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Physiological parameters and nitrogen use contribution to yield in rice (*Oryza sativa* L.)

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Abstract

A field experiment was conducted to study the genetic variation for nitrogen use efficiency and yield related traits in nine crosses of rice genotypes. Based on the nitrogen use efficiency and yield performance, six rice genotypes *viz.*, MTU-1001, WGL-2395, MTU-1010, Pothana, Bhadrakali and JGL-1798 were selected and nine crosses were made. From each cross six generations *i.e.*, P₁, P₂, F₁, F₂, B₁ and B₂ were generated and analyzed in an experimental trial conducted in *rabi*, 2012-13. Hybrids showed superior performance. Among the crosses, MTU-1001 X JGL-1798 followed by MTU-1010 X JGL-1798 recorded maximum SCMR values, photosynthetic rate, nitrogen use efficiency and grain yield. The cultivars with high uptake efficiency had higher nitrogen contents than cultivars with low uptake efficiency from nitrogen application. Therefore, selection of hybrids with high uptake efficiency could reduce the losses of nitrogen and facilitates increased nitrogen uptake and yield.

Keywords: SCMR values, photosynthetic rate, nitrogen use efficiency and rice yield

Introduction

Rice (*Oryza sativa* L.) is one of the major food crops of the world. It is staple food for more than 60% of the global population and forms the cheapest source of food and energy (Zhao *et al.*, 2011) [22]. Besides being the chief source of carbohydrate and protein in Asia, it also provides minerals and fiber. The present world population of 6.3 billion is likely to reach 8.5 billion by 2030, increasing the demand of rice up to 38%. To meet this challenge there is a need to develop rice varieties with higher yield potential and greater yield stability (Lea and Miflin 2003) [11].

Nitrogen plays an important role in rice production. Increased nitrogen application increases rice yield per unit area and nitrogen fertilizer has a key role in rice life cycle. In the past 50 years, the application of nitrogen fertilizer to rice field resulted in a dramatic increase in yields but with considerable negative impacts on the environment. Continuous increase in rice production has to be achieved with less nitrogen fertilizer by improving nitrogen use efficiency (NUE) through better nitrogen fertilizer management and development of new nitrogen use efficient rice varieties (Ahrens *et al.* 2010 and Kang *et al.* 2013) [1, 9].

The genotypic variation in NUE has been realized and however, plant traits that are associated with high grain yield and high NUE should be identified so that breeders are able to use these traits easily as selection criteria in the breeding programme to develop nitrogen use efficient varieties without reduction in yield potential. Fundamental approach to develop cultivars with enhanced nitrogen use efficiency, in contrast to just improved yield requires evaluating the segregating population obtained by crossing low nitrogen efficient genotype to high nitrogen use efficient genotype and vice versa under native soil nitrogen condition so as to identify a nitrogen use efficient plants and compare its performance with that of other genotypes. In view of above facts an attempt was made to study genetic response for nitrogen use efficient genotypes with better traits and grain yield in rice generations.

With regard to rice breeding it is very important to know about genetic structure of each trait including inheritability, gene mode of action and number of controller genes. This information makes breeders to design appropriate strategies. Generation mean analysis can be commonly used for evaluating of effect of those genes which are involved in quantitative traits (Kearsey and Pooni, 1996) [10]. Estimates of genetic effects using generation mean analysis, genes with additive effects must be completely associated with the parents.

Therefore, selection of contrasting parents for the trait being measured is crucial for this type of investigation (Wilson *et al.*, 2000) [20].

