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RESEARCH ARTICLE

Physiological Response of Rice Genotypes to Different Nitrogen Levels

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ABSTRACT

An experiment was conducted to study the rice genotypes for nitrogen use efficiency at the Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore during *Kharif*, 2017. Forty rice genotypes were used for this study with two nitrogen levels *viz*., 50% Recommended Dose of Nitrogen (RDN) and 100% RDN and the experiment was laid out in Factorial Randomized Block Design with two replications. The rice genotypes were subjected to 100% RDN and 50% RDN and various morpho-physiological, biochemical and yield traits were observed. Among the genotypes, IRGC 6386-1 showed higher photosynthetic rate at 100% RDN and 50% RDN followed by WAS 169. Similarly, higher grain yield per plant was noticed in IRGC 6386-1 at 100% RDN (60.22 g) and 50% RDN (58.41 g). From the results, it is evident that the increased amount of nitrogen could enhance the growth dynamics and yield attributes of rice genotypes. However, the present study demonstrated that certain genotypes had performed better even at 50% RDN in terms of growth characters and yield attributes.

Keywords: *Rice, Nitrogen levels, RDN, Nitrogen efficient genotypes*

Rice (*Oryza sativa* L.) is one of the most important staple food crops in the world. In Asia, more than two billion people are dependent on rice for their livelihood. It is the agricultural commodity with the third highest worldwide production (741.5 million tonnes in 2014). The demand for rice is increasing because of the population growth and an expected diet change (Joshi *et al*., 2009). India has a total rice production of 157.2 million tonnes (FAOSTAT 2017). However, the Indian rice productivity is still well below the world's average yield of 4.6 t/ha (FAOSTAT, 2017).

In rice growing regions, N is considered as one of the most yield limiting nutrients for its production. Rapid N loss through volatilization and denitrification in the soil-flood water system from source is more in rice crop than other cereal crops (Kirk and Kronzucker, 2005). Applied inorganic N is rapidly lost since NUE varies from 18 to 40% in rice soils. The cultivation of genotypes with high NUE will lower the cost of production and reduce the environmental pollution. Thus, the identification of genotypes from the existing germplasm or development of rice cultivars that can make the best use of N in low-nitrogen soils is essential for the sustainability of agriculture (Lian *et al*., 2006). Different approaches must be sought to increase both grain yield and NUE in rice genotypes, so that the future demand could be met and environmental costs be mitigated (Peng and Bouman, 2007).

Material and Methods

Field experiment was conducted in the Field No.H7a at Department of Rice, Tamil Nadu Agricultural University, Coimbatore during 2017. The experimental location is geographically situated in western agro climatic zone of Tamil Nadu at 11˚N latitude and 77˚E longitude with an altitude of 426.72 m above Mean Sea Level. Total dry matter production was estimated by pulling out the entire plant at different stages of each treatment. Root and shoot portions were weighed separately after drying at 70 ± 2^{o}c for 48 hours. The total dry matter production was arrived and the values expressed as g plant^{-1}. Chlorophyll content in leaves was analyzed by following the method of Hiscox and Israelstam, (1979) and expressed in mg g^{-1} fresh weight. Gas exchange parameters were measured using a portable photosynthesis system (LI-6400 XT; LI-COR Inc. Lincoln, Nebraska, USA). Soluble protein content of leaf was estimated as per the method of Lowry *et al*(1951) and expressed as mg g^{-1} fresh weight. The grain yield per plant was derived from the mean of five plants from each treatment and expressed in g plant^{-1}.

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Results and Discussion

There were significant effects of nitrogen fertilizer levels among the genotypes on dry matter production. The mean values of data suggested that at maximum tillering stage, the higher dry matter production (45.23 g) was recorded in plants treated with 100% RDN which was better than 50% RDN (36.13 g).

