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Nitrogen Dynamics in Komatsuna (*Brassica rapa*) Cultivation Due to Incorporation Of Water Hyacinth Residues into the System

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Abstract: Nitrogen derived (N_{dev}) from water hyacinth (WH) residues and recovered (N_{rec}) in Komatsuna (*Brassica rapa* L.) was measured to evaluate the effect of different amounts of water hyacinth residues (0, 30, 45, 60 and 100%) added during komatsuna cultivation on the performance of the crop and amount of N released from WH residues into the system. There were no significant differences on dry matter production among treatments both in the 1st and 2nd sampling. N yield of Komatsuna decreased as the amounts of added WH residues increased in the 1st sampling but no significant differences were observed in N yield among treatments in the 2nd sampling. The N_{dev} from WH residues was significantly increased as amounts of added WH residues increased. In contrast, there were no significant differences found in N_{rec} from Komatsuna both in the 1st and 2nd sampling. In conclusion different quantities of added WH residues influenced the performance of Komatsuna, and the N dynamics in the soil-Komatsuna systems. The combination of 30% WH residues: 70% ammonium sulphate seems to be the most appropriate ratio that may be applied in the field.

Key words: Dynamics N, derived-N and recovered-N, Komatsuna, mineralization-immobilization turnover, water hyacinth residues

Introduction

The world consumption of N fertilizer increased in the last few decades as consequence of the increase in world food demand. It was reported that the world N fertilizer consumption was about 76 MT annually, with 28 MT year^{-1} consumed in the developed countries and 48 MT year^{-1} in the developing world (Schenk, 1998). Vegetables especially require a high amount of fertilizer in their cultivation in order to achieve high production in quality and quantity. However, excess of N in farmland due to the misapplication may cause problem on environment.

In agricultural ecosystem, the quantity and quality of both soil organic carbon (SOC) and soil organic nitrogen (SON) pools are determined by the quality of soil. Therefore, to maintain the quality of agricultural systems the content of these two pools (SOC and SON) should be properly maintained by adding organic materials such as animal wastes (Bol *et al.,* 2000; Matsushita *et al.,* 2000), crop residues (Yaacob and Blair 1980; Norman *et al.*, 1990; Jordan *et al.*, 1996; Widjajanto *et al.,* 2001), and wastes of agricultural-products (Henry *et al.,* 1999) into soil. Constraints often occur in connection with the application of organic materials into soil because the crop residues contain heterogenous chemical compounds that may have differences in the rate of decomposition. The decomposition of organic material itself is dependent on factors such as quantity and quality of materials (Contantinides and Fownes, 1994) physical and chemical status of soil, activity of soil microorganisms and environmental condition (Paul, 1984; Vestgarden, 2001). The decomposition rate of organic materials is influenced by the initial N content of the material, and amount of added-N into soil-crop system (Vestgarden, 2001).

Instead of chemical fertilizer, organic materials such as crop residues, animal wastes or green manures may also be added as sources of N in agricultural farmland. The benefit of using either crop residues such as water hyacinth (WH) residues has been reported in previous works (Widjajanto *et al.*, 2001, 2002). The incorporation of WH residues into soil-crop systems showed no significant difference in N recovery at the late stage growth period of rice compared to that of added fertilizer. Oki and Une (1994) reported that WH contains high amount of some elements such as 3.15% (2.14 - 3.70%) of N; 0.53% (0.46-0.61%) of P and 5.39% (4.79-6.03%) of K that may be utilized during its incorporation in the soil-crop systems.

As a crop residue, WH consists of elements with different rates of decompositions: easily decomposed materials (sugars and amino acids), slowly decomposed materials (cellulose and hemi-cellulose), and recalcitrant (lignin) (Van Veen *et al.,* 1985). It was reported that lignin content of WH ranges between 6.0 to 8.7% and total cellulose is between 49.9 to 57.7% (Joedodibroto *et al.,* 1983).

