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# Variation of Nitrogen Use Efficiency and Its Relationships with Growth Characteristics in Rice Cultivars

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**ABSTRACT: This experiment was conducted to investigate the variation of nitrogen use efficiency, nitrogen uptake efficiency, physiological utilization efficiency and their relationships with growth characteristics in the 28 Korean rice cultivars. Nitrogen use efficiency of 28 rice cultivars was 47.74, nitrogen uptake efficiency was 0.71, and physiological utilization efficiency was 68.76 in average. Nitrogen use efficiency of rice cultivars had low variation ranged from 44.09 to 51.91, but nitrogen uptake efficiency were relatively high variation from 0.51 to 0.90, and physiological utilization efficiency was from 51.71 to 94.26. The high efficient group in nitrogen uptake efficiency whose value was calculated above 0.80 included Daeanbyeo, Seojinbyeo, Ansungbyeo, Dongjinbyeo, and Hwaanbyeo, while the low efficient group with below 0.60 was Kwanganbyeo, Sampyeongbyeo, Soorabyeo, and Hwasungbyeo. Hwasungbyeo, Sampyeongbyeo, Soorabyeo for physiological utilization efficiency were more efficient cultivars, while Daeanbyeo, Seojinbyeo, Ansungbyeo were less efficient cultivars. Nitrogen uptake efficiency had positive correlation coefficients between dry matter weight of plant (0.842**), leaf area index (0.761**), and leaf nitrogen content (0.599**), respectively. Therefore, the dry matter weight of rice plant and leaf area index was important characters to evaluate nitrogen uptake efficiency in rice cultivars. Also, more efficient cultivar in nitrogen uptake had higher chlorophyll meter value, which was appeared dark green color.**

***Keywords***: nitrogen use efficiency, nitrogen uptake efficiency, physiological utilization efficiency, chlorophyll meter value

Nitrogen is an essential element for crop growth and high yield. Many farmers have applied a high level of nitrogen for high yield. Nitrogen that was not absorbed has created environmental pollution problem by nitrification, denitrification, ammonia volatilization, and runoff. It is important to use nitrogen efficient crop cultivars to produce the high yield and to reduce the environmental contamination.

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Nitrogen use efficiency has been researched for rice (Singh *et al.*, 1998; Ladha *et al.*, 1998; Broadbent *et al.*, 1987), wheat (Ortiz. *et al.*, 1997), and maize (Hirel *et al.*, 2001). Nitrogen use efficiency was calculated as grain yield / available nitrogen content (soil + fertilizer nitrogen or only fertilizer nitrogen). Nitrogen use efficiency was divided into nitrogen uptake efficiency, nitrogen utilization efficiency. Nitrogen uptake efficiency was calculated as plant nitrogen content / available nitrogen content (soil + fertilizer nitrogen or only fertilizer nitrogen), nitrogen utilization efficiency was calculated as grain yield / plant nitrogen content (Moll *et al.*, 1982). Also, nitrogen utilization efficiency was called physiological nitrogen utilization efficiency (Singh *et al.*, 1998) or nitrogen use efficiency for grain production (Borrell *et al.*, 1998).

Broadbent *et al.* (1987) has used plant parameters for evaluating nitrogen utilization efficiency of 24 rice cultivars. Those plant parameters were dry matter production, total nitrogen uptake, uptake of soil nitrogen, uptake of fertilizer nitrogen, percent nitrogen derived from fertilizer, weight of panicle, grain yield, harvest index, and nitrogen harvest index. They have has founded weight of panicle / uptake of fertilizer nitrogen, weight of panicle / uptake of soil nitrogen, weight of panicle were correlated with dry matter production / uptake of fertilizer N, weight of panicle / total N uptake, grain yield. Also, they have ranked the rice cultivars according to weight of panicle / uptake of fertilizer nitrogen, weight of panicle / uptake of soil nitrogen, and grain yield / total nitrogen uptake.

We have carried out this experiment to investigate the variation of the nitrogen use efficiency in Korean rice cultivars, and to find the possibility of cultivar selection with high nitrogen use efficiency, and its relationships with the growth characteristics of rice cultivars.

