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Soil Mineral Nitrogen Upteke and Corn Growth from Hairy Vetch with Conventional and No-Tillage Systems

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ABSTRACT: Winter hairy vetch (HV) can be used as green manure with conventional tillage system (CT), in which chemical N fertilizer required for cultivation of subsequent corn could be fully saved, or as cover crop with no-tillage system (NT) in which soil could be protected from erosion, control of weed, and the reduction of N fertilizer application. This experiment was carried out to compare the enrichment of soil mineral nitrogen (SMN) at corn root zone, and the changes of corn growth and N uptake according to HV amounts (winter fallow, aboveground HV removed, intact HV, and HV added from aboveground HV removed) under two tillage systems in the upland field of National Crop Experiment Station, Suwon, Korea in 1996. HV cultivation during winter decreased SMN a little at corn planting. HV incorporation with CT increased SMN rapidly during early growth stage according to rapid decomposition of HV. SMN by HV cover with NT was increased slowly and its increase was higher in the surface soil (soil layer 0~7.5cm) compared to deep soil layer 7.5~22cm. Corn growth and N status at corn silking stage, corn yield and N uptake at harvest were increased in proportion to aboveground HV amounts regardless of tillage system. Average hairy vetch nitrogen (HV-N) uptake efficiency by corn was 10% higher with CT than with NT in which average HV-N uptake efficiency was 43%. Corn yields were not different between two tillage systems, but corn N uptake was increased by 33 kg N/ha more with CT than with NT due to the increase of corn N concentration. The increase of SMN and corn N uptake from HV cover with NT could not be disregarded though those with CT were higher than with NT

Key words: Hairy vetch, Green manure, Cover crop, Soil mineral nitrogen, Corn nitrogen uptake

Annual winter legume, hairy vetch (HV) is one of the major cover crops or green manure crops for the expansion of sustainable or environment-friendly agriculture. HV as cover crop or green manure has many advantageous points such as high over-wintering ability and high plant N concentration (4%), so almost N fertilizer for the cultivation of subsequent corn could be reduced. There are optional two tillage systems with hairy vetch in cropping of corn. One is conventional tillage system (CT) in which HV is incorporated to soil as green manure, and the other is no-tillage system (NT) in which HV is killed with herbicide and covered on soil surface. Use of HV as cover crop with NT is not common in Korea now because no-till drill for planting corn is not available in farm, though over 50% of cultivation area is seeded with conservation tillage systems including no-tillage in USA. But we have many chances to introduce NT in silage corn or soybean production because major crops are getting cultivated in large scale area and costs for crop production in NT are lower than those in CT (Kim *et al.,* 1998; Lee, 2002) and soil erosion by heavy rain in summer could be reduced with NT largely.

The supply of hairy vetch nitrogen (HV-N) for soil and corn is high in case HV is incorporated to soil as green manure because HV incorporated to soil is decomposed easily by soil microbes with the release of mineral N from HV, which could be absorbed by corn at early stage (Power, 1991; Varco, 1989; Sarrantonio, 1988). But the decomposition or N release from HV covered on the soil surface is slower than that from HV green manure. The HV-N loss by ammonia volatilization and nitrification is higher with NT than with CT, particularly in condition of little rainfall during the HV decomposition(Wilson and Hargrove, 1986; Groffman *et al.,* 1987; Seo *et al,* 1998). Also soil mineral nitrogen (SMN) accumulated at surface soil (07.5cm) from HV cover with NT could be lost as N_2 gas easily depending on soil condition (Janzen, 1991; Power, 1991). In addition, corn could not use HV-N before corn silking stage at which corn absorbs 60~80% of total corn N because it takes a time for corn root to absorb mineral N soaked from HV cover into soil (Mitchell, 1977; Ebelhar, 1984; Blevins, 1990; Huntington *et al.,* 1985). But there are several papers that report enough N contribution from HV cover with NT for subsequent corn as much as 112 kg N/ha (Mitchell, 1977), 90~100 kg N/ha (Ebelhar, 1984) and 75 kg N/ha (Blevins, 1990) though its N contribution was lower than that of HV green manure with CT. So the purpose of this experiment was to compare the HV-N effect for soil and corn in the con-

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dition of between soil cover with NT and green manure with CT according to the amounts of aboveground HV .

