Korean J. Crop Sci. 47(2): 137~141(2002)

Decomposition and N Release of Hairy Vetch Applied as a Green Manure and its Effects on Rice Yield in Paddy Field

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ABSTRACT : Decomposition of green manure is necessary for the nutrient supply in farm soil. Hairy vetch as a green manure is superior to other winter legumes in terms of wintering ability and N accumulation. This experiment was carried out to investigate the decomposition and N release of hairy vetch and its effect on rice production as the following crop in paddy field. Decomposition of hairy vetch placed by soil depth of 0, 10 and 20 cm at transplanting time was investigated by mesh bag method, which was enclosed chopped residue in mesh bags. The fate of ^{15}N derived from ^{15}N-labeled hairy vetch was investigated at harvest in three levels of N fertilization. Grain yield of the transplanted paddy rice cultured with hairy vetch as starter N were compared with that of applying urea as starter N in the field. Hairy vetch residue decomposed very rapidly both in transplanted and dry-seeded paddy field. In transplanted paddy field, hairy vetch residue lost 72~81% and 86~90% of its weight after one and five month, respectively, as affected by incorporation depth. The C/N ratio of the decomposing vetch residue increased sharply during the early stages and after then, decreased slowly. The amounts of N and P released from the vetch were about 90% and 97% of initial content after one month, respectively. Recoveries of hairy vetch-^{15}N by rice plant were 30.6, 34.6 and 35.7% in 0, 6 and 12 kg urea-N $10a^{-1}$ application, respectively, indicating that N fertilization increased the recovery of hairy vetch-^{15}N. Hairy vetch residue incorporated as starter maintained significant NH_4^+-N concentration in soil water of plow layer until effective tillering stage. Grain yield in the plot applied with hairy vetch was not significantly different from that in the plot with urea. We concluded that hairy vetch incorporation could substitute starter N fertilization and showed possibility to reduce N amount of top-dressing.

Keywords : rice, hairy vetch, green manure, crop residue decomposition, nitrogen recovery, phosphorus

As the large nutrient requirement was required for high grain yield, the high input of fertilizers has been essential practice in rice culture. It has been reported that if chemical fertilizers are used on a long term, there could be negative influences to soil and the environment. The green manure incorporation has been considered as an alternative source of nutrients to chemical fertilizers, as long as it readily decomposed in field. Therefore, many species of legume were screened to use as green manure in various cropping system (Clement *et al.*, 1998; Daimon, 1999).

Vetches are widely grown in temperate regions of the world for green manure and forage and they are more tolerant to acid soil conditions than other legume crops. Hairy vetch, *Vicia villosa* Roth, as a cold-hardy vetch species is more tolerant in poorly drained soils than common vetch or hybrids (Hoveland and Donnelly, 1966). Nitrogen yield of hairy vetch in upland of Korea decreased as planting time was delayed in autumn and the maximum yield at next spring harvest was about 280 kg N ha^{-1} (Seo *et al.*, 2000). It was reported that hairy vetch can be used nitrogen supplier in various cropping system due to high plant nitrogen content and vigorous growth characteristics (Power, 1991; Seo *et al.*, 2000a; Seo *et al.*, 2000b; Seo *et al.*, 2001; Utomo, 1990).

Although several researchers have been studied on decomposition and nitrogen supply of hairy vetch in upland (Ranells and Wagger, 1996; Seo *et al.*, 1998; Stute and Posner, 1995), There has been little information available on the decomposition and N release of hairy vetch in paddy field. The purpose of this study was to investigate the decomposition and the fate of N released from hairy vetch and their effects on rice yield in paddy field.

MATERIALS AND METHODS

Decomposition of hairy vetch manure in paddy fields

A field study was conducted in silt loam soil of paddy fields at College Farm, Seoul National University, Suwon, Korea. The field was moderately well drained and soil plow layer contained 2.0% organic matter. The field was applied with 8 kg P_2O_5 $10a^{-1}$ and 8 kg K_2O $10a^{-1}$ as starter. Nitrogen fertilizer was split-applied with urea as starter N of 5 kg N $10a^{-1}$, topdressed N of 2.5 kg N $10a^{-1}$ at tillering stage and

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2.5 kg N $10a^{-1}$ at panicle initiation stage.

Hairy vetch manure that was dried and chopped into 10cm length was packed into 10 by 20 cm, 0.5 mm mesh nylon bag. Chemical compositions of the vetch were 32.0 mg N g^{-1} and 3.8 mg P g^{-1}. The bags were buried in soil depth; 0, 10 and 20 cm in transplanted and dry-seeded paddy fields and also, buried between rows of standing rice plant on June 1.