However, it is found that it contain 4.8% of lignin, 29.3% of cellulose and 33.2% of hemi-cellulose.

Although there are benefits of using organic materials in farming systems, the responses to these additions are plant specific. Matsumoto and Yamagata (1999) found that crops such as lettuce, cabbage and spinach showed different response to the addition of organic materials when planted in the mixture of rice bran and rice straw amended-soil. In their report, N uptake by lettuce was more in control than that in the plots of amended-soils. In contrast, cabbage and spinach planted in organic materials amended-soil showed opposite response in absorbing N than that of the control.

Komatsuna (*Brassica rapa*) (Japanese mustard spinach) is a fast-growing vegetable, which in warm climates can be harvested about 35 days after sowing. In the temperate and subtropical areas, komatsuna may be cultivated all year round but is at its best in the spring and autumn seasons. It grows well in rich fields of loamy soils with high water retention (Amanda, 2000).

This experiment was conducted to study the effect of added water hyacinth residues into soil-crop systems of komatsuna and the performance of the crops in terms of vegetative yield under such conditions. It was also aimed at finding the most favorable ratio of WH residues to inorganic fertilizers that is appropriate for the crop.

Materials and Methods

A greenhouse experiment was carried out during vegetable cropping season (May to August 2002), in the Faculty of Agriculture Kagoshima University, Kagoshima City, Japan. Soil used was taken from upland field in Shibushi area, Kagoshima Prefecture (Fig. 1). The soil already classified as andosol (Anonymous, 1996), has chemical properties. ^{15}N-labeled-water hyacinth used contained 0.739% of N total, 37.7% of C total and 1.76% ^{15}N atom%.

Experimental procedure and chemical analysis: A 1.50 kg aliquot of fresh soil (75% DM) were put into cylindrical plasticpots with a upper and lower diameter of 17 and 11 cm, respectively and height 14 cm. Doses of 200 mg 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) 30% ^{15}N-labeled WH- 70% unlabeled fertilizer (UF), T_1; (iii) 45% ^{15}N-labeled WH-55% UF, T_2; (iv) 60% ^{15}N-labeled WH - 40% UF, T_3; and (v) 0% ^{15}N-labeled WH - 100% UF, T_4, respectively.

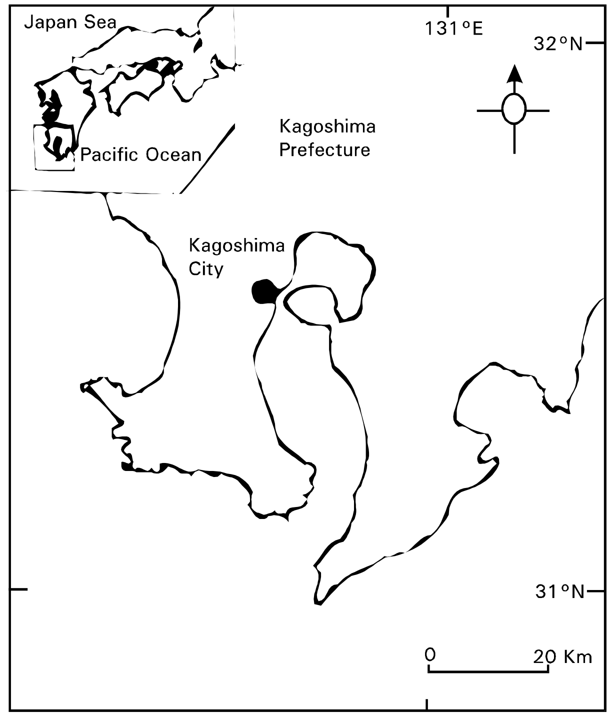

Fig. 1: Map of Kagoshima Prefecture, southern Kyushu, japan, showing the location where the experiment was conducted

