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Genotypic variations on nitrogen absorption efficiency in transplanted rice : Effect of seasons

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Abstract: Identification of rice genotypes, which are efficient in absorbing and utilizing N from soil-flood water system, is the recent focus of research related to nitrogen use efficiency (NUE). Our research attempted to identify the genotypes that support maximum grain production and having higher nitrogen absorption efficiency (NAE). From the field experiments conducted in three growing periods, different genotypes exhibited consistent and significant variations in the NAE. Ranking of genotypes were done using different NAE parameters like, N concentration, uptake, crude protein yield etc. Individually the genotypic performance were compared between different growing periods and between growth duration. Statistically significant difference among genotypes were observed and short duration genotypes showed higher efficiency with respect to both grain yield and N absorption parameters. Genotypic variations also manifested by different growing periods, which have differences in weather conditions. The results could be used in the genetic improvement of rice towards evolving efficient genotypes that would have higher N use efficiency.

Key words : Nitrogen use efficiency, Seasonal influence, Genotypic variation, Transplanted rice.

Introduction

Exploitation of genotypic differences for enhancing utilization of soil and fertilizer nitrogen (N) has been one of the key issues in rice production. Since long, while much has been accomplished through improved management of fertilizers, soils, and water (De Datta and Patrick, 1986). These traditional approaches can be augmented by exploiting genotype differences in N absorption efficiency. Genotypes may differ in their ability to take up soil N because of diverse plant characteristics. Varieties may differ in their ability to use soil N because of associative biological nitrogen fixation, and perhaps due to the effect of rice roots on rhizosphere N mineralization, subsoil N uptake, increased root length density, and higher absorption per unit root length (App *et al.* 1986). Since the mineral uptake, transport and metabolism in plants are vested with genetic make up of a plant, the different genotypes respond differently to same or diverse N supply conditions (Mae, 1997). Some genotypes absorbed similar amounts of N but produced different grain yield (Tirol-Padre *et al.* 1996) and variability in N uptake and grain yield among genotypes may decrease at low N levels. Therefore, the identification of rice genotypes, which are efficient in absorbing and utilizing N from soil and applied sources, is the recent focus of research related to NUE (Guindo *et al.* 1994).

Large differences in N acquisition were found to exist between different growth duration varieties and between indica and japonica subspecies. In short duration varieties, the rate of N uptake followed a simple sigmoidal curve and long duration varieties, had two phases of uptake rate with one peak at maximum tillering and another at ear initiation stage (Tanaka *et al.* 1959). In Japonica varieties, N uptake continued even after flowering but on a smaller scale. This suggested that during the ripening period indica varieties had an efficient redistribution of N. The high yielding rice cultivars had a higher N concentraion at heading and early panicle formation stage than low yielding cultivars (Murayama, 1979). Efficiency on uptake of available N by plants is an important component of overall N utilization efficiency, besides N concentration in plant parts. Significant differences in soil N uptake have been observed among genotypes (Broadbent *et al.* 1987, De Datta and Broadbent, 1990). Teo *et al.* (1995) stated that the differences in nutrient uptake by rice cultivars occurred primarily during vegetative growth and partially attributed to differences in the ion uptake characteristics. Therefore, the availability of such information from the wide range of genotypes grown in Paddy Breeding Station, Tamil Nadu Agricultural University, Coimbatore, combined with different growing periods, provided an excellent opportunity to determine if genetic lines differ in their N absorption efficiency. The fundamental objective of the experiments was to identify genotypic variability in N absorption ability and grain yield production from the same

Table 1. Grain yield (at 14% moisture), N concentration and uptake of straw and grains crude protein concentration and yield of grains in different rice genotypes of Experiment a.

