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Influence of Nitrogen Levels on Physiological Response, Nitrogen Use Efficiency and Yield of Rice (*Oryza sativa* L.) Genotypes

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Authors' contributions

This work was carried out in collaboration between both authors. Authors RK and RT designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript, managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during 2011-12 to evaluate the efficiency of varying nitrogen fertilizer rates on growth and yield parameters, along with nitrogen use efficiency with two nitrogen levels 60 and 120 kg N ha^{-1} as main treatments and twenty six rice genotypes as sub treatments. Application of appropriate level of nitrogen fertilization is a major objective to increase nitrogen use efficiency by rice varieties. Among the genotypes, MTU-1001 recorded the maximum grain yield of 5021 kg ha^{-1} even under application of 60 kg N ha^{-1} with maximum NUE (Nitrogen Use Efficiency) in 60 kg N ha^{-1} (83.68) and minimum in 120 kg N ha^{-1} (45.53). NUE did not increase linearly with the amount of nitrogen application and higher nitrogen levels showed significantly lower NUE values. Maximum yield can be attributed to maximum SCMR (SPAD Chlorophyll meter reading) values, more photosynthetic rate, more tillers and panicles, more number of grains $hill^{-1}$, maximum filled grain percentage and minimum spikelet sterility.

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1. INTRODUCTION

Rice (*Oryza sativa* L.) is the world's second most important cereal crop and referred to as "Global Grain". It is staple food for more than 60% of the global population and forms the cheapest source of food and energy [1]. Nitrogen (N) is the most important macro nutrient. Assimilation of fertilizer N by plants plays a major role in plant growth and yield. Incomplete capture or poor conversion of fertilizer N causes global warming through nitrous oxide emissions. Crop production with less dependence on high N input is essential for sustainable agriculture. Use of adequate nitrogen rate is important not only for obtaining maximum economic returns, but also to reduce environmental pollution. Excessive nitrogen application can result in accumulation of large amounts of post-harvest residual soil nitrogen. Residual soil nitrate (NO^{-3}) may be available for subsequent crops in the next season, but such nitrogen is highly susceptible to leaching during non-crop periods [2].

The excessive use of nitrogen fertilizers resulted in decrease of physiological NUE and cause serious environmental pollution [3]. One of the critical steps limiting the efficient use of nitrogen is the ability of plants to acquire it from applied fertilizer [4]. Improving nitrogen use efficiency in the major cereals is critical for more sustainable nitrogen use in high input agriculture, but our understanding of the potential for NUE improvement is limited by a scarcity of reliable measurements [5]. Nitrogen fertilizer applied in the form of urea significantly increases growth, yield and yield components of the rice crop and is the main nitrogen carrier worldwide in annual crop production and generally favored by the growers due to lower application cost than other nitrogenous sources [6]. Therefore, it is essential to achieve efficient use of nitrogen in chemical fertilizers, through cultivation techniques and fertilizer management with high nitrogen use efficiency and reducing nitrogen inputs from farming to the environment. Evaluating the reaction of rice to diverse doses of nitrogen will aid in the development of high nitrogen use efficiency in varieties and to screen and select appropriate genotypes for all cultivated conditions. Nagegowda and Biradar [7] opined that site specific nutrient management approach had positive influence on available nutrients in the soil. Understanding the mechanisms regulating the processes of nitrogen uptake, assimilation, utilization efficiency and remobilization are crucial for the improvement of NUE in crop plants. One important approach is to develop an understanding of the plant response to different nitrogen regimes and studying plants that show better growth under nitrogen limiting conditions. Hence, the objective of this study has been to investigate in response to varying nitrogen fertilizer levels among 26 rice genotypes and to elicit information for the breeding of varieties that are suitable for cultivation with reduced dose of N fertilizer for eco-friendly sustainable agriculture.