MATERIAL AND METHOD

This experiment was carried out at the upland field of National Crop Experiment Station, Suwon, Korea in 1996. Soil properties of the field are shown at Table 1. Total precipitation during corn growing season from May 10th to August 31th, was 609 mm. Precipitation (27 mm) in May 1996 was as much as 70 mm less than that (95 mm) of 30 years normal average (Table 2). HV originated from Nebraska imported from USA (Pennington seed company), and was planted on September 20th previous crop year at seeding rate of 35 kg/ha. After over-wintering, HV was incorporated into soil as green manure by plow (22cm depth) and rotary tillage (CT) or covered on soil as cover crop killed by herbicide, Paraquat (1,1'dimethyl-4, 4-bipyridiumion) (NT). At one day before treatment, aboveground HV in one m^2 was cut and dried for the measurement of dry matter and N concentration. The amount of fresh matter, dry matter and N amount of aboveground hairy vetch were 13.8 ton/ha, 1.88 ton/ha and 77 kg N/ha, respectively (Table 3). The experimental plots were laid out in a split-plot design with 4 replications. Main plots were tillage systems which were consisted of conventional tillage system (CT) and no-tillage systems (NT), and sub-plots were aboveground HV amounts which were consisted of winter fallow-no N fertilizer (WF0), aboveground HV removed-no N fertilizer (HV0), intact HV (HV1), and HV added from aboveground HV removed (HV2), respectively. No chemical nitrogen was applied at all plots, and total phosphate (fused phosphate, 66 kg P/ha) and potassium (potassium chloride, 125 kg K/ha) were applied as basal fertilizer at corn planting. Corn variety was Pioneer 3394 (P3394) which has 115 days relative maturity and planting date was May 10th which was 5 days after HV treatment. Plant population was 66,667 plants/

Table 1. Physico-chemical properies of experimental soil.

Soil Texture (%)			Bulk Density	pH	Organic Matter	Available Phosphate	Ex. Cations (cmol$^+$/kg)		
Sand	Silt	Clay	(g/cm^3)	(1:5)	(g/kg)	(mg/kg)	K	Ca	Mg
41.4	45.9	12.7	1.28	5.70	15	51.0	0.24	2.30	0.95

Table 2. Mean temperature and precipitation during corn growing season in 1996.

Month	Ten days	Mean temperature (°C)		Precipitation (mm)	
		1996	30-years† average	1996	30-years† average
4	Early	6.4	9.0	5.0	22.7
	Middle	8.2	11.2	14.9	24.8
	Late	14.5	13.5	31.2	28.6
5	Early	15.0	15.0	23.0	33.3
	Middle	17.6	16.4	1.7	37.2
	Late	19.9	18.4	1.8	24.6
6	Early	22.4	20.0	44.2	33.2
	Middle	22.7	21.6	174.8	32.8
	Late	21.9	22.6	67.4	67.4
7	Early	23.4	23.6	57.1	95.9
	Middle	24.7	24.5	52.8	97.8
	Late	27.0	26.2	131.2	109.2
8	Early	28.7	26.0	0.8	103.4
	Middle	27.9	25.7	0.2	95.7
	Late	23.1	24.0	76.5	106.8

30-years: 1966~1996

Table 3. Dry weight, N concentration and N content of hairy vetch at corn planting.

Fresh weight (ton/ha)	Ratio of dry weight (%)	Dry weight (ton/ha)	N concentration (%)	N content (kg N/ha)
13.8	13.6	1.88	4.1	77

ha (75×20cm) and the area of one plot was 45 m^2 (5×9 m).

