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Nitrogen Release from Green Manure of Water Hyacinth in Rice Cropping Systems

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Abstract: Nitrogen derived from water hyacinth and recovered in rice crops was measured to evaluate the effect of different amounts of added water hyacinth residues into rice cultivation on the performance of rice crop, N derived (N_{dev}) from residues and N recovery (N_{rec}) in rice crop. Dry matter production and N yield of rice crop decreased significantly as the amounts of added water hyacinth increased. The N_{dev} from water hyacinth was significantly increased as amounts of added water hyacinth increased. In contrast, the N_{rec} in rice crop was significantly decreased as amounts of added water hyacinth increased. In conclusion different quantities of added water hyacinth residues influenced the performance of rice, and the N dynamics of soil-rice systems.

Key words: Water hyacinth, green manure, mineralization-immobilization, turnover, derived N, recovery of N

Introduction

Mineralization-immobilization turnover (MIT) of organic materials added into soil-crop systems play an important role in soil nutrient cycles. Application of organic materials into soil-crop systems influence the performance of crops due to the increase in nutrient availability for crops (Yaacob *et al.*, 1980; Morris *et al.*, 1986; Norman *et al.*, 1990; Hood *et al.*, 1999; Matsushita *et al.*, 2000; Widjajanto *et al.*, 2001). Besides, the addition of organic materials into soil may also create better environment by minimizing the loss of nutrient into environment.

Application of organic materials as a green manure (GM) have been recognized as a strategy in improving both soil fertility and soil physical properties (Mann and Garrity, 1994). Green manure (GM), such as sunn hemp (*Crotalaria juncea*), Sesbania and Ipomoea, contributed about 74.5, 49.9 and 35.3kg N ha^{-1} into rice-wheat systems, respectively (Mann and Garrity, 1994). It was reported that those GM increased the rice production up to 5.0t ha^{-1} (sunn hemp); 4.7t ha^{-1} (Sesbania); and 4.2t ha^{-1} (Ipomoea) compared to the site un-amended GM where the rice production was only 3.4t ha^{-1}. However, constrains such as costly in land and seed preparation, crop establishment and problem on pest and disease make the limitation of applying GM in rice soils (Garrity and Becker, 1994). These problems may be solved by minimizing the cost of providing GM or by other potential crops, such as rice straw, soybean, wheat, mungbean, cowpea, and water hyacinth that may be utilized as a GM. It was reported that about 33 to 49% of N has been derived from the application of mungbean and cowpea residues into rice crop (Morris *et al.*, 1986). Whereas, about 3, 11, and 37% of ^{15}N-labeled rice straw, soybean, and wheat residues, respectively, have been recovered in rice crops (Norman *et al.*, 1990). Moreover, Hood *et al.* (1999) found that about 5-21% N of *Casuarina equisitifolia* has been released and derived to maize crop.

Water hyacinth (WH) is one of the most troublesome aquatic weeds that may be used as a GM as it contains high amount of some chemical elements (1.8%, N; 0.6%, P; 4.9%, K, 1.9% Ca, 0.4%, Mg) that may be released into soil-crop systems (Widjajanto *et al.*, 2001). Unfortunately, the great biomass of WH has been left unused. It was found that the incorporation of WH residues into soil-crop systems showed non-significantly different performance of rice crops compared with that of added fertilizer (Widjajanto *et al.*, 2001). This result was assumed because the increase of inorganic N-pool as available N has been released from WH residues into the systems. It was reported that about 8 – 40 % and 1–6 % of N released from WH residues have been recovered in the shoot and root of rice, respectively.

The quantity, quality, chemical composition and C to N ratio of added organic materials (Constantinides *et al.*, 1994) and such external factors as soil and climatic conditions where the experiment conducted have been recognized to influence the release of nutrient availability for crops (Paul, 1984). Therefore, evaluation of different quantities of added organic materials into soil systems should be considered as it seems to be worthy in connection with the implementation of organic materials into agricultural farmland. Moreover, the synchronization between the release of nutrient from added organic materials and the nutrient demand of crops is an important key to obtain high production of crops.

The objectives of the experiment were: (I) to evaluate the effect of different amounts of added water hyacinth residues incorporation into soil-crop systems on the performance of rice and (ii) to investigate the dynamics of N in soil-rice systems.