Table 1. Effect of nitrogen levels on total dry matter production (g plant^{-1})

Genotypes	Maximum tillering stage			% of reduction	Flowering stage			% of reduction
	100% RDN	50% RDN	Mean		100% RDN	50% RDN	Mean	
IRGC 6087-1	36.84	28.52	32.68	22.58	53.26	43.95	48.61	17.48
IRGC 6386-1	73.18	57.89	65.54	20.89	97.47	83.24	90.36	14.60
BINULAWAN	29.54	23.07	26.31	21.90	47.91	37.25	42.58	22.25
IRGC 70215-1	45.22	40.06	42.64	11.41	64.68	55.31	60.00	14.49
IRGC 116981-1	33.57	26.42	30.00	21.30	50.54	42.27	46.41	16.36
IRGC 32675-C1-G1	35.42	30.04	32.73	15.19	60.51	49.02	54.77	18.99
IRGC 63493-C1-G1	40.54	36.83	38.69	9.15	60.56	52.76	56.66	12.88
IR 72	54.04	35.42	44.73	34.46	57.24	50.62	53.93	11.57
NIONOKA	46.53	36.40	41.47	21.77	63.60	51.70	57.65	18.71
WAS 200	53.05	42.68	47.87	19.55	71.40	59.17	65.29	17.13
IR 20	38.34	28.13	33.24	26.63	46.55	43.02	44.79	7.58
WAS 199	52.45	43.31	47.88	17.43	73.49	60.30	66.90	17.95
CO 51	49.30	36.77	43.04	25.42	62.23	51.77	57.00	16.81
ADT 43	40.36	33.69	37.03	16.53	65.70	50.07	57.89	23.79
ASD 16	53.97	49.33	51.65	8.60	84.46	69.65	77.06	17.53
IR 64	51.10	42.45	46.78	16.93	60.23	57.60	58.92	4.37
N22	52.71	44.42	48.57	15.73	68.31	61.88	65.10	9.41
IRGC 8177-1	52.15	51.05	51.60	2.11	88.26	81.22	84.74	7.98
CHANG	47.08	37.62	42.35	20.09	61.00	54.40	57.70	10.82
CO 18	97.62	74.05	85.84	24.14	105.92	92.41	99.17	12.75
IR 36	24.76	18.65	21.71	24.68	45.57	31.83	38.70	30.15
IRGC 116967-1	34.30	29.77	32.04	13.21	52.19	47.04	49.62	9.87
IRGC 117005-1	27.80	23.35	25.58	16.01	42.64	38.15	40.40	10.53
IRGC 74762-1	47.22	31.72	39.47	32.83	52.26	49.46	50.86	5.36
IRGC 64917-1	53.52	48.34	50.93	9.68	71.23	62.71	66.97	11.96
IRGC 8266-C1-G1	41.81	31.92	36.87	23.65	59.35	49.84	54.60	16.02
TSIPALA FOTSY	38.64	32.62	35.63	15.58	59.77	50.07	54.92	16.23
WAS 169	32.07	26.52	29.30	17.31	49.09	42.89	45.99	12.63
WAS 182	49.51	42.23	45.87	14.70	63.46	55.50	59.48	12.54
WAS 202	48.43	31.11	39.77	35.76	52.13	49.45	50.79	5.14
WAS 207	49.70	40.04	44.87	19.44	60.52	54.96	57.74	9.19
WAS 20	48.80	31.11	39.96	36.25	58.91	49.19	54.05	16.50
WAS 30	44.32	35.98	40.15	18.82	57.60	50.68	54.14	12.01
WAS 62	43.35	30.55	36.95	29.53	58.13	49.06	53.60	15.60
CT 6510	50.64	34.81	42.73	31.26	57.47	50.32	53.90	12.44
IRGC 26971-C1	21.53	19.23	20.38	10.68	42.20	36.31	39.26	13.96
WAS 203	38.10	25.94	32.02	31.92	47.47	41.58	44.53	12.41
CO 50	44.88	39.13	42.01	12.81	61.93	54.84	58.39	11.45
CO 52	43.50	37.82	40.66	13.06	61.50	54.52	58.01	11.35
Jai Sri Ram	43.26	36.25	39.76	16.20	57.51	51.03	54.27	11.27
Mean	45.23	36.13	40.68	19.88	61.36	52.93	57.14	13.75
	G	T	G X T		G	T	G X T	
SEd	1.23	0.27	1.75		1.59	0.35	2.25	
CD(0.05)	2.46**	0.55**	3.48**		3.17**	0.70**	4.48**	

Similar trend was observed at flowering stage also. Significantly higher value was recorded in CO 18 at 100% RDN (105.92 g) and 50 % RDN (92.41 g) followed by IRGC 6386-1 at 100% RDN (97.47 g) and 50% RDN (83.24 g) during flowering stage. Minimum mean dry matter value was recorded in IR 36 at maximum tillering stage (21.71 g) and flowering stage (38.70 g).

