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Yield and Nitrogen Uptake of Corn in Corn after Soybean Cropping

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ABSTRACT : Soybean can produce high-N residue due to N-fixation, so soybean rotation may increase yield of subsequent corn and reduce N fertilizer on the corn fairly. To find out the contribution of nitrogen to subsequent corn following soybean cultivation, soil nitrate, corn yield, and nitrogen uptake were measured for three continuous corn cropping years after soybean rotation. Three N rates of 0, 80, and 160 kg/ha were applied to three continuous corn following soybean cropping. At 6-leaf stage, soil nitrate amount at the soil depth of 0~30 cm ranged from 60 to 80 kg N/ha higher in the first corn cropping year than that in the second and third corn cropping years. Judging from corn N status such as SPAD value, N concentration of ear-leaf and stover at silking stage, N contribution of previous soybean to corn in the first corn year was N fertilizer of approximately 80 kg N/ha. Stover N uptake at silking stage increased from 47 to 52 kg N/ha at the 0, and 80 kg N/ha of N rates in the first corn cropping year compared with those in the second and third corn cropping years. Corn grain yield at the 0 kg N/ha of N rate was 6~7 ton/ha higher in the first corn cropping year than that in the second and third corn cropping years, respectively. When compared the first corn year following soybean cropping with the second and third corn cropping years, N uptake of grain and stover at harvest with low N rates such as 0 and 80 kg N/ha increased from 45 to 67kg N/ha, from 35 to 60 kg N/ha, respectively. N uptake of whole plant by soybean rotation increased from 93 to 118 kg N/ha in the first year compared with that in the second and third corn cropping years. However, the N contribution by soybean cropping was small in the second and third continuous corn cropping years. Therefore, it was concluded that the nitrogen fertilizer of 80~100 kg N/ha in the first corn cropping year could be saved by soybean rotation and annual alternative corn-soybean rotation could be the best rotation system.

Keywords : corn-soybean rotation, soil nitrate, corn yield, and N uptake

It is necessary for the rotation of corn and soybean to obtain sustainable yield and to reduce nitrogen fertilizer greatly. Rotation of corn and soybean results in increasing over 25% in corn yield and N uptake (Walter, 1997; Porter 1997). However, prediction of the nitrogen contribution by legume is difficult (Bundy *et al.*, 1993) and the impact of legumes on yield and N uptake of corn may depend on water use and weather condition (Oyer & Touchton, 1990; Sarrantonio & Scott, 1988). Its increase in yield and N uptake of corn with legume crop may be due to both rotation effect and N contribution effect by nitrogen fixation (Oplinger, 1999). Corn yield in rotation with soybean increased mainly not due to a rotation effect, but due to N contribution by soybean N fixation (Oyer & Touchton, 1990). Power *et al.* (1986) reported that almost all the N in soybean residue was readily available to the subsequent crop. Oplinger (1999) reported that continuous corn yield with nitrogen fertilizer of 90 kg N/ha was similar to that of corn following soybean without additional nitrogen fertilizer.

Rotational cropping between corn and soybean in Korea has rarely done due to different purpose of each crop's cultivation in comparison with USA. However, now reduction of N fertilizer for corn by rotation with legume is required in Korean farm, particularly in sustainable agriculture farm. This study was conducted to investigate N contribution of soybean residue to three-year continuous corn cropping after soybean, respectively.

MATERIALS AND METHODS

A field experiment was conducted for three years from 1997 to 1999 on typical loam soil for upland crops at the National Crop Experimental Station, Suwon, Korea. Corn cultivar, P3394, was grown at the field in 1995 and then soybean cultivar, Shinpaldalkong 2, was grown without any fertilizer application in 1996. Corn cultivar, P3352, was grown continuously for three years from 1997 to 1999 after soybean cultivation in 1996. Experimental plots were laid out in a randomized block design with 5 replications. Ammonium nitrate (NH_4NO_3) as a nitrogen fertilizer was applied with the N rates of 0, 80, and 160 kg N/ha. Nitrogen fertilizer was applied as the basal fertilizer at corn planting in both 1997 and 1998 but was split-applied with the basal fertilizer (50%) and the supplementary fertilizer (50%) at corn 6-leaf stage in

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1999. Phosphorus (P_2O_5, 150 kg/ha) and potassium (K_2O, 150 kg/ha) were also applied as the basal fertilizer for 3 years, respectively. The area of one plot was 4.5 m × 4.5 m. Corn was planted in early May and planting distance of corn was 75 cm × 20 cm.