2. MATERIALS AND METHODS

A field experiment was conducted during 2011-12 at college farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. The experiment was laid out in a split plot design with two nitrogen levels i.e., Optimum of 120 kg N ha^{-1} [N120], Sub optimal of 60 kg N ha^{-1} [N60] as main treatments and twenty six rice genotypes as sub treatments and the experiment was replicated thrice. The rice genotypes were sown separately in raised bed nursery and thirty day old seedlings were transplanted into 6 m^2 (2m x 3m) plots by adopting a spacing of 20 cm between rows and 15 cm between plants with in a row. Nitrogen was applied in three equal splits in the form of urea. Depending on the nitrogen treatments one third dose of nitrogen was applied as basal dose at the time of planting of the crop. Remaining two equal splits of nitrogen was broadcasted at maximum tillering and panicle initiation stages. Phosphorus was applied at the rate of 60 kg P_2O_5 ha^{-1} in the form of single super phosphate and potassium 40 kg K_2O ha^{-1} in the form of muriate of potash as basal dose at the time of transplanting. Irrigation and weed management were done from time to time. The border rows were harvested first and then, the net plot area was harvested, produce was threshed by beating on a threshing bench, cleaned and sun dried to 14 percent moisture level. Plants in one m^2 area were tagged separately.

Five plants in each plot were tagged and observations on physiological characters at maximum tillering, flowering and maturity stages were recorded. 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 (IRGA- Infra Red Gas Analyser) portable photosynthetic measurement system. During measurements, the PAR (Photosynthetically Active Radiation) was kept at 1200 µmol m^{-2} s^{-1} and CO_2 concentration at 387 ± 6 ppm. These measurements were made between 10.00 am to 12.00 noon at all the sampling dates and expressed as µmol CO_2 m^{-2} 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 the method given by Panse and Sukhatme [8].

3. RESULTS AND DISCUSSION

3.1 SPAD Chlorophyll Meter Reading (SCMR)

Results on SCMR as influenced by nitrogen application in rice genotypes were presented in Table 1. The role of chlorophyll in photosynthesis is well established but the relationship between chlorophyll content and rate of photosynthesis were equivocal. SCMR values increased from maximum tillering stage (37.8) to flowering stage (42.5) and thereafter declined towards maturity (32.5). There was significant increase in SCMR values due to nitrogen application rates. Among the treatments, application of 120 kg N ha^{-1} resulted in mean SCMR values of 38.4 at maximum tillering stage which increased to 43.4 at flowering stage and reduced to 33.8 at maturity stage. Plants which were grown in 60 kg N ha^{-1} recorded the minimum SCMR values at all the stages.

The interaction between treatment levels and genotypes at maximum tillering stage was non significant. Genotypes which maintained high chlorophyll content from panicle initiation stage to grain filling stage were important in determining grain yield [9]. The interaction between treatments and genotypes was significant at flowering and maturity stages. MTU-1001 recorded maximum SCMR values at flowering stage in 120 kg N ha^{-1} (47.4) and 60 kg N ha^{-1} (43.2) and minimum in Varalu at N 120 (41.2) and at N 60 (39.8) treatments. Similarly at maturity stage the maximum SCMR values were recorded by the genotype MTU-1001 in 120 kg N ha^{-1} (36.1).

3.2 Photosynthetic Rate (μ mol CO_2 m^{-2} s^{-1})

Nitrogen nutrition influences the content of photosynthetic pigments, synthesis of the enzymes taking part in the carbon reduction, formation of the membrane system of chloroplasts, etc. Photosynthetic rate increased from maximum tillering (18.41 μ mol CO_2 m^{-2} s^{-1}) to flowering stage (22.24 μ mol CO_2 m^{-2} s^{-1}) and recorded a decrease thereafter towards maturity stage (13.23 μ mol CO_2 m^{-2} s^{-1}) (Table 4). Significant increase in leaf photosynthetic rate was recorded due to nitrogen application. Nitrogen application at 120 kg N ha^{-1} had resulted in mean leaf photosynthetic rate of 19.47 μ mol CO_2 m^{-2} s^{-1} at maximum tillering stage which increased to 23.43 μ mol CO_2 m^{-2} s^{-1} at flowering stage and decreased to 13.63 μ mol CO_2 m^{-2} s^{-1} by maturity stage. Photosynthetic rate recorded was low at all the stages when nitrogen fertilizers were applied at 60 kg N ha^{-1}. Hassan et al. [10] suggested that low levels of nitrogen can reduce photosynthetic rate as well as leaf chlorophyll content and photosynthetic efficiency. Significant differences were observed between the genotypes in photosynthetic rate at maximum tillering and flowering stage, but the differences were non significant at maturity stage. At maximum tillering stage, photosynthetic rate ranged from 16.84 μ mol CO_2 m^{-2} s^{-1} to 19.44 μ mol CO_2 m^{-2} s^{-1}, at flowering stage from 20.49 μ mol CO_2 m^{-2} s^{-1} to 23.14 μ mol CO_2 m^{-2} s^{-1}. Maximum values were recorded in MTU-1001 at both maximum tillering and flowering stages (19.44 and 23.14 μ mol CO_2 m^{-2} s^{-1} respectively). Genotypes that maintain higher leaf chlorophyll content during crop growth period may be considered as potential donors for the ability to produce higher photosynthetic rate.