The changes of SMN were investigated at the plots of NT-HV1, CT-HV1, NT-WF0 and CT-HV1, respectively in two weeks interval from HV treatment time. Soil samples over soil 0~7.5 and 7.522cm depth were taken by auger from ten sites per plot at middle line between two corn rows and mixed well. At the time of sampling soil, 3 cores (100cm^3) per plot were also collected for soil bulk density from soil layer 07.5cm and 7.522cm. Soil ammonium was determined by the Indolphenol Blue method and soil nitrate was determined colorimetrically with Griess-Ilosvay method followed by reduction of nitrate to nitrite by copperized cadmium column (Keeny, 1982), respectively. The SMN amount over soil 0~7.5 and 7.5~22cm were calculated from the concentrations of SMN corrected by soil bulk density, respectively.

Stalk height, ear height and stem thickness were measured at corn silking stage. Chlorophyll meter reading (SPAD value) and ear-leaf N concentration and dead leaf percent were measured for corn N status of corn at silking stage. Chlorophyll meter reading (SPAD value) from 30 corn plants per plot were measured by using SPAD 502 (Minolta Corp., Japan). Furthermore, ten corn plants were harvested and its fresh weight was measured at silking stage. Three plants out of ten plants were collected and dried at 60°C for 48 hours for the determination of dry matter yield and corn nitrogen uptake at silking stage. Ten corn ear-leaves per plot were collected at silking stage. Ear-leaves were dried in dryer (60°C) for 48 hours and 5th internodes were dried at oven(105°C) for two hour and then dried at dryer (60°C) for 48 hours just after collecting it. Corn at stage of physiological maturity was harvested on September 1st. Thirty plants were sampled within two rows per plot. At harvest, three stovers and ten ears per plot were taken and stovers were chopped, dried with ear at 60°C for 48 hours, and weighed dry matters. Dried ears were hulled and grain moistures were measured by digital moisture tester (Burrows DMC 700, Seedburo, USA) and cobs were included to stovers. Grain yields were adjusted to 15.5 % moisture content. Corn stover at silking stage, and corn stover (including cob) and grain at harvest were ground by Wiley mill (Brabender, Germany). Total N concentrations of ear-leaf at silking stage and of stalk and grain at harvest were analyzed by the method of Na salicylate-Na Nitroprusside (Baethgen, 1989)

REESULTS AND DISCUSSION

Changes of soil mineral nitrogen

Fig. 1. shows the changes of soil mineral nitrogen (SMN) investigated at plots of CT-WF0, CT-HV1, NT-WF0 and NT-HV1 in two weeks interval from treatment, respectively.

