(Korean J. Crop Sci.) 44(1) : 44~48(1999)

Nitrogen Translocation and Dry Matter Accumulation of Direct Seeded Rice in No Tillage Rice-Vetch Cropping

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ABSTRACT

Uptake, assimilation and translocation of nitrogen and dry matter assimilation and translocation in ten rice cultivars were observed in no-till direct-sown rice-vetch cropping system. There was a large degree of variation in N-uptake, grain yield, nitrogen translocation efficiency and dry matter assimilation and translocation in tested rice cultivars.

Forty kg N/ha base, as compound fertilizer (21-17-21% of N-P-K) three weeks after sowing and 30 kg N/ha top-dressed at panicle initiation stage as in the form of $(NH_4)_2CO_2$ was applied.

'Newbonnet', 'Daesanbyeo', and 'Hwayeongbyeo' showed higher translocation efficiency. The contribution of pre-heading dry matter assimilates to grain ranged from 33% to 99% of dry grain weight. Dry matter of 'Calrose 76' was lower than Newbonnet but N content was higher in Calrose 76 than Newbonnet. By maturity, N content in vegetative parts declined considerably more than dry matter, vegetative and reproductive parts, N translocation efficiency, and N harvest index. Nitrogen translocation efficiency was greater in 'Nonganbyeo', Daesanbyeo, and Newbonnet.

Grain N concentration was positively correlated with N concentration or N content of the vegetative parts at heading in Nonganbyeo, 'Dasanbyeo', 'Dongjinbyeo', and Newbonnet.

These results indicated that the greater amount of dry matter and N accumulated before heading stage, the higher translocation rates of dry matter to grain and the greater net losses at maturity.

Key word : N translocation, no-tillage, direct-sowing, rice, cultivar, translocation efficiency.

Photosynthetic assimilates and nitrogen accumulated in the rice body before heading are of great importance because grain yield greatly depends on translocation of pre-heading assimilates to the grain (Tadahiko & Koji, 1981). Jiang (1994) indicated that a higher proportion of panicle-bearing tillers lead to the higher rate of photosynthesis of leaves after heading as well as dry matter production at the milk-ripening stage. But the different climatic conditions resulted in delayed heading time which reduced the filled grain ratio and grain weight very seriously in Korea, Japan, and China. Although big panicle will improve the photosynthetic rate, cultivars with big panicle have late heading which reduce the grain fertilization and grain filling rate (Jiang, 1994). Late heading of late maturing rice is a very serious problem in direct-seeded rice because heading of direct seeded rice is about 10 days later than the conventional transplanting system : delayed heading leads to decrease in photosynthesis.

The real amount of vegetative dry matter that is lost during the ripening period is difficult to assess though these loses cannot be considered as merely the result of wasteful respiration because they instead represent a necessary expenditure of energy for synthetic reactions in connection with the reallocation process (Austin et al., 1977). The calculated proportion of yield provided by translocation of pre-heading assimilates for rice was reported to be 45% to 63% (Tadahiko & Koji, 1981). Strong agreement between the calculated assimilate demand by kernels and the changes in dry weight and total nonstructural carbohydrates genetic variability in dry matter mobilization has been reported. It was also reported that translocation depends on environmental conditions as well as on the genetic control (Fujita & Yoshida, 1984)

Total N accumulation in cereal crops is maximized by the time of heading and subsequently decreases throughout maturity, with final N contents of 60% to 80% of that found at heading (Mae & Ohira, 1981). Several studies have indicated that grain N in rice primarily originates as a result of translocation from vegetative parts after heading (Fujita & Yoshida, 1984). Other studies have shown that the relationship between grain protein concentration and N translocation or N-translocation efficiency is not consistent (Peterson et al., 1975). However, Bhatia & Rabson (1976) have reported that protein concentration in grain might be improved by selecting genotypes that translocate a higher percentage of N from vegetative organs to the grain.