3.3 Nitrogen Use Efficiency (NUE)

NUE largely depends on nutrient balance, water availability, light intensity and cultivated variety. Nitrogen efficient genotype is considered in two different terms: the ability to convert high nitrogen input into yield comparatively better than other genotypes or the ability to realize an above average yield at suboptimal nitrogen level. Rice genotypes showed different nitrogen uptake ability and NUE at different nitrogen levels [11].

NUE data as influenced by nitrogen supply in rice genotypes is presented in Table 3. Maximum NUE was recorded at 60 kg N ha^{-1} (66.42) and minimum in 120 kg N ha^{-1} (38.32). The results showed that the NUE did not increase linearly with the amount of nitrogen application. Kang et al. [11] also reported that higher nitrogen levels showed significantly lower NUE values. NUE values ranged from 34.88 to 64.61 with a general mean of 52.37. MTU-1001 recorded maximum NUE (64.61) and Varalu recorded the minimum value (34.88). Interaction effect revealed that MTU-1001 recorded maximum NUE (83.68) at 60 kg N $ha^{-1}$where as Varalu recorded minimum NUE (27.29) at 120 kg N ha^{-1}. Rice varieties responded well to higher levels of nitrogen but nitrogen use efficiency was comparatively better in lower levels. Excessive N rate, low nitrogen uptake and irrational application, timing were the key reasons for low nitrogen use efficiency. However, grain yield increased linearly with incremental dose of nitrogen [12].

3.4 Yield and Yield Attributes

The yield ultimately depends on the better expression of yield attributing characters like panicle number $hill^{-1}$, number of filled grains and unfilled grains $panicle^{-1}$ and yield.

Table 1. The influence of nitrogen on SCMR values in rice genotypes at different stages of crop during kharif-2011

Genotypes		Maximum tillering stage			Flowering stage			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-14		36.5	38.5	37.5	40.5	41.6	41.1	30.1	34.8	32.5
BPT-5204		37.0	39.5	38.2	41.6	43.8	42.7	32.5	35.1	33.8
WGL-2395		37.2	39.2	38.2	41.6	42.2	41.9	32.5	34.3	33.4
Divya		37.7	39.4	38.6	40.4	41.5	41.0	31.3	32.1	31.7
JGL-11727		37.8	39.1	38.4	41.7	46.8	44.3	32.4	33.5	32.9
Pothana		36.9	38.7	37.8	41.0	42.7	41.9	31.3	34.4	32.9
RNR-C-28		37.5	38.6	38.0	41.4	43.7	42.6	31.6	34.4	33.0
RNR-2354		35.9	37.2	36.5	42.5	45.4	44.0	31.9	34.7	33.3
RNR-2465		36.0	38.0	37.0	40.8	41.1	40.9	31.0	31.4	31.2
JGL-3855		38.9	37.5	38.2	42.9	44.8	43.9	32.1	36.1	34.1
NDLR-7		37.2	38.7	37.9	42.9	44.2	43.6	31.1	34.5	32.8
Surekha		38.1	39.1	38.6	42.9	42.7	42.8	29.5	31.9	30.7
RNR-2458		37.0	38.8	37.9	42.4	43.4	42.9	31.6	33.5	32.6
MTU-1001		37.8	40.9	39.3	43.2	47.4	45.1	34.6	36.1	35.4
Erramallelu		36.7	38.0	37.4	40.3	40.9	40.6	29.4	31.3	30.4
Bhadrakali		37.4	38.5	37.9	40.9	42.5	41.7	31.4	33.9	32.6
JGL-1798		36.7	38.4	37.6	41.3	43.1	42.2	32.3	33.8	33.1
Godavari isukalu		38.6	38.8	38.7	41.1	42.8	41.9	30.7	32.8	31.7
Kavya		37.2	38.3	37.8	42.5	44.7	43.6	30.6	34.5	32.6
MTU-1010		37.3	39.5	38.4	42.4	45.1	43.8	32.8	35.8	34.3
Chittimutyalu		37.2	38.8	38.0	41.4	42.9	42.1	29.2	32.8	31.0
WGL-32100		36.1	37.7	36.9	41.2	44.2	42.7	32.4	35.3	33.9
Varalu		35.4	36.3	35.9	39.8	41.2	40.5	28.8	30.6	29.7
JGL-1470		37.3	38.1	37.7	41.6	43.6	42.6	31.1	33.6	32.4
JGL-3844		36.6	37.8	37.2	40.4	42.1	41.3	30.2	32.7	31.5
JGL-3828		35.9	36.3	36.1	41.1	43.3	42.2	30.0	33.9	32.0
Mean		37.1	38.4	37.8	41.5	43.4	42.5	31.2	33.8	32.5
C.D (5%)	Treatments (T)	1.225			0.671			1.251		
	Genotypes (G)	NS			1.251			0.888		
	T x G	NS			1.825			1.642		