## MATERIALS AND METHODS

This experiment was conducted at the paddy field in Kyonggido Agricultural Research and Extension Services. The 28 rice cultivars were transplanted with the planting

density of 30 × 14 cm on 20 May, 2002. We have applied nitrogen, phosphorus, potassium with 110 - 45 - 57 kg/ha, respectively. The split application rates of nitrogen were 50 %, 30%, 20% at basal, tillering stage, panicle initiation stage application, respectively, while 100% of phosphorus amount at basal application, and 70%, 30% of potassium amount were applied at basal, panicle initiation application, respectively. The soil characteristics of paddy field were analyzed as shown in Table 1.

Plant samples of the 28 rice cultivars were taken at 7days after nitrogen application of panicle initiation stage, and were dried at 72°C, for 72hours. Nitrogen was analyzed with Kjeltec Auto 1032 / 38 (Tecator Inc.). Rice leaves of fresh weight 0.5g were powdered with liquid nitrogen, and pigments were extracted with 4 volumes of 80% (v/v) acetone until complete bleaching. Total chlorophyll was quantified by measuring Abs652nm, and its concentration was calculated as described by Arnon (1949).

We have collected data of plant dry weight, leaf area index with Li-3000 (Li-Cor. Inc), and green color of rice leaf with chlorophyll meter 1000 (Spectrum Tec., Inc) at 7days after nitrogen application at panicle initiation stage.

We have evaluated N efficiency in terms of nitrogen use efficiency (yield / nitrogen application rate), uptake efficiency (plant nitrogen content / nitrogen application rate), and physiological utilization efficiency (yield / plant nitrogen content) of rice cultivars.

## RESULTS AND DISCUSSIONS

### Variation of nitrogen use efficiency in rice cultivars

Although many rice cultivars have been cultured for a long time in Korea, there were not many reports about nitrogen economy of the Korean cultivars in paddy field.

In 28 Korean cultivars, nitrogen use efficiency of 28 rice cultivars was 47.74, nitrogen uptake efficiency was 0.71, and physiological utilization efficiency was 68.76 in average (Table 2). Nitrogen use efficiency of rice cultivars showed low variation ranging from 44.09 to 51.91, but nitrogen uptake efficiency showed relatively high variation from 0.51 to 0.90, and physiological utilization efficiency was from 51.71 to 94.26.

We have classified the rice cultivars into three groups as high group, medium group, and low group in nitrogen efficiency. The high efficient group in nitrogen uptake efficiency whose value was calculated above 0.80 included Daeanbyeo, Seojinbyeo, Ansungbyeo, Dongjinbyeo, and Hwaanbyeo, while the low efficient groups with below 0.60 were Kwanganbyeo, Sampyongbyeo, Soorabyeo, and Hwasungbyeo. Hwasungbyeo, Sampyeongbyeo, Soorabyeo for physiological utilization efficiency were more efficient cultivars, while Daeanbyeo, Seojinbyeo, Ansungbyeo were low efficient cultivars (Table 3). Variation of uptake efficiency may result from differences in quantity and rate of N uptake from soil depths, plant associative $N_2$ fixation, rhizosphere effects and N mineralization pattern in the soil. Variation of physiological utilization efficiency may result from differences in critical N requirement concentration for expansion, growth, mass accumulation, organ formation, and the ability to translocate, distribute, redistribute the absorbed N among various organs, use in photosynthesis (Ladha *et al.*, 1998).

Nitrogen uptake efficiency of rice cultivars had positive correlation with dry matter weight of plant, leaf area index, leaf nitrogen content. The uptake efficiency had significant correlation coefficients among dry matter weight of plant, (0.842**), leaf area index (0.761**), and leaf nitrogen content (0.599**), respectively. Therefore, the dry matter weight of rice plant, leaf area index and leaf nitrogen content can be used important characters for selecting rice cultivars with high uptake efficiency. But, they had negative correlation coefficients with physiological utilization efficiency. Physiological utilization efficiency of rice plants had positive correlation with yield (Table 4). Hwasungbyeo had higher physiological utilization efficiency than other cultivars. Hwasungbyeo had larger grain yield and the nitrogen content absorbed from fertilizer was lower than other rice cultivars.

