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Physiological and agronomical indicators for assessing nitrogen use efficiency in rice genotypes at two nitrogen treatments

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Abstract
Nitrogen is essential macronutrient and is a major nutrient element required for the developing high yielding rice cultivars. This study was investigating the genotypic differences in N content among root, stem, leaf, and grain of 12 different rice genotypes under two different nitrogen levels *viz*., 50% (T1) and 100% (T2) recommended dose of nitrogen. Different agronomical and physiological characters were measured in selected 12 genotypes, growing in the field. The leaf N was recorded higher (1.45%) with rice genotype Vardhan. Chlorophyll content was recorded at the maximum vegetative and reproductive stage. Vardhan genotype recorded maximum and Jaya genotype recorded minimum under T1 and T2 treatments at both the stages. Leaf nitrogen content was higher in high NUE genotype Vardhan. High chlorophyll content and Nitrogen in the case of Vardhan support their higher grain yield. Nitrogen efficient genotypes Vardhan x MTU 1010/2, Rasi x Jaya/2, Vardhan and BPT 5204 genotypes showed a <5% reduction in grain yield over recommended N level. The experiment revealed significant genetic variability for NUE, nitrogen uptake efficiency (NUPE) and nitrogen utilization efficiency (NUTE) in both high N.

Keywords: Nitrogen, genotypes, rice, nitrogen uptake efficiency, nitrogen utilization efficiency

Introduction
Rice (*Oryza sativa* L.), which is one of the most important food crops and is considered as a major source of calories for more than half of the global population (Carrijo *et al.*, 2017) [1]. Nitrogen is one of the essential macronutrient responsible for forming yield components such as the number of panicles, grain number, and grain weight (Fageria 2007) [2]. In rice, N content influences the grain number which determines the yield. Leaf N can affect the size and morphology of chloroplasts and thus plays a major role in biomass production through photosynthesis and it is closely correlated with the single-leaf photosynthetic rate (Peng *et al.*, 1996) [9]. The increased nitrogen supply generally results in increased N. However, nitrogen (N) fertilizer is substantially overused which is leads to environmental problems such as greenhouse gas (GHG) emissions, soil acidification, eutrophication and a loss of biodiversity. At present, there is a need for maintaining food production while reducing the detrimental effects of anthropogenic N application for global food security and environmental sustainability.

Rice leaf N content accounts for 75% of total N present in plant and is important in dry matter production through photosynthesis. Rice plants require N during the vegetative stage to promote growth and tillering, which determines the potential number of panicles as well as to carbohydrate accumulation in culms and leaf sheaths during the pre heading stage and in grain during the grain-filling stage by being a component of photosynthesis (Mae *et al.* 1981) [6]. Grain N concentration is directly related to the protein content in the grain (Mosse *et al.*, 1985).

We hypothesized that high grain yield and NUE in rice can be achieved through optimum N usage. Therefore, in this study, we investigated the ability of optimum N management to regulate rice yield in field studies conducted in IIRR, Rajendranagar. We also examined the N content in root, stem, leaf, and grain at maximum vegetative stage and harvest.

Materials and Methods
Site description: The field experiment was conducted at the Indian Institute of Rice Research, Rajendranagar, Hyderabad during *Kharif* 2016. The weather data on rainfall, number of rainy days, mean maximum and minimum temperatures, relative humidity, evaporation and sunshine hours recorded from June to November 2016 at the Meteorological Observatory of Agricultural Research Institute, Rajendranagar, Hyderabad. During the cropping period in 2016, the average maximum and minimum temperatures were 28.7 and 20.35 respectively.

The total rainfall received was 839 mm and the average maximum and minimum relative humidity were 88.3 and 57.83%. The average bright sunshine hours were 5.2 h with an average evaporation rate of 3.95 mm (Fig. 1).

Experimental design and crop management

A field experiment was conducted with 2 nitrogen levels of 50% Recommended Dose of Nitrogen-T1 and 100% Dose of Nitrogen-T2 with 12 rice genotypes and 3 replications in split-plot design. Along with two treatments of nitrogen recommended P: K (60:40) was applied. Nitrogen was applied in three splits at the basal stage, maximum vegetative stage and panicle initiation stage whereas P_2O_5 and K_2O were applied @ 60:40 kg/ha as basal. One-month-old seedlings were transplanted in the main field. A spacing of 20x10cm was adopted uniformly. A layer of 2-3 cm water was maintained constantly until the establishment of seedlings. Thereafter about 5 cm of water was maintained up to the dough stage of the crop. Irrigation was withheld at the physiological maturity of the crop.

Sampling, observation, and calculation

Five plants per plot were sampled at the vegetative stage, flowering and harvest for recording the observations. The observations were made on chlorophyll content, N content in root, stem, leaf, and grain at both vegetative stage and harvest and grain yield.

Chlorophyll content

The quantitative determination of leaf chlorophyll content was done using a spectrophotometer. The chlorophyll content expressed in mg/g fresh weight was measured at the maximum vegetative and flowering stage. The content of chlorophyll content and Carotenoids were calculated as per the formulae given by Lichtenthaler and Wellburn (1983) [5].

Chlorophyll a (μg/ml) = $12.25\ A_{663.2} – 2.79\ A_{646.8}$
Chlorophyll b (μg/ml) = $21.5\ A_{646.8} – 5.1\ A_{663.2}$
Total chlorophyll (μg/ml) = Chlorophyll a + Chlorophyll b
Carotenoids = (1000 A_{470} – 1.82 Chlorophyll a – 85.02 Chlorophyll b) / 198

Nitrogen content in shoot, root and grain

Nitrogen content in shoot (stem and leaf) and root at maximum vegetative and harvest stage and grain at harvest stage was estimated according to kjeldahl using block digestion and steam distillation.
Nitrogen content was expressed as percent by using the formula:

$$N(\%) = \frac{(T - B) \times N \times 14007 \times 100}{\text{sample weight (mg)}}$$

T= Titration volume for sample (ml)
B= Titration volume for blank (ml)
N= Normality of acid to four places of decimals

Internal efficiency (IE): (grain yield -%N content of grain) + (straw yield - % N content of straw) Witt *et al*., (1999) [12].
Total plant Nitrogen Uptake (TPNU): (Grain N content x Grain yield)+(Straw N content x Straw yield) expressed in kg ha^{-1}
Nitrogen Uptake Efficiency (NUPE): TPNU/Nsupply expressed in kg N kg^{-1} N
Nitrogen Utilization Efficiency (NUTE): grain yield/ TNUP expressed in kg grain kg^{-1} N

Statistical Analysis

The data generated on various parameters were statistically analyzed by applying the technique of ANOVA (Gomez, 1984) using SPSS. Whenever the treatment differences were found significant it is denoted by * and "NS" if they were not significant.

