Journal of Biology, Agriculture and Healthcare www.iiste.org
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.3, No.5, 2013

Influence of Flooding Levels on Changes in C, N and Weight of Rice Straw in a Paddy Soil

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Abstract
It is imperative to have a better understanding of the effects of different flooding levels in paddy soils on changes in soil chemical properties, especially information on the N recovery and N mineralization when the rice straw is incorporated into soil as a source of soil organic matter under tropic conditions, such as in Metro, Lampung. A glasshouse study was carried out to determine the effects of different flooding levels (2.5, 5.0, 7.5, and 10.0 cm) on changes in carbon (C), nitrogen (N) contents and weight of rice straw incorporated into paddy soil. The treatments were arranged in a completely randomized block design with six replications. The results showed that C content of the rice straw at the beginning of the trial was 33–40%. These values decreased 2 weeks after flooding except for the flooding level of 10 cm the C content still decreased until 4 weeks after flooding. And then for all flooding levels the values tended to return to the initial values 8 weeks after flooding. Meanwhile, the N content at the beginning of the trial was 0.56-0.60%. The N contents for all flooding levels increased with increasing time of observation (1.34-1.48%). The C:N ratios for all flooding levels at the beginning of the trial greatly decreased until 2 weeks after flooding. Thereafter, the ratios decreased slightly until 8 weeks after flooding. Furthermore, flooding level of 2.5 cm gave the lowest weight of rice straw 8 weeks after flooding, whereas, flooding level of 10.0 cm gave the highest weight of rice straw, suggesting that the lesser the flooding level, the faster the litter decomposition rate. This confirms other findings that at the depth of 1-2 cm below water surface of a paddy field are an aerobic zone, where the litter decomposed most rapidly.
Keywords: Flooding levels, decomposition, C, N, rice straw

1. Introduction

In many Asian rice producing countries, such as in Indonesia, the management practice of post-harvest rice residues is the elimination of straw by open-air burning to accelerate the growing season. Burning the straw may control or reduce disease and pest (Ponnamperuma 1984), but, this practice may also results in greenhouse gases and particulate matter (Cao *et al*. 2008). After harvesting paddy rice, large quantities of rice straw were produced from paddy fields as an agricultural waste, amounting 2-9 t/ha (Becker *et al.* 1994; Cao *et al*. 2008). The incorporation of the rice straw into the paddy soil has been widely accepted to be an alternative to burning of the straw (Cassman & Pingali 1995), although long-term experiments on continuous irrigated rice systems in the tropics reported that it may reduce rice yields (Cassman *et al*. 1995).

In paddy soil, soil organic matter (SOM) mainly results from plant litter and biomass (Quideau 2002; Sahrawat 2004) and this consisted of two types of compounds, namely non-humic substances, such as carbohydrates, and humic substances (Quideau 2002). Studies have reported that SOM is one of important sources of N in paddy ecosystems and several factors, including rice straw application influenced the accumulation of N in paddy rice soils (Ponnamperuma 1984; Golhaber & Kaplan 1995; Sundareshwar *et al.* 2003). Furthermore, Olk *et al*. (1996) also reported that the soil under flood fallow receiving application of rice straw significantly had higher N content compared to the soil under dry fallow without any rice straw application.

Castillo *et al.* (1992) found that reducing the amount of water-use for lowland paddy rice production significantly reduced rice growth and yields. In addition, De Datta (1981) reported that the water should be available enough along the rice growing season to avoid yield reduction. For instance, soil moisture content of -50 kPa (slightly above field capacity) may result in yield reduction by 20-25. In general, to control weeds most of farmers keep several centimetre of water in their paddy fields. However, this condition results in an adverse affect on rice growth because of the limited O2 supply and the increase of anaerobic microorganism that decay plant residues (Courreges 2004).

Oxygen is one of most important factors controlling the decomposition of organic matter in rice soils. Drainage of flooded soils which increases oxygen availability increases the rates of soil organic matter decomposition and N mineralization (Sahrawat 1983). Meanwhile, Howeler & Bouldin (1971) noted that lack of oxygen in submerged soil resulted in lower rate of organic matter decomposition. Therefore, it is imperative to have a better understanding of the effects of different flooding levels in paddy soils on changes in soil chemical properties, especially information on the N recovery and N mineralization when the rice straw is returned to the soil as a source of SOM. This information is important to determine feasible water management practices that suitable for rice growth and yield in lowland paddy fields where the abundant straw is incorporated into the soil under tropic conditions, such as in Metro, Lampung. The objectives of this study were to determine the effects of different flooding levels on the carbon (C), nitrogen (N) contents and weight of rice straw incorporated into a paddy soil.

