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Use of Hairy Vetch Green Manure as Nitrogen Fertilizer for Corn Production

Jong-ho Seo*†, Ho-jin Lee, Il-bong Hur*, Si-ju Kim*, Chung-kuk Kim* and Hyeon-suk Jo***

*National Crop Experiment Station, RDA. Suwon 441-100, Korea
**College of Agric. & Life Sciences, Seoul National University, Suwon 441-744, Korea

ABSTRACT: Hairy vetch (*Vicia villosa* Roth) winter annual is very effective on reducing chemical nitrogen fertilizer for subsequent corn by fixed organic green manure nitrogen fixed during hairy vetch growth. In this experiment, hairy vetch produced above-ground dry matter of 5 ton/ha, nitrogen yield 200 kgN/ha, at corn planting on the average during 1997 and 1998. Changes in corn yield and nitrogen uptake for two years were investigated after application of nitrogen fertilizer 0, 60, 120, 180, 240 kgN/ha on plot of winter fallow and hairy vetch green manure, respectively. Nitrogen status such as ear-leaf N%, SPAD value at silk and dough stage, and corn yield decreased in proportion to reduction of nitrogen fertilizer at winter fallow, but nitrogen status and yield of corn were not different among nitrogen fertilizer rate at hairy vetch green manure. Corn yield (total dry matter) at 0 kgN/ha plot of hairy vetch was 22, 20 ton/ha in 1997, 1998, respectively and corn could produce more dry matter 9, 13 ton/ha by hairy vetch green manure compared with winter fallow under the condition of no nitrogen fertilizer in 1997, 1998, respectively. Corn yield (total dry matter) at 60 kgN/ha of hairy vetch green manure was higher than that of high N fertilizer rate such as 180, 240 kgN/ha of winter fallow. Nitrogen uptake of corn at plot of hairy vetch-no nitrogen fertilizer slightly decreased than at plot of hairy vetch - nitrogen fertilizer, but corn absorbed more nitrogen of 141, 159 kgN/ha by hairy vetch green manure compared with winter fallow under no nitrogen fertilizer condition in 1997, 1998, respectively. Nitrogen fertilizer reduction for corn by hairy vetch green manure was 149, 161kgN/ha in 1997, 1998, respectively. Still more, corn could absorb more soil nitrogen by nitrogen fertilizer 60 kgN/ha of hairy vetch green manure than by high nitrogen fertilizer such as 180, 240 kgN/ha at winter fallow. It is concluded that nitrogen fertilizer for corn could be reduced by winter cultivation and soil incorporation of hairy vetch at corn planting.

Keywords : hairy vetch, green manure, corn, nitrogen uptake, reduction of nitrogen fertilizer.

The technology of using green manure crops is one of the most environmental friendly agricultural technologies which could provide better conditions of soil by improving the physical properties, fertilization of soil and micro-flora of soil. Furthermore, leguminous green manure crops would be much effective than that of gramineous crops because they would fix the atmospheric N_2 to NH_4^+ and release the biologically fixed nitrogen to soil and reduce nitrogen fertilizer for a subsequent crop. Hairy vetch is one of the most frequently used crops as a green manure crop in many countries because it has high winter survival and nitrogen fixation ability. Incorporated hairy vetch residue is rapidly decomposed and release much inorganic N in soil due to high plant nitrogen concentration (4% N, C/N ratio : 10) acquired from vigorous nitrogen fixation activity at low temperature conditions in early spring after overwintering (Power, 1991; Varco, 1989; Sarrantonio, 1988).

It was reported that corn yield increased twice by soil incorporation of hairy vetch compared with soil covering of hairy vetch (Power, 1991) and corn absorbed more soil nitrogen 60 kgN/ha by incorporation of hairy vetch compared with soil covering of hairy vetch(Varco, 1989). Utomo (1990) reported that incorporation of hairy vetch could reduce the application amount of nitrogen fertilizer as much as nitrogen fertilizer 170 kgN/ha showing 7.85 ton/ha grain yield of corn.

This study was conducted to investigate saving effects of the nitrogen fertilizer for corn by hairy vetch green manure through studying the rotation between corn and hairy vetch.

MATERIALS AND METHODS

A field study was conducted in 1997 and 1998. Hairy vetch was drill-seeded in seeding rate of 35 kg/ha and 60cm spacing on Sep. 10 in 1996 and 1997 and cultured until late April in the next year of 1997 and 1998. Yields of hairy vetch were measured by sampling above-ground hairy vetch of 1 at each plot just before soil incorporation. Hairy vetch and basal chemical nitrogen fertilizer, ammonium nitrate were incorporated to soil on May 2 in 1997 and April 21 in 1998, respectively. Corn was planted at one week after incorporation of hairy vetch and N fertilizer. Hairy vetch was first plowed and incorporated under soil depth 2530cm, and then soil was prepared with rotary tillage.