Mass and nutrient loss were determined from mesh bag recovered after a given time interval. The samples recovered from soil were washed the soil particles with water, and then dried at 70°C for more than 2 days, weighed and ground to pass a 1-mm sieve for chemical analysis. Total nitrogen was determined by the Kjeldahl method (Kjeltec auto sampler system 1035 analyzer). Phosphorus was determined by Molybdenum-blue method after digestion with 1 M HCl solution. Cellulose, lignin and silica contents were determined by Van Soest method with Fibertec system (Tecator Co., Sweden).

Fates of hairy vetch-^{15}N

A pot experiment was conducted to measure the fate of the vetch-^{15}N under different N fertilization levels between June and October. Pots of 1/5000a were filled with 4 kg of air-dried, sieved (1 cm) loam soil that contained 14.9 mg total C g^{-1} and 1.7 mg total N g^{-1}. At the same time, hairy vetch contained 33.8 mg N g^{-1} and 2.91 atom % ^{15}N was cut into 1 cm pieces and thoroughly mixed with the soil at the rate of 4 g DM/pot. And then, pots were submerged for 3 days before transplanting and kept submerged with a 5 cm water layer afterward. On June 1, two hills of 35 days old rice seedlings (cv. Hwaseongbyeo) were transplanted in each pot.

Nitrogen fertilization levels were 0, 120 and 240 mg N/pot. Nitrogen was split-applied as starter, tillering fertilizer and panicle initiation fertilizer with the rate of 50%, 25% and 25% respectively. Phosphate and potash were applied with the same amount of 80 mg/pot in 120 mg N/pot and 160 mg/pot in 240 mg N/pot.

The experiment was replicated four times in a randomized complete design. Rice plants in pots were grown under outdoor condition and kept enough space preventing shade. At harvest, plant samples were oven-dried at 70°C to a constant weight, weighed and ground to pass a 0.5 mm sieve. Soil samples that were excluded fresh organic matter were air-dried and ground to pass a 0.5 mm sieve to determine total N and ^{15}N. And then sub-samples of the soil were shaken with 2 M KCl solution for 1 hour and residual soils were air-dried to determine KCl non-extractable ^{15}N. Total N and ^{15}N of plant and soil were analyzed with stable isotope mass spectrometer (Isoprime-EA, Micromass co. UK).

Table 1. The amount of hairy vetch residue incorporation and N fertilization level in transplanted paddy field.

Treatment	Total N	Hairy vetch§	Urea N		
			Starter N	Top-dressing at TS†	Top-dressing at PIS‡
			kg N $10a^{-1}$		
T1	0	-	-	-	-
T2	6.2	6.2	-	-	-
T3	12	-	6	3	3
T4	12.2	6.2	none	3	3

†Tillering stage
‡Panicle initiation stage.
§200 kg DM $10a^{-1}$

The effects of hairy vetch incorporation on rice yield

A field experiment was conducted on silt loam soil of paddy fields at College Farm, Seoul National University, Suwon. The field was moderately well drained and soil plow layer contained about 2% organic matter. Before soil plowing, rice straw residue was completely removed by hand. Thirty-five days old rice seedlings of cv. 'Hwaseongbyeo' was transplanted at hill spacing of 30 cm by 15 cm on 25 May. Dried hairy vetch was incorporated into paddy soil at the rate of 200 kg DM $10a^{-1}$. Plots were arranged in a randomized complete block design with three replications. Rice yield was compared in combination of the vetch and urea N treatment (Table 1).

Soil water samples were taken from two sites within each plot and analyzed for NH_4^+-N by the indophenol method. Soil water was sampled just above hardpan of soil layer with vacuum pressure water sampler and filtered with Watman no. 42 filter paper prior to analysis.

RESULTS AND DISCUSSION

Decomposition rate of hairy vetch green manure

The vetch incorporated at transplanting date showed rapid decomposition regardless of incorporation depth in transplanted paddy field (Fig. 1). The fast decomposition of the vetch is probably due to higher N concentration and low C/N ratio. After first month incorporation, the vetch lost 72~81% of initial weight, after then, the loss was very small. During the rice growing season the decomposition rates of the vetch ranged 86~90% at three soil depths in paddy field. There was no difference in decomposition rate between soil incorporation depths. We also observed that all remains in mesh bags were mainly consisted of stem, which meant decomposition of leaf was faster than stem.

