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Nitrogen uptake and N use efficiency in hybrid and common rice as influenced by nitrogen fertilization

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ABSTRACT

Nitrogen uptake and N use efficiency in hybrid and common rice as influenced by nitrogen fertilization were studied in a field experiment. Nitrogen content in rice plant was affected significantly by both genotype and nitrogen fertilization. N content increased with N uptake rate in all plant parts. The grain contained 66, 59 and 60% of total N at N_0, N_1 *and* N_2 *levels, respectively. The interaction effect of genotype and nitrogen rates on N content in leaf at tillering and heading and in grain at maturity was significant. Both genotype and nitrogen fertilization affected physiological N use efficiency significantly and higher PNUE was observed in common rice. Agronomic N use efficiency and efficiency of fertilizer N didn't differ significantly among genotypes and N rates.*

Key words: *Rice, nitrogen, N use efficiency, uptake, yield*

Nitrogen (N) represents approximately 70% of the total fertilizer consumed in agriculture (FAO, 1987) and in Asia about 60% N fertilizer is used in rice (Stangel and De Datta, 1985). Nitrogen use efficiency differed among varieties (Bollich, 1994; Norman *et al*. (1995). Brandon *et al*. (1985) suggested the amount and time of N application required for maximum yield differed among rice varieties because of their efficiency of N utilization or because of lodging, disease, physiological problems and other factors limiting their yield at higher N rates. Many researchers have suggested that modern semi-dwarf varieties require higher N rates than taller varieties (Roberts *et al*., 1993 and Guindo *et al*., 1994), though N use was similar for both types (Norman *et al*., 1992). Increasing crop utilization and reducing loss of chemical N fertilizer will be an important focus for efficient N management in rice field because of increasing cultivation cost and environmental hazards. Poor utilization of chemical N fertilizer by rice is thought to be largely due to N losses from the soil-plant system through volatilization, denitrification, runoff and leaching. Research results on the relationship between loss of applied N and its application rate are inconsistent. The N loss increased with N rates (Sudjadi *et al.*, 1987), but the effect was not consistent (Badin *et al.*, 1987). Therefore, it is required to assess the site fertility and required optimum N rate for getting higher grain yield and N use efficiencies. The present field experiment was conducted with an aim to optimize N dose for hybrid and common rice.

Field experiment was carried out at Huajia Pond Campus of Zhejiang University, Hangzhou, China in late season of 1999 to study the effect of nitrogen fertilization on nitrogen uptake and its efficiencies in hybrid (Indica spp.) and common rice (*japonica* spp.). The experimental soil was sandy loam with 7.23-soil pH and 0.99 % organic matter. The availability of nitrogen, phosphorus and potassium was 104.7, 39.9 and 30.5 mg kg^{-1} of soil, respectively. Two rice cultivars, Shanyou 10 (hybrid) and Xiushui 63 (Common) and three nitrogen levels 0 (N_0), 80 (N_1) and 120 (N_2) kg ha^{-1} were used. The experiment was conducted in factorial randomized block design with three replications. Thirty six days old seedlings were transplanted on July 24. Hybrid and common rice were transplanted with two and four seedlings $hill^{-1}$, respectively. The distance between hills and lines were 17cm and 13cm, respectively. The nitrogen was applied as urea in the ratio of 50 % at transplanting, 30 % at tillering (30 DAT) and 20 % at booting stage (55 DAT).

After initiation of the first tiller, 10 hills $plot^{-1}$

were tagged to count tillers each week. Five hills were sampled at tillering, heading and maturity from each plot and samples were divided into leaf and stem at tillering and heading while ear and shoot (stem and leaf) at maturity, respectively. Leaf Area Meter (Model LI-3000) determined leaf area and after oven dried for 24 hours at 85^0C, these samples were weighed and ground for N analysis. N content was analyzed with Kjeldhal using $H_2S0_{4-}H_20_2$ digested solutions. At maturity, plant height and yield components were recorded. The nitrogen efficiencies i.e. physiological N use efficiency kg grain kg^{-1} uptake and agronomic N use efficiency (grain yield in fertilized plot–grain yield in control/ nitrogen applied) and efficiency of fertilizer N (efficiency of N utilization x apparent recovery) were calculated.

