REGULAR ARTICLE

STUDIES ON GENETIC DIVERGENCE AND REACTION TO IRON CHLOROSIS IN AEROBIC RICE ON VERTISOLS IN MAHARASTRA

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ABSTRACT

The present study was carried out to study the genetic parameters for yield, yield contributing, quality and nutritional characters along with reaction of genotypes against iron chlorosis in vertisols. The experiment consisted of 50 promising genotypes along with standard checks viz., Basmati-370, Parag and Avishkar were grown in randomized block design with three replications. The analysis of variance revealed that all the characters under study. Different genotypes showed some degrees of tolerance to iron chlorosis. And, some other characteristics like number of effective tillers per plant, number of filled grains per panicle, number of unfilled grains per panicle, gel consistency, flag leaf area, straw yield, grain yield per plot and grain yield per plant showed high estimates of phenotypic coefficient of variation, high heritability with high genetic advance. All characters which exhibited high estimates of both genotypic and phenotypic variances coupled with high heritability and high genetic advance can be employed for simple selection for crop improvement. Furthermore, variation in such characters are result of additive gene effects and can be explored and studied for potentialities of being used as parents in breeding program for improvement for particular traits.

Keywords: Iron chlorosis, Vertisols, Rice, Heritability, Genetic advance, Variance

INTRODUCTION

Rice crop is a staple food on which more than half of world population depended for consumption and income generation [1]. About 95 per cent of global output of rice is produced and consumed in developing countries as it is most important food crop for 2.89 billion people in Asia, 40 million in Africa and 1.3 million in the Americas [2]. India is considered as self-sufficient in grain production and is second largest exporter of quality rice [3] where cultivation area of rice is estimated about 43.97 million hectares with production of 104.3 million tones and productivity of 2372 kg/ha. In Maharashtra, rice is grown over a wide area and ranks 13th in rice production in country. Maharashtra is classified into four rice growing region viz., Konkan, Western Maharashtra, Marathwada and Vidarbha region. The highest area under rice crop is in Vidarbha region (7.954 lakh hectares), while the highest productivity is in Konkan region i.e. 2.75 t/ha (3.83 t/ha for rough rice). Marathwada region is the non-traditional rice growing area in Maharashtra [4].

Iron is a very important element in plant kingdom [5]. This kind of malady is commonly found in heavy clay soil of Maharashtra [6]. The researchers have reported that grain yield of rice is strongly negatively correlated with iron chlorosis reaction and similarly, contribution of majority of yield contributing characters via iron chlorosis reaction is negative to grain yield [7; 8]. The rice varieties grown in Marathwada region are old and tall varieties which are inferior in the farmers preferred qualities traits. Varieties like Prabhavati, Sugandha, Parag and Aviskar have been developed by the efforts of agriculture university and research station [8]. Yet, the number of robust and promising varietal options to the farmers which are better in both yield and quality characters, is the major shortfall. Hence, this investigation was carried out to discern the variability in rice genotypes for grain yield, yield contributing characters, nutritional and quality characteristics and assess the reaction of genotypes to iron chlorosis which will be instrumental in identifying the genotypes with better yield and quality traits with iron chlorosis tolerance. Furthermore, the identified genotypes with desired traits can be used in pre-breeding. This will be ultimately obliging in enhancing the yield, productivity and area of production of rice in Marathwada region of Maharashtra, India.

MATERIALS AND METHODS

This study was carried out at farm of Department of Agricultural Botany, Vasantrao Naik Marathwada Krishi

Vidhyapeeth, Parbhani. Parbhani situated above 408-500 m above sea level and lies between 180 58' to 200 2' north latitude and 760 4' to 770 42' east longitude. Soil of experimental site was found deep black having godrainage. The mean maximum temperature of Parbhani varies from 29 °C to 45 °C in summer and minimum temperature varies from 11 °C to 25 °C in winter season with average rainfall of 800 to 900 mm received mostly during June to September. The experimental materials consisting 50 promising genotypes (table 1) of rice including three genotypes viz., Parag, Basmati-370 and Avishkar as checks were allocated in randomized block design in *Kharif* season of year 2013 and each plot assigned to each genotypes was 0.9 x 3 m2.