We have considered that the cultivars with high uptake efficiency can be used for environmentally friend farming system. The cultivars with high uptake efficiency had higher nitrogen content than cultivars with low uptake efficiency from nitrogen application. Therefore, the cultivars with high uptake efficiency could reduce the contamination of water environments including river and sea. The rice cultivars with high physiological utilization efficiency had high grain yield, low plant N content. Physiological utilization efficiency was used for high-yielding rice production.

**Table 1.** The soil characteristics of experimental paddy field.

| pH (1 : 5) | O.M (g/kg) | Av.$P_2O_5$ (mg/kg) | EC (dS/m) | T-N (mg/kg) | Ex. Ca.(cmol/kg) | | | Av.$SiO_2$ (mg/kg) |
|---|---|---|---|---|---|---|---|---|
| | | | | | K | Ca | Mg | |
| 5.7 | 22.8 | 46.2 | 11.5 | 0.13 | 0.38 | 6.90 | 1.65 | 206 |

**Table 2.** Variation of nitrogen use efficiency, uptake efficiency, physiological utilization efficiency, plant nitrogen content, yield in rice cultivars.

| Maturity group | Cultivar | NUE[1)] | UE[2)] | PUE[3)] | Plant N Content (kg/10a) | Yield (kg/10a) |
|---|---|---|---|---|---|---|
| Early | Daejinbyeo | 48.00 | 0.63 | 75.86 | 6.96 | 528 |
| | Sampaekbyeo | 48.45 | 0.66 | 73.50 | 7.25 | 533 |
| | Sangmibyeo | 48.91 | 0.62 | 78.32 | 6.87 | 538 |
| | Odaebyeo | 48.18 | 0.72 | 66.80 | 7.93 | 530 |
| | Obongbyeo | 48.18 | 0.66 | 73.04 | 7.26 | 530 |
| | Jinbubyeo | 47.73 | 0.68 | 69.78 | 7.52 | 525 |
| | Taebongbyeo | 50.73 | 0.70 | 77.20 | 7.73 | 558 |
| Medium | Kwanganbyeo | 46.73 | 0.56 | 82.76 | 6.21 | 514 |
| | Bongkwangbyeo | 44.09 | 0.74 | 59.95 | 8.09 | 485 |
| | Sampyeongbyeo | 50.27 | 0.54 | 93.83 | 5.89 | 553 |
| | Seojinbyeo | 46.82 | 0.89 | 52.45 | 9.82 | 515 |
| | Seokjungbyeo | 49.18 | 0.64 | 77.16 | 7.01 | 541 |
| | Soorabyeo | 49.55 | 0.54 | 92.59 | 5.89 | 545 |
| | Ansanbyeo | 51.55 | 0.63 | 81.42 | 6.96 | 567 |
| | Ansungbyeo | 47.36 | 0.88 | 53.69 | 9.70 | 521 |
| | Anjungbyeo | 46.64 | 0.81 | 57.75 | 8.88 | 513 |
| | Janganbyeo | 44.18 | 0.75 | 58.54 | 8.30 | 486 |
| | Jinpumbyeo | 45.45 | 0.66 | 68.92 | 7.26 | 500 |
| | Hwasungbyeo | 48.36 | 0.51 | 94.26 | 5.64 | 532 |
| | Hwajungbyeo | 44.27 | 0.75 | 58.94 | 8.26 | 487 |
| | Hwajinbyeo | 46.45 | 0.78 | 59.89 | 8.53 | 511 |
| Late | Daeanbyeo | 46.64 | 0.90 | 51.71 | 9.92 | 513 |
| | Dongjinbyeo | 51.91 | 0.86 | 60.22 | 9.48 | 571 |
| | Saechuchungbyeo | 46.09 | 0.76 | 60.98 | 8.31 | 507 |
| | Ilpoombyeo | 47.45 | 0.69 | 68.35 | 7.64 | 522 |
| | Chuchungbyeo | 45.18 | 0.69 | 65.66 | 7.57 | 497 |
| | Hwamyeongbyeo | 49.91 | 0.83 | 60.33 | 9.10 | 549 |
| | Hwaanbyeo | 48.55 | 0.86 | 56.47 | 9.46 | 534 |
| | Mean | 47.74 | 0.71 | 68.76 | 7.84 | 525.18 |
| | SD | 2.10 | 0.11 | 12.32 | 1.22 | 23.12 |
| | CV(%) | 4.40 | 15.61 | 17.92 | 15.60 | 4.40 |

