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Studies on the Release of N from Water Hyacinth Incorporated into Soil-Crop Systems Using ^{15}N-labeling Techniques

Didik Wisnu Widjajanto, Kozo Matsushita, Terumasa Honmura and Nobufumi Miyauchi
The United Graduate School of Agricultural Science, Kagoshima University,
Korimoto 1-21-24, Kagoshima City 890-0065, Japan

Abstract: Nitrogen derived from water hyacinth and recovered in rice crops was measured by employing ^{15}N-labeling techniques. Either ^{15}N-labeled water hyacinth or ^{15}N-ammonium sulphate was incorporated into soil separately. Derived N was significantly detected in shoot of rice at all stages (Tillering Stage, TS; Panicle Initiation Stage, PIS; Heading Stage, HS; and Harvesting Stage, HVS), while there was non-significant difference between treatments in derived N to root throughout the growth season. On the other hand, N was significantly recovered in shoot of rice at TS and PIS only. There were no significant differences between treatments in recovering N at all stages in root of rice crop. About 8.2 – 39.6% and 30.2 – 38.9% of N from water hyacinth and fertilizer, was recovered from the shoot of rice, respectively, whereas, only 1.1 – 5.7% and 2.2 – 5.9% from root of rice crop.
It was proved that fertilizer derived more N than that derived by water hyacinth. N recovery of water hyacinth in rice crop in early stage was lower than that of fertilizer, however, in the late stages the figure was similar between the two.

Key words: Water hyacinth residues, mineralization-immobilization, derived and recovered N

Introduction

Increasing food demand in the last few decades influence the management of agricultural activity. Applying more chemical fertilizer, introducing mechanization in the agricultural farmland management, therefore, has been carried out. However, these were suspected to cause degradation of environment. Researchers reported that a certain amount of residual N was detected in the agricultural farmland due to the application of chemical fertilizer. In Japan, for example, about 71% of residual N resulted from the application of chemical fertilizer (Mashima *et al.*, 1999).

Instead of chemical fertilizer, organic materials such as crop residues, animal wastes or green manures may also be practiced as sources of N in agricultural farmland. The benefit of using either crop residues or animal wastes on agricultural farmland has been evaluated continuously (Yaacob *et al.*, 1980; Norman *et al.*, 1990; Kamimura *et al.*, 1994; Jordan *et al.*, 1996; Matsushita *et al.*, 2000). In general, it was reported that application of either crop residues or animal wastes improved the soil N availability for crops. On the other hand, addition of organic matter into soil not only maintain soil N status, but also create better environment by minimizing the loss of nutrient into environment.

The application of organic matter has been widely published, while the information on the incorporation of water hyacinth residues in agricultural farmland cannot be found easily. Water hyacinth may be used as a source of nutrient for crop as water hyacinth contains chemical elements that may be released into soil. In addition, using water hyacinth as an organic fertilizer may decrease environmental problems. In Kagoshima Prefecture Japan, at least 20 community habitats of water hyacinth can be found in irrigation and transport canals, ponds, rivers, and sluices (Honmura and Miyauchi, 1999). This potential may be explored in order to find nutrient sources that may be supplied from water hyacinth when it is incorporated into soil-crop systems.

This experiment was aimed (I) to evaluate whether a certain amount of N released from the incorporation of water hyacinth into soil-crop systems, and (ii) to measure the N derived from water hyacinth residues and its recovery in rice crops.

Materials and Methods

Experimental location and soil used: Experiment was carried out at Kagoshima Prefecture Agricultural Experiment Station (KPAES), Kagoshima City, in southwestern Japan. Kagoshima city is located between 31°24'-31°41' N and 130°26'-130°43' E. The annual mean temperature and precipitation are 17.6 °C and 2,000 mm, respectively (Anonymous, 1999). The soil used was taken from the experimental site of KPAES. It is classified as a Gray Lowland Soil, whose parent material derived mainly from "Shirasu" pyroclastic flown from Aira volcano. Then, the soil was air-dried and sieved to about 2 mm in size. After that, parts of soil samples were taken for chemical analysis, and the general properties of soil was determined as follows: pH (H_2O), 5.2; pH (KCl), 4.2; total N, 1.32 g kg^{-1}; total C, 11.6 g kg^{-1}; available-P_2O_5, 203 mg kg^{-1} and CEC, 75.7 mmol kg^{-1}.