For all the quantitative characters, observations were recorded from five representative and randomly selected plants while quality characters for each genotype were computed from the bulked samples. For recording observations on iron chlorosis, 1 to 9 scale adopted by Singh and Singh [9] was utilized with modification i.e., taking the 1, 3, 5, 7and 9 grades as 0, 1, 2, 3 and 4 respectively. Observation on parameters like, Days to 50% flowering, plant height, panicle length, number of effective tillers per plant, number of effective tillers per meter length, days to maturity, number of filled grains per panicle, number of unfilled grains per panicle, 1000 grain weight, grain yield per plant, grain yield per plot were recorded and averaged. For calculating flag leaf area, product of length and breadth of leaf was multiplied by leaf area constant 0.818 as suggested by Jadhav *et al.* [10]. Grain quality characters viz., L: B ratio, relative density, water absorption, gel consistency, volume expansion, amylose content, crude protein content, gelatinization temperature, grain translucency, kernel elongation ration and elongation index were computed from the bulked grains for each genotypes. Elongation ratio was computed as described by Parikh *et al.* [11]. Crude protein was estimated by Micro-kjeldhal method [12] and gel consistency was observed by method described by

Cagampang *et al.* [13]. Amylose content was estimated by method described by Juliano [14].

The statistical analysis were performed on data collected of both quantitative and quality characters from genetic parameters of variability, heritability and expected genetic advance. Analysis of variance was performed as suggested by Panse and Sukhatme [15] while both genotypic and phenotypic variance were estimated by suing formulae as per Burton [16]. Heritability (broad sense) was calculated according to the method suggested by Hanson *et al.* [17]. Expected genetic advance (EGA) was calculated by the method suggested by Johnson *et al.* [18].

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance was worked out to assess the variability in the rice genotypes for grain yield, yield components and grain quality characters. The observations are shown in table 2 and 3. There was significant variations in between the genotypes in respect of all the characters viz., plant height, days to 50% flowering, days to maturity, effective tillers per plant, effective tillers per metre length, panicle length, flag leaf area, 1000 grain weight, number of filled grains per panicle, number of unfilled grains per panicle, grain yield per plant, grain yield per plot and straw yield per plot were significant. The differences among the genotypes with respect to physico-chemical characteristics of rice grain, viz., elongation ratio, elongation index, L: B ratio, volume expansion, gel consistency, relative density (g/ml), water absorption per unit weight of rice, protein content and amylose content were also found significant. The results prove that there is a genetical divergence. These findings are in accordance with the earlier reports [19-21], who also observed significant variability for yield and its components and grain quality characters in rice.

Table 1: List of genotypes included in the study

S. No.	Genotypes	S. No.	Genotypes
1.	NDR 1143	2.	CR 3693-1-1
3.	OR 2172-7-1	4.	CR 3635-1-1
5.	RP 5214-18-6-2-1-1-1-B	6.	PBNR-03-10
7.	GK 5022	8.	Rewa 1207-15
9.	PBNR-04-28	10.	CR 3632-1-2
11.	CRR 599-4-1	12.	CR 2991-1-2-1-1-1
13.	R 2212-RF-75	14.	CRR 452-23-1-1-1-1
15.	CRR 596-8-1	16.	CR 3692-1-1
17.	CB 09 516	18.	TJP 148
19.	CB 10-504	20.	OR 1946-2-1
21.	MAS 946 (RC 2)	22.	RP Bio 4918-166-9
23.	CR 3695-1-1	24.	BAU 408-05
25.	CR 3634-1-3	26.	CR 3690-1-1
27.	CR 3630-1-3	28.	CRR 617-B-47-3
29.	CR 3633-1-3	30.	PBNR-03-07
31.	R-RF-48	32.	MAULS-15
33.	PBNR-08–07	34.	CRR 635-3-2
35.	BAU 389-02	36.	CR 3616-2-1-2-1-1
37.	PAU 3832-79-4-3-1	38.	RP 5216-13-7-2-1-1-1
39.	R 1700-2240-4-2295-1	40.	CRR 499-11-2-12-1
41.	UPRI 2012-16	42.	Tulasi
43.	CRR 614-4-1	44.	PBNR–08–04
45.	RP 5125-17-6-3-2-1	46.	CRR 451-15-B-A1
47.	PBNR-03–20	48.	Basmati 370 (check)
49.	Parag (check)	50.	Avishkar (check)