The pot experiments were placed inside the greenhouse and left without crops for about 4 weeks. Every week, each pot was sampled for NH_4^+-N and NO_3CN analysis. At the end of incubation, ten seeds of Komatsuna were germinated in the experimental pots directly. Seedlings were trimmed into 2 crops ten days later. Then, pots were allowed to grow inside the greenhouse for about 55 days from trimming. To maintain moisture pots were irrigated using ionized-water. Sampling was carried out 2 times, 32 days after trimming and 23 days after the 1st sampling. At harvesting, Komatsuna was air-dried in the greenhouse for 48 hours, and then it was transferred into oven at 80°C for 48 h. Samples were weighed thereafter to determine dry matter production and cut into small pieces and pulverized for atom% ^{15}N and N total analysis, which was analyzed using mass spectrometry DELTA^{plus} XL (Thermo Finnigan, Germany). Inorganic-N content of soil used was determined using the Kjeldahl digestion method (Bremner, 1965).

Derived and recovered N: Percentage and amount of N derived from water hyacinth residues and its recovery in Komatsuna was calculated as follows:

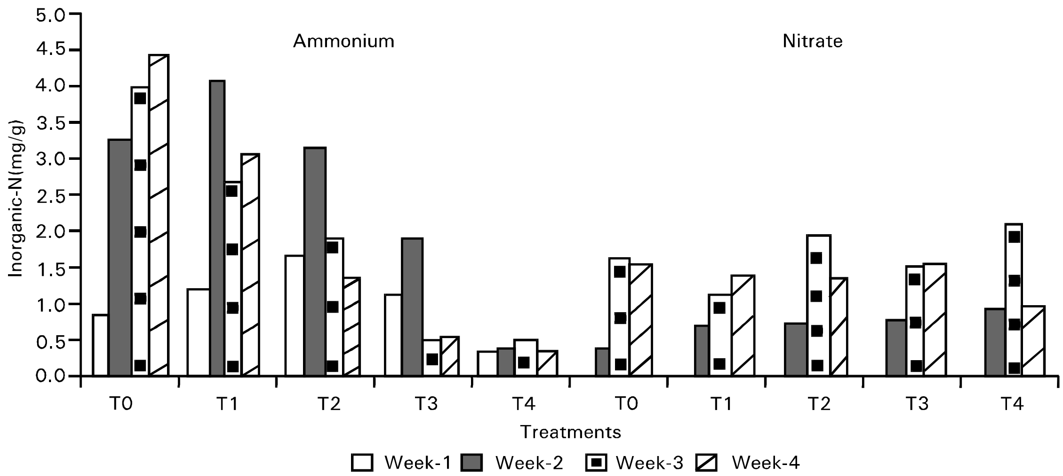

Fig. 2: Inorganic-N content of soil during incubation

Derived-N (%) = (^{15}N atom% excess of N)/(^{15}N atom% excess of applied N) x 100; Derived-N (mg) = (^{15}N atom% excess of N)/(^{15}N atom% excess of applied N) x total N; and N recovery (%) = (amount of derived-N, mg)/ (amount of applied-N, mg) x 100 (Hauck and Bremner, 1976; Barrachlough, 1997; Hood *et al.*, 1999).

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

Results and Discussion

The inorganic-N content of soil during incubation time: The content of NH_4^+-N were detected throughout incubation, while the content of NO_3^--N was detected after 2 weeks of incubation. However, both H_4^+-N and NO_3^--N content were not detected at the 1st and 2nd sampling (Fig. 2).

Fig. 2 showed that NH_4^+-N content peaked at 2-week of incubation with exception occurring at T_0 and T_4, where the pattern of it at T_0 and T_4 peaked at 4 and 3-week of incubation, respectively. While the content of NO_3^cN showed unstable pattern. This phenomenon suggests that mineralization-immobilization process and losses of N have occurred during incubation. Addition of either organic or inorganic materials into soil is usually followed by mineralization-immobilization (Azam *et al.,* 1993; Kuzyakov *et al.,* 2000). The losses of N in bare soil during incubation may occur as available-N resulted from mineralization process may be immobilized by microorganisms only.