Soil samples were taken at the soil depth of 0~15 cm and 15~30 cm from ten sites within each plot at corn seeding stage, 6-leaf stage, silking stage, and harvesting stage, respectively and then mixed well to analyze soil nitrate. The concentration of soil nitrate was colorimetrically determined with Griess-Ilosvay method after nitrate was reduced to nitrite by copperized cadmium column (Keeney, 1982). Soil nitrate amount was calculated from nitrate concentration corrected by soil bulk density.

Every ten days after corn 6-leaf stage, SPAD value was randomly measured from 30 plants per plot by using SPAD 502 (Minolta Corp., Japan). Stalk height, stem diameter of 5th internode, LAI, and corn nitrogen status such as ear-leaf N concentration and stem nitrate were measured at corn silking stage. Furthermore, ten corn plants at silking stage were harvested and its fresh weight was measured. Three plants out of ten plants were collected and dried at 60°C for 48 hours for dry weight determination. Corn was harvested at physiological maturity when black layer was shown at the bottom of kernel. Thirty plants were sampled within two rows per plot. At harvesting stage, two corn stovers were sampled for stalk and ten ears for grain per plot and then dried at 60 oven for 48 hours to obtain dry weight. Grain weight per ear was adjusted to 15.5% moisture content. Corn stover at silking stage, and corn stover (including cob) and grain at harvest stage were ground by Wiley mill (Brabender, Germany). Total nitrogen of stalk and grain was analyzed by the Kjeldahl method (Kjel-Auto, MRK Co., Japan).

Soil properties of the field experiment were shown in Table 1. Precipitation from May to September for three years varied from 881 mm to 1251 mm. Precipitation in 1999 was lower in June but not lower in both July and August (Table 2). Temperatures were similar in all growing seasons.

Table 1. Physico-chemical properties of experimental field soil.

Soil texture	Bulk density (g/cm^3)	pH (1:5)	OM (%)	Av. P_2O_5 (mg/kg)	Ex. Cations ($cmol^+/kg$)			CEC ($cmol^+/kg$)
					K	Ca	Mg	
loam	1.3	5.6	1.5	184	0.46	1.66	0.83	8.1

Table 2. Precipitation and mean temperature during three continuous corn cropping seasons following soybean cropping.

Month	Precipitation (mm)			Mean temperature (°C)		
	1997	1998	1999	1997	1998	1999
April	61	144	47	12.0	15.2	12.8
May	258	173	121	17.9	18.5	16.9
June	319	180	77	22.8	21.7	22.4
July	332	306	345	25.8	26.0	25.4
August	290	592	338	26.9	26.3	26.0