†Corresponding author: (Phone) +82-31-290-6758 (E-mail) sih3022@rda.go.kr
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The experimental plot was arranged in split-plot design with five replicates. Main plots consisted of hairy vetch (green manure) and winter fallow, and split plots, measuring 65, consisted of nitrogen rate 0, 60, 120, 180 and 240 kgN/ha. Ammonium sulfate as the supplementary nitrogen fertilizer was applied at 6 leaf stage of corn and amount of supplementary nitrogen fertilizer was half of total nitrogen fertilizer which was recommending amount of N in corn cultivation. Corn cultivar was P3352(Pioneer corp., USA) and its planting distance was 7520 cm.

Stalk height was measured at silking stage. Chlorophyll contents were collected using SPAD502 (Minolta corp., Japan) at silking stage and dough stage of corn. SPADs were taken at central point between the margin and the mid-rib from ear-leaves of 30 corn plants. Total fresh weight and ear weight of corn were measured from 30 plants at physiological maturity when black layer was formed below kernel.

Representative stovers and ears were selected and weighed from each plot, and after drying at 60°C for 48 hours, dry matters of stover and ear were weighed. Ears were shelled and grain weight was measured to get grain percent of ear. Grain yields were adjusted to 15.5% moisture content. Hairy vetch, 2 corn stovers and grain from 10 corn ears were ground by willey mill. Total N concentrations were analyzed by Kjeldahl method (Kjel-Auto, Co. MRK, Japan).

RESULTS AND DISCUSSION

Growth and yield of corn

Dry weight and nitrogen yield of aboveground hairy vetch sampled at soil incorporation in 1997 and 1998 were showed in Table 1. Dry weight of hairy vetch was 5.5 ton/ha in 1997 and 4.3 ton/ha in 1998. Hairy vetch nitrogen was 205 and 195 kgN/ha in 1997 and 1998, respectively. So, average dry weight and nitrogen yield of hairy vetch for two years were 5 ton/ha, 200 kgN/ha, respectively.

Days to emergence, days to silking, and stalk height of corn were shown in Table 2. Mean of days to emergence at hairy vetch plots was 11.6 day which was 1.6 day delayed compared to the mean of day to emergence obtained in 1997, but it was not different in 1998 compared with at winter fallow plots. Days to silking and stalk height were not different among nitrogen rates at hairy vetch plots. But silk-

Table 1. Fresh weights and nitrogen yields of hairy vetch (aboveground) at soil incorporation as green manure.

Year	Date	Fresh weight (ton/ha)	Dry weight (ton/ha)	N %	N yield (kgN/ha)
1997	May 5	48.22	5.50	3.72	205
1998	April 20	35.62	4.33	4.50	195
Mean		41.92	4.92	4.11	200

Table 2. Growth status of corn affected by hairy vetch and nitrogen fertilizer rate.

Winter cropping	N rate (kgN/ha)	1997			1998		
		Days to emergence (day)	Days to silking (day)	Stalk height (cm)	Days to emergence (day)	Days to silking (day)	Stalk height (cm)
Hairy vetch	0	11.6	71.8	304	9.0	76.8	281
	60	11.8	71.8	305	9.0	77.4	281
	120	11.6	72.0	308	9.0	78.0	277
	180	11.4	71.4	308	9.0	78.2	279
	240	11.4	71.2	305	9.0	78.0	276
	Mean	11.6	71.6	306	9.0	77.7	279
Winter fallow†	0	10.0	74.0	276	9.0	84.4	194
	60	10.0	72.0	292	9.0	77.2	258
	120	10.0	71.2	302	9.0	77.2	274
	180	10.0	71.4	303	9.0	77.6	281
	240	10.0	71.0	302	9.0	77.2	273
	Mean	10.0	71.9	295	9.0	78.7	256
LSD(0.05)							
‡WC(C)		0.5	NS	8	-	1.3	12
N rate(N)		NS	0.7	8	-	1.1	11
C × N		NS	**	**	-	**	**
CV(%)		5	1	2	-	1	3

** Significant at the 0.01 probability level.
†Hairy vetch was incorporated to soil as green manure at one week before planting corn.
‡Winter cropping.

Table 3. Ear leaf nitrogen status of corn at silk and dough stage affected by hairy vetch and nitrogen fertilizer rate.

