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Nitrogen Use and Yield of Silage Corn as Affected by Hairy Vetch (*Vicia villosa* Roth) Soil-incorporated at Different Time in Spring

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ABSTRACT : Winter green manure crops including legume increase grain yield of subsequent crop and substitute N fertilizer requirement with organic-N. Hairy vetch grows vigorously and can provide N-rich green manure for corn with its soil incorporation after wintering. But, grain yield of corn as succeeding crop would be reduced if its planting time is delayed until late spring. This experiment was carried out to find the proper incorporation time of hairy vetch green manure and planting time of subsequent corn in cropping system with winter hairy vetch(green manure)-summer corn. Hairy vetch was incorporated into soil at a ten-day interval between April 10 and May 10 and corn was planted at 5 days after each hairy vetch incorporation. Soil nitrate concentration on April 10 and 20 in hairy vetch plot was slightly lower than that at winter fallow. Above-ground dry matter and organic-N of hairy vetch increased linearly with delayed hairy vetch incorporation time from April 10 to May 10. Average dry matter and organic-N produced by hairy vetch were 5.7 ton/ha and 248 kgN/ha, respectively. Corn growth and yield decreased as delayed corn planting time after May in spite of increasing dry matter and N-yield of hairy vetch. Nitrogen concentration of corn grain, stalk and whole plant at harvest were the highest in May 5 planting, but total N-uptake of May 5 planting were not different from that of April 25 planting because of lower grain yield. It was concluded that the proper incorporation time of hairy vetch and corn planting time were April 20 and April 25, respectively, because grain yield was the highest and corn could use hairy vetch-N effectively to produce dry matter.

Keywords : hairy vetch, green manure, incorporation time, corn, nitrogen.

Modern farming which is highly dependent on chemical fertilizer has been blamed to increase soil erosion and acidification and to reduce soil organic matter in view of soil conservation. Sequential cropping of corn can drain the nutritional elements from soil to cause nutritional imbalance to succeeding crop. Therefore, it is necessary for corn culture to adapt crop rotation with green manure or cover crop of legume, typically soybean. However, cattle farms in Korea raise silage corn for major summer forage production, not enabling to rotate with summer legumes like soybean in the same season. It is essential to introduce winter legume to maintain soil fertility and to improve forage production. Hairy vetch is one of the best choices for winter legumes in corn-legume cropping system (Mitchell, 1977; Smith, 1987).

Hairy vetch can be used as a rotation crop for corn and its soil incorporation after wintering improves soil fertility and can supply additional nitrogen for succeeding corn growth (Power, 1991; Torbert, 1996; Utomo, 1990; Varco, 1989).

As hairy vetch has vigorous growth and high nitrogen fixation activity from mid-April to mid-May, the late harvest may increase both dry matter and nitrogen yield (Wager 1989).

The optimum planting date of corn in Korea is known as from mid to late in April. Thereafter then, there are sharp yield decrease with delayed planting (Kim, 1996). Therefore, we have to determine the optimum incorporation time of hairy vetch considering vetch growth and corn yields.

Our objective was to determine the optimum time of soil incorporation of hairy vetch as a green manure crop to maximize the succeeding corn yield and to improve N use efficiency.

MATERIALS AND METHODS

Field experiment was conducted at upland field of the Crop Experimental Station, Suwon, Korea. Hairy vetch, introduced from Pennington Company, Nebraska USA, was planted on September 10 and incorporated into soil on April 10, April 20, April 30 or May 10. At five days after vetch incorporation, medium-maturing corn variety, P3352 was sown on April 15, April 25, May 5 or May 15, respectively. This experiment was arranged in randomized block design with four replication and control plots were included in the respective treatments; different hairy vetch incorporation and corn seeding time. The control plot fallowed during winter and was applied with 200 kgN/ha, 150 kgP/ha, and

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150 kgK/ha for corn. Nitrogen fertilizer was split-applied with urea as starter N of 100 kgN/ha and topdressed N of 100 kgN/ha at 6 leaf stage. The green manure vetch plots were applied with 150 kgP/ha and 150 kgK/ha without N. At harvesting time of vetch, soil nitrate was examined in the four vetch incorporation and winter fallow treatments from soil depths of 0~15 cm and 15~30 cm. The concentration of soil nitrate was colorimeterically determined with Griess-Ilosvay method after NO_3^--N was reduced to NO_2^--N by copperized cadmium column (Keeney, 1982). Soil nitrate amount was calculated from nitrate concentration corrected by bulk density of soil.

The growth characteristics of corn were determined on June 18 and silking stage, and harvested at physiological maturity that appears black layer below kernel. Each sample size was 30 plants within two rows per plot.

At harvesting stage two corn plants were sampled for stalk and ten plants for grain per plot and dried in oven to obtain dry weight. Grain weight per ear was adjusted to 15.5% moisture content.