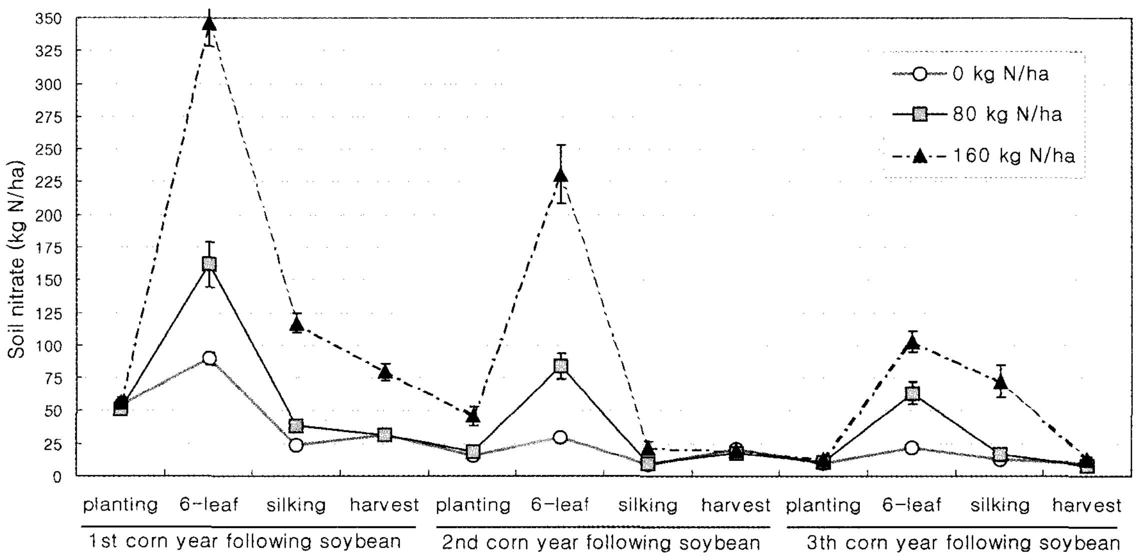

Fig. 1. Changes of soil nitrate (kg N/ha) at the soil laryer of 0~30 cm during three corn cropping seasons. Nitrogen fertilizer was applied with three rates such as 0, 80, and 160 kg N/ha. Nitrogen fertilizer was applied as the basal fertilizer at corn planting in the first and second year and then split-applied with the basal fertilizer (50%) and the supplementary fertilizer (50%) at corn-6-leaf stage in the third year.

RESULTS AND DISCUSSION

Change of soil nitrate and corn growth status

Change of soil nitrate at the soil depth of 0~30 cm for three continuous corn cropping years is shown in Fig. 1. Soil nitrate amount at 6-leaf stage in the first corn cropping year was 61, 78, 115 kg N/ha higher than that in the second and third corn cropping years at the three N rates, respectively. It was considered that higher soil nitrate in the first corn cropping year was owing to rapid mineralization of soybean residue from previous year (Oyer & Touchton, 1990). Approximately 50 kg N/ha of soil nitrate at harvest in the first corn year was remained without being absorbed when compared with that of the second and third corn cropping years. However, soil nitrate amount at harvest in the second and third corn cropping year was not different among the three N rates. At the standpoint of soil nitrate, the soil N contribution by soybean in the first corn year was 60~110 kg N/ha and its N contribution in the second and third corn year was relatively small.

Change in SPAD value after 6-leaf stage is shown in Fig.

