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Yield and Nitrogen Uptake under Reduced Nitrogen Fertilizer during Early Growth of Rice in the Rice-Barley Double Cropping System

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ABSTRACT: N fertilizer required by rice could be reduced greatly in the rice-barley double cropping system than in the rice single cropping system. This study was conducted to investigate how much of the N fertilizer during the early stage of rice in the rice-barley double cropping system, could be saved compared to that in the rice single cropping system. This experiment was carried out at the paddy field of the National Crop Experiment Station in Suwon, Korea during three years from 1999 to 2001. Amounts of soil mineral nitrogen (SMN) and SPAD values of rice leaf during rice growing season in the rice-barley double cropping system were higher than those in the rice single cropping system under the same amount of N application during two years. Yield and N uptakes of rice at harvesting time were also higher in the rice-barley double cropping system than in the rice single cropping system during two years. Yield and N uptake of rice in the rice single cropping system were decreased when basal N fertilizer was omitted, but those reductions were not found by either omitting basal N fertilizer or omitting N fertilizer at tillering stage in the rice-barley double cropping system during 2000 and 2001. But yield and N uptakes of rice were decreased by 70 kg/10a and 2 kg N/10a by the omission of both N application at basal and tillering stages in the rice-barley double cropping system in 2002. It was concluded that N fertilizer as much as tillering N fertilizer could be saved in the rice-barley double cropping system.

Keywords: rice, rice-barley double cropping system, basal N fertilizer, tillering N fertilizer, soil mineral nitrogen, SPAD, rice N uptake.

The double cropping system with winter crops such as barley, wheat and rye in a rice paddy field have several merits such as the increase of rate of land use for the production of food and forage during winter season, the prevention of agricultural environment and the improvement of landscape compared to the single cropping system of rice without winter crops.

But traditional rice-barley double cropping system in paddy field has been decreased with the increase of rice single cropping system since 1970's because of the reduction of net income of grain barley and the policies of rice production with high yielding varieties as Tongil type. Therefore, researches for fertilizer use in the rice-barley double cropping system have not been developed widely, though researches on fertilizer use and systems for rice in the rice single cropping system have been conducted widely. Recently, some researches on fertilizer with use of rice straw or barley straw in rice-barley double cropping system have been conducted (Choi, 1999; Lee *et al.*, 1997; Lee *et al.*, 2000; Yoo *et al.*, 2000, 2001). Furthermore, environment-friendly agriculture requires farmer to reduce excess fertilizer for the diminishment of agricultural pollution as well as production of high quality rice (Roh *et al.*, 1999; Yoo, 1991). Recently, researches for environment-friendly use of fertilizer on rice are needed.

N fertilizer as urea is usually applied twice in the rice-barley double cropping system in a year. It is estimated that some of N fertilizer for rice could be saved during early rice growth because some of N fertilizer applied for barley in early spring would be remained in soil before rice transplanting and also mineralized N would be increased during early rice growth because of barley residue and root after hanvest of barley. So, the main purpose of this experiment is to obtain the basic data for the changes of soil mineral N and rice N uptake for reduction of applied N fertilizer during rice early growth stage in the rice-barley double cropping system compared to the rice single cropping system.

MATERIALS AND METHODS

This experiment was conducted at the paddy field in National Institue of Crop Science, Suwon, Korea from fall in 1999 to fall in 2001. Varieties of barley and rice were Olbori and Hwaseongbyeo, respectively. Planting dates of barley were October 20th and October 21th in 1999 and in 2000, and transplanting dates of rice were June 20th and June 11th in 2000 and in 2001, respectively. Cultivation of rice and barley was based on the standard cultural practices of RDA. Phosphorus and potassium fertilizers were applied as P_2O_5-

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Table 1. Chemical properties of experimental soil.

pH (1:5)	Organic matter (%)	Available phosphate (mg/kg)	Ex. Cations ($cmol^+/kg$)		
			K	Ca	Mg
6.2	2.0	44	0.32	2.10	0.33

K_2O=9-7 kg/10a for barley and P_2O_5-K_2O=7-8 kg/10a for rice as fused phosphate or potassium chloride, respectively. Potassium fertilizer for rice was applied splittly as 70% at transplanting time and 30% at panicle initiating stage, respectively. Chemical soil properties of the field were shown at Table 1. Organic matter and available phosphate of soil were lower compared to general paddy field.

