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Effect of Nitrogen Application from Selected Manures on Growth, Nitrogen Uptake and Biomass Production of Cultivated Forage Rice

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***Abstract*— Cultivation of forage rice (*Oryza sativa* L.) in paddy field is considered as a promising way to enhanced livestock feed supply. Pot experiment was conducted to evaluate the effects of fermented cattle and poultry manures in different levels of N application on the growth, N uptake and biomass production of forage rice. Rice cv. Tachisuzuka, Kusanohoshi and Hinohikari were grown and treated with five levels of N: 0,7,14,21, and 28 g N m^{-2}. The results showed that the effects of manures on plant significantly with all levels of N application. The findings indicated that in forage rice cultivation, Tachisuzuka prospects as whole crop silage (WCS) because of its highest straw biomass production and suitable feed with WCS quality compared with Kusanohoshi and Hinohikari. Application of 14 g N m^{-2} was considered effective for high production of Tachisuzuka forage rice and useful for the reduction of N loading of the environment.**

***Keywords*— Animal manure compost, Biomass production, Forage rice, Nitrogen uptake.**

I. Introduction

Rice has been the staple crop for more than half of the world's population for decades. The challenge to produce sufficient rice for the future is overwhelming as the current rate of population growth outpaces that of rice production. Rice is an important cereal crop in many countries, including all Asian countries, some countries in central and east Africa, most south and Central American countries, Australia and the United State of America [2], [17].

In a different case in Japan, the proportion of paddy fields lying fallow has been increasing for the last two decades owing to a decrease in the domestic consumption of rice and improvement of yields. Rice production adjustment in the country is consisted mainly of the conversion to other crops. The productivity of paddy fields can be sustained by production of moisture-tolerant crop like rice. However, an alternative to that could be forage rice, which can also maintain productivity of paddy fields [3].

Forage rice is a series of new varieties of rice that have been developed for use as whole crop silage for livestock feed [16]. The self-sufficiency ratio of livestock feed is only 25% of the total domestic demand on a total digestive nutrition (TDN) basis in Japan. The whole plant of forage rice, including panicles, leaves and stems is harvested at the yellow ripening stage, conditioned into whole-crop silage and fed to cattle. The Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan [13] have released new rice cultivars for whole crop silage use. Because of the subsidies from the government of Japan, the area of forage rice cultivation has been increasing reaching 26,000 ha in 2013 [4], [8].

The newly developed rice cultivars have potential to increase the biomass production and crop yield. It is easy to introduce animal feed rice to farmers because most of the techniques are similar to those applied in ordinary rice production. There are two main uses of forage rice. The one of them is to provide whole crop silage (WCS), for which goal is to maximize whole plant dry matter (DM) yield and nutrient quality. Tachisuzuka is a new rice cultivar for WCS use whose agronomic characters were recorded from 2007 to 2009 [7], [9], [10], [12]. The culm length of Tachisuzuka was 11 cm longer than that of Kusanohoshi. In addition, straw yield of the former was remarkably higher but its grain yield was lower than then latter. The low grain/straw ratio of Tachisuzuka indicates that the loss of nutrients in the cattle fed with Tachisuzuka WCS should be lower than that of Kusanohoshi WCS. Low sugar content of rice plants is considered to be a cause of silage deterioration. The sugar content of Tachisuzuka was reported to be higher than that of Kusanohoshi [4], [16].

The characteristics of rice varieties required for WCS are not the same as those required for staple food, for example variety Hinohikari. Sakai et al. [13] indicated that high productivity of the whole plant including leaves, culms and grain is more important than grain weight compared to the rice varieties used for food. Multiple resistances to disease and insect pest are also necessary to reduce chemical application [7].

