Variation of Nitrogen Use Efficiency and Its Relationships with Growth Characteristics in Korean 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 of rice cultivars. Variation in nitrogen use efficiency of rice cultivars was very low (44.09 to 51.91), but there were a high variation in nitrogen uptake efficiency (0.51 to 0.90), and physiological utilization efficiency (51.71 to 94.26). On average, nitrogen use efficiency of the 28 rice cultivars was 47.74, nitrogen uptake efficiency was 0.71, and physiological utilization efficiency was 68.76. Nitrogen uptake efficiency was positively correlated with plant dry matter (0.842**), leaf area index (0.761**), and leaf nitrogen content (0.599**). Therefore, the dry matter weight of rice plant was more important than leaf area index and leaf nitrogen content for characterizing nitrogen uptake efficiency, and the rice cultivars with high nitrogen uptake efficiency had higher chlorophyll meter value.

Media summary

It was important to use nitrogen efficient rice cultivars to produce high yields and reduce environmental contamination.

Key Words

Nitrogen use efficiency, nitrogen uptake efficiency, physiological utilization efficiency, chlorophyll meter value

Introduction

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 and nitrogen utilization efficiency. Nitrogen uptake efficiency was calculated as plant nitrogen content / available nitrogen content (soil + fertilizer nitrogen or only fertilizer nitrogen), and 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). We have carried out this experiment to investigate the variation in nitrogen use efficiency of rice cultivars, the selection of rice cultivars with high nitrogen use efficiency, and the relationships of nitrogen use efficiency with the growth characteristics of rice cultivars. 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. He found that weight of panicle / uptake of fertilizer nitrogen, weight of panicle / uptake of soil nitrogen and weight of panicle were correlated with the other parameters. Also, he has 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.

Methods

This experiment was conducted in the paddy field in Kyonggido Agricultural Research and Extension Services, Korea. The 28 rice cultivars were transplanted with a planting density of 30 ? 14cm on 20 May, 2002. We applied nitrogen, phosphorus and potassium at 110, 45 and 57 kg/ha, respectively. The split application rates of nitrogen were 50%, 30%, 20% at basal, tillering, and panicle initiation stages, respectively. All of the phosphorus was applied as a basal dressing, and 70% and 30% of the potassium was applied at basal and panicle initiation stages, respectively. We collected data for 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 7 days after nitrogen application at panicle initiation stage. Plant samples were taken 7 days after nitrogen application of panicle initiation stage, and were dried at 72 ?C, for 72 hours. Nitrogen was analyzed with Kjeltec Auto 1032/38 (Tecator Inc.). We evaluated N efficiency of rice cultivars in the 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).

Results

Although many rice cultivars have been cultured for a long time in Korea, there are few reports about the nitrogen economy of Korean cultivars in paddy fields. Variation in nitrogen use efficiency of 28 Korean cultivars was very low from 44.09 to 51.91, but there were a high variation in nitrogen uptake efficiency (0.51 to 0.90), and physiological utilization efficiency (51.71 to 94.26). On average nitrogen use efficiency of the 28 rice cultivars was 47.74, nitrogen uptake efficiency was 0.71, and physiological utilization efficiency was 68.76 (Table 1). We have classified the cultivars in terms of nitrogen efficiency into three ranking groups, high, medium and low. . The highly efficient group with uptake efficiencies above 0.80 included Daeanbyeo, Seojinbyeo, Ansungbyeo, Dongjinbyeo, and Hwaanbyeo, while the low efficient group (below 0.60) was Kwanganbyeo, Sampyongbyoe, Soorabyo, and Hwasungbyo. For physiological utilization efficiency Hwasungbyeo, Sampyeongbyeo, Soorabyeo were the more efficient cultivars, while Daeanbyeo, Seojinbyeo, and Ansungbyeo were the least efficient cultivars (Table 2). We investigated the reasons why Daeanbyeo had a high nitrogen uptake efficiency, and why Hwasungbyeo had a high physiological utilization efficiency. Nitrogen uptake efficiency was positively correlated with dry matter weight of plant, leaf area index and leaf nitrogen content. The regression coefficients between uptake efficiency and dry matter weight of plant, leaf area index, and leaf nitrogen content were 0.842, 0.761, 0.599, respectively. Therefore, the dry matter weight of rice plants was more important than leaf area index or leaf nitrogen content in characterizing N uptake efficiency. However, these three parameters had negative correlation coefficients with physiological utilization efficiency. Physiological utilization efficiency was positively correlated with yield (Table 3). . Hwasungbyeo had larger grain yield and the nitrogen content absorbed from fertilizer was smaller than other rice cultivars. As nitrogen uptake efficiency of rice cultivars increased, the chlorophyll meter value of rice leaf increased (Fig. 1).

Table 1. Variation in nitrogen use efficiency, uptake efficiency, physiological utilization efficiency, plant nitrogen content, and yield in rice cultivars.