2. Materials and Methods

2.1 Trial Design and Conduct

This pot trial was carried out to observe the effects of different flooding levels (2.5, 5.0, 7.5, and 10.0 cm) on a paddy soil. The treatments were replicated six times in a completely randomized block design in a glasshouse. Each treatment was composed of 10 pots for the observations made every 2 (two) weeks and ended 8 (eight) weeks after flooding (in accordance with the age of rice to reach the panicle initiation).

Two weeks before the trial was started, a bulk sample of soil was taken from a well-irrigated paddy field at soil depth of 0-10 cm, in Metro, Lampung, Indonesia in June, 2008. Air-dry soil was used as the medium where the rice straw was decomposed. Ten kilograms of soil (absolute dry weight) were inserted into the pot, and then flooded with ion-free water. Afterwards, the soil was stirred to form slurry (rice field soil conditions). Rice straw as organic material was cut to the size of 2-3 cm. The rice straw was dried in an open room. Ten grams of the straw (equivalent to absolute dry weight) were inserted into the nylon bag (10 cm x 15 cm) (Armbrust 1980). The nylon bags were placed at a depth of 5 cm below the soil surface. The weight decrease of rice straw biomass was calculated based on the initial weight of the straw (air-dry weight). The measurement was done every two weeks until the period of 56 days to determine the content of total soil N and C from each pot.

2.2 Statistical Analysis

Data were subjected to analysis of variance (ANOVA). The least significant difference (LSD) test at $p < 0.05$ was used when the ANOVA results indicated that there were significant treatment effects (Steel *et al.* 1997).

3. Results and Discussion

The result of the initial soil analysis showed that the ratio of C:N was 6.11 (below 15), indicating that mineralization in the paddy soil was progressing well. In addition, the value of N-total in the soil (0.58%) prior to the experiment was very low. This is likely that the farmers always burn their rice straw.

3.1 Changes in C

Carbon (C) is the major element of organic compounds in plant tissue. Figure 1 shows that the content of C at the beginning of the experiment ranged from 33% to 40%. For the flooding levels of 2.5, 5.0, and 7.5 cm, the C content decreased to approximately 30% until 2 weeks after flooding, and then it increased again. Whereas, for the flooding level of 10.0 cm the C content slightly decreased to about 33% until 4 weeks after flooding, and then it increased again. The dynamics of the C content for each treatment varied with observation time. At the end of the experiment, in general, the content of C for all treatments decreased again. This indicated that there was a reduction in C content for each observation time.

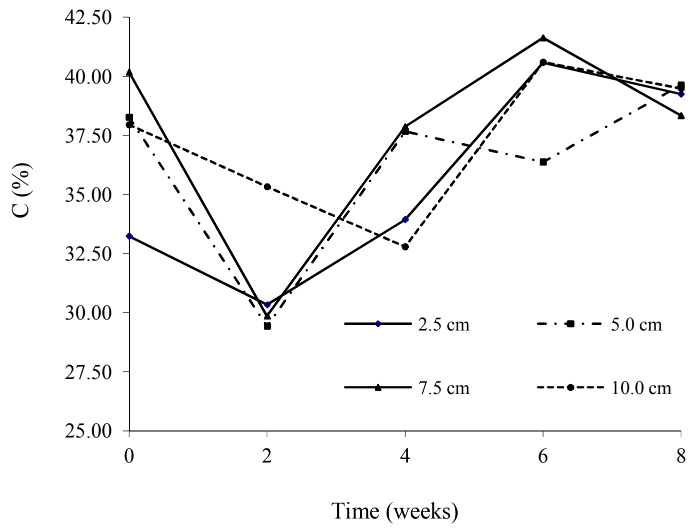

Fig 1. Dynamics of C content in the rice straw under different flooding levels

3.2 Changes in N

At the beginning of the experiment, the N content ranged from 0.56% to 0.60% (Figure 2). By the time the content of N in the incorporated rice straw increased until 8 weeks after flooding, except for the flooding level of 2.5 cm, it increased only until 6 weeks after flooding, and then it decreased again.