Nitrogen (N) is one of the most important nutrients for maximizing rice yield. In Japan, large losses of N from paddy fields and livestock farming threaten the environment. Tajima et al. [15] recommended that N should be used more efficiently by collaboration between paddy fields and livestock farming systems. Forage rice plants can be used to remove N from eutrophied river water because they produce a lot of biomass and can take up a lot of nutrients. Therefore, the objective of this study was to evaluate the effect of N applied as animal manure on forage rice based on the N uptake, growth characteristic, grain yield, and N load on water bodies and soil environment.

II. Material and Methods

A. Experimental Design

Pot study was conducted using a 1/2000a Wagner pot at a greenhouse and in a paddy field of Prefectural University of Hiroshima (PUH) during May to December 2011 season. Two types of manures namely fermented cattle manure (CM) and fermented dry poultry manure (PM) was used as organic N sources. These manures are commercially produced from Hiroshima Prefecture; and are widely used in Hiroshima area. The chemical characteristics of manures, such as: total N, total P, total K, total C, Ca and Mg contents were determined and presented in Table 1.

TABLE I
CHEMICAL CHARACTERISTICS OF THE MANURES (CATTLE MANURE AND POULTRY MANURE)

Characteristic	Cattle Manure	Poultry Manure
Total- N (g mg-1)	1.68	3.38
Total-P (g mg-1)	1.82	5.10
Total-C (g mg-1)	41.10	29.35
K2O (g mg-1)	2.62	4.07
CaO (g mg-1)	0.79	19.17
MgO (g mg-1)	0.79	1.24
NO3-N (mg 100 g-1)	0.63	8.75
NH4-N (mg 100 g-1)	41.51	298.04
T-Inorg N (mg 100 g-1)	42.14	306.79
C/N ratio	24.47	8.69

NO3-N, NH4-N was analysed by 15% KCl extract solution; K2O, CaO, MgO was wet analysis.

TABLE II
AMOUNTS OF MANURES APPLIED IN EACH EXPERIMENTAL POT.

N application (g m-2)	Manures (g)		
	Cattle manure (CM)	Poultry manure (PM)	Seracoot
0	0	0	0
7	100	7	0.5
14	100	18	1.0
21	100	29	1.5
28	100	39	2.0

In this experiment, each pot was filled with 10 kg of air-dried soil sieved through a 5-mm sieve from paddy field of the PUH, which was classified as Andosol. Five levels of manures were applied in pots at rates of 0, 7, 14, 21, and 28 g equivalent to available g N m-2 (Table 2.) at one time application. In addition, basal application of inorganic fertilizer “Seracoat” was done at seedling of rice following the Japan standard for rice (J-std) at rates of N: P2O5: K2O (14-18-14). The manure levels used were computed based on the estimation of N availability from manure as 30% of total N content in CM and 70% in PM. This was to ensure that the same amount of nutrient N is obtained from the two different types of manures. Two varieties of forage rice “Kusanohoshi and Tachisuzuka” and one variety of edible rice “Hinohikari” were transplanted in June 2011. The latter being a popular cultivar of rice in South-Western Japan. During the period of rice growth, the pots were flooded with water and the level of water was maintained at 3 – 5 cm above the soil surface.

B. Analysis of Rice Growth Characteristic

Rice growth characteristics (height and number of tillers) were monitored for every week during the rice-growing season.

C. N Analysis in Plant and Soil Samples

The total N content of soil and plant samples (straw, root and grain) were determined by a CN Corder instrument (Macrocorder JM 1000CN, J-science, Kyoto, Japan). At the maturity stage, rice plants were cut at 2-3 cm above ground, and the dry-matter weight of straw, grain and root were determined. Root samples were taken by carefully washing to remove all soil particles. These plant parts were air-dried to a constant weight at 65oC for 72 h and grinded for chemical determination of total C and total N contents. The soil samples were taken at two layers of soil profile in experimental pots, upper layer (0-10 cm) and lower layer (20-25cm). The soil samples were air-dried and sieved to pass a 2 mm sieve.

