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Nitrogen Balance and Biological Nitrogen Fixation of Soybean in Soybean-Barley Cropping System

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ABSTRACT : This experiment was conducted to investigate the soil nitrogen credit of biological nitrogen fixation (BNF) and the nitrogen balance of soybean in soybean-barley cropping systems. Soybean cultivar, Shinpaldalkong2 and barley cultivar, Olbori, were used in soybean monocropping (SM), barley monocropping (BM), and barley-soybean double cropping system. The barley-soybean double cropping system was treated with two different levels of nitrogen fertilizers, 0 nitrogen fertilizer (BS-F0), and standard nitrogen fertilizer (BS-F1). Nitrogen and organic matter concentrations in soil of BS-F1 plot on October, 2001 were increased 4.8% and 5.9%, respectively, compared with those on October, 2000. The ranges of BNF rate in soybean were 69.1 ~ 88.2% in two years, and the rate was the highest in BS-F0 plot and the lowest in SM plot. The ranges of nitrogen harvest index (NHI) in all treatments were 83.9 ~ 86.7%. The yield was 270 kg/10a in BS-F1 plot and 215 kg/10a in BS-F0 plot. However, the nitrogen balances were +0.6 kg/10a of gain of soil nitrogen in BS-F0 plot and -0.4 kg/10a of loss of soil nitrogen in BS-F1 plot. In comparisons of SM and BS-F1 plots, although the seed yields were similar in two plots, the loss of soil nitrogen was higher in SM than BS-F1 plot. Overall, our results suggest that barley-soybean double cropping system was more effective in respect to seed productivity and soil nitrogen conservation than soybean monocropping system, and the N credit to following crops by soybean cultivation was identified in soybean double cropping system.

***Keywords*:** soybean, biological nitrogen fixation, nitrogen harvest index, nitrogen balance, barley, cropping system

During the last decades, the condition of agricultural environment in Korea has been worsen by the over use of cheap nitrogen fertilizers in order to increase up crop productivity. This became a major problem of agricultural production system in Korea. To solve this problem, agricultural dependence on biological nitrogen fixation (BNF) of legumes have been re-introduced in cropping-system with reduction of the use of nitrogen fertilizer and at the same time the development of sustainable agricultural systems is necessary. Many of reviewed articles about the possibility and the application of BNF in agricultural production were published (Graham & Vance, 2000; Peoples *et al.*, 1995a; Unkovich & Pate, 2000; van Kessel & Hartly, 2000). Amount of BNF by soybean was 0 ~ 450 kg/ha dependent on the experimental conditions and measuring methods (Peoples *et al.*, 1995a). Nitrogen credits to following crops of soybean were estimated -69 ~ +45 kg/ha (Herridge & Holland, 1992) and -22 ~ 220 kg/ha (Bundy *et al.*, 1993). And, several researches showed that the effects of soybean N credit were distinct in rotational or double cropping system with maize and cereal crops (Omay *et al.*, 1998; Peoples *et al.*, 1995b; Yamoah *et al.*, 1998). Ennin & Clegg (2001) reported that possibility of a net positive N balance of soybean was over 20,000 plant/ha plant populations. Gentry *et al.* (2001) was published that the N credits of soybean was increased from in the residual nitrogen in soil of symbiotic fixation. Therefore, this experiment was conducted to investigate soil N credit of BNF and the nitrogen balance of soybean, and to identify the N credit to following crops by soybean cultivation in soybean-barley cropping systems.

MATERIALS AND METHODS

This experiment was carried out at the field of National Institute of Crop Science in Suwon province in 2001 and 2002. Soybean cultivar, Shinpaldalkong2 and barley cultivar, Olbori, were used. Three cropping systems were conducted by soybean monocropping (SM), barley monocropping (BM), and barley-soybean double cropping system. Barley-soybean double cropping system was treated with two different levels of nitrogen fertilizer, without application of N fertilizer (BS-F0), N : P_2O_5 : K_2O = 0 : 3 : 3.4 (kg/10a), and standard N fertilizer (BS-F1), N : P_2O_5 : K_2O = 3 : 3 : 3.4 (kg/10a). Fertilizer were incorporated in the soil before planting as basal dressing. Barley was planted on October 20, 2001 and soybean was planted on June 21, 2002. Planting and cultivation were followed by standard cultivation methods.