Results

Percent reduction of SPAD values in leaves at the maximum vegetative stage and harvest was 7.56% and 11.7% at 120 kg N ha^{-1} compared with 60 kg N ha^{-1} was observed. Across N levels, the maximum SPAD value was recorded for genotype Vardhan (42.45, 37.92) at both the stages (Fig. 2). Non-significant differences were observed among treatments and genotypes for leaf chlorophyll, while genotypes showed a significant difference in carotenoids at both vegetative and flowering stages. These pigment levels were more in genotype Vardhan. The total chlorophyll content increased with increased N content. Similar results were observed by Pramanik and Bera, 2013 [11]. Interaction between the N level and genotypes on chlorophyll content in leaves was significant. Poshtmasari *et al*. (2007) [10] showed similar results. The highest chlorophyll content in leaves (12.81mg/g fw) was found in Vardhan. From the regression study contribution at T1(R^2=0.141) and T2 (R^2=0.040) leaf chlorophyll at harvest to grain yield was found (Fig 3). It shows the increased grain yield with increase chlorophyll content.
With increasing N supply the N content in the component parts also increased at both vegetative and harvest stages. The leaf has high N content when compared to the root and shoot. Nitrogen significantly influenced the N concentration in the root. At the vegetative stage, mean value of leaf N was lowest (1.49%) in Rasi and highest (2.07%) in Vardhan. Stem N was lowest (0.44%) in Vardhan and highest (0.85%) in Rasi genotype and root N was lowest (0.70%) in Sampada x Jaya/3 genotype and highest (0.97%) in Rasi genotype. At harvest stage the mean value of leaf N was lowest (1.24%) in Rasi and highest (2.14%) in Vardhan, stem N was lowest (0.46%) in Jaya and highest (0.85%) in Sampada genotype and root N was lowest (0.74%) in Sampada x Jaya/3 and highest (1.09%) in Rasi genotype. Grain N content was highest (0.98) in Vardhan and lowest (0.77) in MTU-1010.
The Internal efficiency of Nitrogen is the efficiency with which the plant uses absorbed N to produce grain. N rate had no significant effect on IEN. The analysis of our experiment indicated genotypic differences in IEN**.** However, in order to obtain a high yield, the genotypes with high N use efficiency need to combine high IEN with high N acquisition. Comparing all data, grain yield and N uptake (Fig 4) were significantly correlated (R2 = 0.42 in T1 and R2 = 0.08 in T2). At 95% CI for the slope to predict grain yield from N uptake is 0.026 to 0.28 at T1 and -0.132 to 0.322 at T2.
Nitrogen use efficiency of the rice variety increased at applied nitrogen of 60 kg N ha−1 and thereafter declined. The results showed that the NUE was higher at T1 when compared to T2 (Fig 5). There was a significant difference in NUE among the treatments. It is due to the low potential to absorb and utilize N at high N when compared to low N.
The grain yield obtained at T2 is more compared to T1 (Fig 6). The percentage reduction in grain yield from T2 to T1 is 2.9 which is <5%. The genotypes had a significant effect on

the grain yield of rice that was independent of N levels. The number of panicles at T1 was higher than that of T2, whereas the filled grains rate at T1 was significantly lower than that of T2. There was a reduction in spikelet sterility while there was no difference in 1000 grain weight between T1 and T2. Among treatments, T1 recorded more panicle dry weight when compared to T2. Across the genotypes, Vardhan recorded the highest panicle weight (906.5g).

Furthermore, the NUE-related parameters PNUE, NUPE and NUTE at T1 were significantly higher than that of T2, with the percent change of 3.7%, 75%and 9.6%, respectively. The mean and standard deviation calculated for the differences in grain yield, yield components, and the NUE-related parameters among treatments and genotypes are presented in Tables 1. The results revealed NHIs, were not significantly different. Similar results were reported by Fageria and Barbosa Filho (2001).

Correlation studies

The correlation between grain yield and total dry matter was found to be positive at two N levels. At 60 kg N ha^{-1} N content in plant was positively correlated with green leaves, panicle length was positively correlated with panicle number, panicle dry weight was positively correlated with shoot root ratio and panicle number, number of filled grain was positively correlated with panicle length, total dry matter was positively correlated with shoot root ratio and panicle dry weight and grain yield was positively correlated with shoot root ratio, panicle dry weight and total dry matter (Table II). At 120 kg N ha^{-1} panicle length was positively correlated with panicle number, panicle dry weight was positively correlated with panicle number and panicle length, number of filled grain was positively correlated with shoot root ratio, total dry matter was positively correlated with panicle number, panicle length and panicle dry weight and grain yield was positively correlated with panicle number, panicle length, panicle dry weight and total dry matter (Table III).

Contribution of NUPE and NUTE to NUE

The NUE of the 12 varieties ranged from 79.3 to 136.5 kg grain kg−1 under T1 and from 3.38 to 7.25 kg grain kg−1 under T2. The variation was higher under T1 than T2. A significant positive correlation was observed between NUE and NUPE of the genotypes under T1(r= 0.84) and T2 (r=0.97) (Table 4), between NUE and NUTE under T1 (r =0.49) (Table 5). The variation in nitrogen uptake efficiency explained the variation in NUE better than nitrogen utilization efficiency. Correlations between NUPE and NUTE were not significant. The genotype Vardhan presented the highest overall average NUE and NUPE. However, the two N treatments affected Vardhan NUTE differently. Vardhan ranked 7^{th} under the T1 treatment and 9th under the T2 treatment, respectively.

Discussion

Improving rice productivity while reducing the environmental impacts of N management is a major challenge for intensive agriculture (West *et al.* 2014). Similarly, in our study, the percent reduction in grain yield was observed as 2.9% in T1 compared with that in T2. Interestingly, although there was no significant difference in grain yield between the treatments, a significant difference in yield components like panicle length, number of filled grains per panicle, number of unfilled grains per panicle, spikelet sterility was observed. This was attributed to an increase in the number of panicles per m^2 and panicle weight in response to the N supply. These results are in accordance with the studies of Wei *et al*. (2011), who reported that the application of N increasingly affects various traits such as CGR and panicle number per m2, which are correlated with grain yield.