3.5 Panicle Number Hill^{-1}

The number of panicles hill^{-1} increased significantly with increase in N application from 60 kg N ha^{-1} (11.7) to 120 kg N ha^{-1} (13.5) (Table 4). Increment in panicle number with increase in nitrogen application in rice was earlier reported by Gosh et al. [13]. Among the genotypes, the number of panicle hill^{-1} ranged from 11.5 to 14.5 with a mean of 12.6 panicles hill^{-1} and the difference were statistically significant. The genotype MTU-1001 (14.5) recorded maximum number of panicles hill^{-1} which was on par with MTU-1010 (14.0), BPT-5204 (13.7), the minimum number of panicles hill^{-1} was recorded in Varalu (11.5). The cultivar having large panicles may be the best option but the adequate numbers of panicles need to be maintained properly in terms of sink-source balance [14].

3.6 Number of Filled Grains Hill^{-1}

The result on number of filled grains hill^{-1} revealed that there was significant increase in this parameter with increase in nitrogen application which ranged from 1039 (N60) to 1290 (N120) with a mean of 1165 filled grains hill $^{-1}$ (Table 4). Among the genotype MTU-1001 recorded maximum value of 1507 filled grains hill^{-1}. Suryaprabha et al. [15] found that number of filled grains per panicle had significant positive effect on rice grain yield.

Table 2. The influence of nitrogen on photosynthetic rate (μ mol CO_2 m^{-2} s^{-1}) in rice genotypes at different stages of crop during kharif-2011

Genotypes		Maximum tillering stage			Flowering stage			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-14		18.33	19.09	18.71	21.57	23.10	22.33	12.44	14.46	13.45
BPT-5204		16.58	19.16	17.87	20.65	23.51	22.08	11.94	14.31	13.12
WGL-2395		17.31	19.85	18.58	20.74	23.84	22.29	12.65	13.31	12.98
Divya		16.27	17.40	16.84	19.54	21.43	20.49	12.20	14.20	13.20
JGL-11727		16.80	19.88	18.34	20.94	23.94	22.44	11.27	14.67	12.97
Pothana		16.11	18.76	17.44	20.35	22.86	21.61	12.88	14.23	13.56
RNR-C-28		17.02	17.77	17.39	20.96	21.86	21.41	12.20	12.75	12.48
RNR-2354		18.16	19.00	18.58	21.55	23.09	22.32	14.33	14.03	14.18
RNR-2465		16.35	19.60	17.97	19.86	23.43	21.65	14.82	14.62	14.72
JGL-3855		17.49	20.18	18.83	21.55	24.03	22.79	12.70	14.36	13.53
NDLR-7		17.65	20.03	18.84	21.60	23.73	22.67	14.02	12.52	13.27
Surekha		17.35	18.73	18.04	21.31	22.69	22.00	13.00	13.40	13.20
RNR-2458		16.59	19.68	18.14	20.99	23.66	22.33	12.28	12.60	12.44
MTU-1001		18.39	20.48	19.44	21.84	24.44	23.14	12.23	12.92	12.58
Erramallelu		18.64	19.00	18.82	21.47	22.74	22.11	13.70	13.77	13.73
Bhadrakali		16.08	18.60	17.34	20.12	22.80	21.46	12.93	14.55	13.74
JGL-1798		16.37	19.11	17.74	20.42	23.46	21.94	12.79	13.43	13.11
Godavari isukalu		16.79	20.12	18.45	20.76	24.04	22.40	12.04	12.82	12.43
Kavya		17.61	20.02	18.82	20.69	23.56	22.13	12.70	12.42	12.56
MTU-1010		18.91	19.81	19.36	21.82	24.39	23.11	12.37	13.12	12.74
Chittimutyalu		16.97	20.43	18.70	20.68	23.83	22.26	11.98	13.32	12.65
WGL-32100		18.02	20.51	19.26	21.80	24.15	22.97	13.93	13.79	13.86
Varalu		18.32	19.30	18.81	21.18	23.56	22.37	12.55	13.09	12.82
JGL-1470		17.61	20.07	18.84	21.91	23.54	22.72	14.01	13.50	13.75
JGL-3844		17.51	20.32	18.92	21.60	23.78	22.69	12.65	13.27	12.96
JGL-3828		17.74	19.45	18.59	21.43	23.68	22.55	13.06	14.92	13.99
Mean		17.35	19.47	18.41	21.05	23.43	22.24	12.83	13.63	13.23
C.D (5%)	Treatments (T)	0.482			0.056			0.362		
	Genotypes (G)	1.219			1.196			NS		
	T x G	NS			NS			NS		