Dry matter and N yield of Kumatsuna: Dry matter (DM) production of Komatsuna showed similar pattern both in the 1st and 2nd sampling. It increased from T_0 (0% WH) to T_1 (30% WH) treatment, and then decreased afterward.

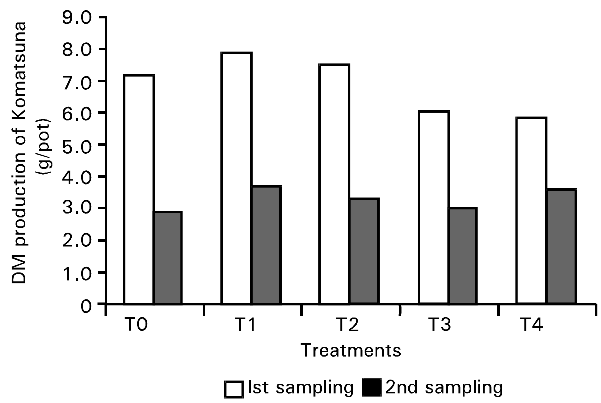

Fig. 3: DM production of komatsuna in the 1st and 2nd sampling

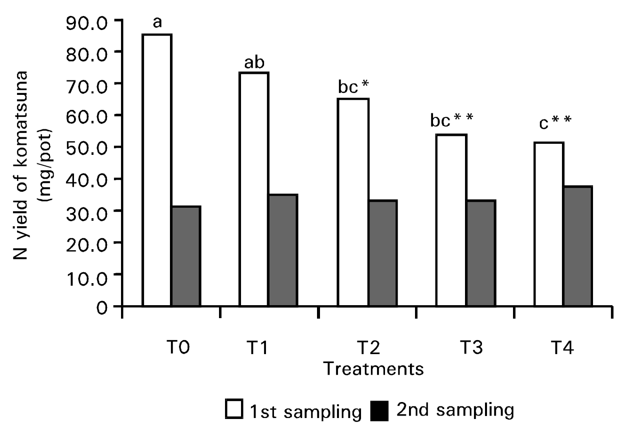

Fig. 4: N yield of komatsuna in the 1st and 2nd sampling Different letters in the same sampling of komatsuna indicate statistically significant differences (*P < 0.05; ** P < 0.01)

However, no significant differences among treatments were detected in DM production both in the 1st and 2nd sampling (Fig. 3). N yield of Komatsuna among treatments was significant in the 1st sampling. It however decreased as the amount of amended WH residues increased. There were no significant differences between N yield of T_0 (0% WH) with T_1(30%WH) treatments. However, N yield of T_0 (0% WH) was significantly different ($P<0.05$, $P<0.01$) compared to that of T_2 (45% WH), T_3 (60% WH) and T_4 (100% WH) treatments, respectively. In contrast, in the 2nd sampling, N yield of Komatsuna was detected no significant differences among treatments (Fig. 4)

In the 1st sampling, N yield of komatsuna decreased significantly as added WH residues increased (Fig. 4). This is due to the fact that available-N during the 1st growing period mainly was provided by N release from chemical fertilizer rather than WH residues as decomposition of it may not have been completed. This performance was supported by data of inorganic-N (Fig. 2), which the content of inorganic-N mainly ammonium-N decreased as added WH residues increased during incubation and resulted in different status of inorganic-N in this growth period. Available inorganic-N released from water hyacinth residues in the 2nd growth period however, may have affected N yield of komatsuna (Fig. 4). In this period, process of mineralization of water hyacinth residues may have occurred constantly and determined N yield of Komatsuna, hence resulted in the lowest of N yield at T_0 and peaked at T_4.