Table 2. Effect of nitrogen levels on total chlorophyll (mg g^{-1}) content

Genotypes	Maximum tillering stage			% of reduction	Flowering stage			% of reduction
	100% RDN	50% RDN	Mean		100% RDN	50% RDN	Mean	
IRGC 6087-1	2.58	2.37	2.48	8.14	3.27	3.04	3.16	7.03
IRGC 6386-1	3.31	3.09	3.20	6.65	4.35	4.12	4.24	5.29
BINULAWAN	1.54	1.48	1.51	3.90	3.46	1.81	2.64	47.69
IRGC 70215-1	1.82	1.54	1.68	15.38	2.43	2.17	2.30	10.70
IRGC 116981-1	2.54	2.28	2.41	10.24	3.29	3.04	3.17	7.60
IRGC 32675-C1-G1	2.23	2.20	2.22	1.35	3.17	2.91	3.04	8.20
IRGC 63493-C1-G1	1.78	1.58	1.68	11.24	2.61	2.26	2.44	13.41
IR 72	2.99	2.54	2.77	15.05	3.57	3.21	3.39	10.08
NIONOKA	2.78	2.52	2.65	9.35	3.42	3.19	3.31	6.73
WAS 200	2.98	2.75	2.87	7.72	3.81	3.26	3.54	14.44
IR 20	2.54	2.21	2.38	12.99	3.38	2.92	3.15	13.61
WAS 199	2.46	2.28	2.37	7.32	3.38	3.03	3.21	10.36
CO 51	2.57	2.41	2.49	6.23	3.38	3.15	3.27	6.80
ADT 43	2.91	2.70	2.81	7.22	3.39	3.25	3.32	4.13
ASD 16	2.75	2.58	2.67	6.18	3.37	3.22	3.30	4.45
IR 64	2.98	2.89	2.94	3.02	3.37	3.05	3.21	9.50
N22	2.58	2.41	2.50	6.59	3.29	3.13	3.21	4.86
IRGC 8177-1	3.43	2.91	3.17	15.16	3.98	3.57	3.78	10.30
CHANG	1.72	1.58	1.65	8.14	2.64	2.22	2.43	15.91
CO 18	2.32	2.18	2.25	6.03	3.48	2.88	3.18	17.24
IR 36	1.77	1.52	1.65	14.12	2.97	2.16	2.57	27.27
IRGC 116967-1	2.28	1.98	2.13	13.16	2.95	2.39	2.67	18.98
IRGC 117005-1	1.89	1.57	1.73	16.93	2.46	2.21	2.34	10.16
IRGC 74762-1	1.99	1.87	1.93	6.03	3.06	2.28	2.67	25.49
IRGC 64917-1	2.94	2.78	2.86	5.44	3.47	3.29	3.38	5.19
IRGC 8266-C1-G1	2.37	2.15	2.26	9.28	3.21	2.82	3.02	12.15
TSIPALA FOTSY	2.15	1.93	2.04	10.23	2.53	2.36	2.45	6.72
WAS 169	2.57	2.39	2.48	7.00	3.31	3.09	3.20	6.65
WAS 182	2.61	2.41	2.51	7.66	3.39	3.16	3.28	6.78
WAS 202	2.97	2.24	2.61	24.58	3.37	3.02	3.20	10.39
WAS 207	3.02	2.95	2.99	2.32	4.35	4.07	4.21	6.44
WAS 20	2.45	2.13	2.29	13.06	2.99	2.54	2.77	15.05
WAS 30	2.84	2.50	2.67	11.97	3.48	3.17	3.33	8.91
WAS 62	2.02	1.82	1.92	9.90	2.57	2.28	2.43	11.28
CT 6510	2.14	2.03	2.09	5.14	2.61	2.42	2.52	7.28
IRGC 26971-C1	1.91	1.76	1.84	7.85	2.89	2.27	2.58	21.45
WAS 203	2.37	2.15	2.26	9.28	3.15	2.75	2.95	12.70
CO 50	1.95	1.78	1.87	8.72	2.42	2.27	2.35	6.20
CO 52	1.57	1.49	1.53	5.10	2.78	2.12	2.45	23.74
Jai Sri Ram	2.16	2.09	2.13	3.24	2.69	2.47	2.58	8.18
Mean	2.42	2.20	2.31	8.97	3.19	2.81	3.01	11.98
	G	T	G X T		G	T	G X T	
SEd	0.07	0.02	0.1		0.09	0.02	0.13	
CD(0.05)	0.14**	0.03**	0.20*		0.18**	0.04**	0.25**	