Hybrid and common rice did not differ significantly in grain yield though the former gave 3.14 % higher yield (Table 1), which may be attributed to its more grains $panicle^{-1}$. Common rice had more panicles m^{-2}, due to more tillers $hill^{-1}$, but the filled grains $panicle^{-1}$ were fewer. Since the common rice (Xiushui 63) was 10 days older than hybrid rice in developing phase, its grain filling stage was affected severely by lower temperature in late autumn. All yield parameters differed significantly between two genotypes except grain weight.

Nitrogen application had significant effect on grain yield and yield parameters. Grain yield in N_2 was significantly higher than in N_1 and N_0 level, being 8.57 and 28.10 % higher at N_2, respectively. Higher grain yield was the result of more panicles and grain $panicle^{-1}$ at N2 level, while grain weight was basically same at N1 and N2 levels. The number of unfilled grain increased with N levels because the higher N rate prolonged the growth duration, leading to severe damage of grain filling by decreased temperature. Won *et al*. (1999) also found difference in yield and yield parameters as affected by N rates.

Leaf N content of both genotypes was same at tillering, but hybrid rice had relative higher value (Table 2). Nitrogen fertilizer affected greatly the N content of leaf and stem at tillering. The highest N content was recorded at N_1 in leaf as well as in stem followed by N_2 level. The total N uptake didn't differ significantly between N_1 and N_2, though the higher value

Table 1.Grain yield and its components for two rice cultivars in different N application

Treatments		Plant Height (cm)	Panicles m^{-2}	Grain weight (mg)	Filled grains $Panicle^{-1}$	Unfilled grains $Panicle^{-1}$	Grain yield kg ha^{-1}
Genotypes	Shanyou 10	90.96a	367.11b	23.20a	71a	11a	7356a
	Xiushui 63	77.06b	391.56a	23.20a	66b	12a	7132a
Nitrogenlevels	N_0 (0 kg ha^{-1})	83.73a	308.33c	23.71a	67a	8c	5913c
	N_1 (80 kg ha^{-1})	83.95a	390.83b	23.86a	68a	11b	7575b
	N_2 (120 kg ha^{-1})	84.33a	438.83a	22.76a	71a	14a	8224a
Interaction		ns	ns	ns	s	s	s

The same letters in a column means no significant difference: ns and s means no significant and significant at 95% probability, respectively.

Table 2. Nitrogen content (%) of two genotypes at tillering, heading and at maturity

Treatments		Tillering		Heading		Maturity	
		Leaf	Stem	Leaf	Stem	Grain	Shoot
Genotypes	Shanyou 10	3.83 a	2.05 a	2.81 a	1.22 a	1.59 a	1.23 a
	Xiushui 63	3.71 a	1.89 b	2.82 a	1.27 a	1.40 b	1.12 b
Nitrogenlevels	N_0 (0 kg ha^{-1})	3.28 c	1.65 b	2.47 c	1.14 b	1.27 c	0.89 c
	N_1 (80g ha^{-1})	4.120 a	2.18 a	2.89 b	1.27 a	1.48 b	1.28 b
	N_2 (120 kg ha^{-1})	3.93 b	2.08 a	3.08 a	1.33 a	1.74 a	1.39 a
Interaction		ns	ns	ns	s	s	s

The same letters in a column means no significant difference, ns and s mean not-significant and significant, respectively.

was recorded at N_2. N accumulation in leaves was also same at both N_1 and N_2 levels.

At heading, the N concentration in leaf and stem didn't differ significantly between both the cultivars but the total N uptake by Shanyou 10 was higher because of higher N uptake by leaf and stem. (Table.2). Nitrogen content in leaf and stem increased with N rates and N2 gave significantly higher N content in both parts. The total N uptake was also highest at N_2 level because of higher N uptake by leaves and stem. The N uptake by stem did not differ between N_1 and N_2 level but it differed significantly in leaves. The higher N uptake at N_2 level was because of higher N content in leaf and stem.

At maturity, N uptake in hybrid rice grain was higher because of more grain weight and higher N content (Table 3). Though N accumulation in shoot did not differ in two the genotypes, the higher value was found in hybrid rice. Finally, total N accumulation was significantly greater in hybrid rice because of higher N content and more biomass. Hybrid rice contained 62.28% N and common rice 59.08% N in grain. The maximum N accumulation was found at N_2 level. Safeena *et al*. (1999) reported higher N uptake at increasing N rates due to more solubility of urea and greater root development.