Materials and Methods

Based on the yield performance and nitrogen use, six rice genotypes *viz.*, MTU-1001, WGL-2395, MTU-1010, Pothana, Bhadrakali and JGL-1798 were selected from *Kharif*-2011 and nine crosses *viz.*, MTU- 1001 X Pothana, MTU- 1001 X Bhadrakali, MTU- 1001 X JGL-1798, WGL-2395 X Pothana, WGL-2395 X Bhadrakali, WGL-2395 X JGL-1798, MTU-1010 X Pothana, MTU-1010 X Bhadrakali and MTU-1010 X JGL-1798 were made to produce F₁ generation in *Rabi* 2011-12. F₁ were selfed to produce F₂ generations in *Kharif* 2012 and backcrossed with parents to produce 18 backcross generations. The experiment was carried out in six generations *viz.*, P₁, P₂, F₁, F₂, B₁ and B₂ and raised during *Rabi*- 2012-13 at college farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. The female and male parents are indicated as P₁ and P₂. Thirty day old seedlings were transplanted into 6 m² (2m X 3m) plots by adopting a spacing of 20 cm between rows and 15 cm between plants with in a row. The recommended agronomic practices were followed to raise the crop. Five plants in each plot were tagged and observations were recorded on physiological characters at maximum tillering, flowering and maturity stages. The third leaf from top was used for measuring SCMR (SPAD Chlorophyll meter reading), which was taken midway between the leaf base and tip. Mean of five values from five hills at maximum tillering, flowering and maturity stages were recorded. Photosynthetic rate measurements were recorded from leaves that had fully expanded recently by using Infra Red Gas Analyser (IRGA) portable photosynthetic measurement system. During measurements, the Photosynthetically Active Radiation (PAR) was kept at 1200 $\mu\text{mol m}^{-2} \text{s}^{-1}$ and CO₂ concentration at 387 \pm 6 ppm. These measurements were made between 10.00 am to 12.00 noon at all the sampling dates and expressed as $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$.

NUE defined as the ratio of grain yield to applied fertilizer nitrogen is a key parameter for evaluating a crop cultivar. Grain from net plot area was thoroughly sun dried, threshed, cleaned and weight of grains was recorded and expressed in yield per hectare. The data were analyzed statistically following by Singh and Chaudhary (2001) [17].

Results and Discussion

The performances of six generations (P₁, P₂, F₁, F₂, B₁ and B₂) of nine crosses on grain yield and yield traits have been analyzed and presented. Among the nine crosses, only two crosses *viz.*, MTU-1001 X JGL-1798 and MTU-1010 X JGL-1798 recorded improvement in SCMR, photosynthetic rate at flowering stages, nitrogen use efficiency and influenced grain yield.

SPAD Chlorophyll meter reading (SCMR)

The improvement and contribution of SCMR in rice parents and their subsequent generations is presented (Table 1). SCMR values increased from maximum tillering stage (38.4) to flowering stage (42.2) and thereafter declined towards maturity (33.7). Among the treatments, due to increase in application of nitrogen there was significant increase in SCMR. At maximum tillering stage the mean SCMR value was 37.4 with 60 kg N ha⁻¹ which increased to 39.4 with nitrogen 120 kg N ha⁻¹. Plants which were grown in 60 kg N ha⁻¹ recorded the SCMR values of 41.5 at flowering stage which increased to 42.9 with 120 kg N ha⁻¹. Similarly at maturity stage the SCMR value was 32.5 at 60 kg N ha⁻¹ which increased to 35.0 with 120 kg N ha⁻¹. Non significant differences were observed among the parents in SCMR at maximum tillering and flowering stage, but significant differences were observed at maturity stage and values ranged from 33.1 to 34.7. Maximum SCMR values were recorded in parent MTU-1001 (34.7) where as minimum was recorded in parent JGL-1798 (33.1) at maturity stage. The interaction effects between nitrogen levels and parents for SCMR were non significant at all the crop growth stages.

Table 1: SCMR values in rice parents as influenced by nitrogen supply at different crop growth stages during *rabi*-2012-13

Parents	At maximum tillering stage			At flowering stage			At maturity stage		
	60 kg N ha ⁻¹	120 kg N ha ⁻¹	Mean	60 kg N ha ⁻¹	120 kg N ha ⁻¹	Mean	60 kg N ha ⁻¹	120 kg N ha ⁻¹	Mean
WGL-2395	37.0	39.7	38.4	41.7	42.4	42.0	33.4	35.4	34.4
Pothana	36.6	39.0	37.8	41.1	42.5	41.8	31.9	35.0	33.5
MTU-1001	38.2	40.2	39.2	42.3	43.5	42.9	33.6	35.7	34.7
Bhadrakali	37.2	38.3	37.8	40.6	42.7	41.6	31.7	34.7	33.2
JGL-1798	37.7	39.4	38.5	41.5	42.8	42.1	31.8	34.4	33.1
MTU-1010	37.6	40.0	38.8	42.1	43.6	42.9	32.6	34.7	33.6
Mean	37.4	39.4	38.4	41.5	42.9	42.2	32.5	35.0	33.7
CD (5%)	Treatments (T)	1.543		1.287			1.698		
	Parents (P)	NS		NS			1.087		
	T X P	NS		NS			NS		