The objective of this study was to asses the varietal differences of ten rice cultivars in accumulation of dry matter and nitrogen accumulation in the leaf sheath and culm and remobilization of these assimilates to grain under a no-till direct sown rice-vetch cropping system. The study was also conducted to investigate the extent of possible net N losses which occurred from heading to maturity and to clarify the translocation of nitrogen and dry matter by the panicle size.

MATERIALS AND METHODS

The experiment was carried out on a farm at Sacheon, Korea during the vetch and rice growing seasons in

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Received 7 Jan. 1999.

1996~1997. The ten rice cultivars used were Calrose 76, Newbonnet, Nonganbyeo, Dasanbyeo, Daesanbyeo, Donganbyeo, Hwasambyeo, Chucheongbyeo, Dongjinbyeo, and Hwayeongbyeo.

The experimental design was a complete block with three replications at a rate of nitrogen (N) which was applied three weeks after sowing with compound fertilizer (21-17-21%, N-P-K) and 30kg/ha of N was top-dressed at panicle initiation stage as $(NH_4)_2CO_2$. Plots were 5 m long and consisted of 10 rows with a width of 40 cm.

Pre-germinated rice seeds of ten rice cultivars were directly over-sown in a lodged vetch canopy at the rate of 75 kg/ha on June 2, 1997. Submerged condition was maintained for 10 days before sowing at the maturing stage of vetch. The soil was clay loam, 30%, 39%, and 38% of sand, silt, and clay, respectively with pH 5.7 and 1.7% of organic matters.

One meter row segments of plant samples from each plot were taken at heading and maturity times. Heading stage was determined when 50% of the panicle was headed and maturity was decided when almost all the spikelets in the plot showed complete loss of green color. The whole plants including root part were pulled out of the soil and were separated into leaf gleen color. The whole plants including the roots were pulled out of the soil and were separated into leaf blade, culm and leaf sheath, and panicle at heading, and also at maturity. These samples were dried at 70℃ and weighed. Grain yield in each plot was determinated by harvesting a 1m² area. All dry vegetative samples were first ground in a sample mill and then finely reground using a 60-mesh screen in Cyclotec. Grain samples were ground directly using the same screen. Nitrogen concentration was determinated by the standard macro-Kjeldhal procedure.

The various parameters referring to dry matter and N movement within the rice plant were evaluated by the following equations:

* Dry matter translocation (ton/ha)=Dry matter at heading- [(leaf+culm)+panicle] dry matter at maturity.
* Dry matter translocation efficiency (%)=(Dry matter translocation/dry matter at anthesis)×100.
* Contribution of pre-heading assimilate to grain (%) =(Dry matter translocation/grain yield)×100.
* Harvest Index (HI)=grain yield/total above ground biomass at maturity.
* Nitrogen translocation (kg/ha)=N content at heading- [(leaf+culm)+panicel] N content at maturity.
* Nitrogen translocation efficiency (%)=(N translocation/N content at heading) × 100.
* Nitrogen lost (−) or gained (kg/ha)=N content at maturity-N content at heading.
* Nitrogen at heading lost or gained (%)=(N lost or gained/N content at heading)×100.
* Nitrogen harvest index (HI_N)=Grain N/total N content of aboveground parts at maturity.

RESULTS AND DISCUSS ION

Dry matter accumulation and remobilization

Differences in dry matter at heading and maturity were observed among the cultivars (Table 1). Amounts of above ground vegetative dry matter at heading time was the highest in Newbonnet but was the lowest in Chucheongbyeo. The highest vegetative dry matter of Newbonnet at heading stage originated from fast vegetat-

Table 1. Varietal difference in dry matter (DM) of different parts of rice plant at heading and maturing stages, dry matter translocation efficiency (DMTLE), and N harvest index in ten rice cultivars under rice-vetch relaying cropping system.