However, total weight loss from the mesh bags could be attributed to various loss components such as leaching,

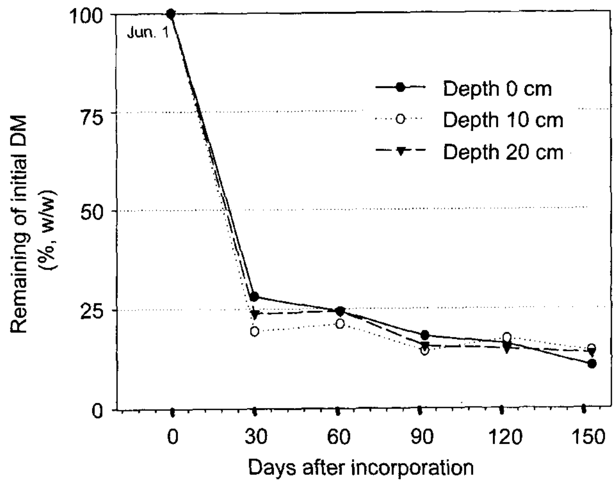

Fig. 1. Decomposition of hairy vetch at three soil incorporation depths in transplanted paddy.

microbial decomposition, loss of particles through mesh openings and clean-up procedure. It is generally accepted that legume residue was more fragile than cereal straw, so that physical losses were thought to a significant decomposition factor. Thus, it may be necessary to investigate the physical losses in the residue decomposition study.

Decomposition of the vetch incorporated into dry-seeded paddy field that was flooded in one month later also showed exponential decay pattern at three incorporation depths (Fig. 2). The vetch layered at soil surface was slowly decomposed than the vetch soil buried for initial two months. After flooding, however, the vetch layered at soil surface showed faster decomposition than the vetch soil buried, but it showed similar decomposition rate to the vetch soil buried in later decomposition stages. This result is caused by lack of moisture at soil surface during initial decomposition period. After five months the decomposition rate of the vetch reached around 95% regardless to incorporation depth.

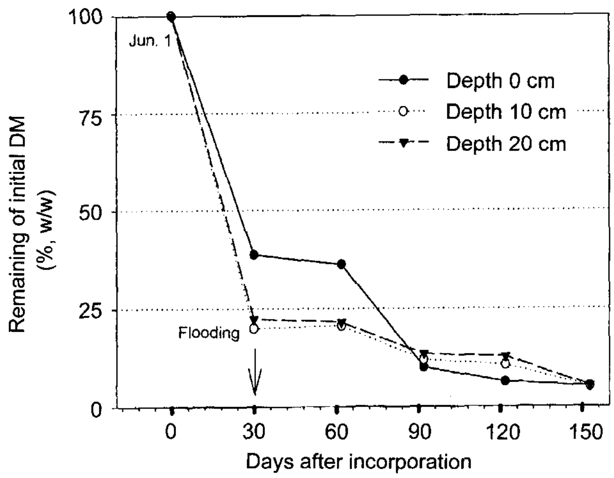

Fig. 2. Decomposition of hairy vetch at three soil incorporation depths in dry-seeded paddy.

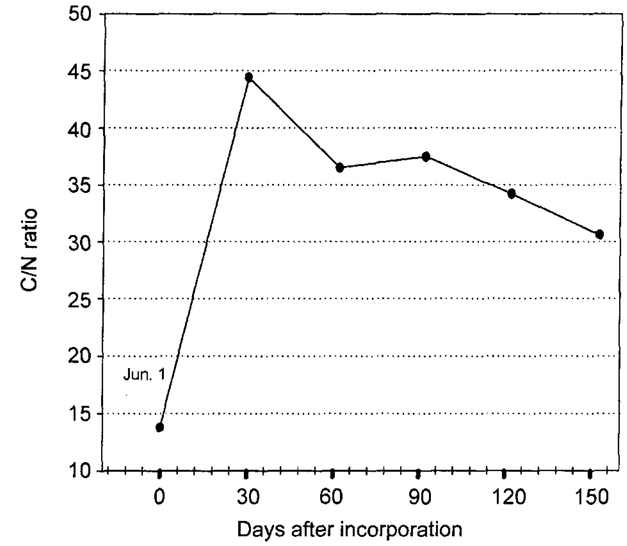

Fig. 3. Temporal changes of C/N ratio in hairy vetch residue decomposing at 10 cm incorporation depth in transplanted paddy.