Rice yield is determined by number of filled grains which depends on N content. Vegetative organs especially leaves translocates N to grains. Leaf nitrogen is essential for maintaining photosynthetic capacity, while its remobilization to the panicle is also required for the formation of sound grains during grain-filling (Mae and Ohira 1981) [6].

Additionally, high N exacerbates environmental pressures, as the excess N is lost to the atmosphere along with water (Chen *et al.* 2014). In this study, NUE was significantly affected by different N treatments (Fig 5), with NUE under T2 associated with poor uptake and utilization efficiency. These results indicated that the increased grain yield and yield components at T1 may be due to the enhanced NUE (including total N uptake, plant N content, N utilization efficiency). Similar results were reported by Sui *et al.* (2013) and Guo *et al.* (2017). The plant biomass, N content, N uptake, and NUE are all indicators of rice plant N status.

The estimation of nitrogen use efficiency (NUE) assesses the fate of applied nitrogen and its role in improving economic yield through utilization efficiency by the plant. The reduced NUE at higher N rates shows that rice plants are unable to absorb or utilize N. Nitrogen usually lost through ammonia volatilization, denitrification, surface runoff and leaching in the soil floodwater system.

The major source of remobilized N is the leaf, followed by grain, stem, and root. As a greater proportion of the rice plant N is present in leaves, the chloroplasts help in plant photosynthesis thus producing dry matter. The grain yield per plant > stem dry weight > root dry weight. Improving N uptake in grain results in improved grain yield. In the grain, N derived from vegetative parts after anthesis is remobilized and relocated in the grain hence contributing to a high proportion of the applied N in the grain than any other part of the plant. (Zhou *et al*., 2019) [13]. Additionally, the higher concentration of N in the grain is a result of decrease in the pools of N reserves soon after anthesis and thus a considerable amount is translocated to the grain (Fergusson, 1999). The lower value of the chlorophyll/carotenoid ratio is indicates senescence of the plant. In the present study, Vardhan had a higher chlorophyll/carotenoid ratio, especially at T1, indicating its strength for NUE.

N fertilization had significant effects on the morphological and physiological characteristics of roots, which were beneficial in acquiring nutrients, water and subsequently, engaging in biosynthesis (Guo *et al*. 2017). Hence, the achievement of high yield as well as high fertilizer use efficiency is important in sustainable agricultural development.

Conclusion

In conclusion, the present study found that there are variations in N content in component plant parts among 12 genotypes under two nitrogen regimes. The amount of leaf N is affected by N supply. N content in leaf was higher followed by grain, root, and stem. Since grain N is positively associated with yield, improving N uptake in grain can increase grain yield. With the exception of Vardhan x MTU 1010/6, MTU 1010 and Rasi other entries included in this trial showed a decrease in grain yield under T1. Vardhan entry included in this field experiment showed the highest N content in leaf as well as grain yield under T1 and T2. Vardhan x MTU 1010/2, Rasi x Jaya/2, Vardhan and BPT 5204 genotypes showed a <5% reduction in grain yield over recommended N level. Nitrogen-efficient genotypes yield more even under low N supply due to higher N uptake efficiency. These genotypes can be further utilized in breeding and molecular studies to develop varieties with high NUE, and to understand the molecular and physiological basis.

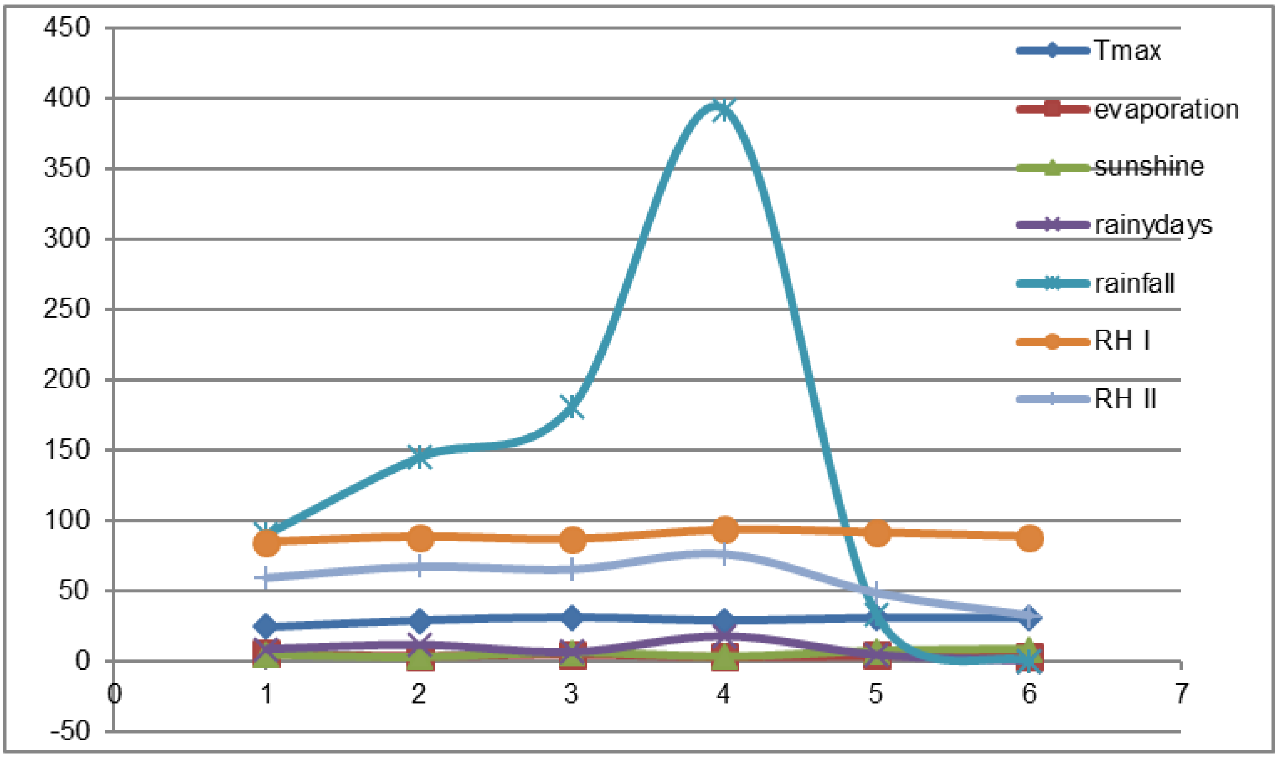

Fig 1: Cumulated rainfall distribution, evaporation, sunshine hours, rainy days, relative humidity during cropping season (June-November, 2016) at the IIRR.