Amounts of N fertilizer applied for barley or rice in the rice single and the rice-barley double cropping system were shown at Table 2. The amount of N fertilizer for barley was 12 kg N/10a, and half N was applied and incorporated into soil with rotary plow at planting time in fall, and the other half N was broadcasted at early March, regrowth stage. The experimental plots were laid out as randomized block design with 4 replications. All straws of rice and barley were removed from plots at harvest. The amount of N fertilizer as urea for rice was 11 kg N/10a. Number of N treatments in the rice single and rice-barley double cropping system were 5 and 6 in 2000 and in 2001, respectively. Details of N treatment were shown at Table 2. In the rice single cropping system, the plot of "No N" in 2000 was replaced to the plot of "Tillering N omitted" in 2001. In the rice-barley double cropping system, the plot of "Standard N" in 2000 was replaced to the plot of "Basal N omitted" in 2001 and the N treatment, "Basal and Tillering N omitted" was also added newly in the rice-barley double cropping system. At the plot of "Basal and tillering N omitted" in the rice-barley double cropping system in 2001, rice had been planted for several years as rice single cropping system, but barley was planted during winter season between from 2000 to 2001.

Ten soil samples per plot were taken by auger at the soil depth of 0-15 cm and were mixed well at five growth stages of rice (at transplanting, at tillering initiation, at panicle initiation, at heading and at harvesting), during 2 experimental years and were kept at freezing container (-25°C) until analyzing soil ammonium and nitrate. Soil ammonium concentrations were determined by the Indolphenol Blue method and soil nitrate concentrations were colorimetrically determined with Griess-Ilosvay method followed by reduction of nitrate to nitrite by copperized cadmium column (Keeny and Nelson, 1982), respectively. In a interval of every ten days from tillering initiation stage to maturing stage, chlorophyll meter readings (SPAD value) of rice leaf were also measured from 30 rice plants per replication by using SPAD 502 (Minolta Corp., Japan) in 2001.

Heading date, growth status at heading stage, yields and yield components at harvest, were measured for barley and rice, respectively. Ten rice plants were sampled from two middle rows of each plot for rice dry matters and N uptakes at harvest. Panicles and straws dried at 60°C for 48 hours were weighed, chopped and ground by Wiley mill (Brabender, Germany). Total N concentrations of panicle and straw at harvest were analyzed by the Kjeldahl method (Kjel-Auto, MRK Co., Japan).

Table 2. Amounts of N fertilizer as urea for barley or rice in two cropping systems.

Year	Cropping system	N treatment for rice	Barley		Rice		
			at P†	at EM	at TP	at TI	at PI
			kg N/10a				
2000	Rice single	No N	-	-	0	0	0
		Basal N omitted	-	-	0	3.3	3.3
		Standard N	-	-	4.4	3.3	3.3
	Barley-Rice double	Basal N omitted	6	6	0	3.3	3.3
		Standard N	6	6	4.4	3.3	3.3
2001	Rice single	Standard N	-	-	4.4	3.3	3.3
		Tillering N omitted	-	-	4.4	0	3.3
		Basal N omitted	-	-	0	3.3	3.3
	Barley-Rice double	Tillering N omitted	6	6	4.4	0	3.3
		Basal N omitted	6	6	0	3.3	3.3
		Basal and Tillering N omitted	6	6	0	0	3.3

†P : planting, EM : early March, TP : transplanting,
TI : tillering initiation stage, PI : panicle initiation stage.

RESULTS

Growth, N uptakes of rice and soil mineral nitrogens in 2000

Growth status and yields of winter barley in 2000 and 2001 were shown at Table 3. Heading dates were May 2nd and May 15th in 2000 and 2001, respectively. Growth status of barley in 2001 was slightly higher than that in 2000 because of the spring drought during barley growing season in 2000.

Soil mineral nitrogen (SMN) concentrations during rice growing season in 2000 were shown in Fig. 1. SMN concentrations at rice transplanting for all plots except "No N fertilizer" in the rice single cropping system, were not different with the ranges between 11 and 13 mg/kg. SMN concentrations at tillering initiation stage at "Standard N" were higher than those at "Tillering N omitted" in two cropping systems. SMN concentrations at rice tillering initiation stage at "Standard N" in the rice single cropping system were 5 mg/kg higher than those in the rice-barley double cropping system. Particularly, SMN concentrations at "Standard N" in the rice-barley double cropping system were 5~10 mg/kg higher at the stages of tillering initiation and 10 mg/kg or so higher at the stages of panicle initiation than those at other plots, respectively. After heading stage, SMN concentrations showed no difference.