Percentage reduction over 100% N was also observed on total dry matter production and it was 19.88 per cent during maximum tillering stage and 13.75 per cent during flowering stage. Among the genotypes, least reduction was noticed in IR 64 (4.37 %) followed by WAS 202 (5.14 %), IRGC 74762-1 (5.36 %) at flowering stage. The interaction effect between the nitrogen levels and genotype was observed to be significant (Table 1). Similar findings were reported by Chowdhury *et al.* (1994) in rice crop, that dry matter production was lowest at 30 days after planting thereafter, it was increased. Further, they explained that dry matter accumulation was maximum at 150% recommended dose of nitrogen per hectare.

Table 3. Effect of nitrogen levels on Photosynthetic rate (µmol CO_2 m^{-2} s^{-1})

Genotypes	Maximum tillering stage			% of reduction	Flowering stage			% of reduction
	100% RDN	50% RDN	Mean		100% RDN	50% RDN	Mean	
IRGC 6087-1	23.32	22.23	23.28	4.67	33.63	27.67	30.65	17.72
IRGC 6386-1	30.26	28.91	30.09	4.46	33.14	32.61	32.88	1.60
BINULAWAN	25.09	21.61	23.35	13.87	30.55	29.15	29.85	4.58
IRGC 70215-1	21.66	18.06	19.86	16.62	29.52	24.01	26.77	18.67
IRGC 116981-1	25.67	19.16	22.42	25.36	31.51	27.37	29.44	13.14
IRGC 32675-C1-G1	27.09	19.59	23.34	27.69	32.48	28.86	30.67	11.15
IRGC 63493-C1-G1	23.27	17.57	20.42	24.50	30.57	27.72	29.15	9.32
IR 72	28.55	25.43	26.99	10.93	32.37	30.25	31.31	6.55
NIONOKA	26.88	24.83	25.86	7.63	32.18	30.97	31.08	3.76
WAS 200	28.52	26.25	27.39	7.96	32.17	29.54	30.86	8.18
IR 20	27.53	20.49	24.01	25.57	33.55	29.43	31.49	12.28
WAS 199	20.58	20.12	20.14	2.24	33.85	23.96	28.91	29.22
CO 51	30.33	24.54	27.44	19.09	32.15	31.51	31.83	1.99
ADT 43	26.25	24.89	25.57	5.18	28.36	27.85	28.11	1.80
ASD 16	28.54	26.95	27.75	5.57	33.45	30.24	31.85	9.60
IR 64	29.33	28.34	28.84	3.38	33.45	31.77	32.61	5.02
N22	29.25	22.39	25.82	23.45	32.58	30.75	31.67	5.62
IRGC 8177-1	28.34	26.33	27.34	7.09	33.21	29.52	31.37	11.11
CHANG	25.88	22.57	24.23	12.79	33.19	30.54	31.87	7.98
CO 18	25.48	22.11	23.80	13.23	32.58	27.39	29.99	15.93
IR 36	27.05	24.21	25.63	10.50	32.55	29.83	31.19	8.36
IRGC 116967-1	28.97	24.05	26.51	16.98	32.76	30.24	31.50	7.69
IRGC 117005-1	22.15	20.36	21.26	8.08	29.10	26.30	27.70	9.62
IRGC 74762-1	25.36	23.68	24.52	6.62	30.16	28.18	29.17	6.56
IRGC 64917-1	27.32	25.05	26.19	8.31	32.90	30.93	31.92	5.99
IRGC 8266-C1-G1	21.68	20.52	21.10	5.35	31.70	26.07	28.89	17.76
TSIPALA FOTSY	22.56	20.02	21.29	11.26	32.82	27.88	30.35	15.05
WAS 169	27.64	21.30	24.47	22.94	33.98	31.27	32.63	7.98
WAS 182	27.36	25.01	26.19	8.59	31.44	29.02	30.23	7.70
WAS 202	22.39	18.49	20.44	17.42	34.12	25.17	29.65	26.23
WAS 207	28.46	24.61	26.54	13.53	32.47	28.96	30.72	10.81
WAS 20	23.32	19.08	21.20	18.18	31.11	29.16	30.14	6.27
WAS 30	29.56	26.81	28.19	9.30	32.39	30.64	31.52	5.40
WAS 62	25.34	20.34	22.84	19.73	33.91	30.03	31.97	11.44
CT 6510	29.91	21.83	25.87	27.01	33.26	30.25	31.76	9.05
IRGC 26971-C1	24.61	22.56	23.59	8.33	31.25	28.51	29.88	8.77
WAS 203	24.43	22.80	23.62	6.67	32.58	27.89	30.24	14.40
CO 50	26.68	22.68	24.68	14.99	33.07	30.16	31.62	8.80
CO 52	27.23	23.92	25.58	12.16	30.99	28.69	29.84	7.42
Jai Sri Ram	24.58	21.51	23.05	12.49	33.21	29.82	31.52	10.21
Mean	26.21	22.78	24.52	12.99	32.26	29.00	30.62	10.02
	G	T	G X T		G	T	G X T	
SEd	0.78	0.17	1.1		0.89	0.2	1.25	
CD(0.05)	1.55**	0.35**	2.19**		1.77**	0.40**	2.50**	