Genotypes	Grain yield (kg ha^{-1})	N concentration (g kg^{-1})		N uptake (kg ha^{-1})			Crude protein in grains	
		Straw	Grains	Straw	Grains	Total	Concentration (g kg^{-1})	Yield (kg ha^{-1})
ADT38	5889	7.5	15.2	55.2	92.1	157.1	94.9	575
ADT39	3829	8.9	17.6	35.9	119.8	160.8	109.8	748
ASD19	4973	10.3	13.9	77.9	110.2	211.5	86.6	688
Bhavani	4684	9.6	17.6	93.4	122.0	230.4	110.3	762
CB95066	5869	9.6	12.4	79.1	69.3	144.4	77.4	433
CB97083	2536	11.6	21.8	78.9	90.6	225.4	136.5	566
CO43	5895	7.9	15.1	51.8	113.2	175.0	94.1	707
CO45	5759	9.1	16.5	31.7	127.2	168.3	103.3	795
CO46	4443	11.0	17.7	58.8	102.2	165.2	110.7	638
CORH2	5314	8.6	16.6	32.1	116.7	151.5	103.7	729
IR20	5668	10.0	16.5	98.9	141.4	274.0	102.8	883
Ponni	5936	8.8	16.5	54.4	79.3	138.5	102.8	495
TNAU94241	5000	9.5	15.8	88.5	139.1	266.3	98.4	869
TNAU94247	5303	10.5	18.5	85.8	135.3	238.8	115.6	845
TNAU94301	3619	10.0	20.2	84.7	134.3	229.1	126.4	839
TNRH19	6112	11.0	15.5	58.3	136.3	198.6	96.7	851
TNRH21	6524	8.4	15.1	26.0	122.3	157.7	94.1	764
TNRH31	6579	12.3	17.0	44.9	111.7	146.2	106.3	696
White Ponni	4471	9.8	14.8	86.2	737	169.6	92.3	460
Minimum	2536	7.5	12.4	26.0	69.3	2.8	138.5	4150
Maximum	6579	12.3	21.8	98.9	141.4	17.9	274.0	8832
Average	5179	9.7	16.5	64.3	112.4	8.9	189.9	6852
SD	1052	1.2	2.2	23.3	22.4	4.2	42.8	1363
CV (%)	20.3	12.8	13.2	36.2	19.9	47.1	22.6	19.9

soil-flood water environment as influenced by different growing periods and growth duration.

Materials and Methods

In the winter and summer periods of 1998 and 1999, three field experiments were conducted at the Paddy Breeding Station of TNAU, Coimbatore, Tamil Nadu. The growing periods were September to February 1998 and 1999 (Expt-a), October to March 1998 and 1999 (Expt-b) and February to July 1999 (Expt-c). The experiments were conducted in same field and the soils of the experimental sites were clayey and other soil characteristics were as follows: pH: 8.0; Electrical conductivity: 0.38 dSm^{-1}; $KMnO_4$-N: 166 kg ha^{-1}; Olsen-P: 11 kg ha^{-1}; NH4OAC-K: 394 kg ha^{-1}; and organic carbon 6.9 g kg^{-1}. Since, these three experiments were conducted for demonstration purpose involved no replications. A total of sixty-four genotypes were raised in the three experiments *viz.* 19 in Expt-a, 20 in Expt-b and 25 in Expt-c. The different genotypes included varieties, hybrids and pre-release cultures and were grown with common management practices

Table 2. Grain yield (at 14% moisture), N concentration and uptake of straw and grains crude protein concentration and yield of grains in different rice genotypes of Experiment b.

Genotypes	Grain yield (kg ha⁻¹)	N concentration (g kg⁻¹)		N uptake (kg ha⁻¹)			Crude protein in grains	
		Straw	Grains	Straw	Grains	Total	Concentration (g kg⁻¹)	Yield (kg ha⁻¹)
ADT38	3708	7.0	12.8	29.3	85.2	120.1	79.8	532
ADT41	3468	7.0	13.3	40.8	72.2	116.2	82.9	451
ADT42	4722	6.8	12.4	32.1	68.3	110.4	77.5	426
ADT43	3119	7.6	14.9	26.5	64.0	93.5	93.4	400
ADTRH1	4303	7.3	15.3	32.7	99.0	136.9	95.7	618
ASD16	3768	6.4	13.3	37.6	89.9	150.9	83.3	561
ASD18	3569	7.1	15.6	44.4	87.9	153.3	83.3	549
ASD20	4067	8.2	13.3	29.7	83.4	96.0	97.3	521
CB(DH) 85298	5209	8.4	13.8	56.6	75.6	135.5	86.0	472
CB96009	5787	8.2	15.1	51.4	96.4	132.1	94.2	554
CB96026	3357	8.0	16.4	52.6	61.2	127.2	102.3	415
CB96073	5147	7.6	15.1	38.3	115.8	160.0	94.6	723
CO37	4643	7.8	13.0	40.1	86.4	128.8	81.4	539
CORH1	3223	8.5	14.1	56.8	86.5	149.7	88.0	540
IR36	5038	7.9	12.5	42.5	106.1		151.3	77.9
662								
IR50	5040	8.1	14.1	59.3	72.9	13.7	88.4	455
IR64	5147	7.0	14.1	46.5	107.7	159.0	88.0	673
IR72	4131	7.1	13.9	34.2	62.8	100.9	86.8	472
TKM9	3389	7.3	13.4	23.5	58.2	84.9	83.7	363
TNAU93154	5631	8.5	11.5	48.1	97.6	152.1	72.1	506
Minimum	3119	6.4	11.5	23.5	58.2	84.9	72.1	363
Maximum	5787	8.5	16.4	59.3	115.8	160.0	102.3	723
Average	4323	7.5	13.9	41.2	83.9	129.8	86.8	522
SD	853	0.6	1.2	10.7	16.7	23.2	7.6	95.1
CV(%)	19	8.5	8.8	25.9	19.9	17.9	8.8	18.2