^{15}N-labelled water hyacinth used: ^{15}N-labelled water hyacinth was prepared by growing under culture solution that contained nutrients as presented in Table 1. Two hundred mg NH_4-N L^{-1} of ammonium sulphate enriched with 10.5 atom% ^{15}N was added into the culture solution. Water hyacinth was harvested, cut into 2-3 cm pieces, and oven dried at 80 °C for 72 hours. The pieces were milled homogeneously and pulverized for chemical properties and atom% ^{15}N analysis. The chemical properties of ^{15}N-labeled water hyacinth, are presented as follows: 1.8 % N; 0.6 % P; 4.9 % K; 1.9 % Ca; 0.4 % Mg; 0.08 % Fe; 0.07 % Mn; 0.9 % SiO_2 and 7.074 atom% ^{15}N.

Experimental procedure and chemical analysis: A 5.0 kg aliquot of the air-dried soil, water hyacinth, and fertilizer were put into cylindrical plastic pots with a diameter of 24 cm and height 30 cm. The samples in the pot were mixed after submergence in water. Rice seeds (*Oryza sativa* L. cv. Hinohikari) were grown in small cell of seedling box on May 22, 1999. The rice seedlings were transplanted into pots on June 16, 1999. These pots, then, were buried in a paddy field at about 15 cm depth.

During the experiment rice crops were sampled 4 times at Tillering Stage, TS (July 22, 1999); Panicle Initiation Stage, PIS (August 13, 1999); Heading Stage, HS (September 10,

Table 1: Chemical composition of cultural solution for water hyacinth

Chemical com	mg L^{-1}	Element	mg L^{-1}
$Na_2HPO_4.12H_2O$	63.1	P_2O_5	12.5
KCl	39.9	K_2O	25.2
$MgSO_4.7H_2O$	123.0	MgO	20.0
$CaCl_2.2H_2O$	57.7	CaO	22.2
EDTA-Na-Fe salt	20.6	Fe_2O_3	4.3

Source : Oki *et al.* (1978)

Table 2: Dry matter (DM) production of rice crop during the growth season

Stage of rice growth (mg pot^{-1})	TS	PIS	HS	HVS
DM of shoot				
Water hyacinth Plot	2.6±0a	25.1±3a	44.5±2a	55.2±3a
Fertilizer	6.5±0b	37.4±2b	57.0±2b	61.0±3a
DM of root				
Water hyacinth	0.7±0a	6.3±1a	7.5±1a	6.4±1a
Fertilizer	1.2±0a	9.4±0a	7.9±1a	8.1±1a

Tillering stage, TS; Panicle initiation stage, PIS; Heading stage, HS; Harvesting stage, HVS
Different letters in the same column, stages and parameters indicate statistically significant differences (P<0.05)

Table 3: N yield of rice crop during growth season

Stage of rice growth (mg pot^{-1})	TS	PIS	HS	HVS
N of shoot				
Water hyacinth Plot	72.5±17a	231.6±13a	286.0±14a	350.3±28a
Fertilizer	196.4±2b	294.1±11b	332.5±6a	321.8±3a
N of root				
Water hyacinth	9.9±0a	43.4±6a	50.3±5a	44.5±3a
Fertilizer	15.6±6a	55.8±4a	44.5±3a	43.7±6a

Tillering stage, TS; Panicle initiation stage, PIS; Heading stage, HS; Harvesting stage, HVS
Different letters in the same column, stages and parameters indicate statistically significant differences (P<0.05)