Improvement and contribution of SCMR

In the cross MTU-1001 X JGL-1798, significant difference was observed between generations (Table 5). Parent P₁ recorded higher SCMR at tillering stage (39.67) than parent P₂ (39.37). The hybrid F₁ recorded significantly higher value than parents (40.77). F₂ recorded lower SCMR at tillering stage (38.17). Back crosses B₁ (39.64) and B₂ (39.40) were significant and on par with parents. Parent P₂ (42.77) recorded higher SCMR than parent P₁ (42.37) at flowering stage. The hybrid F₁ (45.67) recorded higher SCMR compared to all generations. F₂ (40.94) recorded lower SCMR values at

flowering stage compared to parents. Among back crosses, B₁ (43.03) recorded slightly higher value than B₂ (42.89) and superior to both parents. No significant differences were observed among the generations for SCMR at maturity stage. In the cross MTU-1010 X JGL-1798 with respect to SCMR (Table 6) similar to the above cross recorded significantly higher value were recorded than parents in the hybrid F₁ at tillering (40.53) and flowering stage (45.27). The promotive effect could not be observed at maturity stage. Islam *et al.* (2009) [8] reported the relationship between leaf N content and SPAD value indicating that the rice leaves

showing higher SCMR readings (>35) had higher chlorophyll and nitrogen contents. Singh *et al.* (2002) [16] reported plant need based nitrogen management though chlorophyll meter can reduce N requirement of rice from 12.5 to 25%, with no loss in yield. Miah and Ahmed (2002) [13] also reported that SCMR meter based nitrogen management appeared to be more efficient and would save 20-30 kg N ha⁻¹ than conventional nitrogen management practices to produce similar grain yield.

Photosynthetic rate ($\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$)

There was increase in photosynthetic rate from maximum tillering (18.14 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) to flowering stage (22.26 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) and which decreased there after towards maturity stage (13.13 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) (Table 2). Increase in photosynthetic rate with increase in nitrogen application from 60 to 120 Kg N ha⁻¹ was recorded at all the three stages which

was statistically significant. At maximum tillering stage the increase was from 16.92 to 19.37 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$, at flowering stage from 20.94 to 23.57 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$ while at maturity stage from 12.59 to 13.66 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$ with increase of nitrogen from 60 to 120 Kg N ha⁻¹ respectively. Significant differences were observed between the parents in photosynthetic rate at maximum tillering and flowering stage, but the differences were non significant at maturity stage. The maximum values were recorded in MTU-1001 at both maximum tillering and flowering stages (18.86 and 23.11 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$). Bhadrakali recorded minimum at maximum tillering (17.36 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) and flowering stages (21.48 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$). The interaction effects between nitrogen levels and parents for photosynthetic rate were non significant at all the crop growth stages.

Table 2: Photosynthetic rate ($\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) in rice parents as influenced by nitrogen supply at different crop growth stages during *rabi*-2012-13

Parents	At maximum tillering stage			At flowering stage			At maturity stage		
	60 kg N ha ⁻¹	120 kg N ha ⁻¹	Mean	60 kg N ha ⁻¹	120 kg N ha ⁻¹	Mean	60 kg N ha ⁻¹	120 kg N ha ⁻¹	Mean
WGL-2395	17.37	19.72	18.55	20.80	23.81	22.31	12.53	13.41	12.97
Pothana	16.20	18.64	17.42	20.43	22.79	21.61	12.80	14.31	13.55
MTU-1001	17.67	20.04	18.86	21.85	24.36	23.11	12.19	13.08	12.64
Bhadrakali	16.19	18.53	17.36	20.25	22.72	21.48	12.86	14.49	13.68
JGL-1798	16.48	19.18	17.83	20.52	23.53	22.03	12.73	13.50	13.11
MTU-1010	17.62	20.07	18.85	21.82	24.22	23.02	12.40	13.20	12.80
Mean	16.92	19.37	18.14	20.94	23.57	22.26	12.59	13.66	13.13
CD (5%)	Treatments (T)	0.853		1.252			0.219		
	Parents (P)	0.724		1.103			NS		
	T X P	NS		NS			NS		