including N application for each trial which was a common rate depending on the crop duration group. In Expt-a, the genotypes were of medium duration type (120-145 days) and in the Expt-b and Expt-c, the genotypes were of short duration type (105-120 days). In the Expt-a and c, 15 genotypes were repeated (common) to study the seasonal influence on nitrogen absorption efficiency. The crop was harvested at physiological maturity and grain yield was recorded for individual rice genotypes and expressed in kg ha^{-1} at 14% moisture content.

Results and Discussion

Grain yield and N absorption efficiency parameters for the sixty four genotypes grown in Expt-a, b and c are given in Tables 1 to 3. The minimum, maximum, average, standard deviation and coefficient of variation worked out for these data are also presented in each table.

Significant genotypic differences on grain yield were observed in each experiment. The grain yield ranged from 6579 (TNRH31) to 2536 (CB97083) kg ha^{-1} in Expt-a; 5787 (CB96009)

Table 3. Grain yield (at 14% moisture), N concentration and uptake of straw and grains crude protein concentration and yield of grains in different rice genotypes of Experiment c.

Genotypes	Grain yield (kg ha-1)	N concentration (g kg-1)		N uptake (kg ha-1)			Crude protein in grains	
		Straw	Grain	Straw	Grain	Total	Concentration (g kg-1)	Yield (kg ha-1)
ADT38	6321	8.1	16.5	64.0	122.0	197.2	103.0	762
ADT43	7210	10.3	17.5	98.6	121.7	229.1	109.5	760
ADTRH1	7043	9.3	15.6	46.9	88.6	138.9	97.8	554
ASD16	7445	8.1	17.1	56.0	125.9	194.8	106.7	787
ASD18	7752	7.	16.5	80.6	138.9	234.6	103.0	868
ASD20	7109	8.7	16.3	77.8	140.4	224.7	101.8	877
CB96024	6500	8.1	13.8	98.2	81.9	193.1	86.5	512
CB96026	5174	6.3	16.2	43.4	106.9	157.3	101.4	668
CB96073	5923	8.1	172	52.3	104.0	162.7	107.5	650
CO47	8737	6.8	16.6	82.3	134.2	226.1	103.4	838
CORH1	7974	7.7	15.0	50.0	89.8	147.5	93.8	561
CORH2	7645	9.0	14.0	43.1	88.5	140.3	87.7	553
IR36	7821	7.6	15.1	41.3	126.1	175.8	94.2	788
IR50	5534	8.9	16.5	86.0	141.9	237.7	103.0	886
IR64	6929	8.5	15.1	73.0	105.2	190.7	94.6	657
IR66	6302	10.1	15.8	69.7	117.1	196.9	99.0	731
IR72	6917	9.0	15.4	61.1	92.4	165.1	96.2	577
MDU5	6011	8.1	15.4	47.6	121.9	176.0	96.2	761
TKM9	6648	11.6	19.6	74.2	129.4	220.9	122.8	808
TKM11	5984	6.9	14.8	78.1	88.1	188.4	92.6	550
TNAU97049	6101	7.1	13.8	102.1	112.7	233.0	86.1	704
TNAU93003	6376	8.4	16.2	56.6	108.3	175.5	101.4	676
TNAU93154	4982	7.6	16.9	67.1	149.9	222.3	105.9	936
TNAU96009	5694	6.8	13.1	84.4	121.9	219.2	82.1	761
TNRH31	5935	9.0	14.2	37.8	82.2	130.1	88.6	513
Minimum	4982	6.3	13.1	37.8	81.9	130.1	82.1	512
Maximum	8737	11.6	19.6	102.1	149.9	237.7	122.8	936
Average	6642	8.3	15.8	66.9	113.6	191.1	98.6	710
SD	930	1.2	1.4	19.2	20.3	33.3	8.9	126
CV(%)	14	14.7	9.0	28.7	17.9	17.4	9.0	17.9