1) NUE (Nitrogen Use Efficiency) : Yield / N application rate
2) UE (Uptake Efficiency) : Plant N content / N application rate
3) PUE (Physiological Utilization Efficiency) : Yield / Plant N content

### Relationships between nitrogen uptake efficiency, physiological utilization efficiency, and chlorophyll meter value of rice cultivars

As most nitrogen absorbed by plant root move to shoot including stems, leaves, and grains, leaf color can be an indicators for nitrogen contents during vegetative stage. Chlorophyll meter 1000 that measured leaf color under bright condition was used for non-destructively estimating the nitrogen content of leaf as observing the green color of leaf. Leaf N content was positively correlated with chlorophyll content of rice cultivars (Fig. 1). High chlorophyll meter value means that the leaf has high nitrogen content.

There were the close relationships between nitrogen uptake efficiency, physiological tilization efficiency and chlorophyll meter value of rice leaf. As nitrogen uptake effi-

**Table 3.** Rice cultivars were classified into high, low groups in nitrogen uptake efficiency and physiological utilization efficiency.

| Groups | Cultivars |
|---|---|
| High nitrogen uptake efficiency | Daeanbyeo (0.90), Seojinbyeo (0.89), Ansungbyeo (0.88), Dongjinbyeo (0.86), Hwaanbyeo (0.86) |
| Low nitrogen uptake efficiency | Hwasungbyeo (0.51), Soorabyeo (0.54), Sampyeongbyeo (0.54), Kwanganbyeo (0.56) |
| High physiological utilization efficiency | Hwasungbyeo (94.26), Sampyeongbyeo (93.83), Soorabyeo (92.59), Kwanganbyeo (82.76) |
| Low physiological utilization efficiency | Daeanbyeo (51.71), Seojinbyeo (52.45), Ansungbyeo (53.69), Hwaanbyeo (56.47), Anjungbyeo (57.75) |

**Table 4.** Correlation relationships between uptake efficiency, physiological utilization efficiency and growth characteristic parameters of rice cultivars.

| | Dry matter weight | LAI | Leaf N content | Yield |
|---|---|---|---|---|
| N uptake efficiency | 0.842** | 0.761** | 0.599** | -0.200 |
| N physiological utilization efficiency | -0.814** | -0.765** | -0.617** | 0.456* |