Cultivar	DM at heading time			DM at harvesting time				DMTLE†	CPHG‡	Harvest index
	Leaf +Culm	Hull	Total	Leaf +Culm	Hull	Grain	Total			
	ton/ha							%	%	−
Calrose 76	8.40bc§	0.61a	8.95b	4.23c	1.22a	5.45b	10.83bc	35d	54e	0.50bc
Newbonnet	9.44a	0.15e	9.59a	4.19c	0.31e	4.50e	9.49e	52a	99a	0.53a
Nonganbyeo	8.50b	0.20e	8.73c	4.98b	0.40de	5.39bc	11.04b	37d	56de	0.51b
Dasanbyeo	8.50b	0.54b	8.99b	5.34a	1.08bc	6.42a	12.59a	24e	33f	0.49c
Daesanbyeo	8.20cd	0.24d	8.39e	4.03cd	0.49d	4.52e	9.20f	45b	78c	0.51b
Donganbyeo	8.10c	0.19de	8.29ef	4.97b	0.37de	5.34c	9.98d	34d	60de	0.46e
Hwasambyeo	8.50b	0.15e	8.60d	5.06b	0.30e	5.37bc	10.17b	37d	64d	0.47d
Chucheongbyeo	7.07d	0.50c	8.21f	3.40e	1.00c	4.40f	8.88g	43bc	74c	0.50bc
Dongjinbyeo	850b	0.18de	8.64d	5.00b	0.37de	5.38bc	10.58c	36d	59de	0.49c
Hwayeongbyeo	8.30bc	0.25d	8.56de	3.98d	0.49d	4.47ef	8.86g	46b	87b	0.50bc

† DMTLE: Dry matter translocation efficiency.
‡ CPHG: Contribution of pre-heading assimilates to grain.
§ Means with the same letter in each column are not significantly different at 0.05 probability level by Duncan's multiple range test.

ive growth at the tillering stage. A marked decrease in dry matter of both leaf and culm and hull between heading and maturity was observed in Dasanbyeo, Calrose 76, and Donganbyeo. Vegetative dry matter losses during ripening were also observed in other reports and varied greatly with environmental factors (Akita & Blanco, 1989). However, Yoneyama et al. (1989) reported a cultivar with a dependent increase in vegetative dry matter at maturity.

Cultivars differed markedly in the change of dry matter between heading and maturity and also in dry matter translocation efficiency (Table 1). The greater dry matter at heading revealed the higher proportion of dry matter translocation. Newbonnet, Daesanbyeo, and Hwayeongbyeo showed relatively higher translocation efficiency (52%, 45%, and 46%, respectively). One explanation for the differences in translocation efficiency among cultivars is that in different grain filling period during that time the plant retains an amount of assimilates reserves in the culm and leaf sheath at heading and essentially utilizes these as a supplemental source for various physiological funtionss such as survival and reaction to environmental stresses. The amounts of dry matter retained depends on the cultivars and prevailing growth conditions, which is supported by another report that genetic variability in dry matter translocation has been observed (Akita et al., 1989). The fact that dry matter translocation efficiency of Newbonnet was exceptionally high compared with the other cultivars probably indicates that this cultivar has rapid ripening or structural and funtional high-translocation charactreristics.

Decreasing temperatures and declining soil moisture controls prevailed during ripening after heading in autumn which limits net assimilatioon rates, therefore, the pre-heading dry matter contributes greatly to grain yield. Varietal differences in the contribution of pre-heading assimilates to grain ranged from the highest of 99% to the lowest of 33 % (Table 1). Yoshida (1972) reported that large movement of assimilates can occur under low soil fertility conditions. In this experiments, a no-till direct-sown rice-vetch cropping system was maintained with low chemical fertilizer input every year.

No correlation was found between the harvest index (HI) and dry matter translocation efficiency or the contribution of pre-heading assimilates to grain (data not shown). Although the HI values were highest in Newbonnet, grain yield did not show the highest ranking.

Nitrogen content and translocation

The N content at heading in the leaf and culm and hull was highest in Calrose 76 among the tested rice cultivars. But the dry matter production of Calrose 76 was lower than that of Newbonnet. N content of Newbonnet was high but N concentration was similar to other cultivars. Cultivars differed in their ability to accumulate N in vegetative parts before heading. Varietal variations of N content was associated with both variations in dry matter and N concentration (Table 1 and 2).