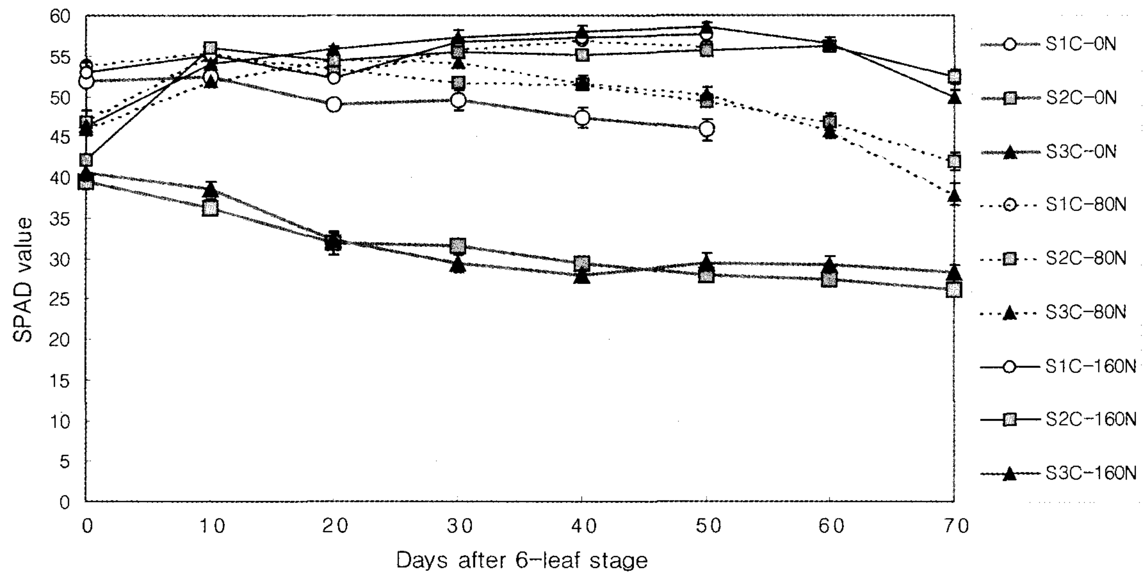

Fig. 2. Changes of SPAD value in corn leaf during three continuous corn cropping seasons following soybean corpping. S1C, S2C, and S3C represent the first, second, and third corn year following soybean cropping, respectively, 0N, 80N, and 160N mean the 0, 80, and 160 kg N/ha of N rates, respectively.

Table 3. Growth and N status of corn at silking stage during three continuous corn growing seasons following soybean corpping.

N rate (kg N/ha)	Corn year following soybean	Days to silking (day)	Stalk height (cm)	Stem diameter (mm)	LAI	Ear leaf N conc. (%)	Stem nitrate conc. (g/kg)
0	1st	74	283	17.6	3.9	2.53	0.10
	2nd	86	191	11.9	2.2	1.28	0.02
	3rd	87	221	17.0	2.1	0.88	0.02
	$LSD_{0.05}$	1	16	1.6	0.4	0.35	0.02
80	1st	74	292	17.9	5.1	3.18	1.03
	2nd	81	264	15.3	4.6	2.53	0.05
	3rd	79	276	20.6	4.1	2.23	0.02
	$LSD_{0.05}$	2	15	1.1	0.2	0.22	0.11
160	1st	73	293	17.9	5.4	3.44	1.34
	2nd	81	262	15.9	5.6	3.19	0.71
	3rd	80	287	21.1	5.6	2.88	0.23
	$LSD_{0.05}$	1	9	1.2	0.2	0.23	0.48
Average							
0		82	232	15.5	2.7	1.57	0.05
80		78	278	17.9	4.6	2.65	0.37
160		78	281	18.3	5.5	3.17	0.76

2. SPAD value at the 0 kg N/ha of N rate in the first corn cropping year was approximately 20 higher than those in the second and third corn cropping years, and similar to those at the 80 kg N/ha of N rate in the second or third corn cropping years. SPAD value at the 80 kg N/ha of N rate in the first corn cropping year was also similar to that at the 160 kg N/ha of N rate in the second corn cropping year. However, SPAD value between the second and the third corn cropping years was not different at all three N rates. At the standpoint of corn leaf SPAD values, the N contribution by soybean to the first corn was approximately 80 kg N/ha. Corn stalk heights and LAIs at silking were much higher in the first corn year than those in the second and third corn year (Table 3). Furthermore, those were highly signficànt at lower N rate. At silking stage, ear-leaf N concentration was higher in the first corn year than that in the second and third corn cropping years. Ear-leaf N concentration at silking is correlated with corn N yield (Tyner & Webb, 1946) and proper ear-leaf nitrogen concentration at silking is 2.75~3.25% (Larson & Hanway, 1997). At the N rate of 80 kg N/ha, ear-leaf N concentration in the first corn year was 3.18% but that in the second and third corn cropping years decreased to 2.53% and 2.23%, respectively. The response was similar to ear-leaf N concentration at the N rate of 0 kg N/ha in the first corn cropping year. The ear-leaf N concentration at the N rate of 0 kg N/ha in the second and third corn cropping years decreased from 2.53% to 1.28% and 0.88%, respectively. Stem nitrate concentration in the first corn cropping year was approximately 0.8 g/kg higher than that in the second and third corn cropping years at three N rates but was not different between the second and the third corn cropping years.

Table 4. N concentration of corn during three continuous corn cropping seasons following soybean cropping.

