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Ammonium and Nitrate Uptake and Utilization Efficiency of Rice varieties as Affected by Different N-Concentrations

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ABSTRACT: To find out the optimum mixture ratio of ammonium and nitrate on rice plant, 4 rice varieties were examined during 14days after transplanting in hydroponics with the different ratio of ammonium to nitrate(100 : 0, 75 : 25, 50 : 50, 25 : 75 and 0 : 100). The highest N uptake from solution and the maximum plant dry weight were 60 ~ 70% ammonium and 30 ~ 40% nitrate mixture treatment both in Japonica and Tongil type rice plants. And with the same varieties N-uptake and N use-efficiency were compared between 10.0 mM and 1.0 mM nitrogen using 70% ammonium and 30% nitrate for 24 days after transplanting. Rice plants absorbed more nitrogen(131 ~ 145%) in 10.0 mM than 1.0 mM treatment but accumulated N in rice plants were almost the same in both treatment. Among the tested rice cultivars, dry matter production and total accumulative nitrogen in rice plants were much high in Tongil type than japonica type rice cultivars. N-recovery ratios of rice plants from uptake N were 90.8 - 99.0% in low concentration N solution(1.0 mM), but 69.4 - 81.7% were observed in high concentration N solution(10.0 mM). It means that suppling low concentration N steadily will be better to prevent loss of N without reducing of growth in rice plants.

***Keywords*:** rice, ammonium, nitrate, concentration, using efficiency

The food capacity in Korea were always not enough before late 1970's, but we achieved self-sufficient in rice production after 1977. Recently, as the development of economic condition of Korea and the change of food consumption patterns of young generations from rice to flour food, the storage status of rice is sufficient.

Now, most Korean people want to have high quality rice cultured without contamination of much nitrogen, herbicides and insecticides. So, the government also agreed reducing nitrogen application in paddy fields.

It is known that the rice plants usually uptake nitrogen as ammonium than nitrate while upland crops prefer nitrate to ammonium. The applied urea on paddy field changes to ammonium by urease and attaches easily to soil.

Urea, the usual nitrogen source in paddy field, is easily to mix in the water and apt to attach with the soil particles as an ammonium. But a lot of nitrate not absorbed by crops is going down under the soil layer by oxidation after excessive application of urea and the nitrogen content in ground water was increased during the growing period (from April to July) of summer crops (Yoo and Choi *et al.*, 1999).

Using hydroponics, a lot of test were conducted to select better varieties by N-using efficiency in corns (Chevalier, 1977), pumpkins (Swiader, 1994), Kentucky bluegrass (Bertauski, 1997) and pearl millet (Alagarswamy, 1988).

Recently, there were a lot of papers about growing vegetables in hydroponics, and the researchers recommended using both ammonium and nitrate at a proper ratio. Using both ammonium and nitrate in hydroponics gives more advantages such as increasing production of vegetables and less adjusting labor of pH than using nitrate only (Kim, 1993 ; Kim & Kim, 2001).

Therefore, this experiment was conducted to know the optimum absorption source of nitrogen, nitrogen using efficiency according to different rice cultivars.

MATERIALS AND METHODS

This experiment was conducted in the greenhouse of University of Illinois in 1999. Two Japonica-type (Ilpumbyeo, Dongjinbyeo) and two Tongil-type (Dasanbyeo, Suwon441) rice cultivars were used for hydroponics. <Experiment 1> was conducted to know the optimum mixture ratio of ammonium and nitrate for best growth and nitrogen uptake of rice plants. Before transplanting, young rice plants were grown in seed bed with 50% ammonium and 50% nitrate for 24 days from sowing. After transplanting, rice cultivars were grown under different ammonium and nitrate concentration with soft aeration, the percentage of nitrate and ammonium were such as 0 : 100, 25 : 75, 50 : 50, 75 : 25, 100 : 0. The concentration of phosphorous, potassium, calcium and magnesium were as shown in table 1.

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Table 1. Total concentration of major nutrient for different ammonium and nitrate ratio.