Cultivars differed in their ability to accumulate N in vegetative parts prior to heading. N uptake in rice cultivars was associated with both variations in dry matter and N concentration (Table 1 and 2). By maturity, the N content in vegetative parts declined more than in dry matter.

Large varietal differences in N-translocation efficiency ranged from 58% in Dasanbyeo to 67% in Newbonnet in this experiment (Table 3). The high-yielding variety Dasanbyeo showed the lowest N-translocation efficiency. This was probably due to the late maturation and maintaining leaf greenness longer before to harvesting time.

Correlation coefficients between N parameters are shown in Table 4.

Grain N concentration was positively correlated with N% and N content of vegetative parts at heading in

Table 2. Nitrogen content (%) and nitrogen yield uptaken by rice plant at heading time in no-till direct-sown rice-vetch cropping systems.

Cultivar	N contents		Amount of N uptaken		
	Leaf+culm	Hull	Leaf+culm	Hull	Total
	%		N kg ha^{-1}		
Calrose 76	1.7cd†	1.6a	108a	9ab	117a
Newbonnet	2.0a	1.3bc	91bc	9ab	100cd
Nonganbyeo	1.8bc	1.4b	93b	10a	102c
Dasanbyeo	1.8bc	1.3bc	89bc	10a	99cd
Daesanbyeo	1.8bc	1.3bc	79c	8bc	87e
Donganbyeo	1.9ab	1.6a	99ab	8bc	107bc
Hwasambyeo	1.6d	1.4b	93b	7cd	100cd
Chucheongbyeo	1.8bc	1.4b	87bc	6d	94d
Dongjinbyeo	1.6d	1.5ab	94ab	8bc	102c
Hwayeongbyeo	1.7cd	1.5ab	98ab	7cd	105bc

† Means with the same letter in each column are not significantly different at 0.05 probability level by Duncan's multiple range test.

Table 3. Nitrogen translocation efficiency and N harvest index at harvesting time of rice in no-till direct-sown rice-vetch cropping system.

Cultivar	N-translocation efficiency†	N harvest index‡
Calrose 76	57.7e§	0.58de
Newbonnet	67.9a	0.64b
Nonganbyeo	66.0ab	0.63bc
Dasanbyeo	58.4d	0.52f
Daesanbyeo	64.1b	0.64b
Donganbyeo	61.2c	0.62c
Hwasambyeo	59.9cd	0.55e
Chucheongbyeo	60.8c	0.59d
Dongjinbyeo	59.2cd	0.59d
Hwayeongbyeo	64.5b	0.68a

† (N translocation / N content at heading) × 100,
‡ Grain N / total N content of aboveground parts at maturity.
§ Means with the same letter in each a column are not significantly different at 0.05 probability level according to Duncan's multiple range test.

Nonganbyeo, Dasanbyeo, and Dongjinbyeo, while nitrogen content was correlated with the grain N only in Newbonnet.

N-translocation efficiency was higher in Nonganbyeo, Dasanbyeo, Daesanbyeo, and Newbonnet. Grain N was correlated with N content at heading and N translocation in Calose 76, Dasanbyeo, and Chucheongbyeo, while no correlation was observed in the other cultivars. The correlation coefficient of HIN vs. N content at heading was negatively correlated in Dasanbyeo, Donganbyeo, Dongjinbyeo, and Hwayeoungbyeo.

Nitrogen losses of rice plant during ripening

Nitrogen content of above ground plant parts at heading and maturity were compared in cultivars (Table 5). The highest N loss was observed in Hwayeongbyeo with 8 kg/ha and the highest gain of N was observed in Dasanbyeo with 36 kg/ha. The nitrogen gains ranged from 1 kg/ha to 36 kg/ha depending on the cultivars. A wide variety of plant species reported N loss from heading to maturity and the loss for rice plants under paddy conditions was also reported (Mae and Ohira, 1981).

Nitrogen loss or gain was associated with both N content of the rice plant at heading and amount of N in the grain at harvest time (Table 5). The above observations supported the idea that the N losses depend primarily on the N content of the rice plant at heading.