Maturity group	Cultivar	NUE[1)]	UE[2)]	PUE[3)]	Plant N content (kg/ha)	Yield (t/ha)
Early	Daejinbyeo	48.00	0.63	75.86	69.6	5.28
	Sampaekbyeo	48.45	0.66	73.50	72.5	5.33
	Sangmibyeo	48.91	0.62	78.32	68.7	5.38

	Odaebyeo	48.18	0.72	66.80	79.3	5.30
	Obongbyeo	48.18	0.66	73.04	72.6	5.30
	Jinbubyeo	47.73	0.68	69.78	75.2	5.25
	Taebongbyeo	50.73	0.70	77.20	77.3	5.58
Medium	Kwanganbyeo	46.73	0.56	82.76	62.1	5.14
	Bongkwangbyeo	44.09	0.74	59.95	80.9	4.85
	Sampyeongbyeo	50.27	0.54	93.83	58.9	5.53
	Seojinbyeo	46.82	0.89	52.45	98.2	5.15
	Seokjungbyeo	49.18	0.64	77.16	70.1	5.41
	Soorabyeo	49.55	0.54	92.59	58.9	5.45
	Ansanbyeo	51.55	0.63	81.42	69.6	5.67
	Ansungbyeo	47.36	0.88	53.69	97.0	5.21
	Anjungbyeo	46.64	0.81	57.75	88.8	5.13
	Janganbyeo	44.18	0.75	58.54	83.0	4.86
	Jinpumbyeo	45.45	0.66	68.92	72.6	5.00
	Hwasungbyeo	48.36	0.51	94.26	56.4	5.32
	Hwajungbyeo	44.27	0.75	58.94	82.6	4.87
	Hwajinbyeo	46.45	0.78	59.89	85.3	5.11
Late	Daeanbyeo	46.64	0.90	51.71	99.2	5.13

Dongjinbyeo	51.91	0.86	60.22	94.8	5.71
Saechuchungbyeo	46.09	0.76	60.98	83.1	5.07
Ilpoombyeo	47.45	0.69	68.35	76.4	5.22
Chuchungbyeo	45.18	0.69	65.66	75.7	4.97
Hwamyeongbyeo	49.91	0.83	60.33	91.0	5.49
Hwaanbyeo	48.55	0.86	56.47	94.6	5.34
Mean	47.74	0.71	68.76	78.4	5.25
SD	2.10	0.11	12.32	12.2	0.23
CV(%)	4.40	15.61	17.92	156.0	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

Table 2. Rice cultivars classified into high and low groups in terms of 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 3. Correlation relationships between uptake efficiency, physiological utilization efficiency, and growth characteristics 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*

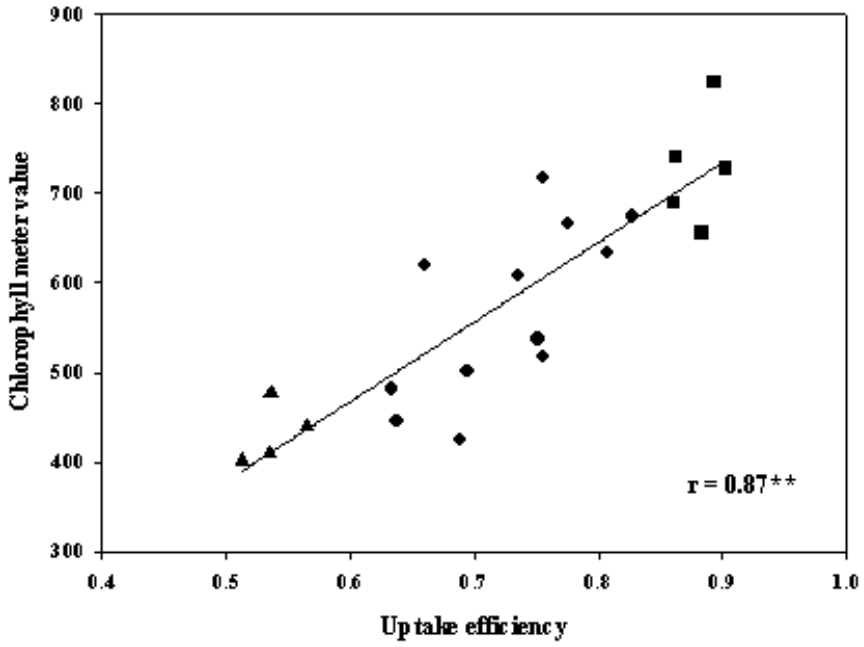

Fig. 1. Relationship between uptake efficiency of rice cultivars and chlorophyll meter value (■; high uptake efficiency, ●; medium, ▲; low).

Conclusion

The cultivars with high uptake efficiency can be used for environmental-friendly farming systems. The cultivars with high uptake efficiency had higher nitrogen contents 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. Physiological utilization efficiency was used for breeding high-yielding rice. When rice yield has increased, even though plant nitrogen content absorbed from fertilizer has decreased, physiological utilization efficiency of rice cultivars has increased.

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