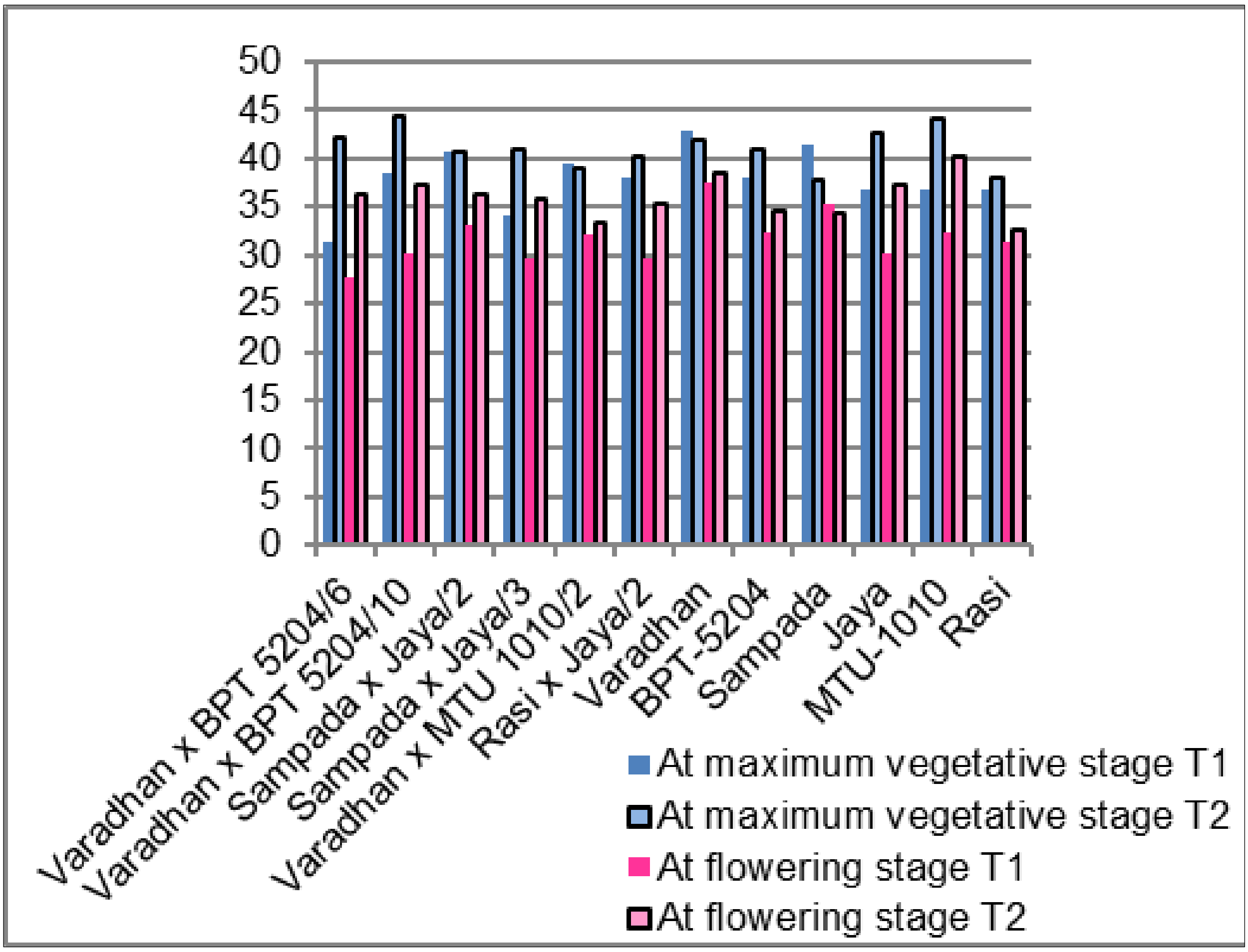

Fig 2: The influence of N levels on SPAD readings at vegetative and flowering stage

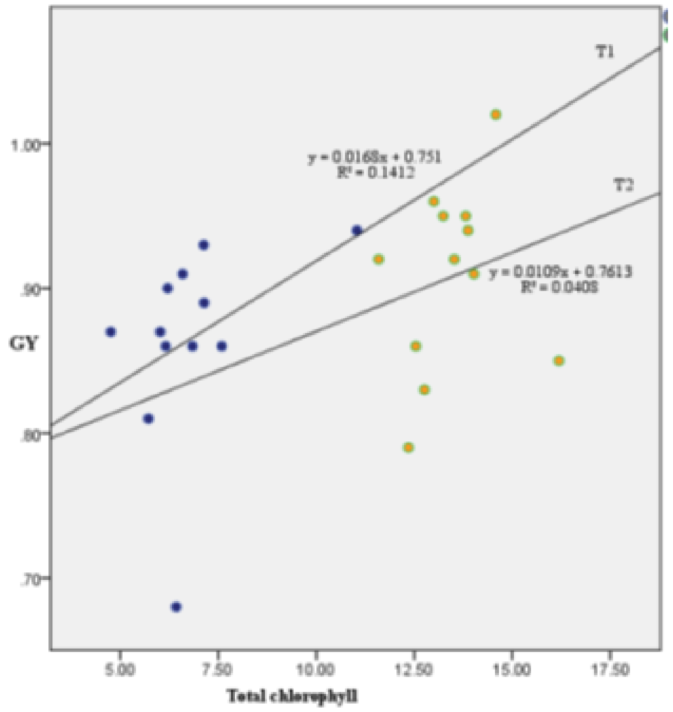

Fig 3: Grain yield as a function of chlorophyll in both T1 and T2 estimated from a linear regression.