N rate (kg N/ha)	Continuous corn cropping year following soybean			
	1st	2nd	3rd	$LSD_{0.05}$
	Nitrogen concentration (%)			
Stover at silking				
0	1.01	0.72	0.52	0.11
80	1.52	1.16	0.91	0.07
160	1.68	1.64	1.25	0.13
Average	1.40	1.17	0.89	
Stover at harvest				
0	0.53	0.39	0.30	0.08
80	0.86	0.38	0.29	0.13
160	0.94	0.62	0.64	0.11
Average	0.78	0.47	0.41	
Grain at harvest				
0	1.17	1.22	1.08	0.09
80	1.34	1.22	1.07	0.07
160	1.37	1.39	1.22	0.07
Average	1.30	1.29	1.13	

Table 5. Dry matter yield and N uptake of corn at silking during three continuous corn cropping seasons following soybean cropping.

N rate (kg N/ha)	Continuous corn cropping year following soybean			
	1st	2nd	3rd	$LSD_{0.05}$
	Dry matter (ton/ha)			
0	8.16	4.23	6.22	0.90
80	9.39	8.20	10.48	0.91
160	9.46	8.75	10.29	0.66
Average	9.01	7.06	9.00	
	Nitrogen uptake (kg N/ha)			
0	83	31	33	16
80	143	94	96	14
160	159	144	128	11
Average	128	90	85	

Changes of yield and N uptake of corn

Stover N concentrations at silking and harvest stage and grain N concentrations are shown in Table 4. Stover N concentration at harvest stage in the first corn cropping year was 0.2%, 0.4%, and 0.3% higher than those in the second and third corn cropping years at three N rates, respectively. However, stover N concentration at harvest with the three different N rates was not different between the second and the third corn cropping years. Grain N concentration at harvest was not different largely indicating 1.07~1.39% regardless of corn cropping years and N rate.

Dry matter yield and N uptake of corn at silking stage during three continuous corn growing seasons following soybean cropping are shown in Table 5. Dry matter yield at silking was lower in the second corn cropping year than those in the first and third corn cropping years because of poor early growth. At the 0 kg N/ha of N rate, dry matter yield at silking in the first corn cropping year decreased more significantly than those in the second and third corn cropping years. N uptake at silking in the first corn cropping year was approximately 50 kg N/ha higher than that in the second corn cropping year at the 0, and 80 kg N/ha of N rate.

Grain yield, stover and whole plant dry matter yield of corn at harvest, and those N uptake are shown in Table 6. Grain yield decreased with continuous corn cropping and grain yields decreased rapidly at lower N level such as 0 kg N/ha of N rate because of N-deficiency. At the 0, 80, 160 kg

Table 6. Dry matter yield and N uptake of corn at harvest stage during three continuous corn cropping seasons following soybean cropping.

Corn part	N rate (kg N/ha)	Continuous corn cropping year following soybean			
		1st	2nd	3rd	$LSD_{0.05}$
		------------ Dry matter (ton/ha) -----------			
Grain	0	8.21	2.25	1.28	0.99
	80	10.30	6.91	5.42	0.67
	160	10.94	8.47	7.00	0.50
	Average	9.82	5.88	4.56	
Whole plant	0	18.05	6.62	7.84	1.77
	80	21.18	16.58	17.01	1.58
	160	21.94	18.85	18.95	1.02
	Average	20.39	14.02	14.60	
		------- Nitrogen uptake (kg N/kg) -------			
Grain	0	81	23	14	9
	80	117	72	58	10
	160	127	100	85	8
	Average	108	65	52	
Whole plant	0	133	40	33	13
	80	210	108	92	18
	160	231	164	161	15
	Average	192	104	95	

Table 7. Changs of dry matter and N uptake in corn from silking stage to harvest stage during three continuous corn cropping seasons following soybean cropping.