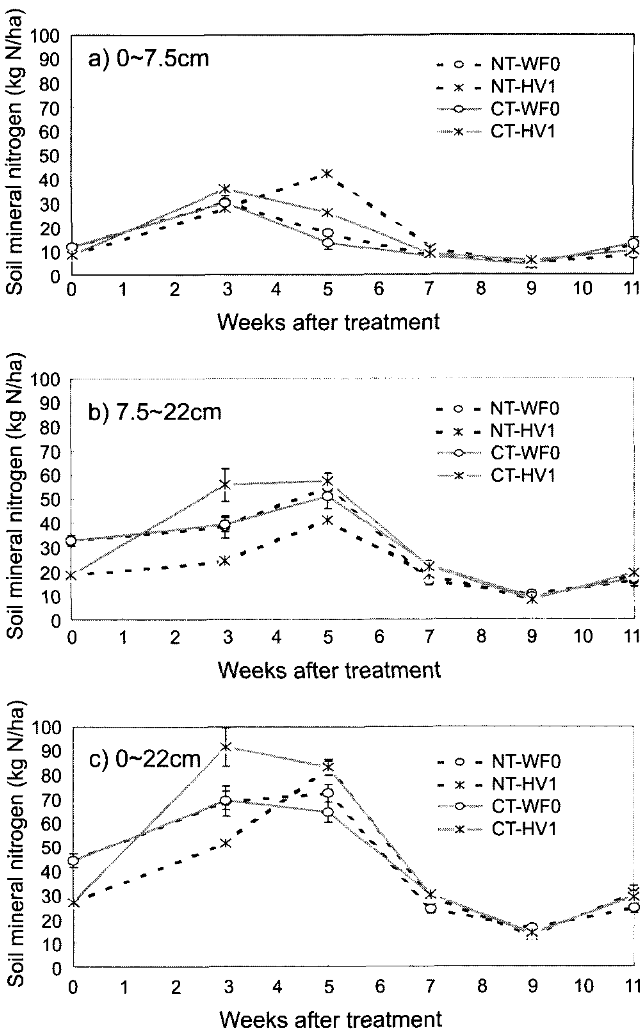

Fig. 1. Changes of amounts of soil mineral nitrogen (NO_3^--N+NH_4^+-N) amount at a) soil layer 0~7.5cm, b) soil layer 7.5~22cm, c) soil 0~22cm during corn growing season in 1996. (NT: no-tillage, CT: conventinal tillage, WF0: winter fallow-no N fertilizer, HV1L intact HV).

SMN amounts at surface soil (0~7.5 cm) at the time of treatment (May 7th) were similar at all plots as 811 kg N/ha (Fig. 1, a). SMN at the plot of CT-HV1 was 5 kg N/ha higher than that at the other plots at 3 weeks after treatment and was 8 and 12 kg N/ha higher than that at plots of NT-WF0 and CT-WF0 at 5 week after treatment, respectively. SMN at the plot of NT-HV1 was similar with those at plots of NT-WF0 and CT-WF at 3 week after treatment, but was 16 kg N/ha higher than that at the plot of CT-HV1 at 3 week after treatment because SMN from HV covered on soil was accumulated in surface soil. SMN amount at surface soil at 7 weeks (June 26th) after treatment were not different among four treatments according to rapid N uptake of corn.

The changes of SMN amount over soil 7.522 cm is shown at Fig. 1, b). SMN amounts over soil 7.522 cm at plots of

HV (NT-HV1 and CT-HV1) were 16 kg N/ha lower than those at plots of winter fallow (NT-WF0, CT-WF0) at treatment time (May 7th) because winter HV absorbed SMN during HV growing season.

SMN amounts over soil 7.522cm between at plots of NT-WF0 and CT-WF0 were similar during corn growing season. SMN amount over soil 7.522cm at the plot of CT-HV1 was 32 kg N/ha higher than that at the plot of NT-HV1 due to more N mineralization from HV incorporated to soil. But SMN amounts at the plot of CT-HV1 from 5 weeks after treatment were similar with those at plots of NT-WF0 and CT-WF0. SMN amount at the plot of NT-HV1 was lower than those of other plots without SMN recovery in soil until 5 weeks after treatment due to early lower level of SMN. This means that much SMN from HV covered on soil was not moved to soil over 7.522cm though mineral N was the highest at surface soil (07.5cm) among four treatments. This low SMN over soil 7.522cm at the plot of NT-HV1 would be related with lower rainfall in May 1996 than average rainfall. Leeves *et al.*(1993) reported that cultivation of winter cover crop such as crimson clover depleted SMN before corn planting and N stress due to the cultivation of crimson clover was not disappeared by N fertilizer until 3 weeks after corn planting. Total SMN amount over soil 022cm at 3 weeks after treatment was the highest at the plot of CT-HV1 and the lowest at the plot of NT-HV1, respectively. But SMN amounts at two plots at 5 weeks after treatment was not different.

The highest SMN amounts over soil 022cm from HV green manure with CT and from HV covered on soil with NT were 60 kg N/ha at 3 weeks after treatment and 50 kg N/ha at 5 weeks after treatment, respectively

Fig. 1. Changes of amounts of soil mineral nitrogen(NO_3^--N+NH_4^+-N) amount at a) soil layer 07.5cm, b) soil layer 7.522cm, c) soil layer 022cm during corn growing season in 1996. (NT: no-tillage, CT: conventional tillage, WF0: winter fallow-no N fertilizer, HV1: intact HV).