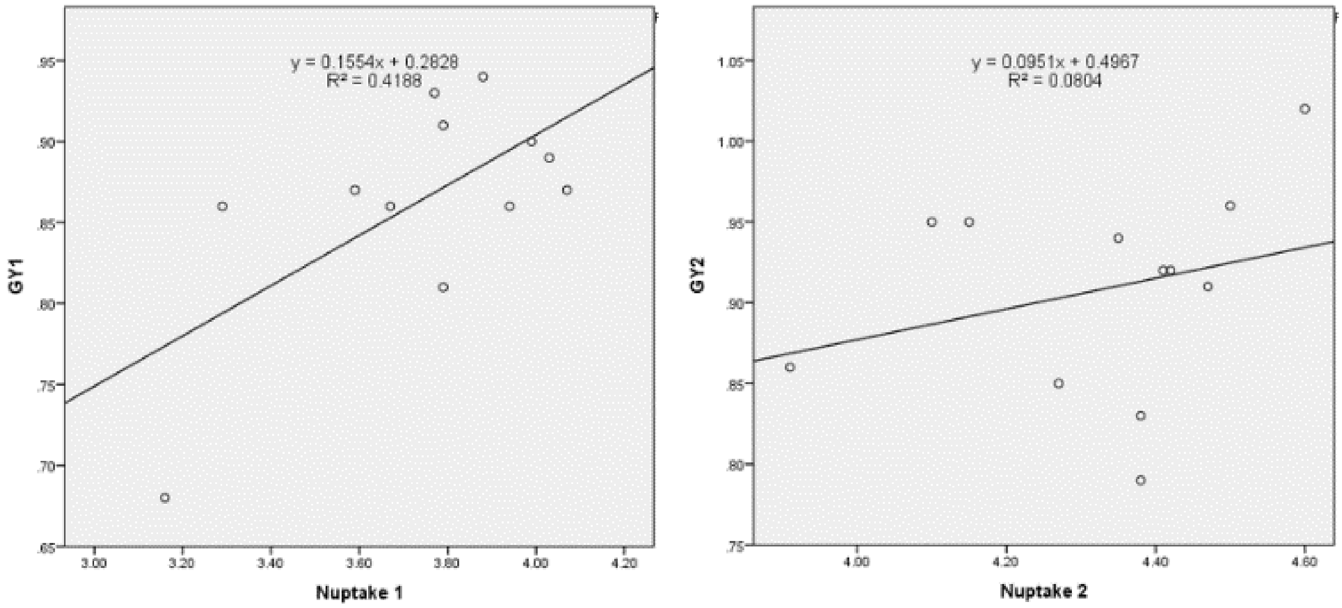

Fig 4: Grain yield as a function of N uptake (grain and straw) in both T1 and T2; estimated from a linear regression.

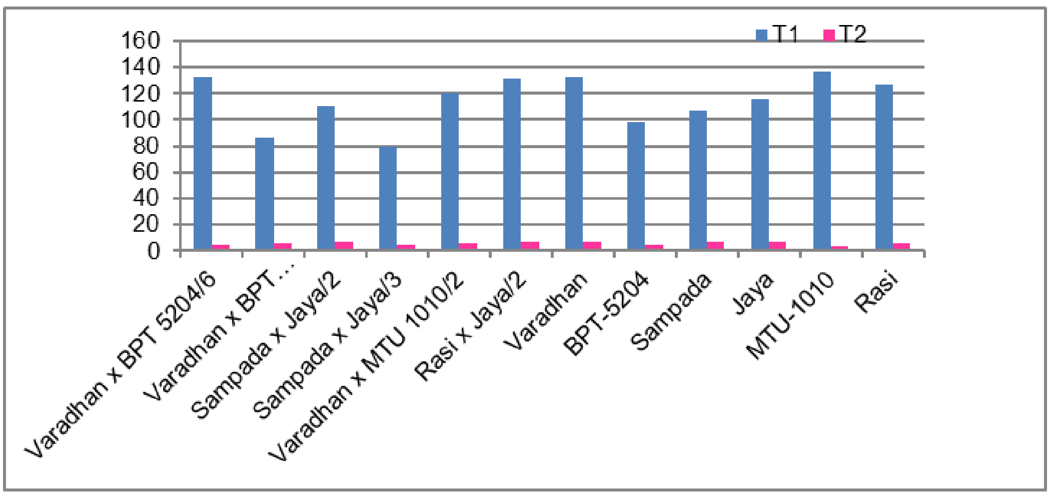

Fig 5: The influence of Nitrogen levels on NUE in different rice genotypes

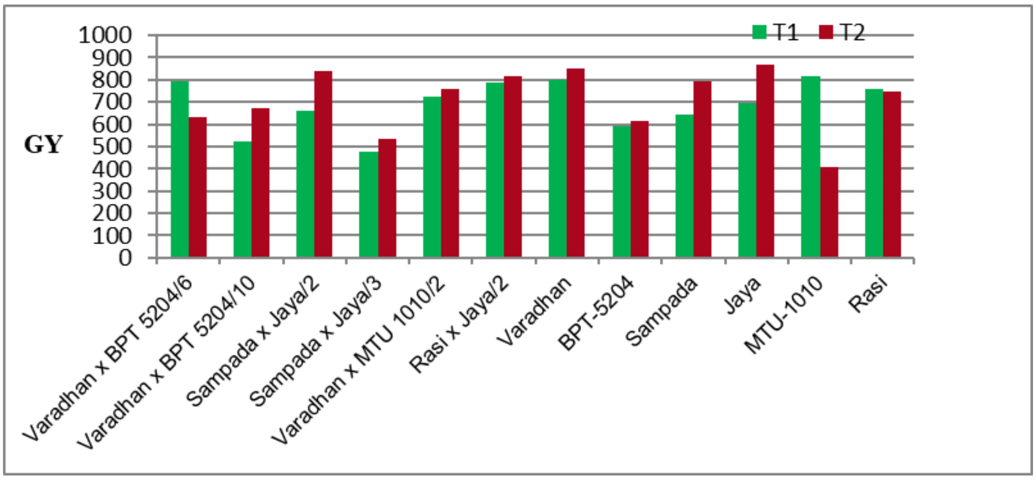

Fig 6: The influence of N levels on Grain yield in different rice genotypes

Table 1: Show the Deviation

	N	Mean	Std. Deviation
NUPE	12	125.7292	18.98218
NUPE 2	12	72.0875	17.08691
NUTE 1	12	.9142	.08754
NUTE 2	12	.8283	.06562
TPNU 1	12	7543.83	1138.972
TPNU 2	12	8650.50	2050.407
HI 1	12	47.33	1.969
HI 2	12	46.67	6.415
GY 1	12	689.17	113.585
GY 2	12	710.50	142.859
Filled grains 1	12	62.42	9.876
Filled grains 2	12	70.58	23.812
spikelet sterility 1	12	20.08	1.782
spikelet sterility 2	12	16.25	5.446
Panicle number 1	12	447.17	80.461
Panicle number 2	12	456.50	86.354
PNUE 1	12	12.9692	3.67083
PNUE 2	12	12.4967	1.86573
NUE 1	12	114.8333	18.94352
NUE 2	12	5.9208	1.19190

Table 2: Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	NUE 1 & NUE 2	12	.167	.604
Pair 2	NUPE & NUPE 2	12	.373	.232
Pair 3	NUTE 1 & NUTE 2	12	.106	.744
Pair 4	TPNU 1 & TPNU 2	12	.373	.232
Pair 5	HI 1 & HI 2	12	.132	.683
Pair 6	GY 1 & GY 2	12	.167	.604
Pair 7	Filled grains 1 & Filled grains 2	12	.409	.186
Pair 8	spikelet sterility 1 & spikelet sterility 2	12	.466	.127
Pair 9	Panicle number 1 & Panicle number 2	12	.601	.039
Pair 10	PNUE 1 & PNUE 2	12	.111	.732

Table 3: Mean and standard deviation values, ii. ANOVA table of NUE, NUPE, NUTE, TPNU, HI, GY and PNUE.