Added organic matter into soil-crop systems has been known to influence the performance of crops as a result of the increase in nutrient availability for crops (Yaacob and Blair, 1980; Norman *et al.,* 1990; Matsushita *et al.,* 2000; Widjajanto *et al.,* 2001; 2002). In previous experiment, it was found that incorporation of water hyacinth into soil-crop systems increased the performance of rice crops (Widjajanto *et al.,* 2001). These results were assumed to be due to the increase of soil N availability as N has been released from WH residues into the systems. Moreover, the amounts of N release into the cropping systems are also determined by the amounts of organic materials incorporated into the system. In the case of rice cropping system, the incorporation of WH residues has been suspected to have influenced the increase of inorganic N pool. This was evidenced on the data of inorganic-N remaining in the soil during the growing season of rice. The amount of NH_4^+-N remaining in the soil at panicle initiation stage was higher (0.28- 0.31 mg NH_4^+-N g^{-1}) than that at heading (0.20 - 0.23 mg NH_4^+-N g^{-1}) but lower than that harvesting stage (0.34-0.38 mg NH_4^+-N g^{-1}), respectively (unpublished data). Even though, previous experiment mentioned was conducted on different soil type (gray lowland soil vs upland soil) and soil cropping systems (rice cropping system vs vegetables cropping system) compared to the present experiment, the inorganic-N data found in the previous experiment indicated that the decomposition process of WH residues occurred and accelerated particularly in the later stage and led to increase in inorganic N availability. The phenomenon of releasing N resulted from mineralization process due to addition of WH residues into soil was also found during incubation, which the content of NH_4^+-N and NO_3^--N in the soil increased compared to the initial characteristics of soil (Fig. 2). In addition, Matsushita *et al.* (2000) reported that application of composted cow dung and co-composted cow dung-ammonium sulphate into paddy field affects the performance of rice crops due to the mineralized-N release from these two materials.

Derived-N from WH residues and fertilizer and its recovery from Komatsuna: N derived from water hyacinth residues (%N_{dev}WH) was detected among treatments both in the 1st and 2nd sampling. In these two sampling, the %N_{dev}WH increased significantly ($P<0.01$) as the amount of added WH residues increased. In contrast, the percentage of N derived from fertilizer (%N_{dev}F) decreased from 78% in the 1st sampling to 59.9% in the 2nd sampling. Both in the 1st and 2nd sampling, the %N_{dev}WH in T_3 (60% WH) and T_4 (100% WH) treatments detected exceeded 100% (Fig. 5).

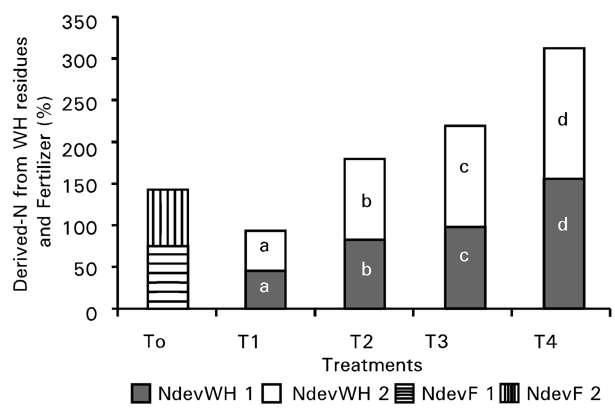

Fig. 5: N derived from WH residues and fertilizer in the 1st and 2nd sampling

Different letters in the same sampling of komatsuna indicate statistically significant differences ($P < 0.01$)

In this experiment, the addition of WH residues into Komatsuna cropping systems may not only increase the mineralization of WH residues but probably, also cause the apparent of added-N interaction from native soil. The release of N from native soil during mineralization process may add the amounts of inorganic N absorbed by vegetables and therefore the $\%N_{dev}WH$ in the vegetables exceeded 100%. The addition of both organic and inorganic materials into soil may stimulate mineralization (Fig. 5) not only on the added-material but also on the native soil organic material, a phenomenon known as added-N interaction (ANI) (Hauck and Bremner, 1976; Jenkinson *et al.*, 1985; Azam *et al.*, 1993; Kuzyakov *et al.*, 2000; Azam, 2002). The occurrence of this phenomenon may be due to the fact that addition of the residues into soil improved soil physical condition and lead to the improvement of soil microbial biomass (SOM) distribution and population. This condition may also increase the activity of SOM and in turn the acceleration of mineralization process. Azam *et al.* (1993) reported that mineralization of native soil N was found when such crop residues as soybean, corn and vetch residues were added into soil.