Table 3. The influence of nitrogen on grain yield (Kg ha^{-1}) and nitrogen use efficiency in rice genotypes during kharif-2011

Genotypes		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-14		3200	4423	3811	53.33	36.86	45.09
BPT-5204		4810	5036	4923	80.17	41.80	60.98
WGL-2395		4976	5175	5076	82.93	43.99	63.46
Divya		4740	4856	4798	78.99	40.47	59.73
JGL-11727		4741	4983	4862	79.02	41.53	60.27
Pothana		4869	5046	4957	81.15	42.05	61.60
RNR-C-28		4219	4402	4310	70.31	36.68	53.50
RNR-2354		3148	4230	3689	52.47	35.25	43.86
RNR-2465		3072	4072	3572	51.21	33.93	42.57
JGL-3855		3750	4618	4184	62.51	38.49	50.50
NDLR-7		3073	3798	3436	51.22	31.65	41.43
Surekha		2636	3458	3047	43.94	28.81	36.38
RNR-2458		3847	4504	4175	64.11	37.53	50.82
MTU-1001		5021	5364	5192	83.68	45.53	64.61
Erramallelu		2923	3641	3282	48.72	30.34	39.53
Bhadrakali		4821	5001	4911	80.36	41.68	61.02
JGL-1798		4918	5141	5030	81.97	42.84	62.41
Godavari isukalu		4130	4772	4451	68.83	39.77	54.30
Kavya		4720	4873	4797	78.66	40.61	59.64
MTU-1010		5015	5338	5176	83.58	44.48	64.03
Chittimutyalu		4144	4816	4480	69.06	40.13	54.60
WGL-32100		3445	4697	4071	57.42	39.14	48.28
Varalu		2549	3275	2912	42.48	27.29	34.88
JGL-1470		3649	4818	4233	60.81	40.15	50.48
JGL-3844		3111	4399	3755	51.85	36.66	44.26
JGL-3828		4094	4634	4364	68.24	38.62	53.43
Mean		3985	4591	4288	66.42	38.32	52.37
C.D (5%)	Treatments (T)	73.546			0.855		
	Genotypes (G)	108.665			1.446		
	T x G	163.049			2.132		

3.7 Number of Unfilled Grains $Hill^{-1}$

Results on unfilled grains $hill^{-1}$ as influenced by nitrogen supply in rice genotypes is presented in Table 4. Significant differences were noticed between the treatments and increase in nitrogen level reduced the unfilled grains $hill^{-1}$ from 449 to 573. Unfilled grains $hill^{-1}$ was minimum with application of 120 kg N ha^{-1} (449) and maximum was recorded at 60 kg N ha^{-1} (573). Among the rice genotypes there was significant difference in number of unfilled grains $hill^{-1}$ which ranged from 429 to 641 with a mean of 511. Minimum number of unfilled grains $hill^{-1}$ was recorded in MTU-1001 (429) where as maximum number of unfilled grains $hill^{-1}$ was recorded in Kavya (641).

Interaction showed minimum number of unfilled grains $hill^{-1}$ at 120 kg N ha^{-1} (374) in genotype MTU-1001 where as maximum unfilled grains $hill^{-1}$ was recorded at 60 kg N ha^{-1} (756) in WGL-32100.