Improvement and contribution of Photosynthetic rate

In the cross MTU-1001 X JGL-1798, Photosynthetic rate (Table 5) at tillering stage for parent P₁ (19.72 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) recorded on par values with parent P₂ (19.18). The hybrid F₁ recorded higher photosynthetic rate compared to all generations (21.27 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$). F₂ recorded better value than parents (20.55 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$). Among the back crosses, B₁ (20.83 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) was almost similar to B₂ (20.16 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$). Photosynthetic rate at flowering stage for parent P₁ (23.81 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) was on par with parent P₂ (23.53 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$). The hybrid F₁ (27.66 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) recorded higher photosynthetic rate compared to all generations. F₂ (26.15 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) recorded higher values than both parents. Among the back crosses, B₁ (26.39 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) was higher than B₂ (24.477 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) and both of them were significantly superior to parents. Photosynthetic rate at maturity stage for parent P₂ (13.50 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) was on par with parent P₁ (13.41 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$). The hybrid F₁ (16.28 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) recorded higher photosynthetic rate than parents, while F₂ (15.86 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) photosynthetic rate was better than parents. Among the back crosses, B₂ (15.94 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) was higher than B₁ (15.06 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$).

In the cross MTU-1010 X JGL-1798 with respect to photosynthetic rate (Table 6) similar to the above cross recorded significantly higher value than parents in the hybrid F₁ at tillering (20.99 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$), at flowering (27.35 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) and at maturity stage (16.59 $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$).

Hassan *et al.* (2007) [7] observed significant differences in photosynthetic activity at flowering under variable nutrient levels of rice. High nutrient level recorded significantly high photosynthetic rate followed by medium nutrient level and control. At low nitrogen levels, there was significant reduction in the net photosynthetic rate in rice cultivars (Ligeng *et al.*, 2005) [12]. Genotypes maintaining higher leaf chlorophyll content during crop growth period may be considered as potential donors for the ability of producing higher photosynthetic rate in leaf blades (Miah *et al.*, 1997) [14]. Win and Mochizuki (2010) [21] observed that a high rate of photosynthesis with low leaf nitrogen content is a desirable physiological trait for improving nitrogen use efficiency of rice.

Number of filled grains hill⁻¹ and 1000 grain weight (g)

The data on number of filled grains hill⁻¹ as influenced by nitrogen application in parents is presented (Table 3). There was significant increase in number of filled grains hill⁻¹ with increase in nitrogen application. Application of nitrogen at 120 kg ha⁻¹ has resulted in maximum number of filled grains hill⁻¹ (1415) while at 60 kg N ha⁻¹ it was minimum (1243). The differences among the parents for number of filled grains hill⁻¹ are statistically significant which ranged from 1183 to 1499. The parent MTU-1001 recorded maximum number of 1499 filled grains hill⁻¹ followed by MTU-1010 (1446 filled grains hill⁻¹) while minimum number of filled grains hill⁻¹ (1183) was recorded in Bhadrakali. The interaction between nitrogen levels and parents were also statistically significant which ranged from 1069 to 1565. MTU-1001 recorded maximum number of filled grains hill⁻¹ (1565) while minimum number

of filled grains hill⁻¹ (1297) was recorded in Bhadrakali at 120 kg N ha⁻¹. The 1000 grain weight was significantly influenced by nitrogen application in rice parents which ranged from 15.70 to 17.60 g (Table 3). Significant increase in test weight with increase in nitrogen application was recorded. Maximum weight of 17.60 g was recorded at 120 kg N ha⁻¹, whereas at 60 kg N ha⁻¹ the value was 15.70 g. Among the parents

significant difference for 1000 grain weight ranged from 14.53g (Bhadrakali) to 20.05g (MTU-1010). The interaction effect between nitrogen levels and parents were significant for 1000 grain weight which ranged from 14.02 to 22.05 g. Among the interaction MTU-1010 has recorded maximum 1000 grain weight of 22.05 g, whereas Bhadrakali recorded minimum grain weight of 15.05 g at 120 kg N ha⁻¹.