Table 2: ANOVA for yield and yield contributing characters

S. No.	Characters	Mean sum of squares		
		Replication	Treatments	Error
1.	Days to 50% flowering	0.04	137.55**	41.05
2.	Plant height (cm)	34.60	646.06**	54.93
3.	Panicle length (cm)	0.01	8.94**	3.06
4.	No. of tillers/plant	0.07	5.36**	0.15
5.	No. of tillers/meter	2.36	2316.32**	52.42
6.	Flag Leaf Area (cm²)	11.69	121.96**	4.98
7.	Days to maturity	0.52	173.43**	61.32
8.	No. of filled grains/panicle	6.61	1547.45**	98.03
9.	No. of unfilled grains/panicle	25.01	410.35**	16.18
10.	Test weight (g)	2.49	44.19**	1.18
11.	Grain yield/plant	0.76	120.72**	2.83
12.	Grain yield/plot (kg)	0.005	0.20**	0.01
13.	Straw yield/Plot (kg)	0.01	0.63**	0.01

**Significant at 1% level

Table 3: ANOVA for grain quality characters

S. No.	Characters	Mean sum of squares		
		Replication	Treatments	Error
1.	Elongation ratio	0.0012	0.057**	0.003
2.	Elongation index	0.0002	0.019**	0.006
3.	Length breadth ratio	0.018	1.052**	0.023
4.	Volume expansion	0.0008	1.607**	0.018
5.	Water absorption	0.0021	1.026**	0.018
6.	Relative density (gm/ml)	0.0022	0.241**	0.007
7.	Protein content (%)	0.6378	7.563**	0.610
8.	Gel consistency (mm)	46.512	670.24**	10.18
9.	Amylose content (%)	0.0096	40.566**	2.265

**Significant at 1% level

Mean performance

Mean performance of genotypes for different characters are depicted in table 4, 5, and 6. The genotype PBNR 03-07 was tall in height and had highest flag leaf area. The genotype CR 3690-1-1 had longest panicle length, whereas, genotype PBNR 04-28 had recorded maximum number of effective tillers per plant and number of effective tillers per meter length. The variety Tulasi recorded early in maturity and minimum number of unfilled grains per panicle. The maximum number of filled grains per panicle was recorded in check Avishkar. The genotype RP Bio 4918-166-9 was found to record lowest test weight whereas, genotype CR 452-23-1-1-1-1 recorded minimum straw yield per plot. However, maximum grain yield per plot was recorded by genotype NDR 1143. Among the grain quality characters, genotype CRR 596-8-1 recorded high elongation ratio along with highest elongation index and absorbed significantly more water. The genotype Tulasi has recorded lowest volume expansion ratio. None of the genotype was observed with bold and round grains. Relative density was highest in genotype CRR 617-b-47-3, whereas, genotype PAU 3832-79-4-3-1 recorded highest protein content. Important grain quality parameters were recorded in genotypes PBNR 03-07, PBNR 03-20, PBNR 04-28, PBNR 08-04, CRR 596-8-1, CR 3690-1-1, MAULS-15,R 1700-2240-4-2295-1, and UPRI 499-11-2-12-1. These results are in conformity with findings of Das et al. [22] and Binod et al. [23].

Genotypic and phenotypic coefficient of variation

The phenotypic coefficient of variation was higher than that of genotypic coefficient of variation. Similar findings were reported by Panwar and Mathur [24]. But the differences between PCV and GCV for many traits were less, suggesting the less influence of environment for traits like plant height, number of filled grains per panicle, 1000 grain weight and grain yield per plant. These results were confirmatory with Devi et al. [25], Prajapati et al. [26], Tuwar et al. [27]. High values of genotypic and phenotypic coefficient of variation were recorded for grain yield per plant (54.32 and 52.46) and number of unfilled grains per panicle (52.78 and 49.80). Similarly, characters like grain yield per plot (36.61 and 36.72) and straw yield (33.88 and 32.84) also showed high GCV and PCV. This result was in accordance with findings of Deosarkar et al. [7] and Fukrei et al. [28]. Grain quality characters viz. (43.73 and 43.01), water absorption (35.49 and 34.57), relative density (24.66 and 23.46) and gel consistency (23.44 and 22.91) were with higher GVC and PCV. Similar finding was reported by Dhanwani et al. [20].