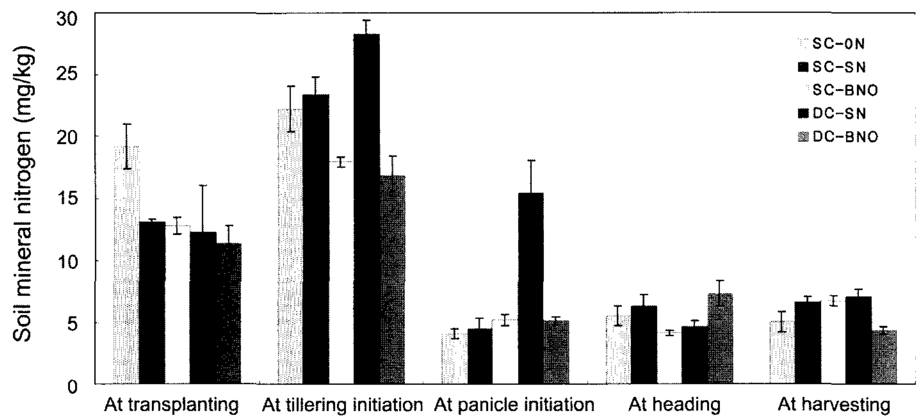

Fig. 1. Changes of soil mineral nitrogen during rice growing season in 2000 according to different cropping systems and N fertilizer treatments (SC-0N : rice single cropping and no N fertilizer, SC-SN : rice single cropping and standard N, SC-BNO : rice single cropping and basal N omitted, DC-SN : rice-barley double cropping and standard N, DC-BNO : rice-barley double cropping and basal N omitted).

Table 3. The growth status and yields of barley in the rice-barley double cropping system in 2000 and in 2001.

Year	Heading (month. date)	Stem length (cm)	Panicle length (cm)	No. of panicles per m^2	No. of spikelets per panicle	1,000 grain weight of brown rice (g)	Coarse grain yield (kg/10a)
2000	May 2th	64	4.1	453	46	37.2	400
2001	May 15th	66	4.9	467	47	30.8	483

Seeding dates of barley in 1999 and 2000 were Oct. 20th and Oct. 21th, respectively.

Table 4. Changes of growths, yields and nitrogen uptakes by rice in 2000 according to different cropping systems and N fertilizer treatments.

Cropping system	N fertilizer treatment	Heading	Stem length (cm)	Panicle length (cm)	No of panicles per m^2	1,000 grain of brown rice (g)	Yield of brown rice (kg/10a)	Dry matter (kg/10a)	N uptake (kg/10a)
Rice single	No N	Aug. 12th	66	19.4	293	21.4	400	1,002	6.7
	Basal N omitted	Aug. 14th	69	20.9	313	21.9	425	1,125	7.5
	Standard N	Aug. 14th	77	21.4	358	21.3	442	1,266	9.8
Barley-Rice double	Basal N omitted	Aug. 15th	74	21.7	350	21.9	468	1,145	9.2
	Standard N	Aug. 15th	76	22.0	396	21.7	467	1,285	10.3
LSD(0.05)		-	2	0.6	27	NS	30	107	1.6

Rice transplanting date was June 20th.

Growth status, yields and N uptakes of rice at harvest in 2000 were shown at Table 4. Panicle numbers and yields of brown rice were higher in the rice-barley double cropping system than in the rice single cropping system at both "Basal N omitted" and "Standard N". Yields of brown rice in the rice single cropping system were increased with the increase of N fertilizer on rice. However, yields of brown rice between at "Basal N omitted" (468 kg/10a) and at "Standard N" (467 kg/10a) in the rice-barley double cropping system were not different and those yields didn't show significant difference with that at "Standard N" in the rice single cropping system. This results suggested that SMN at "Basal N omitted" was enough to produce rice yield similar to that at "Standard N" in the rice-barley double cropping system. N uptakes of rice were increased in proportion to the increase of yield of brown rice at all plots. Rice N uptake at "Standard N" in the rice-barley double cropping system was the highest as 10.3 kg N/10a together with the highest dry matter of rice 1,285 kg/10a. Rice N uptakes were also not different between at "Standard N" in the single cropping system and at "Basal N omitted" in the rice-barley double cropping system ranging 9.8~9.2 kg N/10a. However, the fact that N uptake of rice at "Basal N omitted" was 2.3 kg N/10a lower than that at "Standard N" in the rice single cropping system indicates that N fertilizer amount applied for rice at "Basal N omitted" in the rice single cropping system was not enough.