During flowering, highest total chlorophyll content was recorded in IRGC 6386-1 (4.35 mg g^{-1} at 100% RDN and 4.12 mg g^{-1}at 50% RDN) followed by WAS 207 (4.35 at 100% RDN and 4.07 at 50% RDN). The least total chlorophyll content was recorded in IRGC 70215-1 (2.43 at 100% RDN and 2.17 at 50% RDN) followed by IRGC 117005-1 (2.46 at 100% RDN and 2.34 at 50% RDN). Percentage reduction over 100% N was also observed in total chlorophyll content (11.98 %) during flowering stage.

Table 4. Effect of nitrogen levels on soluble protein content (mg g^{-1})

Genotypes	Maximum tillering stage			% of reduction	Flowering stage			% of reduction
	100% RDN	50% RDN	Mean		100% RDN	50% RDN	Mean	
IRGC 6087-1	10.30	9.90	10.10	3.88	16.40	13.60	15.00	17.07
IRGC 6386-1	16.10	15.20	15.65	5.59	16.60	16.30	16.45	1.81
BINULAWAN	8.10	7.40	7.75	8.64	10.20	8.00	9.10	21.57
IRGC 70215-1	9.60	7.60	8.60	20.83	9.20	8.30	8.75	9.78
IRGC 116981-1	10.70	9.50	10.10	11.21	14.60	13.40	14.00	8.22
IRGC 32675-C1-G1	7.90	7.60	7.75	3.80	10.10	9.50	9.80	5.94
IRGC 63493-C1-G1	8.00	7.60	7.80	5.00	10.40	8.60	9.50	17.31
IR 72	11.50	10.20	10.85	11.30	14.70	13.90	14.30	5.44
NIONOKA	10.80	10.10	10.45	6.48	15.90	13.60	14.75	14.47
WAS 200	13.70	12.10	12.90	11.68	15.60	14.90	15.25	4.49
IR 20	10.40	8.10	9.25	22.12	14.90	10.80	12.85	27.52
WAS 199	9.40	8.00	8.70	14.89	13.50	10.60	12.05	21.48
CO 51	9.20	8.60	8.90	6.52	13.30	11.80	12.55	11.28
ADT 43	13.30	10.70	12.00	19.55	16.40	14.90	15.65	9.15
ASD 16	12.70	10.70	11.70	15.75	15.50	14.70	15.10	5.16
IR 64	13.50	12.20	12.85	9.63	16.40	15.50	15.95	5.49
N22	9.40	8.60	9.00	8.51	15.80	11.40	13.60	27.85
IRGC 8177-1	14.20	13.40	13.80	5.63	16.50	15.70	16.10	4.85
CHANG	7.80	7.60	7.70	2.56	10.70	9.00	9.85	15.89
CO 18	8.30	7.80	8.05	6.02	12.80	10.10	11.45	21.09
IR 36	8.70	7.70	8.20	11.49	13.00	10.00	11.50	23.08
IRGC 116967-1	9.60	8.20	8.90	14.58	15.30	11.00	13.15	28.10
IRGC 117005-1	8.00	7.50	7.75	6.25	10.80	8.10	9.45	25.00
IRGC 74762-1	9.10	8.80	8.95	3.30	13.80	12.10	12.95	12.32
IRGC 64917-1	13.10	12.10	12.60	7.63	16.70	15.50	16.10	7.19
IRGC 8266-C1-G1	8.60	8.30	8.45	3.49	14.40	11.10	12.75	22.92
TSIPALA FOTSY	11.10	9.20	10.15	17.12	15.50	13.30	14.40	14.19
WAS 169	8.40	8.10	8.25	3.57	12.20	10.90	11.55	10.66
WAS 182	11.80	10.30	11.05	12.71	14.90	14.10	14.50	5.37
WAS 202	8.30	7.90	8.10	4.82	11.70	10.50	11.10	10.26
WAS 207	15.40	14.20	14.80	7.79	16.80	15.60	16.20	7.14
WAS 20	8.10	7.80	7.95	3.70	10.80	10.40	10.60	3.70
WAS 30	12.90	10.50	11.70	18.60	15.40	14.40	14.90	6.49
WAS 62	9.10	8.70	8.90	4.40	13.70	12.10	12.90	11.68
CT 6510	9.70	8.10	8.90	16.49	11.60	10.70	11.15	7.76
IRGC 26971-C1	8.20	7.60	7.90	7.32	9.70	8.60	9.15	11.34
WAS 203	9.00	7.90	8.45	12.22	15.00	10.50	12.75	30.00
CO 50	8.40	7.80	8.10	7.14	12.30	10.00	11.15	18.70
CO 52	9.40	7.60	8.50	19.15	9.70	8.50	9.10	12.37
Jai Sri Ram	7.90	7.80	7.85	1.27	11.20	10.20	10.70	8.93
Mean	10.24	9.23	9.73	9.57	13.60	11.81	12.70	13.33
	G	T	G X T		G	T	G X T	
SEd	0.31	0.07	0.44		0.39	0.09	0.55	
CD(0.05)	0.62**	0.14**	0.88**		0.55**	0.17**	1.10**	