Table 3: Number of filled grains hill⁻¹ and 1000 grain weight (g) of rice parents as influenced by nitrogen supply in *rabi* 2012-13

Parents	Number of filled grains hill ⁻¹			1000 grain weight (g)		
	60 kg N ha ⁻¹	120 kg N ha ⁻¹	Mean	60 kg N ha ⁻¹	120 kg N ha ⁻¹	Mean
WGL-2395	1294	1294	1294	15.04	16.58	15.81
Pothana	1102	1102	1102	14.25	15.39	14.82
MTU-1001	1432	1432	1432	17.47	20.09	18.78
Bhadrakali	1069	1069	1069	14.02	15.05	14.53
JGL-1798	1171	1171	1171	15.37	16.46	15.91
MTU-1010	1388	1388	1388	18.04	22.05	20.05
Mean	1243	1243	1243	15.70	17.60	16.65
CD (5%)	Treatments (T)			0.149		
	Parents (P)			0.194		
	T X P			0.282		

Improvement and contribution of filled grains hill⁻¹ and yield

In the cross MTU-1001 X JGL-1798, number of filled grains hill⁻¹ for parent P₁ (1458.67) significantly recorded higher than the parent P₂ (1352.67) (Table 5). The hybrid F₁ (1603.33) recorded higher value than all generations. F₂ (1525.60) generation values were also higher than both the parents. Among the back crosses, B₁ (1527.51) showed higher value than to B₂ (1386.17) for number of filled grains hill⁻¹. 1000 grain weight was significantly different in both the parents and parent P₁ (16.58 g) which recorded values on par with 1000 grain weight than P₂ (16.46 g). The hybrid F₁ (18.56 g) recorded maximum 1000 grain weight than the F₂ (17.51 g). Among the back crosses, significant differences were observed between B₁ (17.25 g) and B₂ (15.70 g) and B₁ was higher in 1000 grain weight than parents. Parent P₁ (5155.27 kg ha⁻¹) recorded higher grain yield than parent P₂ (5120.63 kg ha⁻¹). Among the entire generations, the hybrid F₁ (5581.30 kg ha⁻¹) recorded maximum grain yield, while F₂ (5162.52 kg ha⁻¹) yielded higher grain yield than the parents. Among the back crosses, B₁ (5374.48 kg ha⁻¹) recorded more yield than B₂ (5182.30 kg ha⁻¹), which in turn yielded more than both parents.

In the cross MTU-1010 X JGL-1798, significant difference was observed between generations (Table 6). F₁ (1578.67) hybrid recorded higher number of filled grains hill⁻¹ among all the generations. The hybrid F₁ (19.93 g) recorded maximum 1000 grain weight than the F₂ (18.38 g). Among the back crosses, no significant differences were observed between B₁ (15.65 g) and B₂ (15.37 g). Among the entire generations, the hybrid F₁ (5539.80 kg ha⁻¹) recorded maximum grain yield, while F₂ (5153.04 kg ha⁻¹) yielded higher grain yield than parent P₂.

Bharali and Chandra (1994) [3] reported that factors like adaptability, temperature, soil fertility, transplantation season and time were responsible for 1000 grain weight. Tahir *et al.* (2002) [19] reported highly significant variation of thousand

grain weight in different traits of rice and observed that these traits are under the control of genotypic difference among the genotypes. Nitrogen contributes to carbohydrate accumulation in culms and leaf sheaths during the pre-heading stage and in the grain during the ripening stage of rice (Swain *et al.*, 2010) [18]. Accumulation of nitrogen elements in rice reproductive organs and its distribution are important process which determines the grain yield (Bahmanyar and Ranjbar, 2007) [2].