NH· NO (%)	Nutrient concentration(ppm)						
	N	P	K	Ca	Mg	S	Cl
100 : 0	70	31	100	70	32	131	124
75 : 25	70	31	80	80	32	118	98
50 · 50	70	31	100	80	32	82	107
25 75	70	31	100	90	32	82	36
0 · 100	70	31	120	100	32	54	48

In <experiment 2>, 70% of ammonium and 30% of nitrate mixture solution were selected by the result of experiment 1. Two different nitrogen concentration were used, one was low concentration 14 ppm (1.0 mM) and the other was high concentration 140 ppm (10 0 mM). The concentration of phosphorous, potassium, calcium and magnesium were each 31, 100, 60 and 32 ppm in each 14 ppm and 140 ppm N solution, but the concentration of sulfur and chloride was 78, 96ppm in 14ppm N solution and 130, 107 ppm in 140 ppm N solution. Minor nutrients were also supplied, 0.5 ppm boron, 0.01 ppm molybdenum, 0.5 ppm manganese, 0.02 ppm copper, 0.1 ppm zinc, 5.0 ppm iron in experiment 1 and experiment 2. In the beginning, 7.6 L nutrient solution were supplied in 8.5 L capacity pots, and then added distilled water as the same amount of absorbed water by rice plants everyday.

Six rice plants were transplanted per pot and the worst one plant in each pot was removed 7 days after transplanting.

pH were adjusted to 5.0 - 5.5 with 0.5 N sulfuric acid and potassium hydroxide in experiment 1 and with potassium hydroxide in experiment 2. Additional nitrogen (0.5 or 1.0 mM) were supplied in 1.0mM treatment after measuring the concentration of nitrogen at every 1 or 2 days to prevent the lack of nitrogen. Nitrogen were measured with spectrophotometer, 625 nm for ammonium and 210 nm for nitrate. And all the solutions were newly changed 2 weeks after transplanting.

RESULT AND DISCUSSION

<Experiment 1>

Experiment 1 was carried out to know the optimum mixture ratio of ammonium and nitrate for the N uptake and growth of rice cultivars.

Twenty-four days after sowing, four rice varieties were transplanted (6 plants per pot) from seed bed to nutrient solution pot which contained different ammonium and nitrate mixture ratio All the pot contains 5.0 mM N and the changes of ammonium and nitrate concentration was checked for 14 days after transplanting. The results for 4 rice varieties were shown in table 2.

Among the treatment, as shown in table 2, the highest N uptake were at 75% ammonium to 25% nitrate mixture and 50% ammonium to 50% nitrate mixture which absorbed 3.10 mM and 3.06 mM N and also plant dry weight of each treatment were 1.20 g per plant. In 50% ammonium to 50% nitrate mixture treatment, the absorption ratio of ammonium was 63% and 67% absorption ratio was also observed in 75% ammonium to 25% nitrate mixture treatment.

Table 2. N-uptake from solution by rice grown at different mixture ratio of NH_4 and NO_3 at concentration 5.0 mM.

NH_4 : NO_3 (%)	N-source	N concentration(mM) DAT(days) 0	4	7	11	14	Uptaked-N (mM)	Uptaked ratio(%)	D W. (g/plant)
100 · 0	NO_3	-	-	-	-	-	-	-	1.05
	NH_4	4.98	4 70	4.39	3 42	2 58	2.40	100	
	Total	4.98	4.70	4 39	3 42	2 58	2 40	100	
75 · 25	NO_3	1.40	1.38	1.23	0.91	0.39	1.01	33	1.20
	NH_4	3.63	3 40	3.15	2 39	1 53	2.10	67	
	Total	5.02	4.77	4.38	3.30	1 92	3.10	100	
50 50	NO_3	2.65	2 56	2 38	2.06	1 51	1 14	37	1.20
	NH_4	2.48	2.24	2.06	1.40	0.56	1 92	63	
	Total	5.13	4 80	4.43	3 46	2 07	3.06	100	
25 : 75	NO_3	3.77	3.62	3 44	3.17	2.34	1 43	53	1.16
	NH_4	1.26	1 05	0 80	0.30	0	1.26	47	
	Total	5.03	4.68	4.24	3.47	2.34	2.69	100	
0 · 100	NO_3	5 00	4.85	4.48	4 07	3.29	1.71	100	0 87
	NH_4	-	-	-	-	-	-	-	
	Total	5.00	4.85	4.48	4.07	3.29	1 71	100	

*all the above data were the average of 4 cultivars.