Changes of C/N ratio during the decomposing procedure

C/N ratio of decomposing vetch increased sharply during the first month after incorporation and after then, slowly decreased (Fig. 3). The sharp increase was probably due to microbial decomposition or physical losses of easily decomposable nitrogen such as non-protein N and soluble protein N, and faster decomposition of leaf portion than stem portion of the residue. In general, leaf is generally more decomposable than stem because the N concentration of leaf was higher than that of stem. The N concentrations of leaf and stem of the vetch used were about 3.7% and 2.3%, respectively. We speculated that after the easily decomposable fraction of the vetch with low C/N ratio was disappeared, the decomposing remains changed into the substrate with high C/N ratio, which was fairly persistent to decomposer, therefore decomposition became slow after 1 month.

N and P release from hairy vetch manure

Overall changes of initial N and P content were somewhat similar to that of dry matter (Fig. 4). One month after incorporation there were sharp decreases of dry matter, N and P. The amounts of N and P released from the vetch were about 90% and 97% of initial content after one month, respectively. These large releases of N and P were probably associated with physical decomposition mechanisms such as

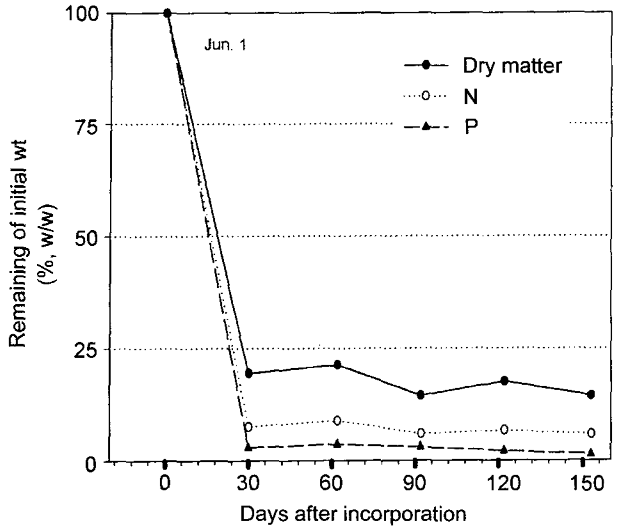

Fig. 4. Decreases in N and P contents of hairy vetch residue decomposing at 10 cm incorporation depth in transplanted paddy.

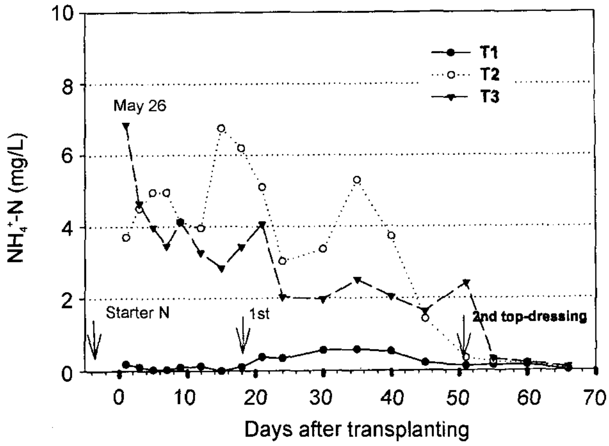

Fig. 5. Changes of NH_4^+-N concentration in paddy water collected hardpan as affected by hairy vetch incorporation and N fertilization levels (T1: 0 kg N 10^{-1}, T2: Hairy vetch only, corresponded 6.2 kg N $10a^{-1}$, T3: Urea 6 kg N $10a^{-1}$, 3 kg N $10a^{-1}$, and 3 kg N $10a^{-1}$ split application as starter, 1st top-dressing, and 2nd top-dressing, respectively).

particulate loss and soluble nutrient leaching. We did not determine the water-soluble substrates, but significant losses of soluble components have been reported (Christensen, 1985). In addition, P release rate was faster than N, because P is probably more easily leachable than N.

Fates of ^{15}N released from ^{15}N-labeled hairy vetch manure

Hairy vetch labeled with ^{15}N was incorporated into pot to investigate the fate of N released from the vetch under three N fertilization levels.

Increased N application with hairy vetch incorporation improved N uptake. There were not significant differences between two fertilization levels (Table 2).