N rate (kg N/ha)	Continuous corn cropping year following soybean			
	1st	2nd	3rd	$LSD_{0.05}$
	-------------- Dry matter (ton/ha) -------------			
0	9.89	2.39	1.62	1.37
80	11.79	8.38	6.53	1.56
160	12.48	10.01	8.66	0.80
Average	11.38	6.96	5.60	
	------------- Nitrogen uptake (kg N/ha) -----------			
0	50	10	1	10
80	67	14	-4	18
160	72	20	33	18
Average	63	14	10	

N/ha of N rate, grain yield in the first corn cropping year was 2.5~6 ton/ha, 4~7 ton/ha higher than that in the second and the third corn cropping years, respectively. Grain yield at the 0 kg N/ha of N rate in the second and the third year was very poor which was 2.25 and 1.28 ton/ha, respectively. Change of whole plant dry matter yield at harvest during three continuous corn cropping seasons was similar to that of grain yield. However, that of stover weight at harvest was not different largely regardless of corn year and N rate except those at the 0 kg N/ha of N rate in the second and third corn cropping years. Whole plant dry matter yield, when compared the first corn cropping year with the second corn cropping year, increased 11.4, 4.6, and 3.1 ton/ha at the 0, 80, and 160 kg N/ha, respectively. However, whole plant dry matter yield was not different between the second and third corn cropping years at the three N rates.

Grain N uptake also increased drastically in the first corn cropping year following soybean cultivation and rapidly decreased with continuous corn cropping, particularly at the 0 kg N/ha of N rate (Table 6). Grain N uptake in the first corn cropping year was 81, 117, and 127 kg N/ha at the 0, 80, and 160 kg N/ha of N rate, respectively. Grain N uptake in the first corn year was 67, 59, and 42 kg N/ha higher than that in the third corn year, at the 0, 80, and 160 kg N/ha of N rate, respectively. Whole N uptake in the first corn cropping year, which was composed of N uptake of grain and stover, was 133, 210, and 231 kg N/ha at the 0, 80, and 160 kg N/ha, respectively. Furthermore, whole N uptake in the first corn cropping year was 93, 102, and 67 kg N/ha higher than that in the second corn year at the 0, 80, and 160 kg N/ha, respectively. Increase of 90~100 kg N/ha in N uptake at the 0 and 80 kg N/ha of N rate in the first corn following soybean cropping, was similar to the result by Oplinger (1999) that soybean rotation could reduce 90 kg N/ha fertilizer on subsequent corn cropping. However, whole N uptakes between the second and the third corn year was not different among three N rates. At the standpoint of whole N uptake at harvest, N contribution to the first corn following soybean cropping was 70~100 kg N/ha and the N contribution to the second and the third continuous corn by soybean rotation was relatively small.

Table 7 represents the increase in dry matter yield and N uptake of corn from silking to harvest for three continuous corn years. Cox (1998) reported that dry matter and N accumulation after silking affected the yield response to rotation more than dry matter and N accumulation during vegetative development did. Dry matter after silking increased highly in the first year when compared with that in the second and third corn cropping years, particularly at the 0 kg N/ha of N rate indicating that dry matter increase from 7.5 to 8.3 ton/ha. Soybean rotation effect on corn was distinctly observed in corn N uptake after silking. N uptake after silking in the first corn cropping year was 40~50 kg N/ha higher than those in the second and third corn cropping years at the three N rates. After silking stage, corn hardly absorbed soil nitrogen in the second and third corn cropping years, particularly at the 0 and 80 kg N/ha of N rate. Therefore, it is considered that 50% (40~50 kg N/ha) out of total N uptake increase, which was 70~100 kg N/ha in the first corn cropping following soybean cropping, would be originated from N absorption by corn after silking.

Considering soil nitrate, N status during corn growing, N concentration and N uptake at harvest, N contribution to subsequent corn by soybean rotation was 80~100 kg N/ha. Furthermore, the corn in the first year after soybean rotation could absorb soil N originated from soybean residue steadily to the harvesting stage, compared with that in the second and third corn cropping years. However, the N contribution to the second or third continuous corn by soybean rotation was relatively small. Therefore, it can be concluded that alternative annual corn-soybean rotation is desirable at the standpoint of increase in corn yield and the reduction of N fertilizer on corn.

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