28 seeds and 66.94 filled seeds were counted from control treatment. An average filled rice seed from control and rice straw treatments was significantly different but filled rice seeds between rice straw ash and rice straw treatments were not significantly different ($p \leq 0.01$). Highest seed yield (0.059 kg m^{-2}) was observed from rice straw ash treatment and was not significantly different ($p \leq 0.01$) with rice straw treatment. But rice grain yield in control was significantly different ($p \leq 0.01$) from rice straw ash and rice straw treatment.

Table 5 Plant height, tiller number, panicle number, plant fresh and weight.

Treatments	Plant height (cm)	Tiller number (number m^{-2})	Panicle number (number m^{-2})	Plant fresh weight (kg m^{-2})	Plant dry weight (kg m^{-2})
Control	106.88c	1031a	818a	9.46c	4.98c
Soil with rice straw	114.42a	794 b	581b	11.19b	5.40b
Soil with rice straw ash	110.34b	821b	584b	11.39a	5.60a
F-Test	**	**	**	**	**
CV (%)	0.94	10.83	0.13	9.25	8.14

Values in a column followed by a common letter are not significantly different at the 5% level by DMRT.
**: significantly different*($p \leq 0.01$)*, ns: not significantly different

Table 6 Amount of filled seed, seed weight, and rice yield.

Treatments	Filled seed (seed ear^{-1})	Seed weight (kg ear^{-1})	1,000 seeds weight (kg)	Rice yield (kg m^{-2})
Control	66.94b	0.045b	0.68a	1.44a
Soil with rice straw	86.90a	0.057a	0.69a	1.36a
Soil with rice straw ash	86.28a	0.059a	0.70a	1.35a
F-Test	**	**	ns	ns
CV (%)	12.12	1.53	3.65	0.23

Values in a column followed by a common letter are not significantly different at the 5% level by DMRT.
**: significantly different ($p \leq 0.01$), ns: not significantly different

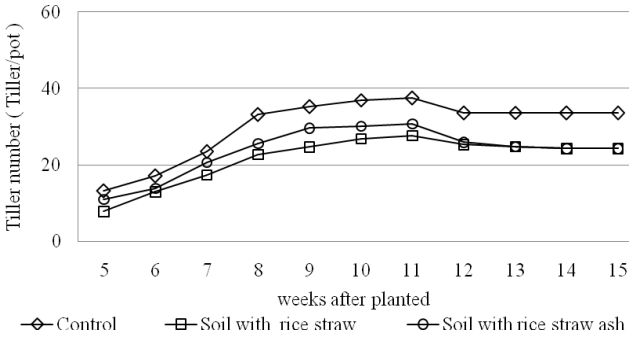

Figure 2 Average number of tiller per pot throughout the growing period from control, rice straw treatment, and rice straw ash treatment

Average rice grain yield from rice straw ash treatment, rice straw treatment, and control was 1.35 1.36 and 1.44 kg m^{-2}, respectively (Table 6). Average rice grain yield per cultivation area was not significantly different among three treatments ($p \leq 0.01$). Rice straw incorporation in rice field did not significantly improve rice yield compared to cultivation without rice straw incorporation (Phongpan and Mosier, 2001).

Conclusions

Application of rice straw and rice straw ash into rice soil without chemical fertilizer application in this study suggested that rice straw increased soil fertility (%OM, %OC and K) but resulted in lower rice growth rate in comparison to control. The results suggested that rice straw induces soil fertility for rice cultivation. Incorporating the rice straw in rice soil (both in form of rice straw and rice straw ash) served nutrients recycling. In addition, rice straw incorporation resulted in low soil bulk density, which is helpful for soil preparation. Therefore, straw return in soil perhaps is a good practice to maintain soil fertility and improves grain weight.

Acknowledgments

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