Corn Growth and N uptake

Table 4. represents growth and N status of corn at silking stage according to tillage system and aboveground HV amount. Corn growth and N status at silking stage didn't show significant interaction between tillage system and HV amount, and were not different between two tillage systems. But corn growth and N status at silking stage were getting better with the increase of aboveground HV amount. In the comparison of corn growth and N status at silking stage between at WF0 and at HV0, days to silking, stalk height

Table 4. Corn growth and N status at silking stage affected by tillage system and HV amounts.

Tillage system	HV amount	Days to Silking	Stalk height (cm)	Stem thickness (mm)	SPAD value	Earleaf N conc. (%)	Ratio of dead leaf (%)
CT[†]	WF0[‡]	71	225	18.5	50.9	1.72	36.2
	HV0	73	221	18.6	48.3	2.00	28.1
	HV1	71	230	19.4	54.6	2.62	25.8
	HV2	70	233	20.4	57.5	2.69	25.1
NT	WF0	71	226	18.0	47.9	2.10	36.6
	HV0	73	211	17.4	44.1	1.88	35.7
	HV1	71	222	18.5	51.2	2.18	28.5
	HV2	70	225	19.5	53.3	2.32	22.4
Average							
CT		71	227	19.2	52.8	2.26	28.8
NT		71	221	18.3	49.1	2.12	30.8
WF0		71	225	18.2	49.4	1.91	31.4
HV0		73	216	18.0	46.2	1.94	31.9
HV1		71	226	18.9	52.9	2.40	27.2
HV2		69	229	19.9	55.4	2.50	23.8
LSD(0.05)							
Tillage(T)		NS	NS	NS	NS	NS	NS
HV (H)		1	8	0.9	2.6	0.29	7.1
T×H		NS	NS	NS	NS	NS	NS
CV(%)		1.8	3.4	4.6	4.8	12.6	22.7

[†]CT: conventional tillage, NT: no-tillage
[‡]WF0: winter fallow-no N fertilizer, HV0: aboveground HV removed-no N fertilizer
HV1: intact HV, HV2: HV added from aboveground HV removed

and SPAD value were lower at HV0 than at WF0, but its difference was not significant. Stover DM at silking stage, whole DM and TDN yield at harvest didn't show significant interaction between tillage system and HV amount, and were not different between two tillage systems (Table 5). Stover DMs at silking stage, corn DM and TDN yields at

Table 5. Corn yields affected by tillage systems and HV amounts.

Tillage system	HV amount	Stover DM at silking (ton/ha)	DM yield (ton/ha)			TDN (ton/ha)
			Grain	Stover	whole	
CT†	WF0‡	6.77	8.66	9.65	18.31	12.98
	HV0	5.83	7.76	8.94	16.70	11.80
	HV1	7.29	9.65	10.66	20.31	14.41
	HV2	8.62	10.70	10.77	21.47	15.36
NT	WF0	5.86	7.28	8.88	16.16	11.35
	HV0	6.33	6.62	7.89	14.51	10.21
	HV1	6.99	8.51	9.64	18.15	12.84
	HV2	7.20	9.65	10.26	19.92	14.18
Average						
CT		7.12	9.19	10.00	19.20	13.64
NT		6.59	8.01	9.17	17.18	12.15
	WF0	6.32	7.97	9.27	17.24	12.17
	HV0	6.08	7.19	8.49	15.60	11.01
	HV1	7.14	9.08	10.15	19.23	13.62
	HV2	7.91	10.18	10.51	20.69	14.77
LSD(0.05)						
Tillage(T)		NS	NS	NS	NS	NS
HV (H)		0.68	1.41	0.91	2.21	1.66
T×N		NS	NS	NS	NS	NS
CV(%)		9.5	15.6	9.0	11.5	12.2

†, ‡CT, NT, WF0, HV0, HV1 and HV2 are the same as table 5

Table 6. N concentrations and N uptakes of corn at harvest affected by tillage systems and HV amount.