Among the genotypes, least reduction was noticed in ADT 43 (4.13 %) during flowering stage. Significant interaction between genotype and nitrogen levels was observed (Table 2). These results are in agreement with the report of Hansen and Schjoerring (2003) who stated that higher leaf chlorophyll content due to higher N levels reflected on more photosynthetic rate. Similar findings were also reported by (Pramanik and Bera, 2013) and they explained that increasing dose of nitrogen levels resulted in higher chlorophyll pigments and photosynthesis.

Photosynthetic rate was increasing up to flowering stage with respect to increase with nitrogen levels. Among the treatments, 100% RDN exhibited significantly higher mean photosynthetic rate (32.26 µmol CO_2 $m^{-2}s^{-1}$) than 50% RDN (29.00µmol CO_2 m^{-2} s^{-1}) at flowering stage. Among the genotypes, IRGC 6386-1 had higher photosynthetic rate (33.14) at 100% RDN and 50% RDN (32.61) followed by WAS 169 (33.98, 31.27 at 100% RDN and 50% RDN respectively) and IR 64 (33.45 at 100% RDN and 31.77 at 50% RDN). The lowest photosynthetic rate was observed in IRGC 70215-1 (29.52) at 100% RDN and 50% RDN (24.01) followed by IRGC 117005-1 (29.10 at 100% RDN and 24.01 at 50% RDN). Percentage reduction over 100% N was also observed on photosynthetic rate and it was about 12.99 % during maximum tillering stage and 10.02 % during flowering stage. Among the genotypes, least reduction was noticed in IRGC 6386-1 (1.60 %) followed by ADT 43 (1.80 %), CO 51 (1.99 %) and NIONOKA (3.76 %) at flowering stage (Table 3). Ability of the plant to take up N from the soil, the allocation of N within the plant and the requirement of N for various plant functions are main determinants of this differential crop response. Vijayalakshmi *et al*. (2015) reported that photosynthetic rate was less in low NUE genotype. Murata (1961) found that in rice genotypes, higher photosynthetic activity was proportional to the nitrogen content.