D. N Balance

The N-balance of output was estimated by N-uptake by crop, N-retained in soil and N-leached loss or loss from N-input, the manures (CM+PM), Seracoat, and in-situ N in soil). The ratio of N-leached to N-applied from manure was calculated.

E. Statistical analysis

The data were analyzed following standard procedures for analysis of variance (ANOVA) and followed by Fisher’s least significant differences (LSD) test ($P < 0.05$) to test the differences using Statistix 8 software (Analytical Software, Tallahassee, FL, USA).

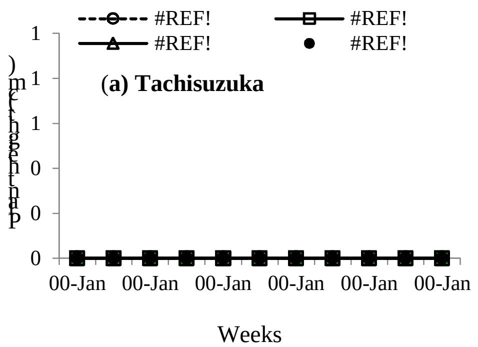
III. Result and Discussion

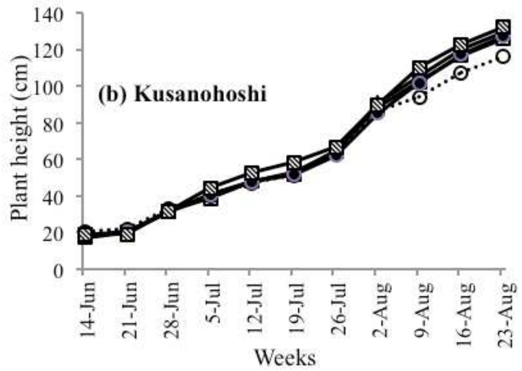
A. Plant growth characteristics

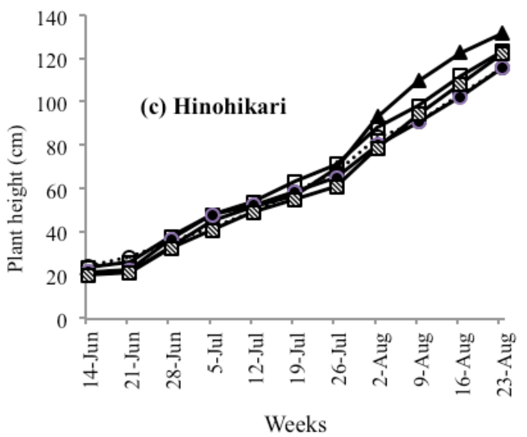
Plant growth characteristics (plant height and number of tillers) of Tachisuzuka, Kusanohoshi and Hinohikari are shown in Fig. 1. Plant height increased with increasing rates of N application. The highest height was recorded in the 28 g N m-2 in all of rice cultivars (Tachisuzuka, Kusanohoshi and

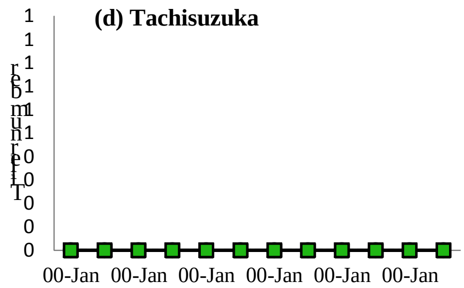
Hinohikari). In comparison of the plant heights, Hinohikari recorded the lowest height (123.27 cm) and Tachisuzuka recorded the highest height (133.67 cm).