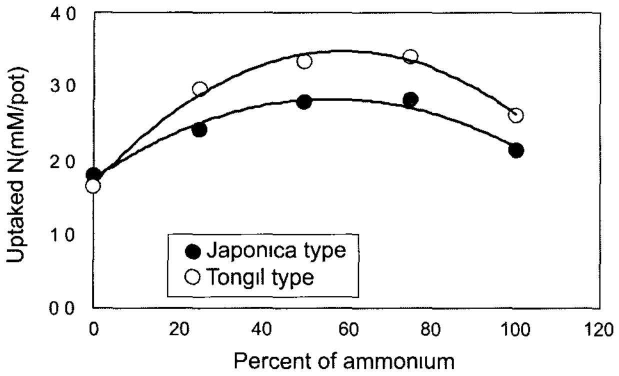

Fig. 1. Total N uptake from solution during 14 days after transplanting by two rice eco-types grown at different NH_4 and NO_3 ratio concentration N 5.0 mM.

The lowest dry weight production was observed in 100% nitrate treatment and the next was 100% ammonium treatment. So, all the treatments mixing ammonium and nitrate were better in N uptake and plant dry weight production than ammonium or nitrate only.

In usual, nitrate was the only N-source in upland vegetable crop during hydroponic culture, but by Kim's (1998, 1993) report, adding ammonium to nitrate solution improved the quality and production of leaf in lettuce and *Perilla frutescens* (8 : 5 in lettuce and 6 : 6 in *Perilla frutescens*).

Among the treatment, 75% ammonium to 25% nitrate mixture was the highest N uptake in each plant type Japonca and Tongil as shown in fig. 1. But in this experiment, ammonium and nitrate were the limited factors 14days after transplanting in each 75 . 25 and 50 : 50 mixture as shown in table 2. Therefore, it was assumed that the optimum N uptake mixture were estimated around 60 - 70% ammonium to 30 - 40% nitrate mixture. And it was also thought that rice plants prefer ammonium to nitrate as N source and compared with ecological type, N uptake ability and dry matter production of Tongil type rice were much higher than Japonica type.

< Experiment 2 >

As the proper mixture of ammonium and nitrate for the best N uptake and dry weight production of rice was estimated 60 - 70% ammonium and 30 - 40% nitrate in experiment 1, the response of rice cultivars and N use-efficiency affected by N concentration was examined with 70% ammonium and 30% nitrate mixture in experiment 2.

Twenty-five days after sowing, five rice plants were transplanted per pot from nursery bed and N uptake ability of rice cultivars during 24 days was compared in table 3.

Tongil type rice plants (Dasanbyeo and Suwon441) absorbed much more N than Japonica type (Ilpumbyeo and Dongjinbyeo) from nutrient solution and the best N uptake ability among tested rices was observed in Suwon441. When compared the uptake ratio of ammonium to nitrate with plant type, Japonica rice absorbed 72 - 73% ammonium and 28 - 27% nitrate but 64 - 66% ammonium and 36 - 34% nitrate was absorbed in Tongil type.

Therefore, Tongil type rice cultivars absorbed much more nitrogen from solution and as the ratio of N-source, absorbed more nitrate than Japonica type rice cultivars.

In general, N absorption ability of Tongil type rice plants have been superior to Japonica type rice varieties, but in the result of Zhong (2001), N use efficiency was high in low concentration of nitrogen and varietal difference was big

Table 3. N-uptake from solution by rice grown at concentration N-10 0 mM of 70% NH_4 and 30% NO_3

Cultivar	N-source	0	4	7	11	14	18	21	24	Uptake-N (mM)	Uptake ratio(%)
		DAT(days)									
		mM									
Ilpum-byeo	NO	3.04	3.07	2.86	2.71	2.38	2.21	1.84	1.58	1.46	28
	NH	7.07	6.93	6.75	6.35	5.51	4.99	4.03	3.34	3.73	72
	Total	10.11	10.00	9.61	9.06	7.89	7.20	5.87	4.92	5.19	100
Dongjin-byeo	NO	3.01	3.04	2.88	2.68	2.33	2.17	1.74	1.47	1.54	27
	NH	7.08	6.94	6.88	6.23	5.33	4.85	3.76	2.94	4.14	73
	Total	10.09	9.98	9.76	8.91	7.66	7.02	5.50	4.41	5.68	100
Dasan-byeo	NO	2.98	3.05	2.75	2.45	2.12	2.01	1.43	0.93	2.05	34
	NH	7.14	6.86	6.68	6.13	5.36	5.24	3.81	3.12	4.02	66
	Total	10.02	9.91	9.43	8.58	7.48	7.25	5.24	4.05	6.07	100
Suwon441	NO	3.01	3.04	2.84	2.39	1.99	1.78	1.11	0.51	2.50	36
	NH	7.08	6.78	6.83	6.07	5.23	4.80	3.43	2.72	4.36	64
	Total	10.09	9.82	9.67	8.46	7.22	6.58	4.54	3.23	6.86	100

*All hydroponic solution were newly changed 14 days after transplanting and the concentration data of nitrogen after 14days were recalculated as the same amount of uptake N from newly changed solution.