Winter cropping	N rate (kg/ha)	1997			1998		
		N % at silking stage	SPAD at silking stage	SPAD at dough stage	N% at silking stage	SPAD at silking stage	SPAD at dough stage
Hairy vetch†	0	3.31	56.6	56.2	2.97	54.3	56.8
	60	3.32	57.3	56.8	3.15	54.9	57.8
	120	3.46	57.5	57.2	3.28	55.9	59.2
	180	3.43	57.4	57.5	3.31	55.8	58.4
	240	3.45	57.5	57.5	3.31	55.6	59.3
	Mean	3.39	57.3	57.0	3.20	55.3	58.3
Winter fallow	0	2.16	45.3	38.6	1.47	32.3	31.1
	60	3.17	56.1	53.4	2.57	49.6	48.1
	120	3.36	57.1	57.0	2.95	55.1	57.2
	180	3.38	57.5	57.4	3.16	56.3	58.1
	240	3.49	57.8	57.7	3.25	56.5	58.5
	Mean	3.11	54.8	52.9	2.68	50.0	50.6
LSD(0.05)							
‡WC(C)		0.30	3.2	3.5	0.27	1.3	2.1
N rate(N)		0.28	3.0	3.1	0.26	1.3	2.4
C × N		**	**	**	**	**	**
CV(%)		7	4	4	7	2	3

**Significant at the 0.01 probability level. †, ‡ are the same as Table 2.

ing date and stalk height at no nitrogen fertilizer plot of winter fallow were more delayed and decreased than the others in 1997 and 1998, respectively.

Nitrogen concentration of ear-leaf at silking stage and SPAD values of ear leaf at silking and dough stage were measured to learn N status of corn during growing period (Table 3). Nitrogen concentrations of ear leaf at silking stage were in 3.31~3.46% range and were not different among nitrogen rates within hairy vetch plots in 1997. But, at 0 kgN/ha plot of hairy vetch in 1998, nitrogen concentration of ear leaf was 2.97% and was considered slightly low for growing plant. At winter fallow plots, nitrogen concentration of ear leaf increased from 2.16 to 3.36% as nitrogen fertilizer rate increased from 0 to 120 kgN/ha in 1997 and from 1.47% to 3.31% as nitrogen fertilizer rate increased from 0 kgN/ha to 180 kgN/ha in 1998. Ear leaf nitrogen concentration at 0 kgN/ha plot of hairy vetch was similar to that between 120 and 180 kgN/ha plot of winter fallow in both years.

Larson and Hanway (1997) reported that proper nitrogen concentration of leaf at silking stage was 2.75~3.25% which is sufficient to produce good grain yield and grain protein concentration. In this experiment, nitrogen concentrations at 0 kgN/ha plot of hairy vetch were 3.31%, 2.97% in 1997, 1998, respectively.

SPAD values at silking and dough stage which is highly correlated with leaf nitrogen concentration and photosynthesis (Wolfe *et al.*, 1988; Wood *et al.*, 1992), were measured (Table 3). SPAD values at hairy vetch plots were not different among nitrogen fertilizer rates in 1997, but those at 0 kgN/ha plot of hairy vetch in 1998 were slightly low such as 54.3 and 56.8 at silking and dough stage, respectively. At winter fallow plots, SPAD values at two stage increased in proportion to increase of nitrogen fertilizer rate from 0 to 120 kgN/ha in 1997 and 1998, and also its trends were more clear at dough stage than silking stage by plant nitrogen transfer of nitrogen from leaf to ear. Blackmer (1995) and Schepers (1992) reported that chlorophyll meter reading at dough stage represented plant nitrogen status well during the reproductive stage and were highly correlated with yield in corn. But, SPAD values were not different among nitrogen fertilizer rates with hairy vetch plots because it is estimated that sufficient nitrogen was absorbed by corn from incorporated hairy vetch.

Yields of corn grain, stover and whole plant for two years were shown in Table 4. Mean yield distinctly increased in hairy vetch manure plot compared to winter fallow plot. Mean yield of whole plant at hairy vetch plots in 1998 was 2 ton/ha lower than that in 1997 due to diminution of grain weight in 1998.

Weights of grain, stover and whole plant were not different among nitrogen fertilizer rates at hairy vetch plot, but yields at winter fallow plots significantly decreased by nitrogen deficiency under nitrogen rate 120 kgN/ha and its trends were more clear in 1998 than in 1997.

Weights of grain and whole plant at 0 kgN/ha plot of hairy

Table 4. Dry yield of corn affected by hairy vetch and nitrogen fertilizer rate.