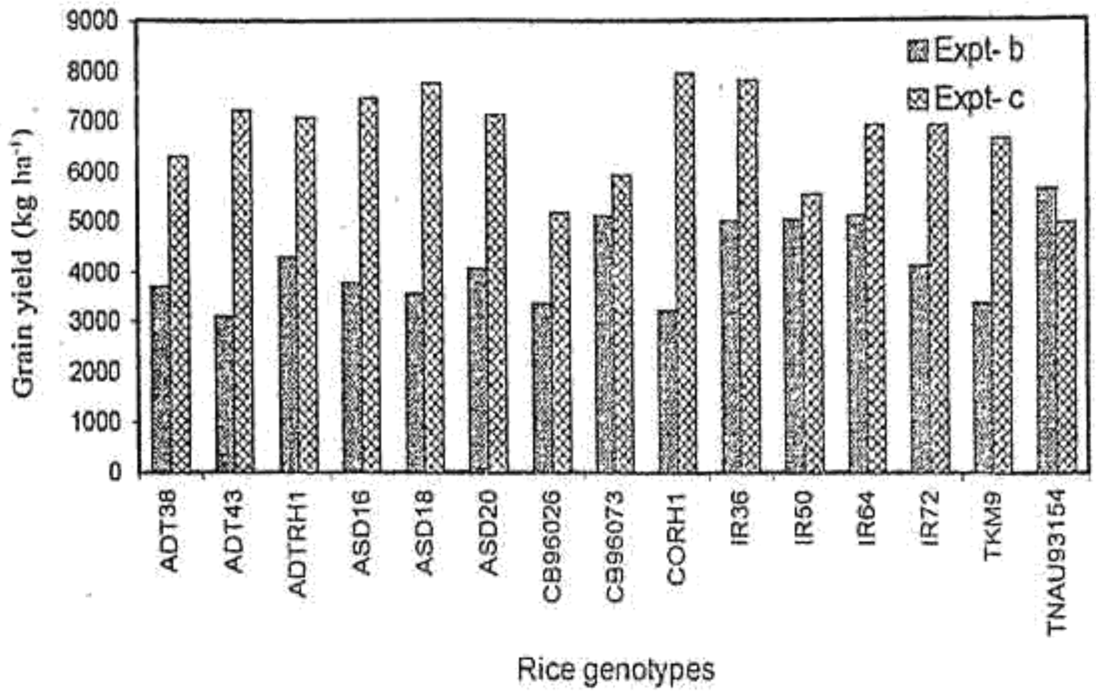

Fig.1. Comparison of grain yield produced by the common rice genotypes (15) grown in Experiment b and c.

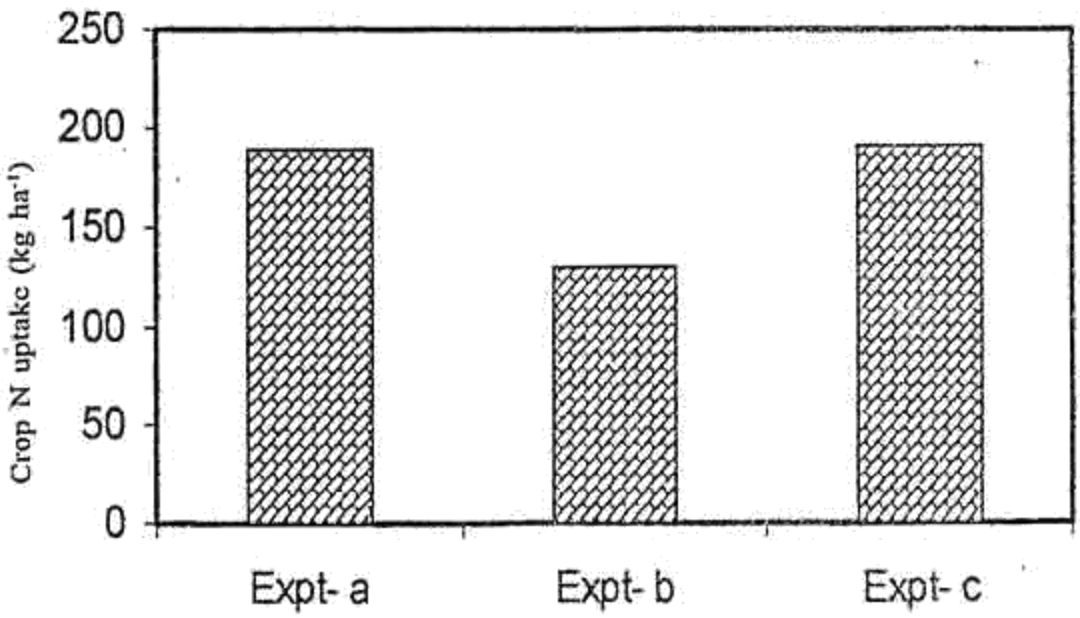

Fig.2. Comparison of the average total crop N uptake of different rice genotypes grown in different growing periods.