3.8 Grain Yield (kg ha^{-1})

Nitrogen is the most essential element that determines the yield potential of intensified agricultural system. Additional doses of nitrogen are usually applied to increase grain yield. A perusal of the data on grain yield indicates that with increased nitrogen levels there was significant increase in the grain yield (Table 3). Highest grain yield9 of 4591 kg ha^{-1} was recorded with 120 Kg N ha^{-1}, while lowest grains yield of 3985 kg ha^{-1} was recorded with 60 Kg N ha^{-1} treatment. MTU-1001 recorded maximum grain yield of 5192 kg ha^{-1}, while the lowest grain yield of 2912 kg ha^{-1} was recorded in Varalu.

Table 4. The influence of nitrogen on number of panicles hill^{-1}, filled and unfilled grains hill^{-1} in rice genotypes during kharif 2011

Genotypes		No. of panicles hill^{-1}			No. of filled grains hill^{-1}			No. of unfilled grains hill^{-1}		
		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-14		11.7	13.0	12.3	1221	1386	1304	565	406	485
BPT-5204		13.0	14.3	13.7	1307	1446	1376	528	416	472
WGL-2395		12.0	14.0	13.0	1297	1467	1382	577	424	501
Divya		12.0	14.3	13.2	990	1241	1115	508	417	463
JGL-11727		11.0	13.0	12.0	1024	1282	1153	512	446	479
Pothana		11.7	13.0	12.3	1113	1305	1209	630	468	549
RNR-C-28		12.0	14.0	13.0	1004	1147	1075	611	491	551
RNR-2354		11.7	14.0	12.8	919	1221	1070	555	475	515
RNR-2465		11.0	12.3	11.7	782	1322	1052	536	448	492
JGL-3855		11.7	13.0	12.3	885	1154	1020	488	402	445
NDLR-7		11.0	13.0	12.0	939	1325	1132	549	457	503
Surekha		11.0	13.0	12.0	890	1065	977	543	428	486
RNR-2458		11.0	12.3	11.7	1021	1217	1119	517	417	467
MTU-1001		13.0	16.0	14.5	1428	1586	1507	484	374	429
Erramallelu		12.0	13.3	12.7	647	1032	840	498	404	451
Bhadrakali		12.0	13.0	12.5	1074	1290	1182	646	493	570
JGL-1798		12.3	13.3	12.8	1166	1357	1261	611	447	529
Godavari isukalu		12.0	14.0	13.0	866	1172	1019	679	554	617
Kavya		11.0	13.3	12.2	1105	1314	1210	734	548	641
MTU-1010		13.0	15.0	14.0	1387	1507	1447	509	396	452
Chittimutyalu		11.3	13.3	12.3	917	1275	1096	667	487	577
WGL-32100		11.7	14.0	12.8	1010	1452	1231	756	511	633
Varalu		10.0	13.0	11.5	917	1146	1032	571	465	518
JGL-1470		11.3	14.3	12.8	953	1352	1153	547	445	496
JGL-3844		12.0	13.0	12.5	1082	1226	1154	506	422	464
JGL-3828		11.0	13.0	12.0	1076	1249	1162	581	431	506
Mean		11.7	13.5	12.6	1039	1290	1165	573	449	511
C.D (5%)	Treatments (T)	0.457			3.993			15.356		
	Genotypes (G)	1.076			34.760			27.172		
	T x G	NS			48.320			39.849		

The interaction between nitrogen levels and rice genotypes was highly significant for grain yield. Highest grain yield of 5364 kg ha^{-1} was recorded with 120 Kg N ha^{-1} in MTU-1001, whereas lowest grain yields of 2548 kg ha^{-1} was recorded in Varalu with application of 60 Kg N ha^{-1}. The grain yield significantly increased with increasing nitrogen levels up to 120 kg N ha^{-1}. 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 [16].

4. CONCLUSION

Rice varieties responded well to higher levels of nitrogen. 120 Kg N ha^{-1} and rice genotypes MTU-1001 has recorded highest grain yield and lowest grain yield was recorded in Varalu with application of 60 Kg N ha^{-1}. The adequate quantity of nitrogen at the right time helped rice plants to produce maximum yield and also accumulation of nitrogen in rice productive organs.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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