Moderate PCV and GCV were recorded for characters protein content (19.66 and 17.49), test weight (19.64 and 18.87), L: B ratio (19.32 and 18.70), plant height (21.44 and 18.96), amylose content (15.63 and 14.40), elongation ratio (11.45 and 10.48) and elongation index (11.11 and 6.96). Similar results were observed by Dhanwani et al. [20] for L: B ratio (15.63 and 14.40), elongation ratio and elongation index, Subbaiah et al. [29] observed for test weight, elongation ratio and L: B ratio and Kundu et al. [30] reported for test weight. Wide range of genotypic variation was observed in number of effective tillers per plant and grain yield per plant which indicates the predominance of additive gene effects. These results are in agreement with earlier results reported by Shukla et al. [31], Kaul and Kumar [32], Debchoudhary and Das [33] and Chauhan [34]. However, low estimates for GCV and

PCV were recorded for days to 50% flowering (9.59 and 3.36) followed by panicle length (9.48 and 5.92) and days to maturity (8.00 and 4.92). Low GCV and PCV values for these traits were also reported by Shivani and Reddy [35], Devi et al. [25], Prajapati et al. [26], Annandrao et al. [36] and Singh et al. [37]. Low value for days to 50% flowering and panicle length have also been reported by Sinha et al. [38] and Sadeghi [39] days to 50% flowering. Tuwar et al. [27] also observed similar result for days to maturity.

Table 4: Mean values of genotypes for grain yield and yield contributing characters

S. No.	Genotypes	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	No. of tillers/plant	No. of tillers/meter	Flag leaf area (cm²)	Days to maturity
1.	NDR 1143	86.33	77.86	23.33	4.80	120.23	26.29	121.66
2.	CR 3693-1-1	89.33	96.03	21.90	5.93	112.00	38.25	122.66
3.	OR 2172-7-1	93.00	73.66	23.86	3.20	83.66	32.04	128.66
4.	CR 3635-1-1	91.66	68.93	23.46	3.26	77.00	22.43	126.00
5.	RP 5214-18-6-2-1-1-1-B	104.33**	68.23	25.76	4.13	101.33	35.34	142.33**
6.	PBNR-03-10	83.33	94.00	26.83	7.33**	182.00**	37.29	119.33
7.	GK 5022	96.00	52.46	21.96	4.86	118.00	32.17	132.33
8.	Rewa 1207-15	91.00	65.20	22.90	4.13	102.33	28.70	125.33
9.	PBNR-04-28	86.66	78.30	21.60	8.40**	198.66**	34.58	124.33
10.	CR 3632-1-2	95.00	65.00	23.80	5.26	126.33	26.46	130.33
11.	CRR 599-4-1	85.00	93.40	23.80	5.13	123.00	30.16	122.00
12.	CR 2991-1-2-1-1-1	101.66**	68.36	25.80	3.13	80.33	31.87	138.66*
13.	R 2212-RF-75	85.00	91.86	24.23	3.13	91.66	26.32	120.33
14.	CRR 452-23-1-1-1-1	90.66	71.26	22.65	5.73	105.66	24.37	124.66
15.	CRR 596-8-1	80.00	82.33	23.56	5.93	118.00	27.10	116.33
16.	CR 3692-1-1	94.33	74.60	22.87	4.06	103.33	31.86	130.33
17.	CB 09 516	94.33	61.33	24.53	3.93	99.33	32.17	129.33
18.	TJP 148	81.00	76.73	23.91	5.60	140.33	37.51	115.33
19.	CB 10-504	95.33	66.13	21.30	4.66	114.00	30.78	131.00
20.	OR 1946-2-1	99.66*	61.60	22.54	3.93	93.00	28.76	136.33*
21.	MAS 946 (RC 2)	98.33*	50.80	21.57	5.20	115.66	26.38	135.33*
22.	RP Bio 4918-166-9	94.66	58.86	22.18	4.26	107.00	33.67	128.66
23.	CR 3695-1-1	91.33	56.53	22.66	3.93	104.00	20.54	126.33
24.	BAU 408-05	79.00	84.46	21.75	5.26	127.66	20.96	111.66
25.	CR 3634-1-3	96.66	64.83	22.76	5.20	117.00	24.63	129.66
26.	CR 3690-1-1	97.66	59.13	28.90	6.13	112.00	22.35	133.33
27.	CR 3630-1-3	92.66	66.30	23.91	4.80	121.66	28.48	126.00
28.	CRR 617-B-47-3	81.00	83.13	23.45	4.73	115.00	21.56	114.66
29.	CR 3633-1-3	88.00	87.00	22.65	4.60	108.33	22.42	123.00
30.	PBNR-03-07	84.66	111.56**	27.02	8.00**	184.00**	45.91**	122.00
31.	R-RF-48	93.66	53.20	20.28	4.06	93.33	19.32	131.66
32.	MAULS-15	78.33	85.80	23.93	5.80	135.00	30.15	111.66
33.	PBNR-08−07	85.00	93.43	24.83	6.53	156.33	40.07	120.33
34.	CRR 635-3-2	84.66	94.06	24.33	5.60	127.66	25.32	115.66
35.	BAU 389-02	89.66	72.96	24.10	3.53	97.00	21.00	124.66
36.	CR 3616-2-1-2-1-1	91.66	80.33	24.23	3.53	92.33	29.49	126.00
37.	PAU 3832-79-4-3-1	90.00	50.63	24.47	4.13	101.66	25.41	126.00
38.	RP 5216-13-7-2-1-1-1	93.33	53.03	23.96	4.06	104.33	31.44	129.66
39.	R 1700-2240-4-2295-1	99.00*	46.33	22.26	3.26	113.66	22.82	136.00*
40.	CRR 499-11-2-12-1	88.66	75.00	20.50	4.13	109.33	27.46	124.33
41.	UPRI 2012-16	91.66	71.20	22.20	2.90	87.33	28.17	127.33
42.	Tulasi	79.66	53.26	21.56	4.60	116.33	19.90	108.00