Corn stalk, ear and hairy vetch were dried at 60 for 48 h and weighed and ground by Willey mill. Total nitrogen of stalk and ear was analyzed by the Kjeldahl method (Kjel-Auto, MRK Co., Japan)

RESULTS AND DISCUSSIONS

Green manure production and soil nitrate-N as affected by soil incorporation time of vetch

Dry matter and nitrogen production of vetch significantly increased as soil incorporation date delayed. Dry matter of vetch increased from 4.61 ton/ha to 7.06 ton/ha as soil incorporation was delayed from April 10 to May 10. Nitrogen production increased from 185 kgN/ha at April 10 to 288 kgN/ha of May 10. Dry matter and nitrogen production were 5.7 ton/ha and 248 kgN/ha, respectively, on an average (Table 1).

Soil nitrate contents of 0~15 cm depth of May 1 and May 10 incorporation were 21.8 kgN/ha and 22 kgN/ha, respectively, which were about three times higher than those of April 10 and April 20 (Table 2). These increases were resulted not only from the increase of soil N mineralization with soil temperature rise, but also from the increase of decomposition in vetch green manure on soil surface. Soil nitrate contents of 15~30 cm depth of April 10 and April 20 incorporation were 7.3 kgN/ha and 7.8 kgN/ha, respectively, which were lower than those of winter fallow plots of April 10 and April 20. This decline was caused by nitrogen uptake of vetch during the winter. The soil nitrate contents of May 1 and May 10 recovered to the same levels of winter fallow plots. As for entire soil depth of 0~30 cm, total nitrate content was slightly decreased on April 10 and April 20 by vetch culture, which was insignificant amount compared to

Table 1. Dry weight and N yield in above-ground part of hairy vetch at soil incorporation.

Date	Fresh weight (ton/ha)	Dry weight (ton/ha)	N content (%)	N yield (kgN/ha)
April 10	34.62 c†	4.61 c	4.0 c	185 c
April 20	39.58 b	5.24 bc	4.5 b	236 b
April 30	42.32 b	5.90 b	5.0 a	284 a
May 10	61.79 a	7.06 a	4.1 c	288 a
Mean	44.58	5.70	4.4	248

†a,b,c : Means within a column not followed by same letter are significantly different by DMRT 5%.

Table 2. Soil nitrate amount at soil incorporation of hairy vetch.

Date	Depth 0~15 cm		Depth 15~30 cm		Depth 0~30 cm	
	Fallow	Vetch	Fallow	Vetch	Fallow	Vetch
	---------- NO_3^--N kgN/ha ----------					
April 10	10.2b†	8.1b	12.9a	7.3b	23.1a	15.4b
April 20	10.5b	8.0b	17.3a	7.8b	27.7a	15.9b
April 30	15.9a	21.8a	15.4a	14.0a	31.3a	35.8a
May 10	14.0ab	22.8a	13.4a	14.4a	27.5a	37.2a

†a,b,c : Means within a column not followed by same letter are significantly different by DMRT 5%.

Table 3. Corn growth on early stage (June 18) and silking stage as affected by planting date under urea control and hairy vetch treatment as green manure.

Planting date	Leaf numbe†		Plant height† (cm)		Stalk heigh‡ (cm)		Stem diameter‡ (mm)		Silking days	
	200N§	HV¶	200N	HV	200N	HV	200N	HV	200N	HV
April 15	7.5a#	7.6a	186a	174a	269a	267a	15.7bc	16.3b	84a	85a
April 25	7.3a	7.3b	159b	164b	271a	275a	16.3ab	17.3a	77b	78b
May 5	5.8b	5.5c	122c	107c	251b	254b	17.5a	16.0b	74bc	74c
May 15	4.2c	4.3d	64d	62d	245c	243c	14.7c	14.9c	71c	70d

†June 18, ‡silking stage.
§200 kgN/ha , ¶hairy vetch incorperation.
#a,b,c : Means within a column not followed by same letter are significantly different by DMRT 5%.

Table 4. Corn grain, dry matter of stover and whole plant at harvest time as affected by planting date under urea control and hairy vetch treatment as green manure.

Planting date	Grain		Stover		Whole plant		
	200N[§]	HV[¶]	200N	HV	200N (C)	HV(H)	H/C (%)
	ton/ha						
April 15	9.43a[#]	8.48a	10.97ab	11.38ab	20.40a	19.86a	97a
April 25	8.72a	8.14a	11.81a	12.07a	20.53a	20.21a	98a
May 5	8.73a	8.06a	10.13bc	10.27bc	18.86ab	18.33ab	97a
May 15	7.47b	7.55a	9.53c	9.86c	17.00b	17.41b	102a

[§,¶,#]the same as Table 3.

Table 5. N-concentration and N-uptake of corn at harvest as affected by planting date under urea control and hairy vetch treatment as green manure.