Growth, N uptakes of rice and soil mineral nitrogens in 2001

Changes of SMN concentrations according to cropping systems and treatments of N fertilizer during the rice growing season in 2001 were shown in Fig. 2. At rice transplanting, SMN concentrations were higher in the rice-barley double cropping system compared to in the rice single crop-

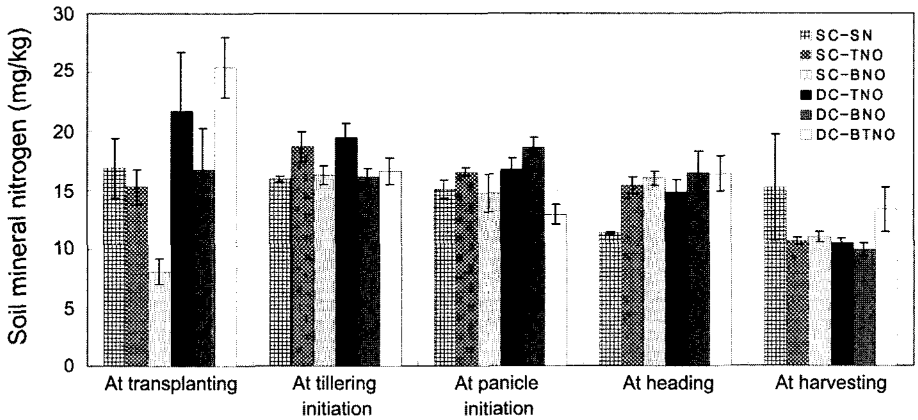

Fig. 2. Changes of soil mineral nitrogen during rice growing season in 2001 according to cropping systems and N fertilizer treatments (SC-SN : rice single cropping and standard N, MC-TNO : rice single cropping and tillering N omitted, SC-BNO : rice single cropping and basal N omitted, DC-TNO : rice-barley double cropping and tillering N omitted, DC-BNO : rice-barley double cropping and basal N omitted, DC-BTNO : rice-barley double cropping and basal-tillering N omitted).

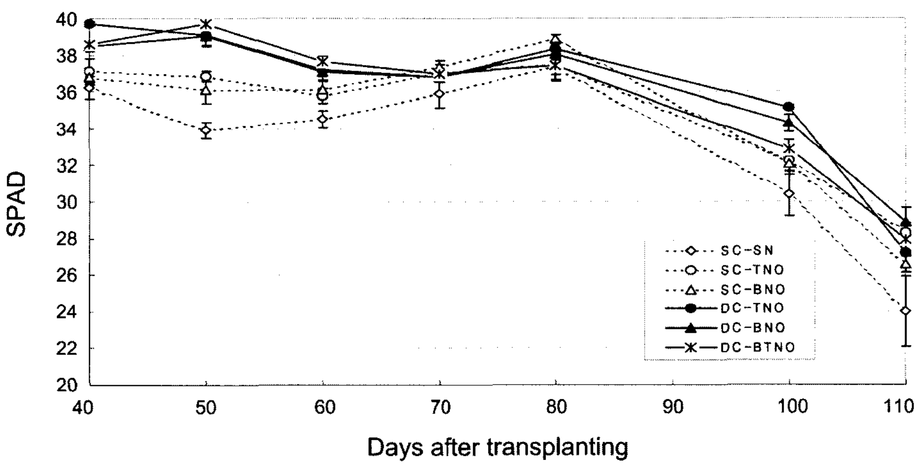

Fig. 3. Changes of SPAD value of rice leaf during rice growing season according to cropping systems and N fertilizer treatments in 2001 (SC-SN, SC-TNO, SC-BNO, DC-TNO, DC-BNO and DC-BTNO are the same as in Fig. 2).

Table 5. Changes of growths, yields and N uptakes of rice in 2001 according to cropping systems and N fertilizer treatments.

Cropping system	Treatmentof N fertilizer	Stem length (cm)	Panicle length (cm)	No of panicles per (m^2)	1,000 grain of brown rice (g)	Yield of brown rice (kg/10a)	Dry matter (kg/10a)	N uptake (kgN/10a)
Rice single	Standard N	77.5	16.7	337	22.8	581	1,471	10.3
	Tillering N omitted	82.5	19.1	352	22.3	622	1,556	12.2
	Basal N omitted	78.6	18.8	347	22.3	603	1,518	11.4
Barley-Rice double	Tillering N omitted	83.7	18.3	359	21.9	653	1,528	12.7
	Basal N omitted	82.3	18.8	354	21.8	654	1,560	12.2
	Basal and tillering N omitted	82.2	19.0	335	22.1	583	1,452	10.8
	LSD(0.05)	1.2	0.7	NS	0.5	38	NS	1.2

Rice transplanting date was June 11th.

ping. At tillering initiation stage, SMN concentrations was increased by 3 mg/kg with application of basal N fertilizer, but difference of SMN concentrations according to cropping systems were not shown. At panicle initiation stage, SMN at "Tillering N omitted" and at "Basal N omitted" in the rice-barley double cropping system were increased more comparing to those in the rice single cropping system, but SMN concentrations at "Basal. Tillering N omitted" in the rice-barley double cropping system were the lowest because no N fertilizer was applied for rice until panicle initiation stage.