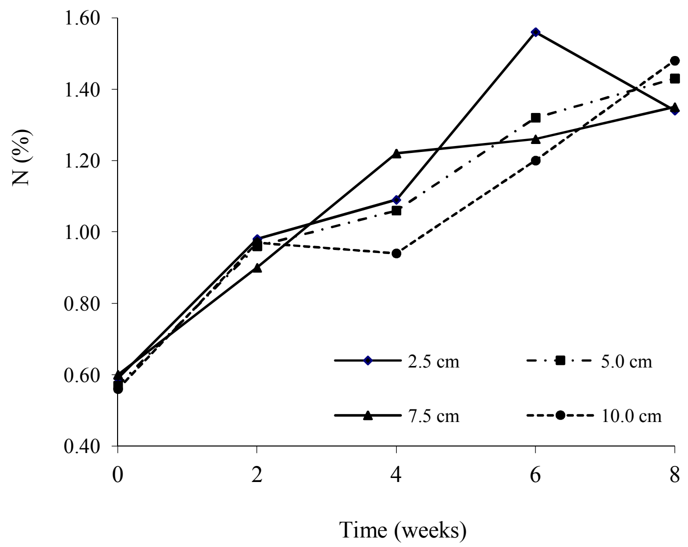

Fig 2. Dynamics of N content in the rice straw under different flooding levels

3.3 Ratio of C:N

In addition to C and N, the observation of C:N ratio is also one of important variables to measure decomposition of organic matters. At the beginning of the study, the ratio of C:N ranged from 56.5 to 67 (Figure 3). After 2 weeks after flooding, the ratio of C:N decreased by 83-120%, indicated by a very steep line (ratio of C:N ranged 31-37). However, thereafter the ratio of C:N decreased slightly.

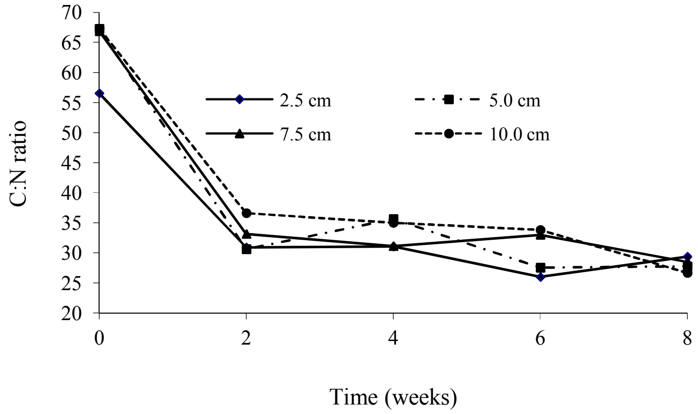

Fig 3. Dynamics of C:N ratio in the rice straw under different flooding levels

3.4 Weight of rice straw

The results in Table 1 showed that, in general, there was no difference in the weight of rice straw for the observation at 2 until 4 week after flooding. However, at 6 and 8 weeks after flooding, there were significant differences in the weight of the rice straw, especially between the flooding level of 2.5 cm and 10.0 cm. This indicated that the thinner the flooding level, the faster the organic matter decomposition rate.

Table 1. Change in rice straw weight (g) under different flooding levels

Flooding Levels (cm)	Time of flood (weeks)				
	0^{ns}	2^{ns}	4^{ns}	6	8
2.5	9.63	8.23	7.10	4.37[1] a	1.90 a
5.0	9.63	8.82	7.33	4.67 a	1.97 a
7.5	9.50	8.53	7.43	4.70 a	2.08 b
10.0	9.70	8.50	7.30	5.20 b	2.08 b
CV (%)	3.05	6.82	6.41	5.91	3.67

Notes: [1]Numbers within the same column followed by the same letters are not significantly different at $p<0.05$

Weight reduction of organic material at the end of the experiment generated by the flooding level of 2.5 cm was significantly different from the flooding level of 7.5 and 10.0 cm, indicating that the paddy soils flooded by 2.5 cm had a higher rate of organic matter weight reduction compared to the soils flooded by the deeper flooding (>5 cm). This could be related to the balance between oxygen in atmosphere with oxygen in the oxidation layer of the paddy soil. According to Sanchez (1976), the layer of 0-1 cm of the top of the rice field is an oxidation zone. Meanwhile, Ponnamperuma (1972) stated that in the waterlogged soil, the layer 1-2 cm is an oxidation layer. This is one reason why aerobic microorganisms are capable to utilize organic materials as a source of energy. In accordance with the findings of Ponnamperuma (1972), Watanabe (1984) also reported that flooding of paddy soil generally increases the rate of decomposition of organic material. In the present study, for each flooding level, the weight of the rice straw decreased obviously, especially from 6 to 8 weeks after flooding, suggesting that the decomposition was occurred. The obvious loss of the straw weight is likely related to the release of carbon dioxide (CO_2), energy, water, plant nutrients and re-synthesized organic carbon compounds during the decomposition process.

4. Conclusions

The different flooding levels of paddy soil had different effects on the decomposition rate of rice straw incorporated into the soil. The flooding level of 2.5 cm resulted in the highest decrease of the straw weight, suggesting that under conditions of flooding level about 2.0 cm, the rice straw spread on the paddy soil surface would be decomposed more rapidly than deeper flooding levels. To have a better management of the rice straw, in practical applications, rice straw supposed to be spread on the soil surface followed by a thin flooding, instead of to be burned.

Acknowledgement: The first author thanks Umar Bamualim of BPTP Maluku for his suggestions on the manuscript.

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