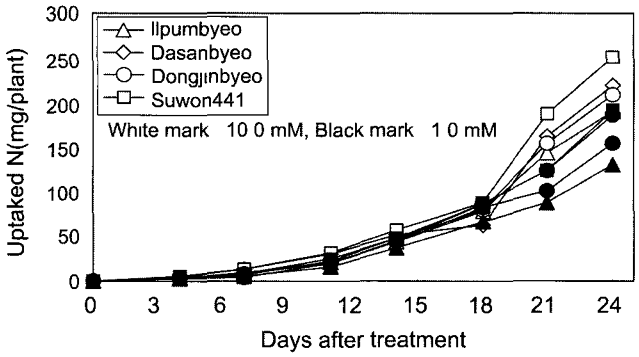

Fig. 2. Cumulative N-uptake from solution by four rice cultivars at 70% NH_4 and 30% NO_3 concentration at 1.0 mM and 10.0 mM nitrogen

among varieties in the same ecological types.

Fig. 2 shows cumulative N uptake of rice cultivars treated in low (1.0 mM) and high (10.0 mM) concentration N for 24 days after transplanting. N uptake ability of rice cultivars in 10 mM N solution were much more high than in 1.0 mM N. Among cultivars, the Tongil type rice (Dasanbyeo and Suwon441) absorbed much more N than Japonica type rice (Ilpumbyeo and Dongjinbyeo) and Suwon441 showed the highest, Ilpumbyeo showed the least uptake ability among tested cultivars in both 10.0 and 1.0 mM N solution.

Dry matter production of rice cultivars affected by different N concentration for 24 days after transplanting are shown in table 4. Considered as average, the dry matter production of rice cultivars were a little more in 1.0 mM N treatment than 10.0 mM N, but no significant difference was observed. And also there were no significant differences on the leaf, stem and root dry matter production between 10.0 mM N and 1.0 mM N treatment. But there were highly significant differences among rice cultivars in every plant partition. With these results, comparatively low concentration N, such as 1.0 mM N, would be better if continuous N-supply is possible than high concentration N application in one time. Because high concentration N application will induce a lot of N loss and the lost N will easily contaminate agricultural environment.

As a different research data, Swiader *et al.*(1994) reported more N accumulation in pumpkin plant from high concentration N(10 mM) than low concentration N (1 mM). But, using low concentration solution such as 1.0 mM, it is very difficult for researchers to know the limitation of N source by low concentration. It is considered that if we could suppling low concentration N continuously the plant could absorb enough N from solution.

Compared between two ecological type, Tongil type rice plants (Dasanbyeo and Suwon441) gained much more dry matter production than Japonica type (Ilpumbyeo and Dongjinbyeo) and especially, Suwon441 gained the highest dry matter production in this experiment condition.

And also, shoot/root ratio in 10.0 mM N treatment was a little high than in 1.0 mM N because shoot growth was relatively high than root growth in 10.0 mM N treatment.

Nitrogen concentrations in rice plant tissue were analyzed with Cataldo's colorimetric assay(1974) and the results are shown in table 5. There were no significant differences in the partitioning of tissue total N and N accumulated ratio according to N concentrations, but there were highly significant differences only in rice cultivars. The absorbed N was distributed each tissue such as 52% N in leaf blade, 30% in leaf sheath, 18% in root. But the N partitioning ratio of leaf blade and leaf sheath were a little higher in Tongil type rice plants than in Japonica type and N partitioning ratio of root

Table 4. Plant dry weight partitioning in rice cultivars as influenced by different N-concentration (NH_4 NO_3 = 7 . 3).