S. No.	Genotypes							
43.	CRR 614-4-1	81.00	89.66	25.66	7.13**	171.33	23.42	114.00
44.	PBNR–08–04	81.33	82.30	25.50	6.93**	164.00	44.06**	116.33
45.	RP 5125-17-6-3-2-1	89.33	73.13	22.36	3.66	102.00	28.31	119.66
46.	CRR 451-15-B-A1	78.00	73.33	22.90	3.60	104.33	27.97	114.00
47.	PBNR-03–20	91.00	87.00	24.60	7.53**	159.66	38.78	119.33
48.	Basmati-370 (ch)	87.33	92.26	26.73	5.00	127.66	29.18	122.33
49.	Parag (ch)	78.66	78.80	24.36	4.93	166.66	38.53	115.33
50.	Avishkar (ch)	79.66	85.40	24.69	5.93	134.00	37.01	117.00
	Mean	89.17	74.022	23.62	4.91	119.33	29.38	124.14
	SE	3.69	4.279	1.01	0.22	4.18	1.28	4.52
	CD 5%	10.38	12.008	2.84	0.64	11.73	3.61	12.69
	CV (%)	7.18	10.012	7.41	8.04	6.06	7.59	6.30

* and ** indicates significant at 5 and 1 per cent level, respectively

Table 5: Mean values of genotypes for grain yield and yield contributing characters