N recovery of water hyacinth residues from Komatsuna ($\%N_{rec}WH$) was detected among treatments both in the 1st and 2nd sampling. In the 1st sampling, the $\%N_{rec}WH$ increased from T_1 (47.3%) to T_2 (60.3%), these then decreased to 46.9% (T_3) and 49.7% (T_4) afterward. Whereas, in the 2nd sampling the $\%N_{rec}WH$ showed a similar pattern as in the 1st sampling, which about 29.2; 33.4; 29.9 and 27.8% of the $\%N_{rec}WH$ were detected in the T_1, T_2, T_3, and T_4, respectively. Meanwhile, the percentage of N recovery of fertilizer from komatsuna was detected as 16.6% in the 1st sampling and decreased to 4.4% in the 2nd sampling (Fig. 6)

The $\%N_{rec}WH$ (Fig. 6) indicated that a certain amount of N has been released from the residue into soil-crop systems. This led to increase in N availability, and in high

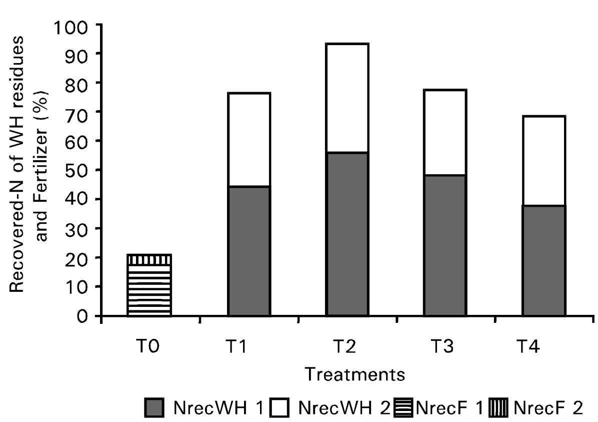

Fig. 6: N recovery of WH residues and fertilizer from komatsuna in the 1st and 2nd sampling

vegetative growth of vegetables. This result is in agreement with previous works (Morris *et al.*, 1986; Harris *et al.*, 1994; Widjajanto *et al.*, 2001), which reported that the addition of organic materials into soil-crop system increased the performance of crops due to the increase of N availability through the process of mineralization. It was found that amounts of added WH residues influenced N recovery from water hyacinth residues. The N uptake by rice crop decreased as the amount of amended-water hyacinth increased (Widjajanto *et al.*, 2002). These were 9.6, 6.8, 5.3 and 4.9%, respectively, for the addition of 25, 50, 75 and 100% of water hyacinth residues into rice cropping systems. In this experiment, the performance of komatsuna varied, with peak production been reached in the B (30% WH) treatment both in the 1st and 2nd sampling. This phenomenon suggests that komatsuna response differ with the different amounts of added WH residues. This is in agreement with Contantinides and Fownes (1994) who mentioned that quantity and quality of added organic materials into soil may influence the decomposition rate and mineralization process. Therefore, different quantity and quality of added organic materials into soil-cropping systems affects N recovery from residues and the performance of crops.

It is concluded that the addition of water hyacinth (WH) residues into Komatsuna cultivation affected the performance of Komatsuna. This is probably due to the increase of N availability released from WH during the process of mineralization. The combination of 30% WH and 70% ammonium sulphate seem to be the most appropriate ratio that may be applied in the field for this experiment. This finding is matching with the previous experiment where the combination of 25% WH : 75% ammonium sulphate seem to be the most favorable compared to other combinations in cultivation of rice.

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