Materials and Methods

Experimental location, soil and water hyacinth used: Field experiment was carried out during the rice cropping season (April to July, 2000), in agricultural area, Shibushi city, Kagoshima Prefecture, Southwestern Japan (31°24^1-31°41^{1}N and 130°26^1-130°43^{1}E). The annual mean temperature and precipitation are 17.6°C and 2,000mm, respectively (Anonymous, 1999). Meanwhile chemical analysis was conducted in the Kagoshima Prefecture Agricultural Experiment Station and in the Soil Laboratory, Faculty of Agriculture, Kagoshima University. Soil used was taken from upland of volcanic soils, Shibushi area, Kagoshima Prefecture. Soil was air-dried and sieved to about 2mm size. After that, parts of soil samples were taken for chemical analysis, (Table 1). Water hyacinth used contains 1.2% N and enriched with 3.260 atom% ^{15}N, while ammonium sulphate was enriched with 2.185 atom % ^{15}N.

Experimental procedure and chemical analysis: A 4.0kg aliquot of the air-dried soil were put into cylindrical plastic pots with a diameter of 24cm and height 30cm. About 200mg of phosphorus (P_2O_5) and potassium (K_2O) were then added into pots. Doses of 400mg N pot^{-1} were added into pots in the form of water hyacinth (WH) residues and ammonium sulphate (fertilizer) with ratio of treatment combinations as follows: (I) 0% unlabeled WH – 100% ^{15}N-labeled fertilizer, T_0; (ii) 25% ^{15}N-labeled WH – 75% unlabeled fertilizer, T_1; (iii) 50% ^{15}N-labeled WH – 50% unlabeled fertilizer, T_2; (iv) 75% ^{15}N-labeled WH – 25% unlabeled fertilizer, T_3; and (v) 100% ^{15}N-labeled WH – 0% unlabeled fertilizer, T_4, respectively.

Seedlings of rice (*Oryza sativa* L. cv. Hinohikari) were transplanted into pots and cultivated during cropping season from April 11 to July 27, 2000. Samples such as height of crops and number of tillers were collected three times at panicle initiation stage, PIS (May 16); heading stage, HS (June 13); and harvesting stage, HVS (July 27). While, number of panicles, dry weight, N content, and N dynamic were collected and determined only at HVS. Samples were taken, oven-dried at 60°C for 72h, weighed to

Table 1: The chemical properties of soil used

pH		Total N	Total C	Available P_2O_5	Exchangeable K	Ca	Mg	CEC
		($g\ kg^{-1}$)	($g\ kg^{-1}$)	($mg\ kg^{-1}$)	$meq\ g^{-1}$ (x 10^{-2})			
H_2O	KCl							
5.7	5.1	2.1	56.3	242	0.25	5.66	0.77	19.1

Table 2: Dry matter production and N yield of crops

Treatments	Root	Shoot	Panicle	Total	N yield
(WH : F)	($g\ pot^{-1}$)				($mg\ pot^{-1}$)
T_0 (0 : 100)	7.5±0.6	40.7±0.7	40.2±1.3	88.3±4. 3a	692±10a
T_1 (25 : 75)	6.1±1.1	29.8±2.8	35.9±0.6	71.7±4.6b	519±96b
T_2 (50 : 50)	6.5±0.4	26.5±1.6	28.3±1.3	61.2±2.5c	444±6c
T_3 (75 : 25)	4.4±0.1	22.7±0.8	26.3±1.9	53.4±0.7d	358±22d
T_4 (100 : 0)	3.6±0.6	19.4±1.8	21.9±1.4	44.9±1.8e	330±14e

Table 3: Percentage of N derived and N recovery

Treatments	N_{dev}WH	N_{dev}F	N_{dev}S	N_{rec}WH	N_{rec}F	N_{rec}S
(WH : F)	(%)					
T_0 (0 : 100)	-	12.4±0.6	87.6±0.9	-	18.0±0.1	82.0±1.9
T_1 (25 : 75)	1.9±0.1a	-	85.8±0.1a	9.6±2.0a	-	72.4±4.3a
T_2 (50 : 50)	3.2±0.2b	-	84.5±1.1b	6.8±0.6b	-	75.2±2.7b*
T_3 (75 : 25)	4.4±0.0c	-	83.3±0.9c	5.3±0.3c	-	76.7±1.6b
T_4 (100 : 0)	6.3±0.4d	-	81.3±0.5d	4.9±0.5c	-	77.1±1.5b

Water hyacinth, WH; Fertilizer, F; Soil, S; derived-N, N_{dev}; N recovery, N_{rec}.
Different letters in the same column indicate statistically significant differences ($P<0.01$); ($P<0.05$)

determine dry matter yields, and cut into small pieces and pulverized. Total N of rice crop was determined using the Micro-Kjeldahl method (Bremner, 1965). Samples for atom% ^{15}N analysis were prepared using Yamamuro method (1981). These, then, were analyzed using emission spectrometry (JASCO AN-160DP type, data processor, Japan Spectroscopic, Co. Ltd.).