Nitrogen Use Efficiency (NUE) and Grain yield (kg ha⁻¹)

Significant differences were observed between the treatments and increase in nitrogen application reduced the NUE to 43.05 (120 kg N ha⁻¹) from 82.22 (60 kg N ha⁻¹) (Table 4). The results showed that the NUE did not increase linearly with the amount of nitrogen application. Kang *et al.* (2013) [9] reported that higher nitrogen levels showed significantly lower NUE values. Among the parents, MTU-1001 recorded maximum NUE of 64.23 and Bhadrakali recorded the minimum NUE of 61.04. The interaction between nitrogen levels and parents were significant. NUE ranged from 41.63 to 83.65. MTU-1001 recorded maximum NUE of 83.65 and Bhadrakali recorded minimum NUE of 80.45 at 60 kg N ha⁻¹.

The adequate quantity of nitrogen (120 kg N ha⁻¹) helped rice plants to promote the yield attributing characters. The data on grain yield indicated significant improvement in grain yield with increase in nitrogen application in rice parents which ranged from 4933 at 60 kg N ha⁻¹ to 5166 kg ha⁻¹ at 120 kg N ha⁻¹ (Table 4). The grain yield among parents MTU-1001 recorded maximum grain yield of 5199 kg ha⁻¹, while the minimum grain yield of 4912 kg ha⁻¹ was recorded by Bhadrakali. The interaction effect between nitrogen levels and rice parents were significant for grain yield with 4827 to 5378 kg ha⁻¹. Among the interaction combinations, MTU-1001 recorded maximum grain yield of 5378 kg ha⁻¹, whereas minimum grain yield of 4996 kg ha⁻¹ recorded in Bhadrakali at 120 kg N ha⁻¹.

Table 4: Grain yield (kg ha⁻¹) and Nitrogen Use Efficiency (NUE) and of rice parents as influenced by nitrogen supply in *rabi* 2012-13

Parents	Grain yield (kg ha ⁻¹)			Nitrogen Use Efficiency (NUE)		
	60 kg N ha ⁻¹	120 kg N ha ⁻¹	Mean	60 kg N ha ⁻¹	120 kg N ha ⁻¹	Mean
WGL-2395	4983	5155	5069	83.05	42.96	63.00
Pothana	4859	5033	4946	80.98	41.94	61.46

MTU-1001	5019	5378	5199	83.65	44.82	64.23
Bhadrakali	4827	4996	4912	80.45	41.63	61.04
JGL-1798	4908	5121	5014	81.80	42.67	62.24
MTU-1010	5004	5312	5158	83.39	44.26	63.83
Mean	4933	5166	5050	82.22	43.05	62.63
C.D (5%)	Treatments (T)	26.653			0.392	
	Parents (P)	36.887			0.406	
	T X P	52.894			0.626	

Improvement and contribution of Nitrogen use efficiency

In the cross MTU-1001 X JGL-1798 NUE of parent P₁ (42.96) recorded was higher than parent P₂ (42.67) (Table 5). The hybrid F₁ (46.51) recorded higher NUE compared to all generations. F₂ (43.02) recorded higher NUE than parent. Among the back crosses, significant differences were observed between B₁ (44.79) and B₂ (43.19) and B₁ was higher in NUE than and parents. In the cross MTU-1010 X JGL-1798 (Table 6) the hybrid F₁ recorded higher NUE compared to all generations (46.17). F₂ recorded lower NUE (42.94) than better parent. Among the back crosses, significant differences were observed and B₁ (43.77) recorded higher NUE than B₂ (42.71). Rice varieties respond well to higher levels of nitrogen but nitrogen use efficiency is

comparatively better at lower nitrogen levels (Cassman *et al.*, 1993) [4]. The current average NUE in the field is approximately 33% and a substantial proportion of the remaining 67% is lost into the environment, especially in the intensively cropped areas (Pathak *et al.*, 2008) [15]. Unlike other quantitative traits, NUE is one which had produced favourable results showing the effectiveness of this approach in selecting genotypes positively contributing to high nitrogen use efficiency.

MTU-1001X JGL-1798 shows superiority of six characters and was on par with parents for SCMR at maturity stage. F₁ better performance observed and yield was also reflected in 1000 grain weight and has a basis in NUE.