to 3119 (ADT43) kg ha^{-1} in Expt-b and 8737 (CO47) to 4982 (TNAU93154) kg ha^{-1} in Expt-c. The coefficients of variation were higher for Expt-a than for Expt-b and c and this indicated the significant influence of genotypic and seasonal variation. The mean grain yield was higher in Expt-c (6642 kg ha^{-1}), followed by the Expt-a (5179 kg ha^{-1}) and b (4323 ka ha^{-1}). This can be attributed to the higher mean total N uptake in Expt-a. Yoshida (1981) reported that the increase in grain yield through N fertilization is a function of both N absorption and the efficiency with which it is utilized for grain production. The grain yield produced by the same genotypes (15 common genotypes in Expt-b and c) grown in two different seasons (October-March and February-July) are represented graphically in Fig 1. All the genotypes produced higher grain yield in February-July season than in October-March season. This could be attributed to the favourable weather conditions faced by the crop during February-July season.

The different genotypes showed considerable variation in N acquisition as measured by N concerntration, uptake and crude protein concentration and yield in different plant parts (Tables 1 to 3).

The straw N concentration ranged from 7.5 to 12.3 g kg^{-1} in Expt-a; 6.4 to 8.5 g kg^{-1} in Expt-b and 6.3 to 11.6 g kg^{-1} in Expt-c. The maximum grain N concentration was recorded by CB97083 (21.8 g kg^{-1}) in Expt-a; CB96026 (16.4 g kg^{-1}) in Expt-b and TKM9 (19.6 g kg^{-1}) in Expt-c. The minimum N concentration of grain varied from 11.5 to 13.1 g kg^{-1}. The values showed the possible minimum and maximum values in the 64 genotypes. The higher coefficient of variation in Expt-c indicated the higher genotypic variation on N concentration in this experiment. When comparing the N concentration of genotypes grown in two different seasons, straw N concentration did not differ much, but grain N concentration was higher in February-July as influenced by the higher sunshine. Hilbert (1990) reported that plants could adjust their physiological status to the prevailing environment, as morphological and physiological characteristics of plants often change considerably in response to resource availablity.

The total crop N uptake as well as the N uptake in different plant parts varied between the different genotypes grown in the particular season. The avacrage crop N uptake was higher in Expt-c (191.1 kg ha^{-1}) followed by Expt-a (189.9 kg ha^{-1}) and Expt-b (129.8 kg ha^{-1}) and represented graphically in Fig. 2. The relatively lower values of N uptake in Expt-a showed that the medium duration genotypes acquired less nitrogen when compared to short duration ones and have less N absorption efficiency. Tanaka *et al.* (1959) found large differences in N acquisition between different growth duration varieties and between *indica* and *japonica* subspecies. The differences between Expt-b and c showed that the crops could take up more N in February-July season (Fig. 2), which had more sunshine than October-March season. Since the October-March season is characterized by low temperatures for the most part, it could have reduced the uptake of N as suggested by Harada (1974). The genotypes having N uptake above the mean for each experiment were considered as the efficient one in taking up N and are listed as follows:

Varieties	:	ADT43, ASD16, ASD18, ASD19, ASD20, CO47, IR36, IR50, IR64, TKM9
Hybrids	:	ADTRH1, TNRH19
Cultures	:	CB96073, CB97083, TNAU94241, TNAU94247, TNAU94301

Significant influence of genotypic variation on protein concentratioin and yield (Tables 1 to 3) was observed in all the experiments as shown by the coefficient of variation (8.8 to 13.2% for protein concentration and 17.9 to 19.9% for protein yield). The mean crude protein concentration and yield was high in Expt-a followed by the Expt-c and Expt-b. The increased grain protein concentration is due to higher absorption of mineral-N and its assimilation by the plant (Bhuyan and Borah, 1997). As observed for crop N uptake, strikingly the maximum protein yeild was recorded by IR20 (883 kg ha^{-1}) in Expt-a; CB96073 (723 kg ha^{-1}) in Expt-b and TNAU93154 (936 kg ha^{-1}) in Expt-c. confirming the higher efficiency of the short duration genotypes to absorb N from the flooded soil.

These data showed that the genotypic variations were manifested by different growing periods, which have differences in weather condition and duration of the genotypes. Short duration genotypes showed higher efficiency of N absorption and were further altered by the seasonal changes. The differences between Expt-b and c showed that the crops could absorb more N and produced higher grain yield in February-July season, which had more sunshine than October-March season.

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