Statistical analysis: Experiment was arranged using completely randomized design (5x3), and collected data were analyzed using ANOVA with Duncan`s multiple range test was employed to determine the differences among treatments.

Calculation of derived and recovered N: The percentage of N derived from water hyacinth residues (%N_{dev}WH) and fertilizer (%N_{dev}F) was calculated using the formula presented by Barrachlough (1997) and Hood *et al.* (1999). The percentage of N recovered from water hyacinth residues (%N_{rec}WH) and fertilizer (%N_{rec}F) was determined using formula introduced by Hauck and Bremner (1976) and Matsushita *et al.* (2000). Our previous study resulted that different amounts of applied N as ammonium sulphate together with water hyacinth in the soil-rice system showed non-significant difference in N_{dev} and N_{rec} of fertilizer (unpublished data). Accordingly, it is assumed that N_{dev} and N_{rec} of fertilizer in control (T_0) may represent the N_{dev} and N_{rec} of fertilizer of other treatments (T_1 to T_4). Therefore, the N_{dev} and N_{rec} of soil may be determined as follows: N_{dev}Soil at T_0 = 100 – N_{dev}F, and it at T_1 to T_4 = 100 – (N_{dev}WH + N_{dev}F at T_0). Whereas N_{rec}Soil at T_0 = 100 – N_{rec}F, and at T_1 to T_4 = 100 – (N_{rec}WH + N_{rec}F at T_0).

Results and Discussion

Number of tillers and panicles decreased with the increase in added water hyacinth (WH) residues (Fig. 1 and 3). The highest number of tillers and panicles were found at T_0 (0% WH), with the increase tiller number were 11, 35 and 16 tillers, respectively, reached between tillering stage (TS) to panicle initiation stage (PIS); panicle initiation stage (PIS) to heading stage (HS); and heading stage (HS) to harvesting stage (HVS) (Fig. 2). These figures decreased as the amounts of added WH residues increased, with the exception occurring at T_1. Whereas, the height of rice crop increased as the amounts of added WH decreased (Fig. 4). The dry matter (DM) production and N yield of rice crop were significantly decreased ($P<0.01$) as the amounts of added WH residues increased (Table 2), with the peak yield reaching at T_0 (control), then subsequently followed by T_1, T_2, T_3, and T_4.

In this experiment it was found that the number of tillers, panicles, height, DM production and N yield of rice increased as the amount

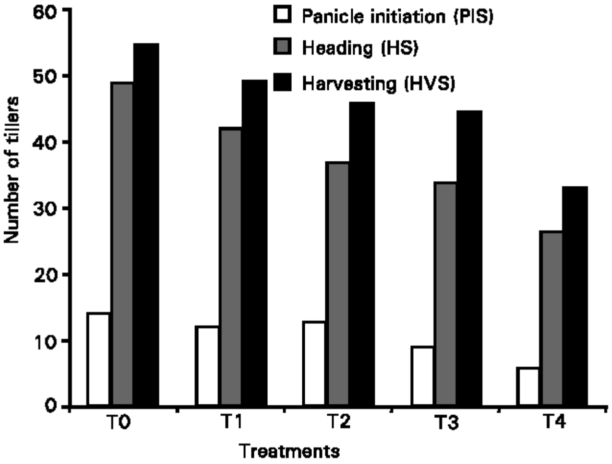

Fig. 1: Number of tillers at different amounts of added water hyacinth. See Table 2 for treatments

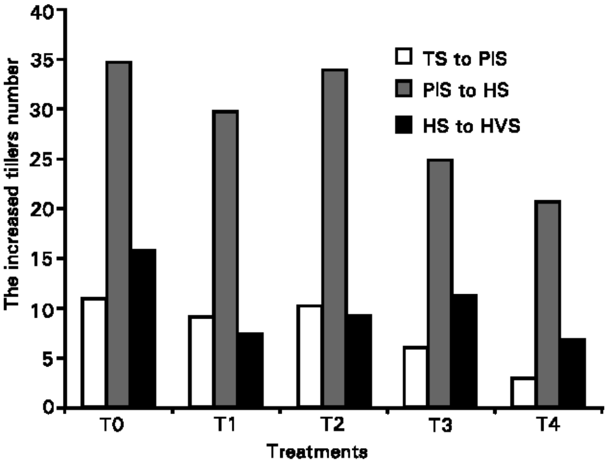

Fig. 2: The increased tillers number at different amount of added water hyacinth. See Table 2 for treatment.