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Experimental design was randomized complete block arrangement with three replications. Experimental soils before planting and after harvesting were sampled by core method and were used to determine the concentration of total nitrogen and organic matter. Nitrogen concentration of whole soybean plant at full maturity stage was measured by Kjeldahl method. Nitrogen fixation rates of soybeans were measured by ureids methods (Herridge *et al.*, 1990). At full maturity growth stage, soybean plants from 2 m row length × 2 rows of each plot were harvested for determining seed yield and yield components. The collected data were subjected to statistical analyses using SAS package for ANOVA and GLM.

RESULTS AND DISCUSSION

The changes of nitrogen and organic matter concentrations in experimental soil on four cropping systems were shown in Fig. 1. The changes of nitrogen concentration were similar to those of organic matter concentrations, and their concentration were decreased after barley cultivation and increased after soybean cultivation in all treatments. Nitrogen and organic matter concentrations in barley-soybean standard fertilization plot (BS-F1) on October 2001 were increased 4.8% and 5.9%, respectively, compared with those on October 2000. In the barley-soybean 0 fertilization plot (BS-F0), those concentrations were shown the similar levels between on October 2000 and on October 2001. These results showed that the soil nitrogen concentration was recovered to the same levels before barley cultivation by soil nitrogen reduction by soybean.

In two years, the changes of BNF rate, measured by ureides method, of soybeans are shown in Table 1 and 2. The BNF rates were 69.1% in 2001 and 77.1 ~ 88.2% in 2002. The BNF rates among the treatments in 2002 showed difference. The BNF rate was the highest in BS-F0 plot and the lowest in

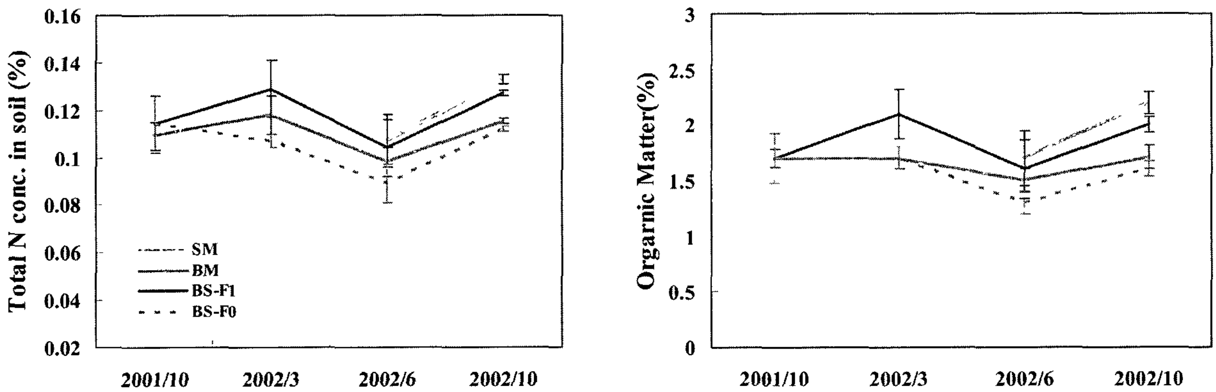

Fig. 1. Changes of nitrogen and organic matter concentration in soils by barley-soybean double cropping systems. (SM: soybean monocropping, BM: barley monocropping, BS-F1 barley-soybean, standard N fertilizer, BS-F0: barley-soybean, no N fertilizer).

Table 1. Changes of nitrogen fixation rate of soybean in soybean monocropping in 2001.

Growth stage	Plant nitrogen		RU†	Biological nitrogen fixation			
	Cumulative	Increment		Pfix‡	Increment¶	Cumulative	Percentage
	(mg/plant)		(%)	(%)	(mg/plant)		(%)
R2	158.0	158.0	54.2	60.9	96.3	96.3	60.9
R3	407 1	249.0	62.9	70.2	174.8	271 1	66.6
R5	458.8	51.7	82.5	88.9	46.0	317.1	69.1

†RU relative ureide-N(%)
‡Pfix : proportion of plant N derived from nitrogen fixation
¶Increment of plant N×Pfix

Table 2. Changes of nitrogen fixation rates of soybean in barley-soybean cropping systems in 2002

Treatment	Biological nitrogen fixation rate (%)
Soybean	77.1
Barley-soybean, standard N fertilization	84 9
Barley-soybean, no N fertilization	88 2

soybean monocropping plot (SM). Thus, the range of BNF rate was 69.1 ~ 88.2%, shown wide variation, in two years.