Table 4: Amount of N derived from water hyacinth and fertilizer to rice crop

Stage of rice growth (mg pot^{-1})	TS	PIS	HS	HVS
N derived to shoot				
Water hyacinth plot	29.7±6a	79.9±14a	92.6±1a	109.7±9a
Fertilizer	136.1±2b	175.2±3b	164.6±6b	141.2±6b
N derived to root				
Water hyacinth	3.0±1a	15.4±4a	17.8±2a	10.7±2a
Fertilizer	10.1±4a	26.5±5a	20.4±3a	19.9±3a

Tillering stage, TS; Panicle initiation stage, PIS; Heading stage, HS; Harvesting stage, HVS
Different letters in the same column, stages and parameters indicate statistically significant differences (P<0.05)

Table 5: Percentage of N recovered from water hyacinth and fertilizer in rice crop

Stage of rice growth (mg pot^{-1})	TS	PIS	HS	HVS
N recovery in shoot				
Water hyacinth plot	8.2±2a	26.2±2a	32.3±2a	39.6±3a
Fertilizer	30.2±0b	38.9±1b	36.6±1a	31.4±1a
N recovery in root				
Water hyacinth	1.1±0a	4.9±1a	5.7±1a	3.9±1a
Fertilizer	2.2±1a	5.9±1a	4.5±1b	4.4±1a

Tillering stage, TS; Panicle initiation stage, PIS; Heading stage, HS; Harvesting stage, HVS
Different letters in the same column, stages and parameters indicate statistically significant differences (P<0.05)

1999); and Harvesting Stage, HVS (October 4, 1999). At any stage, samples were taken, dried at 60 °C for 72 hours, weighed to determine dry matter yields, and cut into small pieces and pulverized. Total N of rice crop was determined using the Micro-Kjeldahl method. 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: Study was designed as water hyacinth and ammonium sulphate enriched with 7.074 and 5.067 atom% ^{15}N, respectively, incorporated into soil separately. Amount of 450 mg N pot^{-1} as $(^{15}NH_4)_2SO_4$, 200 mg P_2O_5 (Super phosphate) and 200 mg K_2O (KCl) were added into soil, and about 2 times of the doses of ammonium sulphate (885 mg N pot^{-1}) of ^{15}N-labeled water hyacinth residue was added separately. A two-paired comparison at 5% probability was used to analyze the differences between two treatments at any stage of rice growth period.

Calculation of derived and recovered N: The percentage of N derived from water hyacinth ($\%N_{dev}WH$) and fertilizer ($\%N_{dev}F$) was calculated using the formula of Barrachlough (1997) and Hood *et al.* (1999). The percentage of N recovered from water hyacinth ($\%N_{rec}WH$) and fertilizer ($\%N_{rec}F$) was determined using formula introduced by Hauck and Bremner (1976) and Matsushita *et al.* (2000).

Results and Discussion

Many works on the release of N from both crop residues and chemical fertilizer have been carried out continuously in the last few decades (Morris *et al.*, 1986; Bremner and Van Kessel, 1992; Harris *et al.*, 1994; Jordan *et al.*, 1996). In general, it was reported that more N had been derived from fertilizer than crop residues. On the other hand, the N recovery from crop residues compared to fertilizer was summarized with ratios of 1 : 2 (leguminous crop residues : fertilizer) and 1 : 8 (non-leguminous : fertilizer) (Kumar and Goh, 1996).