The total recoveries of the vetch-^{15}N in rice plants and soil were 71~78% of the added amount in the vetch as affected by N fertilization (Table 2). The ^{15}N uptake by rice plants was 31~36% from the nitrogen of hairy vetch manure at harvest as affected by N fertilization. The higher N application increased recovery rate due to vigorous growth. N uptakes derived from the vetch by rice plants were relatively high compared with other study. In other study using ^{15}N-labeled hairy vetch residue, corn recovered about 15% of the added ^{15}N (Seo *et al.*, 2000). Soil recoveries of the vetch-^{15}N ranged 40~43% as affected by N fertilization levels and showed larger amount than rice plant recovery (Table 2). About one third to half of soil residual N was existed as inorganic N form at harvest. While N fertilization increased rice plants recovery the vetch-^{15}N, it did not increased soil recovery of the vetch-^{15}N.

Effects of hairy vetch incorporation on rice yield

The concentration of NH_4^+-N of soil water collected above hardpan was analyzed to investigate N supply of hairy vetch (Fig. 5). The plot with urea fertilization (T3) showed the

Table 2. Fates and losses of hairy vetch-^{15}N under different nitrogen fertilization levels in transplanting rice culture.

Treatments		Plant N Uptake§ (mg N/hill)	Recovery of ^{15}N(% of vetch -^{15}N)					Loss
			By plant§	By Soil†			Plant + Soil	
^{15}N -hairy vetch (g/pot)	Urea N (mg N/pot)			KCl extractable	KCl Non-extractable	Total		
4	0	285.2b‡	30.6b§	20.9	19.3	40.2a	70.8a	29.2
4	120	319.3a	34.6a	16.5	26.9	43.3a	77.9a	22.1
4	240	329.4a	35.7a	13.5	29.1	42.6a	78.3a	21.6

†Excluded rice root debris.
‡Values followed by the same letter within a column do not differ significantly at DMRT 5% level.
§Above ground portion.

Table 3. Yield and yield components of rice as affected by organic material input and N fertilization levels.

Treatment	No. of panicles m^{-2}	No. of spikelets/ panicle	Filled grains (%)	1000-grain weight (g)	Grain yield (kg $10a^{-1}$)	Harvest index
T1	285b	68.9a	95.3a	28.1a	475.8c	0.50a
T2	449a	57.3b	92.9b	27.0b	581.2b	0.46c
T3	421a	74.2a	92.3b	26.1b	677.9a	0.48ab
T4	430a	70.2a	89.0c	26.0b	651.8a	0.48bc

¶Values followed by the same letter within a column do not differ significantly at DMRT 5% level.
†T1: 0 kg N $10a^{-1}$, T2: Hairy vetch only, corresponded 6.2 kg N $10a^{-1}$, T3: Urea 6 kg N $10a^{-1}$, 3 kg N $10a^{-1}$, and 3 kg N $10a^{-1}$ split application as starter, 1st top-dressing fertilizer, and 2nd top-dressing fertilizer, respectively, T4: Hairy vetch corresponded 6.2 kg N $10a^{-1}$ as green manure and urea 3 kg N $10a^{-1}$ and 3 kg N $10a^{-1}$ as 1st top-dressing and 2nd top-dressing, respectively.

highest value right after fertilization and had the tendency to decrease continuously. The plot with hairy vetch incorporation (T2) was somewhat different pattern from T3. The plot with hairy vetch incorporation (T2) had the tendency to maintain higher concentration of NH_4^+-N than that of the plot with urea fertilization (T3) until about 40 DAT except early period. Urea became readily decomposed in flooded paddy. After puddling, large portion of N was probably leached through percolating water prior to first sampling for 4 days after starter N fertilization. Meanwhile, the vetch N was more persistent to leaching loss because it was less decomposable than urea.

In early rice growth stage like two weeks after transplanting, small seedlings did not uptake large portion of N fertilizer applied in paddy. The inorganic N could leach readily from plow layer to become unavailable to rice plants.

Grain yield in the plot (T4) that incorporated hairy vetch into soil and applied N top-dressing was not significantly different from that in the plot (T3) applied with urea as starter N without green manure vetch (Table 3). The plot with green manure vetch without top-dressing N (T2) had the sufficient panicles with the effective N supply from the vetch (Fig. 5), decreased the grain yield and harvest index mainly due to fewer spikelet number in panicle induced by N supply shortage. In addition, we observed the excessive growth and lodging in T4, which might have resulted in lower percent of filled grain in T4.

Hairy vetch incorporated into paddy field as green manure was very rapidly decomposed and released most of added N during first month, and persisted N supply effectively to rice plants until around effective tillering stage. Therefore, hairy vetch incorporation to supply starter N had the possibility to substitute chemical N fertilization of top-dressing at tillering stage as well as starter N fertilization.

ACKNOWLEGEMENT

We thank the Brain Korea 21, the Ministry of Science & Technology for the financial support.

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