Table 5: Mean performance of MTU-1001 X JGL-1798 with respect to SCMR, photosynthetic rate and yield related traits of rice during *rabi*, 2012-13

Trait/Cross	MTU-1001 X JGL-1798							S.Em±	C.D (5%)
	P ₁	P ₂	F ₁	F ₂	B ₁	B ₂			
SCMR at tillering stage	39.67	39.37	40.77	38.17	39.64	39.40	0.47	1.35	
SCMR at flowering stage	42.37	42.77	45.67	40.94	43.03	42.89	0.58	1.68	
SCMR at maturity stage	35.37	34.43	34.70	33.17	32.88	33.17	0.44	1.27	
Photosynthetic rate at tillering stage (μ mol CO ₂ m ⁻² s ⁻¹)	19.72	19.18	21.27	20.55	20.83	20.16	0.49	1.42	
Photosynthetic rate at flowering stage (μ mol CO ₂ m ⁻² s ⁻¹)	23.81	23.53	27.66	26.15	26.39	24.77	0.68	1.96	
Photosynthetic rate at maturity stage (μ mol CO ₂ m ⁻² s ⁻¹)	13.41	13.50	16.28	15.86	15.06	15.94	0.41	1.20	
No. of filled grains hill ⁻¹	1458.67	1352.67	1603.33	1525.60	1527.51	1386.17	30.93	89.31	
1000 grain wt (g)	16.58	16.46	18.56	17.51	17.25	15.70	0.27	0.79	
NUE	42.96	42.67	46.51	43.02	44.79	43.19	0.38	1.10	
Grain yield (kg ha ⁻¹)	5155.27	5120.63	5581.30	5162.52	5374.48	5182.30	40.17	115.99	

Table 6: Mean performance of MTU-1010 X JGL-1798 with respect to SCMR, photosynthetic rate and yield related traits of rice during *rabi*, 2012-13

Trait/cross	MTU-1010 X JGL-1798							S.Em±	C.D (5%)
	P ₁	P ₂	F ₁	F ₂	B ₁	B ₂			
SCMR at tillering stage	39.97	39.37	40.53	38.07	38.25	38.43	0.45	1.31	
SCMR at flowering stage	43.63	42.77	45.27	41.21	42.28	43.05	0.46	1.32	
SCMR at maturity stage	34.67	34.43	35.00	33.83	33.22	34.27	0.39	1.13	
Photosynthetic rate at tillering stage (μ mol CO ₂ m ⁻² s ⁻¹)	20.07	19.18	20.99	19.91	20.26	19.68	0.48	1.38	
Photosynthetic rate at flowering stage (μ mol CO ₂ m ⁻² s ⁻¹)	24.22	23.53	27.35	26.28	24.81	24.56	0.59	1.71	
Photosynthetic rate at maturity stage (μ mol CO ₂ m ⁻² s ⁻¹)	13.20	13.50	16.59	16.01	15.41	16.13	0.51	1.46	
No. of filled grains hill ⁻¹	1502.67	1352.67	1578.67	1487.85	1454.07	1368.53	27.08	78.21	
1000 grain wt (g)	22.05	16.46	19.93	18.38	15.65	15.37	0.43	1.25	
NUE	44.26	42.67	46.17	42.94	43.77	42.71	0.37	1.08	
Grain yield (kg ha ⁻¹)	5311.50	5120.63	5539.80	5153.04	5252.39	5125.73	38.83	112.14	

Recurrent selection, biparental mating and diallel selective mating system may also be profitable to exploit both additive and non-additive components for bringing about improvement in grain yield and its attributes. Such a strategy will help in increasing the frequency of favorable alleles while maintaining the genetic variation in breeding population (Hallauer and Miranda, 1988 and Doerksen *et al.*, 2003) [6, 5].

Conclusion

Improvement of traits with simple selection techniques will not be able to fix superior lines in the early segregating generations. Knowledge about the way genes act and interact

will determine the breeding system to optimize gene action more efficiently to elucidate the role of breeding systems in the evolution of crop plants. Cultivars with high uptake efficiency had higher nitrogen contents than cultivars with low uptake efficiency from nitrogen application. This could reduce the losses of N and facilitates increased N uptake and result in the development of superior nitrogen use efficient rice cultivars.

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