Winter cropping	N rate (kgN/ha)	1997			1998		
		Grain	Stover	Whole plant	Grain	Stover	Whole plant
		ton/ha					
Hairy vetch†	0	10.69	11.30	22.00	8.59	11.44	20.03
	60	10.88	12.03	22.92	8.47	11.94	20.43
	120	11.23	11.88	23.11	8.82	11.66	20.48
	180	11.23	11.86	23.08	8.86	11.28	20.14
	240	11.12	11.54	22.67	8.36	11.74	20.10
	Mean	11.03	11.73	22.76	8.62	11.61	20.24
Winter fallow	0	5.36	7.92	13.28	1.83	5.21	7.04
	60	9.15	9.98	19.13	5.79	9.01	14.80
	120	10.62	11.02	21.64	7.88	11.35	19.24
	180	10.88	11.45	22.33	8.45	11.89	20.34
	240	11.05	11.19	22.24	8.33	11.91	20.24
	Mean	9.42	10.31	19.73	6.46	9.88	16.33
LSD(0.05)							
‡WC(C)		1.36	1.53	2.66	0.85	1.27	1.80
N rate(N)		0.96	1.17	1.88	0.64	1.06	1.45
C × N		**	**	**	**	**	**
CV(%)		7	8	7	7	8	6

**Significant at the 0.01 probability level. †, ‡are the same as Table 2.

vetch in 1997 were 10.69 and 22.00 ton/ha, respectively which were 5.33 and 8.7 ton/ha higher than those at 0 kgN/ha plot of winter fallow. In 1998 which was successive corn growing year, weights of grain and whole plant at 0 kgN/ha plot of hairy vetch were 8.59 and 20.03 ton/ha, respectively which were 6.76 and 12.99ton/ha higher than those at 0 kgN/ha plot of winter fallow.

The yields of grain, stover and whole plant at 0 kgN/ha plot of hairy vetch were similar to those between 120 and 180 kgN/ha plot of winter fallow and were not enough to obtain maximum yield. But, those yields at 60 kgN/ha plot of hairy vetch were higher than those at 180, 240 kgN/ha plot of winter fallow. It suggested that corn absorbed enough nitrogen from hairy vetch with nitrogen fertilizer 60 kgN/ha and corn yields more increased due to rotational cropping with winter legume hairy vetch or increase of nutrient uptake from added organic matter of hairy vetch (Torbert, 1996).

Effect of nitrogen fertilizer reduction for corn by hairy vetch green manure

Nitrogen concentrations of grain and stover were not significantly different among nitrogen fertilizer rates at hairy vetch plots in 1997 showing grain N% of 1.43~1.48% and stover N% of 0.92~1.07%, respectively. But nitrogen concentrations of grain and stover at 0 kgN/ha plot of hairy vetch in 1998 slightly decreased by 1.39% and 0.77%, respectively.

At winter fallow plots, nitrogen concentrations of grain and stover were different largely according to nitrogen fertilizer rate. Nitrogen concentration of grain increased from 1.16% to 1.42% as nitrogen fertilizer rate increased from 0 kgN/ha to 120 kgN/ha and nitrogen concentration of stover increased from 0.49% to 0.97% as nitrogen fertilizer rate increased from 0 kgN/ha to 180 kgN/ha in 1997. Change of nitrogen concentration according to N fertilizer rate in 1998 was more clear than that in 1997 showing increase of grain N% from 1.13 to 1.47% as increase of nitrogen fertilizer rate from 0 to 180 kgN/ha and increase of stover N% from 0.38 to 0.91% as increase of nitrogen rate from 0 kgN/ha to 240 kgN/ha.

N concentrations of grain and stover at hairy vetch plots without nitrogen fertilizer were in the middle of nitrogen concentration between 120 and 180 kgN/ha at winter fallow plots in both two years. But nitrogen concentrations of grain and stover at 60 kgN/ha plot of hairy vetch were higher than those at 180 and 240 kgN/ha plot of winter fallow.

Fig. 1. shows regression curves for nitrogen uptake by corn according to nitrogen fertilizer rate within winter fallow plots and hairy vetch plots in 1997 and 1998, respectively. Corn nitrogen uptake, 235 kgN/ha at 0 kgN/ha plot of hairy vetch, was 141 kgN/ha higher than nitrogen uptake, 94 kgN/ha at 0 kgN/ha plot of winter fallow, and nitrogen fertilizer of 149 kgN/ha could be reduce by hairy vetch green

Table 5. Nitrogen concentrations of corn at harvest as affected by hairy vetch and nitrogen fertilizer rates.