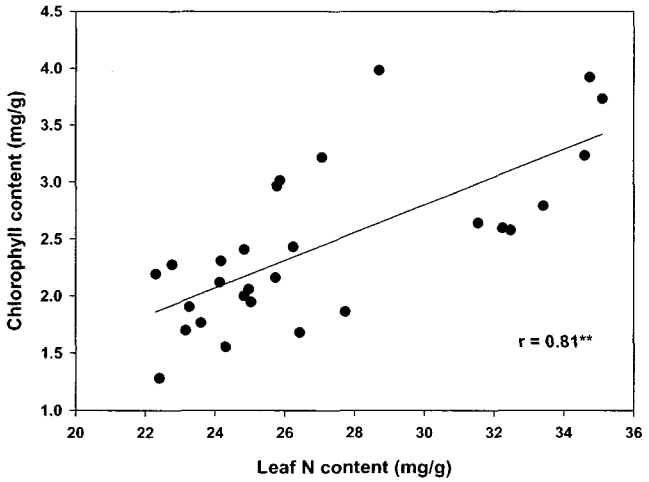


**Fig. 1.** Relationship between leaf N content and chlorophyll content of rice cultivars.

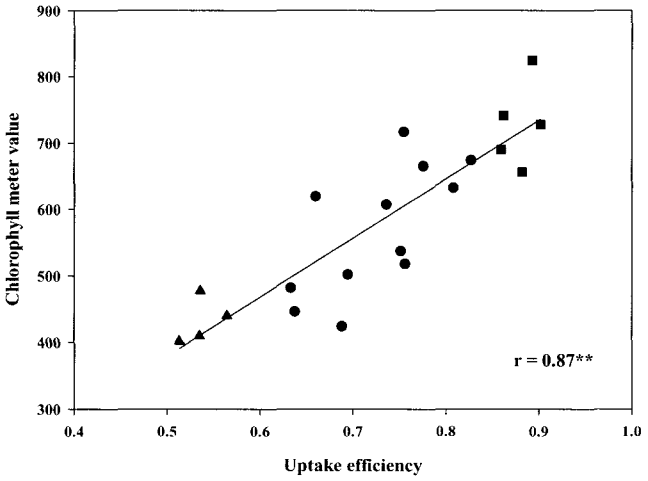


**Fig. 2.** Relationship between uptake efficiency and chlorophyll meter value of rice cultivars (■ ; high uptake efficiency, ● ; medium, ▲ ; low).

ciency of rice cultivars increased, chlorophyll meter value of rice leaf increased (Fig. 2). Rice cultivars with high uptake efficiency had higher nitrogen uptake than cultivars with low uptake efficiency. When physiological utilization efficiency of rice cultivars has increased, chlorophyll meter value of rice leaf has decreased (Fig. 3). Because, high physiological utilization efficiency of rice cultivars means that rice plant with small N content produce high grain yield. So uptake efficiency of rice cultivars positively correlated with chlorophyll meter value and physiological utilization efficiency had negatively correlated with chlorophyll meter value.

Peng *et al.* (1996) has compared N use efficiency of SPAD-based N fertilizer management with recommended N fertilizer applied at each growth stages. Increased recovery efficiency from applied N and greater utilization of the acquired N to produce grain contributed to the significantly greater fertilizer N efficiency of the SPAD based than of recommended N treatments. So, chlorophyll meter 1000 can

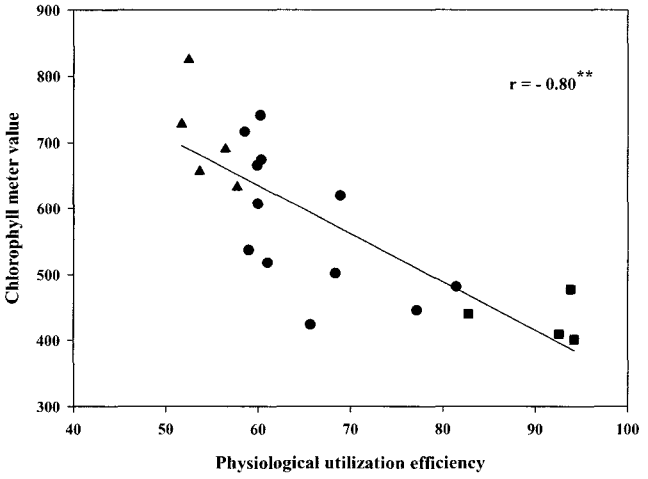


**Fig. 3.** Relationship between physiological utilization efficiency and chlorophyll meter value of rice cultivars (■ ; high physiological utilization efficiency, ● ; medium, ▲; low).

also be used to evaluate nitrogen uptake efficiency and physiological utilization efficiency of rice cultivars as SPAD.

We have researched the variation of nitrogen use efficiency of rice cultivars at N 11 kg/10a application only. It was necessary to evaluate nitrogen use efficiency and its relationships with growth characteristic parameters of rice cultivars with wider levels of nitrogen application rates, and nitrogen application at different growth stages of rice cultivars.

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