	Planting date	Grain		Stover		Whole plant		
		200N[§]	HV[¶]	200N	HV	200N (C)	HV (H)	H/C (%)
		%						
N concentration	April 15	1.47a[#]	1.27b	0.85a	0.76b	1.07ab	0.96b	89bc
	April 25	1.49a	1.38a	0.90a	0.77b	1.13a	0.99b	88c
	May 5	1.52a	1.47a	0.87a	0.90a	1.15a	1.13a	99a
	May 15	1.38b	1.38a	0.73b	0.66c	1.03b	0.95b	92b
		kgN/ha						
N uptake	April 15	112a	93a	92b	86a	204ab	179ab	87a
	April 25	113a	97a	106a	92a	218a	189a	88a
	May 5	115a	103a	88b	92a	203ab	195a	96a
	May 15	95b	90a	69c	65b	164c	156b	95a

[§,¶,#]the same as Table 3.

above-ground nitrogen production of approximately 200 kgN/ha.

Corn growth characteristics and grain yield

Corn growth was compared on June 18 between urea control and vetch incorporation treatment on different planting dates (Table 3). Plant height decreased gradually with the delay of planting both in urea control and vetch incorporation, while leaf number on 15 April and 25 April was similar between the two treatments. Stalk heights of both treatments at silking stage were not different between April 15 and April 25 planting and thereafter, decreased significantly with the delayed planting.

Corn grain yields in vetch incorporation were ranged 7.6-8.5 ton/ha by planting date, showing yield decrease as planting was delayed (Table 4). Corn stover weight did not differ between April plantings, but those of May planting were significantly lower than April plantings. Despite of the high biomass and N accumulation of vetch in May, biomass and grain yield of corn decreased with the delayed planting.

The late planting of corn reduced the total dry weight of corn in both of urea control and vetch incorporation treatment, showing no difference between the two treatments at the same planting date. This result indicated that green manure of vetch could be comparable to chemical N application.

Vetch-N uptake and N use efficiency in corn

Nitrogen concentration of grain, stover and whole plant in succeeding corn increased with the increase of vetch incorporation. But, May 15 planting resulted in poor growth and low nitrogen concentration due to delayed planting, even though large amount incorporation of vetch biomass. In urea control, May 15 planting was also lowest in nitrogen concentration (Table 5).

As shown in Table 5, N-uptake of corn in vetch incorporation ranged 87~96 % compared to urea control in four planting date, being 90% on an average. Thus, it is concluded that vetch incorporation could replace most of the corn N-uptake in urea application.

Amounts of corn N-uptake in vetch incorporation were not different among early three plantings, but there was a significant decrease in May 15 planting. In late planting, succeeding corn which was poor in growth could not use

Table 6. N use efficiency and its component in corn whole plant under urea control and hairy vetch treatment as green manure.

Planting date	N uptake efficiency (Nu/Ns)†		N utilization efficiency (Tw/Nu)†		N use efficiency (Tw/Ns)†	
	200N§	HV¶	200N	HV	200N	HV
April 15	1.02b#	0.97a	93.6ab	104.7a	95.6a	101.2a
April 25	1.09a	0.81b	88.7bc	101.1a	96.8a	81.9b
May 5	1.01b	0.69c	87.2c	88.5b	88.4ab	61.1c
May 15	0.82c	0.55d	97.8a	106.0a	80.0b	57.2c

†Tw : Total dry weight, Ns : Nitrogen applied, Nu : Nitrogen absorbed.
§,¶,#the same as Table 3.

effectively green manure-N despite of increased incorporation of vetch.

Although it was clear that total yield of corn was decreased significantly with the delayed planting after April 25, the incorporation of vetch should be postponed until April 30 (May 5 as successive corn planting date) to obtain a sufficient effect of vetch incorporation which could substitute that of urea fertilizer of 200 kgN/ha.

Nitrogen uptake and use efficiencies of corn were estimated according to Moll's method (Moll, 1982). Chemical N fertilization, as applied with urea form, had better N uptake and use efficiency than green manure vetch. In case of vetch incorporation, nitrogen uptake and use efficiencies decreased significantly with the increase of the vetch-N input by delaying the harvesting date of vetch. In urea control, nitrogen uptake efficiency, the proportion of absorbed N to applied N, was the highest in April 25 planting with 1.09, followed by April 15 with 1.02 and May 5 with 1.01. But, May 15 planting, delayed but largest incorporation of green manure, was the lowest in both nitrogen uptake efficiency and nitrogen use efficiency of 0.82 and 80.0, respectively (Table 6).

In case of winter vetch-corn cropping system, as green manure biomass and nitrogen yield of vetch was increased with the delay of vetch incorporation, nitrogen uptake in succeeding corn increased until May 5 planting. Since late planting in May 15 reduced corn growth and N uptake, the increased vetch-N input did not contribute to the increase of corn dry matter production.

April 25 planting was somewhat higher in the incorporated green manure vetch than April 15 planting, and slightly higher in the corn yield, nitrogen uptake amount and nitrogen uptake efficiency than April 15 planting. Although April 25 planting had produced higher vetch-N input than April 15 planting by 50 kgN/ha, there was no difference in corn grain yields between the two April plantings. Therefore, succeeding corn planting was recommendable to be finished from mid to late April, during which period vetch could produce green manure about 5 ton/ha dry matter and 200 kgN/ha. This amount of green manure-N would be enough to grow succeeding corn without any chemical-N fertilizer.

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