The fig. 2. showed the relationships between nitrogen concentrations in soils and the BNF rates of soybeans during two years experiments. Interestingly, the negative relationship between two components was detected. This is a similar result that the ability of BNF was lower in high nitrate concentration in soil (Harper, 1987). Therefore, it conformed that the BNF rate of soybean is influenced by the nitrogen concentration in soil.

The reduction effects of soil nitrogen were conducted by the estimation of nitrogen balance in legume plants (Peoples *et al.*, 1995a, b). Table 3 showed the nitrogen balances estimated from the substraction BNF rate with nitrogen harvest index (NHI) of soybean plants in all treatments in 2002. The

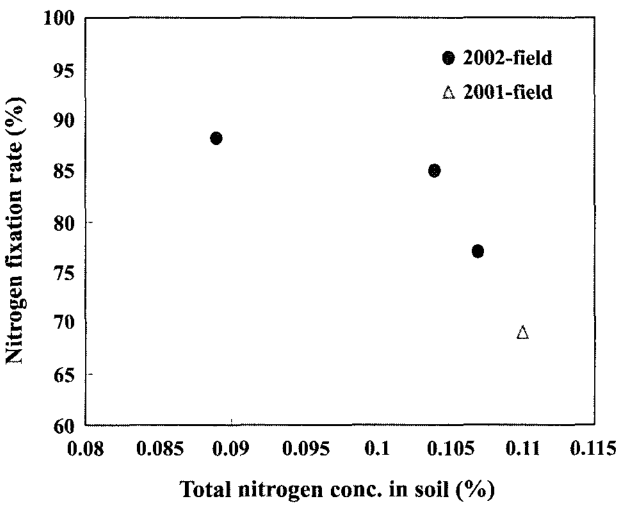

Fig. 2. Relationships between nitrogen concentration in soil and nitrogen fixation rates of soybeans in two years

minus value of nitrogen balance means the loss of nitrogen in soil, and the positive value of nitrogen balance means the gain of nitrogen in soil. The ranges of NHI in all treatments were 83.9 ~ 86.7%, and were narrow variation than those of BNF rates. The reduction effect of soil nitrogen was shown in BS-F0 plot, revealed the highest BNF rate, only and the losses of soil nitrogen were occured in SM and BS-F1 plots. Therefore it appears that the determination of nitrogen balance was more influenced by BNF rate than NHI.

Table 4 showed the soybean seed yield and the estimated quantities of nitrogen balance based on the seed yield and fixed nitrogen per unit area. The yield was 270 kg/10a in BS-F1 plot, the highest yield, and 215 kg/10a in BS-F0 plot, the lowest yield among the treatments. The nitrogen balance was revealed +0.6 kg/10a of nitrogen gain in BS-F0 plot and -0.4 kg/10a of loss of soil nitrogen in BS-F1 plot, and -1.5 kg/10a of nitrogen loss in SM plot. These results mean that in two nitrogen standard fertilization plots, SM and BS-F1 plots, the seed yields of soybeans are sustained but the soil nitrogen was lost by lower BNF rate than NHI. However, although the yield was lower by no nitrogen fertilization in BS-F0 plot, the reduction effect of soil nitrogen was occured by the increase of BNF rate above the NHI. In comparisons of SM and BS-F1 plots, although the seed yields were similar in two plots, the loss of soil nitrogen was higher in SM than BS-F1 plot. Therefore, it appears that critical nitrogen concentration in soil might be existed for increasing BNF and seed productivity, simultaneously.

Overall, our results suggest that barley-soybean double cropping system was more effective in respect to seed productivity and soil nitrogen conservation than soybean monocropping system, and the effect of N credit to following crops by soybean was clear.

Table 3. Nitrogen harvest index, nitrogen fixation rate, and nitrogen balance of soybean in barley-soybean cropping systems in 2002.

Treatment	Nitrogen harvest index	Biological nitrogen fixation rate	Nitrogen balance
	(%)	(%)	
Soybean	83 9	77.1	–
Barley-soybean, standard N fertilization	86.7	84 9	–
Barley-soybean, no N fertilization	85 7	88 2	+
Mean	85 4	83.4	

Table 4. Seed yield and nitrogen balance of soybean per unit area in barley-soybean cropping systems in 2002.

Treatment	Plant population	Seed yield	Seed N	Fixed N	N-balance
	(no./10a)	(kg/10a)			
Soybean	25,417	**263**	19.0	17 5	**-1.5**
Barley-soybean, standard N fertilization	27,708	**270**	22 8	22.4	**-0.4**
Barley-soybean, no N fertilization	30,208	**215**	18.7	19 3	**0.6**

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