Both, rice genotypes and nitrogen fertilization affected physiological N use efficiency (PNUE) significantly. Hybrid rice had lower PNUE than common rice (Table 4). PNUE decreased with increased nitrogen rates, being the highest and lowest at N_0 and N_2 levels, respectively, whereas the agronomic N use efficiency (ANUE) didn't differ significantly between the two rice genotypes and among N levels, but common rice had higher value than hybrid rice. ANUE also decreased with increased N rates. Singh *et al*. (1999) reported that PNUE and ANUE decreased with increased N rates. Both genotypes and nitrogen fertilization had no significant effect on efficiency of N fertilizer use. However, hybrid rice had higher EFN. The EFN decreased with increased N rates (Table 4). Tripathi *et al.* (1999) observed lower N use efficiency at higher N rates. The reason for lower N efficiencies at higher N levels may be possibly due to nitrogen loss either by leaching or run off or volatilization (Daftardar and Savant, 1995) that decreased N utilization and its uptake

Table 3. Nitrogen uptake (g m^{-2}) of two genotypes at tillering, heading and maturity

Treatments		Tillering			Heading			Maturity		
		Leaf	Stem	Total	Leaf	Stem	Total	Grain	Shoot	Total
Genotypes	Shanyou 10	7.70 a	3.78 a	11.48 a	7.03 a	7.06 a	14.09 a	10.27 a	6.22 a	16.49 a
	Xiushui 63	4.97 b	2.73 b	7.70 b	5.57 b	6.14 b	11.71 b	8.52 b	5.83 a	14.42 b
Nitrogenlevels	$N_{0,}$ 0 kg ha^{-1}	4.23 b	2.32 c	6.55 b	4.40 c	5.20 b	9.61 c	6.42 c	3.30 c	9.71 c
	$N_{1,}$ 80 kg ha^{-1}	7.04 a	3.51 b	10.54 a	6.52 b	6.48 a	13.35 b	9.63 b	6.76b	16.39 b
	$N_{2,}$ 120 kg ha^{-}	7.74 a	3.94 a	11.68 a	7.98 a	7.56 a	15.73 a	12.23 a	8.03 a	20.26
aInteraction		ns	ns	ns	ns	ns	ns	s	ns	s

The same letters in a column means no significant difference, ns and s, not-significant and significant, respectively.

Table 4. Nitrogen use efficiencies and harvest index of two rice cultivars under three N levels

Treatments		Physiological N use efficiency (PNUE) (kg grain kg^{-1} N uptake)	Agronomic N use efficiency (ANUE) (kg grain kg^{-1} N applied)	Efficiency of fertilizer N (EFN) (kg grain kg^{-1} N used)	Harvest index
Genotypes	Shanyou 10	40.65 b	10.21 a	21.48 a	0.53 a
	Xiushui 63	43.63 a	13.56 a	20.91 a	0.51 a
NitrogenLevels	N_0 (0 kg ha^{-1})	51.52 a	-	-	0.53 a
	N_1 (80g ha^{-1})	39.71 b	18.59 a	33.15 a	0.53 a
	N_2 (120 kg ha^{-1})	35.19 c	17.08 a	30.44 a	0.50 a
Interaction		s	ns	ns	ns

The same letters in a column means no significant difference, ns and s mean not-significant and significant, respectively.

by crop plants. Neither rice genotype nor nitrogen had significant effect on harvest index, though the higher value was recorded in hybrid rice. N_2 gave the lowest harvest index because of lower ratio of grain to straw. Differences in harvest index were also reported among the cultivars (Bufogle *et al*., 1997).

The results obtained from the present study indicated that hybrid rice, Shanyou 10 gave 3.14 % higher grain yield than common rice, Xiushui 63, that may be attributed to its more filled grains per panicle. Hybrid rice had greater N content and N accumulation in its grains compared to common rice. Efficiency of fertilizer N and harvest index were higher in hybrid rice but common rice had little better PNUE and ANUE. Though the grain yield and yield attributes increased up to 120 kg ha^{-1} but the N content in grains increased up to only 80 kg N ha^{-1}. The PNUE, ANUE, EFN and HI were higher at 80 than in 120 kg N ha^{-1}. Further, shanyou 10 matured 10 days earlier than common rice and escaped from the drastic effect of lowering temperature at grain filling. Therefore, hybrid rice, Shanyou 10 may be grown at 80 kg N ha^{-1} for better EFN and net return.

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