		NUE	NUPE	NUE 2	NUPE 2
NUE	Pearson Correlation	1	.836**	.167	.079
	Sig. (2-tailed)		.001	.604	.807
	N	12	12	12	12
NUPE	Pearson Correlation	.836**	1	.507	.373
	Sig. (2-tailed)	.001		.093	.232
	N	12	12	12	12
NUE 2	Pearson Correlation	.167	.507	1	.926**
	Sig. (2-tailed)	.604	.093		.000
	N	12	12	12	12
NUPE 2	Pearson Correlation	.079	.373	.926**	1

	Sig. (2-tailed)	.807	.232	.000	
	N	12	12	12	12
**. Correlation is significant at the 0.01 level (2-tailed).					

Table 4: Correlation between nitrogen use efficiency and nitrogen uptake efficiency

		NUE 1	NUTE 1	NUE 2	NUTE 2
NUE 1	Pearson Correlation	1	.495	.167	.159
	Sig. (2-tailed)		.102	.604	.621
	N	12	12	12	12
NUTE 1	Pearson Correlation	.495	1	-.491	.106
	Sig. (2-tailed)	.102		.105	.744
	N	12	12	12	12
NUE 2	Pearson Correlation	.167	-.491	1	-.291
	Sig. (2-tailed)	.604	.105		.358
	N	12	12	12	12
NUTE 2	Pearson Correlation	.159	.106	-.291	1
	Sig. (2-tailed)	.621	.744	.358	
	N	12	12	12	12

Table 5: Correlation between nitrogen use efficiency and nitrogen utilization efficiency

	Plant height	Stem thickness	No. of green leaves	Nitrogen content in plant	Shoot-root ratio	Root volume	No. of panicles	Panicle length	Panicle dry weight	No. of filled grains	1000 grain weight	Grain yield	Total dry matter
Plant height	1.000												
Stem thickness	0.082	1.000											
No. of green leaves	-0.511	0.223	1.000										
Nitrogen content in plant	-0.758**	-0.152	0.732**	1.000									
Shoot-root ratio	-0.011	0.079	-0.292	-0.296	1.000								
Root volume	-0.347	-0.772**	-0.080	0.430	-0.051	1.000							
No. of panicles	-0.180	-0.232	-0.019	0.274	0.388	0.195	1.000						
Panicle length	-0.546	0.161	0.268	0.348	0.298	0.095	0.640*	1.000					
Panicle dry weight	0.088	-0.176	-0.390	-0.190	0.756**	0.286	0.638*	0.426	1.000				
No. of filled grains	-0.274	0.291	-0.054	-0.082	0.539	-0.219	0.274	0.583*	0.185	1.000			
1000 grain weight	0.372	-0.146	-0.226	-0.305	-0.101	0.216	-0.632*	-0.664**	0.017	-0.669**	1.000		
Grain yield	0.105	-0.161	-0.321	-0.195	0.805**	0.260	0.567	0.379	0.974**	0.228	0.061	1.000	
Total dry matter	0.290	-0.276	-0.467	-0.384	0.786**	0.150	0.559	0.181	0.905**	0.141	0.054	0.923**	1.000

Table 6: Correlation between yield and yield components at 50% RDN ** Correlation is significant at the 0.01 level (2-tailed)

	Plant height	Stem thickness	No. of green leaves	Nitrogen content in plant	Shoot-root ratio	Root volume	No. of panicles	Panicle length	Panicle dry weight	No. of filled grains	1000 grain weight	Grain yield	Total dry matter
Plant height	1.000												
Stem thickness	0.082	1.000											
No. of green leaves	-0.511	0.223	1.000										
Nitrogen content in plant	-0.758**	-0.152	0.732**	1.000									
Shoot-root ratio	-0.011	0.079	-0.292	-0.296	1.000								
Root volume	-0.347	-0.772**	-0.080	0.430	-0.051	1.000							
No. of panicles	-0.180	-0.232	-0.019	0.274	0.388	0.195	1.000						
Panicle length	-0.546	0.161	0.268	0.348	0.298	0.095	0.640*	1.000					
Panicle dry weight	0.088	-0.176	-0.390	-0.190	0.756**	0.286	0.638*	0.426	1.000				
No. of filled grains	-0.274	0.291	-0.054	-0.082	0.539	-0.219	0.274	0.583*	0.185	1.000			
1000 grain weight	0.372	-0.146	-0.226	-0.305	-0.101	0.216	-0.632*	-0.664**	0.017	-0.669**	1.000		
Grain yield	0.105	-0.161	-0.321	-0.195	0.805**	0.260	0.567	0.379	0.974**	0.228	0.061	1.000	
Total dry matter	0.290	-0.276	-0.467	-0.384	0.786**	0.150	0.559	0.181	0.905**	0.141	0.054	0.923**	1.000

* Correlation is significant at the 0.05 level (2-tailed)

Supplementary tables

Table 7: Correlation between yield and yield components at 100% RDN ** Correlation is significant at the 0.01 level (2-tailed)

Genotypes	Chlorophylla		Chlorophyll b		Total Chlorophyll		Chlorophyll a/Chlorophyll b		Carotenoids		Chlorophyll /Carotenoids	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
Varadhan x BPT 5204/6	6.88	5.58	1.64	1.26	8.51	6.84	4.03	4.45	2.98	2.57	2.2	2.3
Varadhan x BPT 5204/10	5.53	5.77	1.3	1.36	6.83	7.13	4.26	4.24	2.49	2.96	2.26	2.32
Sampada x Jaya/2	5.66	5.82	1.3	1.32	6.97	7.14	4.34	4.41	3.18	3.11	2.21	2.27
Sampada x Jaya/3	5.31	4.62	1.29	1.09	6.6	5.72	4.11	4.24	2.87	2.16	2.31	2.34
Varadhan x MTU 1010/2	5.84	5.35	1.4	1.24	7.05	6.59	4.16	4.33	3.05	2.88	2.19	2.28