Dry matter (DM) and N yield of rice crop: DM of shoot increased either by water hyacinth residue or fertilizer added with the peak yield reaching at HVS. However, DM of root was not consistent in both treatments with peak yield obtained at HS and PIS, respectively, for water hyacinth residues and fertilizer added (Table 2). Significant difference between two treatments was detected in DM shoot with the exception at HVS, where DM shoot at water hyacinth added treatment was non-significantly different as compared to that of added fertilizer. On the other hand, there was no significant difference between two treatments in DM yield of root. The DM of shoot and root of rice crops is presented in Table 2.
The N yield of shoot between two treatments was detected significantly at TS and PIS, while there was non-significant difference of shoot N yield between two treatments at HS and HVS. Whereas, N yield of root at any stage of growth periods of rice crops was detected non-significant differences between two treatments. The N yield of shoot and root are presented in Table 3.
It was reported that application of both crop residues and animal wastes into farmland increased the performance of rice crop (Matsushita *et al.*, 2000) and quantity of grain (Kamimura *et al.*, 1994). This indicated that addition of organic matter into soil-crop systems increased the availability of nutrient for crop and lead to increase the performance of crop. In this experiment, it was detected that the DM and N yield production increased either in ^{15}N-labeled added water hyacinth residue or fertilizer. This proved that water hyacinth residue and fertilizer released a certain amount of N available for rice. However, in early growth period of rice the increase

of DM and N yield (shoot only) was found significant. This indicated that, in this period, fertilizer released more N than water hyacinth. However, the shoot N yield of rice crop increased from HS to HVS due to incorporation of water hyacinth, while it was decreased at the addition of fertilizer (Table 2). On the other hand, there was no significant difference between two treatments in DM and N yield of root (Table 2, 3).

N derived from water hyacinth or fertilizer and recovered in rice crop: The amount of N derived is presented in Table 4. The N recovery in shoot of rice for the two treatments was significantly different at TS and PIS. Whereas, in case of root of rice, the only significant difference was detected at HS. The percentage of N recovery is presented in Table 5.

Data of N derived either from water hyacinth or fertilizer, and its recovery in rice crops, were matching with DM and N yield data. This indicated that a certain amount of N both from water hyacinth and fertilizer had been released into soil-crop systems, therefore, increase in N available for crop, resulted in high performance of rice crop. This is in agreement with Morris *et al.* (1986), who found about 33 – 49% of N, applied in the form of residues of mungbean and cowpea in rice crop. Norman *et al*. (1990), on the other hand, reported that about 3, 11, and 37% of ^{15}N-labeled residues rice straw, soybean, and wheat residues, respectively, have been recovered in rice crops. Whereas, Harris *et al*. (1994) reported that about 40% and 17% of N fertilizer and legume input were recovered in the subsequent crop, respectively. In other case, Jordan *et al.* (1996) reported about 61%, 22% and 16% of N input in the form of fertilizer, clover, and wheat straw being recovered, respectively, in sorghum. In this study, about 8.2 – 39.6% of N from water hyacinth and 30.2 – 38.9% of N fertilizer have been recovered from shoot of rice crop (Table 5). However, the figure between 1.1–5.7% and 2.2–5.9% of N released from water hyacinth and fertilizer, respectively, had been recovered in root of rice crop (Table 5). In early growth period of rice, the N recovery of water hyacinth both in shoot and root of rice was lower than that from fertilizer. However, the figure of N recovery from water hyacinth increased in the late growth period, while N recovery from fertilizer decreased. The reason may be that, in early stage of rice growth period water hyacinth has not been mineralized perfectly.

On the other hand, the N from fertilizer was released faster in the early stage, and decreased in the late growth period of rice. Some factors such as difference in fertilizer sources, rate of fertilizer used, management practice in agricultural activity, the test crop used and climate where experiment was for conducted may also be responsible for variation in N recovery reflected by indicator crop (Kumar and Goh, 2000).

On the basis of the results found in this experiment, it is concluded that a certain amount of N has been released from water hyacinth and recovered in rice crop. It is proved that fertilizer released more N than that released by water hyacinth. N recovery of water hyacinth in rice crop in the early stage was lower than N recovery of fertilizer, however, in the late growth period the figure was similar between the two. Accordingly, further experiment on different doses of added water hyacinth and the composition between water hyacinth and chemical fertilizers are recommended.

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