Volatilization of N and leaching of mobile nitrogenous compounds from the tops of plants explained the larger proportion of N loss. Harper et al. (1987) found that 11% of the potential N available for redistribution was lost as volatile NH_3 in wheat. It is suggested that the N decline in plant tops reflected a lack of carbohydrates. In this situation the conversion of NH3 to amines was delayed, (Allison, 1966) or there was a limited capacity to store fertilizer (Winzeler & Farquhar, 1980).

In summary the vegetative dry matter and N content were always greater at heading than maturity for the conditions adopted in this study. The yield of rice was determined to a great extent by mobilization of dry matter to grain. The dry matter translocation efficiencies reported in this work were quite high, and great amounts of dry matter at heading resulted in a large proportion of translocated dry matter. In these results, rice cultivars, such as Dasanbyeo, Nonganbyeo, and Chucheongbyeo revealed very low grain fertility and grain weight. The conclusion of this study from the data obtained is that Newbonnet is the most adaptable plant type and Dongjinbyeo is also recommended for it's high fertility and 1,000-grain weight for no-till direct sowing rice-vetch

Table 4. Correlation coefficients between various N parameters for ten rice cultivars in no-till rice-vetch relaying cropping system.

Cultivar	Gain N (%) vs.			Gain N yield vs.			HI_N vs.
	N %[a]	N amount†	TE†	N amount‡	NTL‡	NTE‡	N content†
Calrose 76	0.98**	0.81	0.82	0.99**	0.99**	0.99**	−0.85
Newbonnet	0.98**	0.98**	0.91*	0.97**	0.99**	0.91*	−0.86
Nonganbyeo	0.99**	0.84	0.98**	0.97**	0.92*	0.84	−0.95*
Dasanbyeo	0.99**	0.92*	0.98**	0.98**	0.99**	0.99**	−0.99**
Daesanbyeo	0.86	0.93*	0.98**	0.99**	0.94*	0.92*	−0.87
Donganbyeo	0.98**	0.92*	0.96**	0.84	0.70	0.96**	−0.99**
Hwasambyeo	0.91*	0.99**	0.98**	0.93*	0.79	0.95*	−0.72
Chucheongbyeo	0.93*	0.84	0.96**	0.81	0.81	0.99**	−0.95*
Dongjinbyeo	0.99**	0.98**	0.94*	0.97**	0.86	0.94*	−0.99**
Whayeongbyeo	0.98**	0.98**	0.97**	0.98**	0.81	0.90*	−0.99**
Combined	0.96**	0.92**	0.95**	0.94**	0.88**	0.94**	−0.92**

NTL= Translocation, NTE= N-translocation efficiency, HI_N= Nitrogen Harvest index, †: Those at heading time, ‡: Those at harvesting time
*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Table 5. Nitrogen lost(−) or gained, N content at heading, grain yield and percentage of N at heading lost(−) or gained in no-till rice- vetch cropping system.

Cultivar•	N lost or gained N (kg/ha)	N content at heading (kg/ha)	Grain yield (ton/ha)	Percentage of N at heading lost or gained
Calrose 76	0d†	117a	4.72bc	−0.1e
Newbonnet	4d	100d	4.38cd	4.0d
Nonganbyeo	18b	102b	4.96b	17.7b
Dasanbyeo	36a	99b	5.41a	36.5a
Daesanbyeo	13c	87c	4.10d	14.5bc
Donganbyeo	1d	107b	4.07d	1.0de
Hwasambyeo	10d	100b	4.21cd	9.8cd
Chucheongbyeo	2d	94bc	3.93d	1.6de
Dongjinbyeo	13c	102b	4.57c	12.4c
Hwayeongbyeo	−8e	105b	3.85d	−8.0f

† Means with the same letter within a column are not significantly different at 0.05 probability level by Duncan's multiple range test.

cropping system.

ACKNOWLEDGMENTS

This work was supported by Grants-in-Aid from the Ministry of Agriculture and Forestry, Korea.

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