Rasi x Jaya/2	5.02	5.06	1.14	1.15	6.16	6.21	4.38	4.43	2.73	3.09	2.32	2.26
Varadhan	4.93	6.67	1.11	4.37	6.04	11.04	4.4	3.29	2.97	1.91	2.34	4.97
BPT-5204	5.95	3.91	1.48	0.98	7.42	4.76	4.03	3.98	3.15	2.52	2.43	2.31
Sampada	5.47	4.92	1.31	1.24	6.77	6.16	4.18	3.94	2.99	3.38	2.34	2.34
Jaya	4.58	4.84	1.14	1.19	5.72	6.02	4.03	4.08	2.29	2.96	2.39	2.37
MTU-1010	5	5.21	1.22	1.22	6.22	6.43	4.1	4.27	2.78	2.22	2.24	2.37
Rasi	4.93	6.15	1.21	1.44	6.14	7.59	4.08	4.27	2.23	3.35	2.39	2.39
Mean	5.42	5.32	1.3	1.49	6.7	6.8	4.17	4.16	2.81	2.76	2.3	2.54
Treatments (T)	NS		NS		NS		NS		NS		NS	
Genotypes (G)	NS		NS		NS		0.52		0.52		NS	
T xG	1.84		1.95		3.54		0.74		NS		NS	

* Correlation is significant at the 0.05 level (2-tailed)

Table 8: Influence of nitrogen on Chlorophyll a, Chlorophyll b, Total Chlorophyll, Chlorophyll a/b, Carotenoids and Chlorophyll/Carotenoids in different rice genotypes at vegeatative stage

Genotypes	Chlorophyll a		Chlorophyll b		Total Chlorophyll		Chlorophyll a/b		Carotenoids		Chlorophyll/Carotenoids	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
Varadhan x BPT 5204/6	8.23	6.64	2.21	2.19	6.84	16.19	3.72	3.03	4.32	4.12	2.42	1.87
Varadhan x BPT 5204/10	7.62	7.92	2.02	2.11	7.13	13.81	3.77	3.75	4.02	4.23	2.4	1.87
Sampada x Jaya/2	7.32	8.02	2.09	2.26	7.14	14.02	3.5	3.55	5.07	4.92	1.86	2.22
Sampada x Jaya/3	7.66	7.78	2.72	2.52	5.72	12.76	2.81	3.09	4.45	4.21	2.33	1.82
Varadhan x MTU 1010/2	7.92	7.86	2.37	2.42	6.59	13.87	3.34	3.25	4.85	4.26	2.12	1.95
Rasi x Jaya/2	7.65	7.13	2.43	2.47	6.21	12.35	3.14	2.89	4.62	4.92	2.18	2.12
Varadhan	6.32	8.37	2.02	4.44	11.04	14.58	3.17	1.89	4.56	4.42	1.83	1.89
BPT-5204	7.83	6.89	2.53	2.63	4.76	13.52	3.09	2.62	4.96	4.34	2.09	1.79
Sampada	7.36	6.75	2.43	2.57	6.16	13.24	3.03	2.63	4.36	4.26	2.25	1.82
Jaya	6.92	7.82	2.21	2.36	6.02	11.59	3.13	3.31	4.42	4.33	2.07	1.81
MTU-1010	7.33	7.97	2.53	2.59	6.43	12.54	1	3.08	4.26	4.21	2.31	1.88
Rasi	6.99	7.62	2.36	2.56	7.59	13	1	3.17	4.11	4.54	2.27	1.9
Mean	7.43	7.56	2.33	2.59	6.8	13.46	2.89	3.02	4.5	4.4	2.18	1.91
Treatments (T)	NS		NS		NS		NS		NS		NS	
Genotypes (G)	NS		NS		NS		*		*		NS	
T xG	*		*		*		*		NS		NS	

Table 9: Influence of nitrogen on Leaf N, Stem N and Root N in different rice genotypes.

Genotypes	Leaf N				Stem N				Root N			
	At maximum vegetative stage		At harvest		At maximum vegetative stage		At harvest		At maximum vegetative stage		At harvest	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
Varadhan x BPT 5204/6	1.28	2.12	1.18	1.51	0.43	0.5	0.45	0.65	0.72	0.8	0.74	0.83
Varadhan x BPT 5204/10	1.5	1.84	1.1	1.41	0.64	0.65	0.66	0.84	0.7	0.71	0.74	0.75
Sampada x Jaya/2	1.85	1.98	1.05	1.58	0.58	0.79	0.51	1.88	0.71	0.79	0.77	0.84
Sampada x Jaya/3	1.75	2	1.36	1.59	0.66	0.73	0.61	0.66	0.57	0.82	0.61	0.86
Varadhan x MTU 1010/2	1.66	1.98	1.34	1.31	0.5	0.51	0.59	0.71	0.72	0.92	0.8	0.98
Rasi x Jaya/2	1.62	2.11	1.68	1.85	0.5	0.52	2.6	1.01	0.65	0.88	0.69	0.96
Varadhan	1.94	2.22	2.21	2.06	0.4	0.48	0.55	0.72	0.86	0.75	0.93	0.82
BPT-5204	1.91	1.93	1.38	1.63	0.57	0.77	0.54	1.12	0.72	0.79	0.77	0.88
Sampada	1.51	1.66	0.93	1.61	0.62	0.68	1.36	3.47	0.68	0.81	0.79	0.88
Jaya	1.57	1.91	1.32	1.52	0.42	0.81	0.39	0.53	0.73	0.78	0.79	0.84
MTU-1010	1.47	1.65	1.02	2.31	0.36	0.6	0.48	0.53	0.65	0.8	0.7	0.84
Rasi	1.45	1.53	1.32	1.15	0.64	1.06	0.5	0.77	0.99	0.95	1.11	1.09
Mean	1.6	1.9	1.3	1.6	0.53	0.68	0.77	1.09	0.73	0.82	0.79	0.88
Treatments (T)	NS		*		NS		NS		*		NS	
Genotypes (G)	NS		*		*		NS		*		*	
T x G	NS		*		NS		NS		*		*	

Table 10: The influence of nitrogen on grain nitrogen and IEN in different rice genotypes.