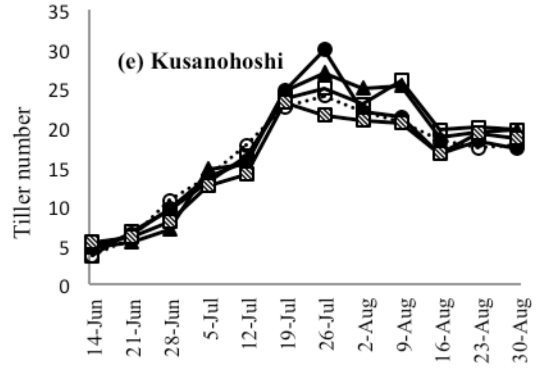
The number of tillers in all of rice cultivars (Tachisuzuka, Kusanohoshi and Hinohikari) increased with increasing rates of N application from animal manures. The largest number of tillers (56.67) was recorded from Hinohikari. However, for all rice cultivars, many tillers were observed at the active tillering period (19th July and 26th July).











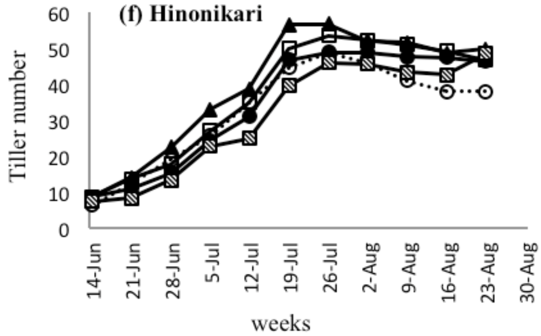


Fig. 1. Change of plant growth characteristics (plant height and tiller number) of rice as effects of N animal manure application on the Tachisuzuka, Kusanohoshi and Hinohikari under the pot experiment. Plant height (a,b,c) and tiller number (d,e,f).

B. Dry Matter and Grain Yield.

Dry matter weight (biomass production) and grain yield of all rice cultivars increased significantly ($p < 0.05$) with increasing levels of N application (Fig. 2). The lowest dry matter yield (249.8 g pot^{-1}) and the highest grain yield (110.8 g pot^{-1}) were recorded from Hinohikari.

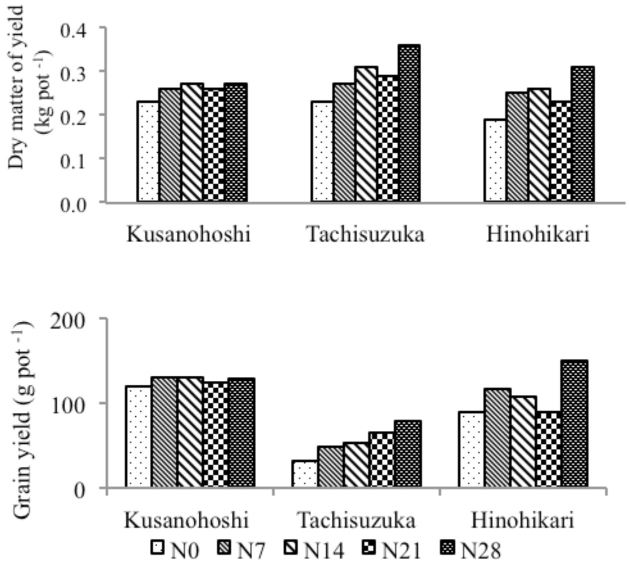


Fig. 2. Comparison of Kusanohoshi, Tachisuzuka, and Hinohikari for total biomass production and grain yield at harvested rice in pot experiment in term of (a). dry matter, and (b). grain yield.

C. N Uptake

Fig. 3 presents the contents of N for the rice plants harvested. Results indicated insignificant ($p<0.05$) increase in N uptake by Kusanohoshi cultivar of rice with increasing levels of N application. In contrast, in Tachisuzuka and Hinohikari cultivars of rice, N uptake was significantly ($p<0.05$) increased by N application. However, the highest N uptake by all rice cultivars was recorded at the highest rate of N (28 g m^{-2}) application.