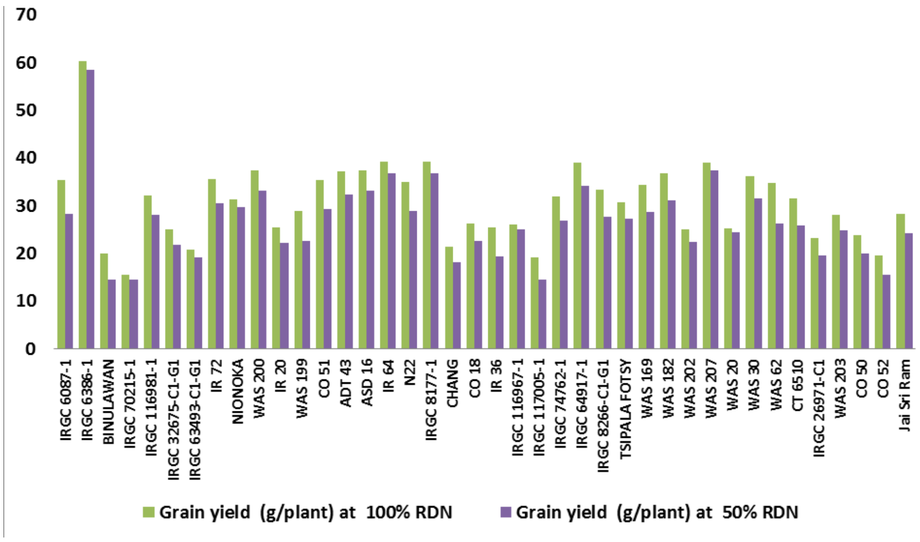

Figure 1. Effect of nitrogen levels on grain yield (g/plant)

The soluble protein was increased with increasing dosage till flowering stage. Among the treatments, 100% RDN treatment showed higher mean soluble protein content (13.60 mg g^{-1}) followed by 50% RDN (11.81 mg g^{-1}). At flowering stage, the highest soluble protein content was recorded in IRGC 6386-1 at 100% RDN (16.60) and 50% RDN (16.30) followed by WAS 207 at 100% RDN (16.80) and 50% RDN (15.60). The least soluble protein content was observed in IRGC 70215-1 at 100% RDN (9.20) and 50% RDN (8.30) followed by BINULAWAN at 100% RDN (10.20) and 50% RDN (8.00) during flowering stage. Percentage reduction over 100% N was also observed and it was about 9.57 % during maximum tillering stage and 13.33 % during flowering stage. Among the genotypes, least reduction was noticed in IRGC 6386-1 (1.81 %) followed by WAS 20 (3.70 %), WAS 200 (4.49 %) and IRGC 8177-1 (4.85 %) during flowering stage (Table 4). The interaction of N levels and genotypes was found to be significant in both the stages. Photosynthetic rate in the rice leaf is closely correlated with *Rubisco* activity and soluble protein content (Saka, 1985). In rice plants, *Rubisco* accounts for more than 50% of total soluble protein and over 25% of total leaf N (Makino *et al.*, 1984).

In the present study, highest mean grain yield per plant (30.75 g) was recorded in 100 % RDN followed by 50 % RDN (26.68 g). Among the genotypes, higher grain yield per plant was noticed at 100% RDN (60.22 g) and 50% RDN (58.41 g) in IRGC 6386-1. The lowest grain yield per plant was recorded at 100% RDN (15.49 g) and 50% RDN (14.51 g) in IRGC 70215-1. Percentage reduction over 100% N was also observed and it was about 13.70 %. Among the genotypes, least reduction was noticed in IRGC 6386-1 (3.01 %) followed by WAS 20 (3.32 %), IRGC 116967-1 (3.98 %), WAS 207 (4.36 %) during maturity stage. The interaction effects were found to be significant between N levels and genotypes (Fig 1). Fageria (2003) reported that in cereals including rice, nitrogen accumulation is associated with dry matter yield of straw and grain. Nitrogen is required during all the growth period of rice plant and it significantly improved the yield of rice by improving yield components like panicle number, 1000 grain weight and reduced grain sterility.

Conclusion

The present investigation showed that there are large variations among the genotypes related to morphological, physiological, biochemical as well as yield and yield attributes under different levels of nitrogen. The increased amount of nitrogen fertilizer could improve growth and yield of rice crop. The present study demonstrated that certain genotypes had performed better at 50% RDN (i.e. 50% reduced N from RDN) in terms of total dry matter production, chlorophyll content, photosynthetic rate, soluble protein content and grain yield where low percentage of reduction was observed over 100% RDN. Right now, developing more nitrogen efficient rice genotypes is highly essential. Identification of rice genotypes with better NUE under low nitrogen levels is necessary and those genotypes could be used in breeding rice genotypes with better NUE.

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