Genotypes	Grain nitrogen (%)		IEN	
	T1	T2	T1	T2
Varadhan x BPT 5204/6	0.86	0.85	86.94	113.62
Varadhan x BPT 5204/10	0.93	0.95	102.36	135.83
Sampada x Jaya/2	0.89	0.91	93.24	189.14
Sampada x Jaya/3	0.81	0.83	92.78	111.28
Varadhan x MTU 1010/2	0.91	0.94	106.35	121.86
Rasi x Jaya/2	0.9	0.79	162.62	108.77
Varadhan	0.94	1.02	111.92	131.45
BPT-5204	0.87	0.92	109.49	190.07

Sampada	0.86	0.95	107.21	233.79
Jaya	0.87	0.92	94.63	114.78
MTU-1010	0.68	0.86	83.55	166.63
Rasi	0.86	0.96	119.767	111.12
Mean	0.87	0.9	105.905	144.028
Treatments (T)	NS		NS	
Genotypes (G)	*		*	
T x G	NS		NS	

Table 11: The influence of nitrogen on photosynthetic nitrogen use efficiency and HI in different rice genotypes.

Genotypes (G)	PNUE			Harvest index (%)		
	T1	**T2**	**Mean**	**T1**	**T2**	**Mean**
Varadhan x BPT 5204/6	23.15	11.84	17.50	51	46	48
Varadhan x BPT 5204/10	12.64	12.69	12.67	45	48	47
Sampada x Jaya/2	11.80	12.29	12.05	49	48	48
Sampada x Jaya/3	10.83	12.17	11.50	46	43	44
Varadhan x MTU 1010/2	13.26	12.31	12.79	49	49	49
Rasi x Jaya/2	9.48	11.02	10.25	49	50	50
Varadhan	12.13	8.10	10.12	48	53	50
BPT-5204	8.55	12.90	10.73	47	43	45
Sampada	14.77	14.83	14.80	48	48	48
Jaya	11.66	12.44	12.05	45	53	49
MTU-1010	13.86	14.00	13.93	46	29	38
Rasi	13.50	15.37	14.44	45	50	47
Mean	12.97	12.50	12.73	47.3	46.5	46.9
Treatments (T)	0.80			NS		
Genotypes (G)	0.17			NS		
T xG	0.29			NS		

Table 12: The influence of nitrogen on Nitrogen Use Efficiency (NUE), Total Plant Nitrogen Uptake (TPNU), Nitrogen Uptake Efficiency (NUPE) and Nitrogen Utilization Efficiency (NUTE) in different rice genotypes.

Genotypes	NUE		TPNU		NUPE		NUTE	
	T1	**T2**	**T1**	**T2**	**T1**	**T2**	**T1**	**T2**
Varadhan x BPT 5204/6	132.3	5.25	8397	6934	139.96	57.78	0.95	0.91
Varadhan x BPT 5204/10	86.6	5.58	6584	7940	109.73	66.17	0.79	0.84
Sampada x Jaya/2	110.5	6.98	6889	10872	114.81	90.60	0.96	0.77
Sampada x Jaya/3	79.3	4.43	5538	6067	92.30	50.56	0.86	0.88
Varadhan x MTU 1010/2	120.3	6.32	7807	8806	130.11	73.38	0.92	0.86
Rasi x Jaya/2	131.5	6.79	9328	9537	155.46	79.47	0.85	0.85
Varadhan	132.8	7.1	9119	10739	151.98	89.50	0.87	0.81
BPT-5204	98.6	5.13	6471	7943	107.85	66.19	0.91	0.77
Sampada	107.3	6.6	7192	11639	119.87	96.99	0.90	0.68
Jaya	115.5	7.25	7547	9614	125.78	80.11	0.92	0.90
MTU-1010	136.5	3.38	7120	4710	118.67	39.25	1.15	0.86
Rasi	126.8	6.24	8534	9005	142.23	75.05	0.89	0.83

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References

1. Carrijo DR, LundyBruce E, Linquist A. Rice yields and water use under alternate wetting and drying irrigation: A meta-analysis. Field Crops Research. 2017; 203:173-180.
2. Fageria N. Yield Physiology of Rice. Journal of Plant Nutrition. 2007; 30:843-879.
3. Fageria NK, de Morais OP, dos Santos AB. Nitrogen use efficiency in upland rice genotypes. Journal of Plant Nutrition. 2010; 33(11):1696-1711.
4. Gomez KA, Gomez A. Statistical Procedure for Agricultural Research-Hand Book. John Wiley & Sons, New York, 1984.
5. Lichtenthaler HK, Wellburn AR. Determinations of total carotenoids and chlorophylls a and b of leaf extracts in different solvents. Biochemical Society Transactions. 1983; 11(5):591-592.
6. Mae T, Ohira K. The remobilization of nitrogen related to leaf growth and senescence in rice plants (*Oryza sativa* L). Plant and Cell Physiology. 1981; 22:1067–1074.
7. Mossé J, Huet JC, Baudet J. The amino acid composition of wheat grain as a function of nitrogen content. Jounal of Cereal Science. 1985; 3:115-130.
8. Mae T, Inaba A, Kaneta Y, Masaki S, Sasaki M, Aizawa M *et al*. A Large-Grain Rice Cultivar, Akita 63, Exhibits High Yields with High Physiological N-Use Efficiency. Field Crops Research. 2006; 97:227-237.
9. Peng S, Garcia FV, Gines HC, Laza RC, Samson MI, Sanico AL. Nitrogen use efficiency of irrigated tropical rice established by broadcast wet-seeding and transplanting. Fertilizer Research. 1996; 45:123-134.
10. Poshtmasari HK, Pirdashti H, Nasiri M, Bahmanyar MA. Chlorophyll content and biological yield of old and modern rice cultivars in different urea fertilizer rates and applications. Asian Journal of Plant Science. 2007; 6(1):177-180.

11. Pramanik K, Bera AK. Effect of Seedling Age and Nitrogen Fertilizer on Growth, Chlorophyll Content, Yield and Economics of Hybrid Rice (*Oryza sativa* L.). International Journal of Agronomy and Plant Production. 2013; 4:3489-3499.
12. Witt C, Dobermann A, Abdulrachman S, Gines HC, Guanghuo Wang, Nagarajan R *et al.* Internal nutrient efficiencies of irrigated lowland rice in tropical and subtropical Asia. Field Crops Research. 1999; 63:113–138.
13. Zhou Bangwei, Serret Maria Dolores, Pie Jordi Bort, Shah Syed Sadaqat, Li Zhijian. Relative Contribution of Nitrogen Absorption, Remobilization, and Partitioning to the Ear During Grain Filling in Chinese Winter Wheat. Frontiers in Plant Science, 2018. https://www.frontiersin.org/article/10.3389/fpls.2018.01351.