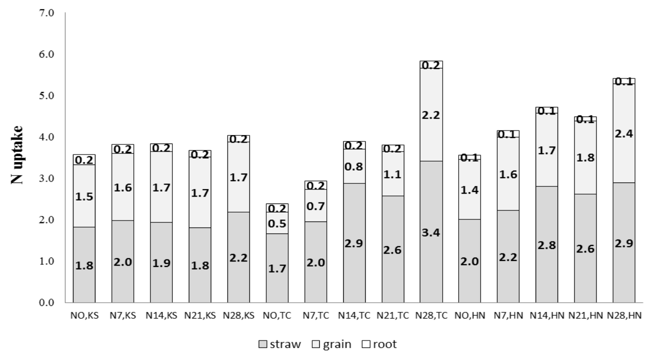


Fig. 3. N uptake of rice as affected by animal manure application at Kusanohoshi, Tachisuzuka, Hihohikari at harvested

Manures application enhanced growth characteristics of rice plants, especially forage rice [1]. In the present study, N application from two type of animal manures (CM+PM) differed in increasing of N availability which largely affected rice growth characteristic including plant height, number of tillers, and the average ear length; and N uptake by plant from the manures applied (Fig. 1, 2). The results reasoned that organic materials such as animal manures contain large amounts plant available N particularly NH_4-N (Table 1). This nutrient composition makes animal manures appropriate in rice cropping because rice plants take more NH_4-N than NO_3-N [11]. The significant effect of N application to rice was observed in Tachisuzuka which was compared with Kusanohoshi and Hinohikari (Fig. 1). These findings suggest availability of most of easily susceptible forms of nutrients including N from animal manures.

The general increases in rice uptake of N and dry matter yield in pot with manures (Fig. 2,3) suggest that the studied manures mineralize soon after application resulting in a potentially great pool of available plant nutrient. Ma et al. [5] noted that gradual release of available N and its use from soils best synchronized with plant demand.

In forage rice cultivation, high productivity in terms of whole crop silage which includes leaves, tillers and grains, is more important than high productivity solely in terms of grain weight, which is the case in rice for human consumption [13]. As findings of this study are in line with those of [13] in Tachisuzuka had the highest biomass compared with Kusanohoshi and Hinohikari. In contrast, the Hinohikari recorded the highest grain yield in pot experiment. These results confirmed that by focusing on the agronomic properties of rice, Hinohikari is a rice variety of staple food and Tachisuzuka and Kusanohoshi are rice cultivars for forage as whole crop silage. Makoto et al [6] report that the characteristic of rice varieties required for WCS are not the same as those required for staple food. For example, high productivity of the whole plant including leaves, culms, and grain is more important than grain weight compared to the varieties for food.

The result of this study indicated that Tachisuzuka produced the largest biomass compared with Kusanohoshi and Hinohikari. These findings suggest that biomass production in Tachisuzuka in effective to minimum application of N to maintain soil fertility and to reduce N losses, which in turn aims at environmental protection by N pollution. Based on the aim to forage rice cultivation, Tachisuzuka cultivar of rice is appropriate for WCS content with high biomass straw hence suitable for feed production.

The agronomic of Tachisuzuka also indicates that is the most resistant cultivar to lodging and is considered favourable for a cultivator or a harvest contractor. The grain loss at harvest and risk of contamination of the following crop in season were lower than those for Kusanohoshi because of low grain yield. Commercial cultivation of Tachisuzuka for WCS has been initiated already in prefectures in a wide area of Japan [7].

IV. Conclusions

High application of N from animal manure in forage rice cultivation was significant improving growth characteristic of rice, N uptake by plant, biomass production in all treatments and rice cultivated in pots and for field experiment. In forage rice cultivation, the Tachisuzuka has prospects as whole crop silage because it is the rice cultivar with the highest straw biomass production, and suitable for feed production of rice WCS of advanced quality compared with Kusanohoshi and Hinohikari. The result showed that the rate of 14 g N m-2 was effective in maintaining soil fertility in paddy fields, efficient for biomass production in Tachisuzuka and friendly to the environment.

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