Cultivar	Solution-N conc. (mM)	Dry weight(g/plant)				Shoot/Root ratio
		Leaf	Stem	Root	Total	
Ilpumbyeo	10.0	1.54	1.29	0.96	3.79	2.95
	1.0	1.44	1.20	0.93	3.57	2.84
Dongjinbyeo	10.0	1.65	1.44	1.05	4.13	2.95
	1.0	1.75	1.46	1.08	4.28	2.98
Dasanbyeo	10.0	1.79	1.41	1.08	4.27	2.95
	1.0	2.01	1.55	1.22	4.78	2.92
Suwon441	10.0	2.25	1.94	1.35	5.53	3.11
	1.0	2.21	1.93	1.41	5.55	2.93
Average	10.0	1.80	1.52	1.11	4.43	2.99
	1.0	1.85	1.53	1.16	4.54	2.92
LSD (0.05)	Concentration	ns	ns	ns	ns	-
	Cultivar	**	**	**	**	
	Conc.xCul.	ns	ns	ns	ns	

Table 5. Partitioning of tissue total-N in rice cultivars as influenced by different N-concentration.

Cultivar	Solution-N conc (mM)	Leaf total-N		Stem total-N		Root total-N	
		(mg)	(%)	(mg)	(%)	(mg)	(%)
Ilpumbyeo	10 0	74	51.8	42	29.6	27	18.6
	1 0	67	51.1	38	29.3	26	19.6
Dongjinbyeo	10 0	78	51.1	45	29.5	30	19.4
	1 0	80	52.4	43	28 4	29	19.2
Dasanbyeo	10.0	83	53.1	47	30.2	26	16.7
	1.0	93	54 1	50	28.9	29	17 0
Suwon441	10.0	108	51.8	64	30.8	36	17.4
	1.0	100	51.9	60	31.0	33	17.1
Average	10 0	86	52.0	50	30.0	30	18 0
	1.0	85	52.4	48	29.4	29	18.2
LSD (0 05)	Concentration	ns		ns		ns	
	Cultivar	**		**		**	
	Conc Cul	ns		ns		ns	

Table 6. N-uptake from solution and N-use efficiency of rice cultivars at different N-concentration during 24 days treatment.

Cultivar	Solution-N conc. (mM)	Uptake from sol. (mg/plant)	Plant-N (mg/plant)	Plant-N before trt. (mg)	Plant-N recovery (%)
Ilpumbyeo	10.0	190	142	4	72 6
	1.0	131	131		96.9
Dongjinbyeo	10.0	208	153	4	71.6
	1.0	154	152		96.1
Dasanbyeo	10 0	219	156	4	69.4
	1.0	185	172		90.8
Suwon441	10.0	251	209	4	81.7
	1 0	191	193		99 0
Average	10 0	217	165	4	73.8
	1.0	165	162		95.7
LSD (0.05)	Concentration	**	ns		
	Cultivar	**	**		
	Conc Cul.	ns	ns		

was around 17% in Tongil type, around 19% in Japonica type rice plants. So, as shown in table 4 and table 5, it was deduced that Tongil type rice plants were higher in shoot/root ratio, transportation ability from root to shoot and root activity than Japonica type rice plants.

To know N use efficiency according to N concentration and rice cultivars, 4 rice cultivars were cultivated in hydroponics for 24 days after transplanting and the results are shown in table 6. The average N absorbed from solution was 31.5% higher and the variation among cultivars were from 18% to 45% higher in 10.0 mM N than in 1.0 mM N treatment. Though, the absorbed N was much higher in 10.0 mM than 1.0 mM N treatment but the accumulated N in rice plants were almost the same and there were no significant differences between N concentrations in rice plants. This result tells that how much we supply nitrogen there were limiting accumulation in rice plants and the suppling method with low concentration nitrogen steadily is better than suppling high concentration nitrogen at once for rice growth and to prevent loss of nitrogen. But, the difference of absorbed N from solution and accumulative N in rice plants is very difficult thing to analyse. In fact, there were no loss of any solution or nitrogen in this experiment and more study should be conducted to detect the difference of absorbed N from solution and accumulative N in plant. Morgan *et al.* (1973) reported influx and efflux of nitrate in perennial ryegrass with hydroponics. From influx N, excessive N was efflux from root and re-absorbed by the plant root again. Swiader *et al.* (1994) also found the difference of N depleted from solution and total plant N, but to now, there were not clear answer in this result. It can be assumed that some efflux N from plant root can be change nitrogen gas and disappear to air.

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