Winter cropping	N rate (kgN/ha)	1997			1998		
		Grain	Stover	Whole plant	Grain	Stover	Whole plant
		N %					
Hairy vetch†	0	1.43	0.92	1.15	1.39	0.77	1.02
	60	1.47	1.00	1.21	1.48	0.91	1.12
	120	1.48	1.07	1.24	1.48	0.98	1.18
	180	1.48	1.02	1.24	1.45	1.00	1.18
	240	1.48	1.05	1.27	1.52	0.98	1.18
	Mean	1.47	1.02	1.22	1.46	0.93	1.14
Winter fallow	0	1.16	0.49	0.72	1.13	0.38	0.56
	60	1.29	0.74	0.98	1.19	0.46	0.70
	120	1.42	0.89	1.08	1.37	0.70	0.95
	180	1.45	0.97	1.18	1.47	0.84	1.08
	240	1.44	0.98	1.19	1.49	0.91	1.12
	Mean	1.35	0.80	1.03	1.33	0.66	0.88
LSD(0.05)							
‡WC(C)		0.06	0.14	0.10	0.10	0.10	0.09
N rate(N)		0.05	0.15	0.10	0.07	0.09	0.08
C × N		**	*	**	**	**	**
CV(%)		3	13	7	4	9	6

*,**Significant at the 0.05 and 0.01 probability levels, respectively. †,‡are the same as Table 2.

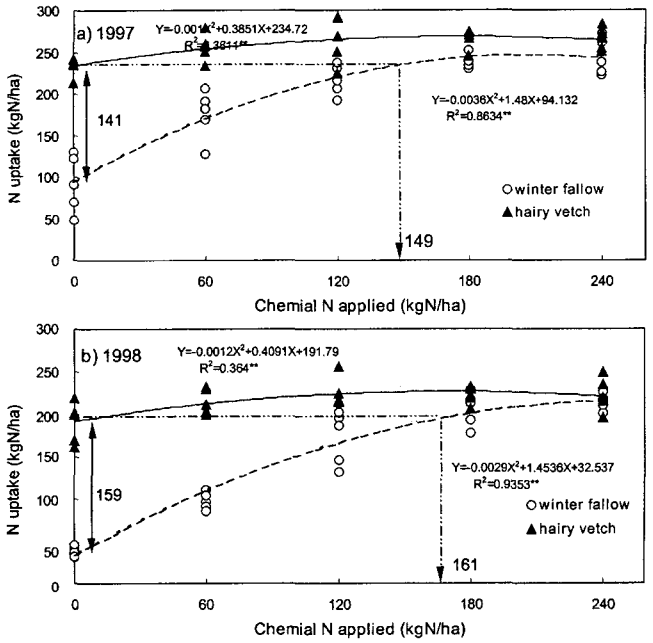

Fig. 1. Changes of nitrogen uptake of corn whole plant as affected by hairy vetch and nitrogen fertilizer rates in a) 1997 and b) 1998.

manure in 1997. Also, in 1998, corn absorbed more 159 kgN/ha at 0 kgN/ha plot of hairy vetch than at 0 kgN/ha plot of winter fallow, and N fertilizer of 161 kgN/ha could be reduced by hairy vetch green manure. On an average of two years, nitrogen uptake of corn increased as much as 159 kgN/ha and nitrogen fertilizer of 161 kgN/ha could be reduced by cultivation of hairy vetch in winter and soil incorporation of above-ground vetch nitrogen, 200 kgN/ha at corn planting. Utomo (1990) also reported that nitrogen fertilizer as much as 170 kgN/ha could be reduced by incorporation of hairy vetch in corn production, these results show that almost nitrogen fertilizer for growing corn could be reduced by cultivation of hairy vetch in winter season and its soil incorporation at corn planting.

But, only hairy vetch green manure without nitrogen fertilizer was slightly deficient for maximum corn production, so it is recommended that supplementary nitrogen, 50 kgN/ha which is 25% of total nitrogen fertilizer applied for corn, needs to be applied as supplementary nitrogen at the six-leaf stage of corn. Especially, yield and N uptake of corn at nitrogen fertilizer 60 kgN/ha of hairy vetch were higher than those at high nitrogen fertilizer plot such as 180 or 240 kgN/ha of winter fallow. In addition to yield increase, cultivation and soil incorporation can improve corn quality such as protein concentration of grain and stover by increase of its nitrogen concentration. Consequently, cultivation of hairy vetch in winter season and soil incorporation at corn planting is very important from standpoint of reducing chemical nitrogen fertilizer and increase of corn yield and quality in environment friendly agriculture. So it is thought that cultivation area of winter hairy vetch will be expanded from now in Korea.

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