Changes of SPAD value during rice growing season in 2001 were shown at Fig. 3. In comparison of SPAD value at "Basal N omitted" and "Tillering N omitted" between two cropping systems, SPAD values in the rice-barley double cropping system were 2~3 higher than those in the rice single cropping system, particularly during the early growth stages from 40 to 60 days after rice transplanting.

Growth status, yields and N uptakes of rice at harvest in 2001 were shown at Table 5. Yields of brown rice at "Tillering N omitted" and at "Basal N omitted" were higher in the rice-barley double cropping system than in the rice single cropping system. In the rice single cropping system, yield of brown rice was reduced slightly at "No basal N", but yields of brown rice in the rice-barley double cropping system were not different between at "Basal N omitted" and at "Tillering N omitted" representing 653, 654 kg N/10a at "Basal N omitted" and at "Tillering N omitted", respectively. But the rice yield at "Basal. Tillering N omitted" in the rice-barley double cropping system was reduced highly because of the shortage of N fertilizer on rice, which indicated that only N fertilizer at panicle initiation without N fertilizer at basal and tillering stage was very insufficient for enough rice growth. N uptakes at "Tillering N omitted" in the rice single cropping system, and N uptakes at "Tillering N omitted" and at "Basal N omitted" in the rice-barley double cropping were similar as 12.2, 12.7 and 12.2 kg N/10a, respectively and then rice N uptakes were decreased in the order of 11.4 kg N/ha at "Basal N omitted" in the rice single cropping system, 10.8 kg N/10a at "Basal. Tillering N omitted" in the rice-barley double cropping system.

DISCUSSION

In the rice single cropping system of this experiment, yields and N uptakes of rice were reduced by the omission of basal N fertilizer (40% of total N applied) compared to the ommission of tillering N fertilizer (30%), but in the rice-barley double cropping system, yields and N uptakes of rice were not reduced by the omission of basal N fertilizer (40% of total N applied) compared to the ommission of tillering N fertilizer (30%) in 2001 (Table 5). No reduction of yield and N uptake of rice at "Basal N omitted" compared to "Tillering N omitted" in the rice-barley double cropping system might be related with much more SMN from residual N for barley or higher SMN by delayed transplanting (June 10th and 11th) compared to normal transplanting date (May 20th or so) in the rice single cropping system (Fujii *et al.*, 1996). Recent agricultural policies in Korea requires farmer to reduce N fertilizer for stable rice yield without lodging, with high quality of rice, and with less impact on environment. To reduce N fertilizer for rice in the rice single cropping system, it is reasonable to reduce tillering N fertilizer than basal or panicle N fertilizer in two cropping systems in consideration of the results from this experiment.

N uptakes of rice in the rice-barley double cropping were higher than those in the rice single cropping system in 2000 (Table 4). It was estimated that higher N uptake of rice in the rice-barley double cropping system was based on higher residual mineral N from N fertilizer applied for barley, higher N mineralization from soil or barley residue and higher early growth of rice by the rotation effect. Judging from SMN and rice N status such as SPAD value during early rice growth, basal N fertilizer (40% of total N amount) on rice in the rice-barley double cropping system could be reduced without the reduction of yield and N uptake of rice in this experiment. But yields and N uptakes of rice in the rice-barley double cropping system were reduced much more by the omission of basal and tillering N fertilizer together (70% of total N). Therefore, half of N (30~40% of total N applied) applied during rice early growth as basal or tillering N fertilizer could be saved without the reduction of yield and N uptake of rice in the rice-barley double cropping system, and it was thought that reducing tillering N fertilizer than basal N fertilizer would be better at the aspect of safe rice production without yield reduction.

Generally, 70% of total N fertilizer is being applied for rice as basal N application without tillering N fertilizer in the rice-barley double cropping system because vegetative rice growing time is shorter and rice growth velocity during early growth stages is faster in the rice-barley double cropping system than in the rice single cropping system according to delayed rice transplanting. Therefore, it is recommended to reduce half of N applied during early rice growth before panicle initiation stage in the rice-barley double cropping system for the higher rice quality and the reduction of environmental pollution associated with over-application of N fertilizer.

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