Tillage system	HV amount	N concentration (%)			N uptake (kg N/ha)		
		Grain	Stover	Whole	Grain	Stover	Whole
CT	WF0	0.88	0.45	0.63	64	44	109
	HV0	0.83	0.50	0.63	55	44	99
	HV1	0.95	0.65	0.78	78	70	148
	HV2	0.98	0.65	0.80	89	70	159
NT	WF0	0.73	0.40	0.53	45	36	81
	HV0	0.70	0.38	0.51	40	29	69
	HV1	0.88	0.45	0.63	64	44	107
	HV2	0.85	0.55	0.68	69	57	126
Average							
CT		0.91	0.57	0.71	72	57	129
NT		0.79	0.44	0.58	55	42	96
	WF0	0.80	0.43	0.58	55	40	95
	HV0	0.76	0.43	0.53	48	37	84
	HV1	0.91	0.55	0.70	71	57	128
	HV2	0.91	0.60	0.74	79	63	143
LSD(0.05)							
Tillage(T)		0.07	0.08	0.07	10	9	19
HV (H)		0.10	0.11	0.09	14	13	27
T×N		NS	NS	NS	NS	NS	NS
CV(%)		11.2	20.2	13.1	21.2	24.2	21.3

†, ‡CT, NT, WF0, HV0, HV1 and HV2 are the same as table 5

harvest also were not different largely between at WF0 and at HV0. But dry matter and TDN yield of corn at silking stage and at harvest, were increased linearly with the increase of aboveground HV amount.

Table 6. represents corn N concentration and N uptake at harvest according to tillage system and aboveground HV amount. Corn N concentration and N uptake at harvest didn't show significant interaction between tillage system, but those were increased more with CT as well as with the increase of aboveground HV amount. N concentrations of corn grain and stover were 0.12~0.13% higher with CT compared to with NT, particularly at plots of CT-WF0 and CT-H0 which were not included with aboveground HV though SMN was not increased at the plot of CT-HV0 (Fig. 1). N concentrations of grain, stover and whole plant were increased by the aboveground HV added from HV0, but the increase of N concentration at HV2 was a little, compared to that at HV1. The higher corn N concentration at the plot of NT-HV1 compared to NT-HV0 or NT-WF0, means that much mineral nitrogen from HV covered on soil was absorbed by corn. Corn absorbed more (33 kg N/ha) total N with CT compared to with NT. N uptakes of grain, stover and whole plant were not different between at WF0 and at HV0, and between at HV1 and at HV2, respectively, but whole plant N uptakes were increased more (33 and 44 kg N/ha) at HV1 compared to at WF0 or at HV0.

Whole N uptakes of corn was more (28 kg N/ha) with CT compared to with NT at WF0, and average whole N uptake was more (33 kg N/ha) with CT than with NT. The reason for higher corn N uptake in CT as much as 33 kg N/ha might be that net mineralization of soil N was greater with CT than with NT during the corn growing season (Skinner et al. 1983; Meisinger *et al.* 1985). Meisinger(1985) reported that the increase of corn whole N uptake with CT compared to with NT was 18 kg N/ha.

Corn N uptakes from aboveground HV at harvest (N uptakes at HV1, HV2 minus N uptake at HV0) were 49, 60 kg N/10a at the plot of CT-HV1 and CT-HV2, respectively and 38, 57 kg N/10a at the plot of NT-HV1 and NT-HV2, respectively. So corn absorbed 39% HV-N (at CT-HV2) and 64% HV-N (at CT-HV1) with CT (average 52%), and 37% HV-N (at NT-HV2) and 49% HV-N (at NT-HV1) with NT(average 43%), repectively. SMN amounts over soil 022cm were increased 60, 50 kg N/ha by aboveground HV with CT at about 3 weeks after treatment and with NT at about 5 weeks after treatment, respectively and it is thought that corn absorbed 80% of SMN increased by aboveground HV in proportion to the SMN amount from HV.

In this experiment, HV-N effect for corn as green manure with CT was higher than that as cover crop with NT, but main purposes of covering HV on soil surface with NT are soil conservation and weed control. We could anticipate enough N effect from HV cover crop with NT besides soil conservation and weed control though the N effect was lower than that of green manure with CT.

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