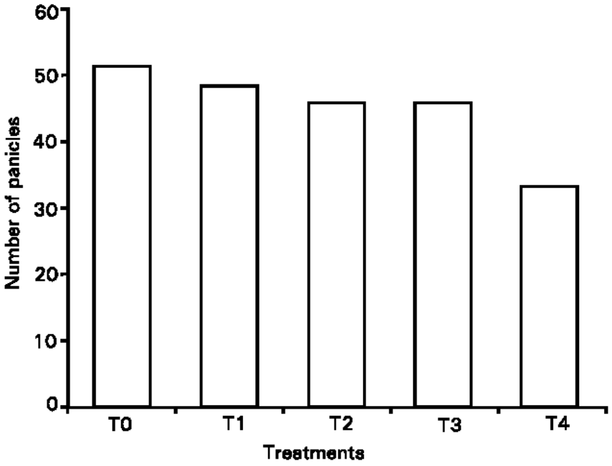

Fig. 3: Number of panicles at different amounts of added water hyacinth (harvesting stage). See Table 2 for treatments.

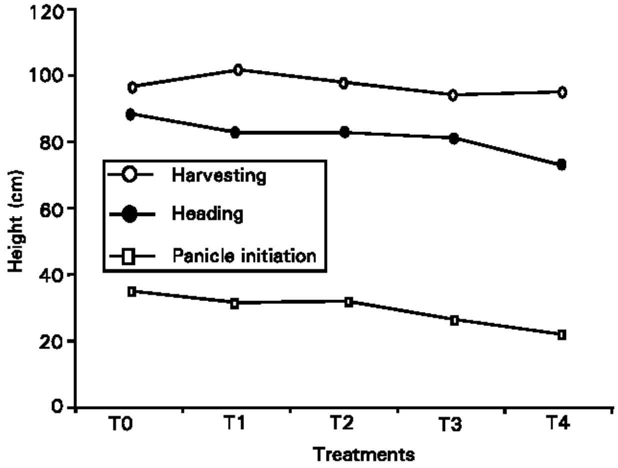

Fig. 4: Height of rice crop at different amounts of added water hyacinth. See Table 2 for treatments.

of added WH residues decreased, with the exception of crop height where it peaked at T_1. Application of organic materials, such as sunn hemp (*Crotalaria juncea*), Sesbania and Ipomoea (Mann and Garrity, 1994), farmyard manure (Kamimura *et al.*, 1994), composted rice straw-cow dung (Matsushita *et al.*, 2000), and water hyacinth residues (Widjajanto *et al.*, 2001) into soil-rice systems influenced the performance of rice. Our present findings are in agreement with the results of previous works as the addition of a certain amount of water hyacinth into soil influence the performance of rice. The addition of organic materials into soil may have been followed by mineralization process and resulted increase on N availability for crops. However, different quantities of added WH residues may have influenced the capacity of immobiolization and leads to affect the rate of mineralization (Constantinides *et al.*, 1994). Hood *et al.* (1999), in contrast, reported that the DM and N yield of maize increased as added *Casuarina equisitifolia* increased up to 25% of addition. It was found that the DM and N yield of maize was lower at control (0% of added *Casuarina equisitifolia*) than that at 25% of added *Casuarina equisitifolia*. The differences in quantity, quality, and chemical properties between crop residues (Water hyacinth and *Casuarina equisitifolia* residues), and catch crop (maize and rice) used (Constantinides *et al.*, 1994), difference in soil and climate where the experiment was conducted (Paul, 1984) may have influenced the difference in results of those experiments.

The N derived from added water hyacinth ($N_{dev}WH$) residues were significantly increased ($P<0.01$) as the amounts of added WH increased. Contrary, the N recovery (N_{rec}) in rice crop decreased as the amounts of added WH increased, with non-significant difference detected between T_3 and T_4. Meanwhile, the N_{dev} from soil ($N_{dev}S$) decreased significantly as the amount of added WH increased, and N_{rec} from soil ($N_{rec}S$) increased as the amount of added WH increased with significant differences detected between $T_1 - T_2$, $T_1 - T_3$, and $T_1 - T_4$ (Table 3). This may be due to the fact that different quantities of added WH residues into soil may have influenced the activity of microorganisms in immobilizing and utilizing the N availability (Hood *et al.*, 1999). This condition may have affected the increased mineralization rate and resulted in higher amounts of released N (Constantinides *et al.*, 1994). These results are also matching with the results of previous works (Yaacob *et al.*, 1980; Morris *et al.*, 1986; Norman *et al.*, 1990).

On the basis of the results it can be concluded that the application of different quantities of added water hyacinth residues into soil-rice systems influenced the performance of rice and the N dynamics in systems. As the N_{rec} of N release from water hyacinth residues decreased significantly as amounts of added water hyacinth increased from 25 to 50%, therefore, further experiments between these two doses are recommended.

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