S. No.	Genotypes	Filled grains per panicle	Unfilled grains per panicle	Test weight (g)	Grain yield per plant(g)	Grain yield/plot (g)	Straw yield/plot (g)	Iron chlorosis reaction
1.	NDR 1143	132.56	22.10	18.73	11.80	1.418*	1.788	2
2.	CR 3693-1-1	101.43	21.60	21.66	13.59	0.676	1.207	3
3.	OR 2172-7-1	107.70	14.06	23.40	8.28	0.402	1.049	4
4.	CR 3635-1-1	103.80	17.50	22.13	7.57	0.837	1.150	3
5.	RP 5214-18-6-2-1-1-1-B	102.70	40.33	13.53	5.83	0.463	1.251	4
6.	PBNR-03-10	134.10	31.56	24.53	24.25	1.114	2.477	0
7.	GK 5022	101.56	36.26	14.80	7.250	0.377	1.406	1
8.	Rewa 1207-15	105.40	20.70	18.93	8.283	0.736	1.193	3
9.	PBNR-04-28	153.80	14.80	17.90	23.04	0.694	2.083	0
10.	CR 3632-1-2	96.70	23.66	17.40	8.72	0.633	1.107	3
11.	CRR 599-4-1	125.96	21.80	17.70	11.51	0.518	0.984	2
12.	CR 2991-1-2-1-1-1	97.66	11.66	20.93	6.33	0.510	1.291	4
13.	R 2212-RF-75	151.10	21.00	20.80	9.61	0.928	1.598	1
14.	CRR 452-23-1-1-1-1	109.40	20.13	18.80	11.70	0.494	0.598	4
15.	CRR 596-8-1	129.30	17.93	19.66	15.04	0.502	0.967	1
16.	CR 3692-1-1	108.93	20.74	21.20	9.38	0.887	1.344	2
17.	CB 09 516	96.10	30.86	14.33	5.33	0.439	1.031	4
18.	TJP 148	125.43	16.73	23.33	16.51	0.849	1.760	0
19.	CB 10-504	153.76	77.30**	15.10	10.90	0.742	1.460	2
20.	OR 1946-2-1	133.03	36.70	13.26	7.03	0.376	0.974	4
21.	MAS 946 (RC 2)	85.96	17.03	20.20	9.15	0.624	1.318	2
22.	RP Bio 4918-166-9	95.80	30.46	12.46	5.18	0.413	1.273	4
23.	CR 3695-1-1	99.10	25.16	21.40	8.29	0.623	1.092	2
24.	BAU 408-05	136.70	17.60	18.46	13.21	0.855	1.112	1
25.	CR 3634-1-3	122.70	15.96	15.46	9.75	0.956	1.331	3
26.	CR 3690-1-1	109.50	26.53	19.06	12.65	0.608	1.067	3
27.	CR 3630-1-3	119.76	24.73	23.80	13.84	0.988	1.316	3
28.	CRR 617-B-47-3	85.53	26.60	20.86	8.49	0.544	0.998	3
29.	CR 3633-1-3	111.90	22.90	22.00	11.38	0.986	1.367	2
30.	PBNR-03-07	151.06	19.06	25.50	29.63	0.998	2.655	0
31.	R-RF-48	100.66	31.60	19.13	9.19	0.571	0.871	4
32.	MAULS-15	102.60	12.26	25.06	14.75	0.995	1.854	0
33.	PBNR-08–07	150.06	26.63	20.93	19.32	1.012	1.646	0
34.	CRR 635-3-2	99.53	35.33	18.30	10.25	0.802	1.771	2
35.	BAU 389-02	127.60	11.13	19.86	8.85	0.727	1.483	2
36.	CR 3616-2-1-2-1-1	117.90	17.70	21.13	8.87	0.875	1.049	3
37.	PAU 3832-79-4-	92.56	11.76	24.93	9.43	0.511	0.857	3

	3-1							
38.	RP 5216-13-7-2-1-1-1	81.70	18.36	13.20	4.49	0.565	1.151	3
39.	R 1700-2240-4-2295-1	121.50	28.83	16.86	6.71	0.618	1.452	2
40.	CRR 499-11-2-12-1	84.20	20.00	14.60	5.17	0.586	1.320	2
41.	UPRI 2012-16	85.86	24.16	20.06	5.02	1.005	1.167	3
42.	Tulasi	119.66	4.23	18.56	10.18	1.141	1.211	2
43.	CRR 614-4-1	122.80	10.93	24.90	22.27	0.921	2.159	0
44.	PBNR–08–04	127.60	17.73	24.53	22.15	1.146	1.846	0
45.	RP 5125-17-6-3-2-1	120.63	25.20	21.60	9.40	0.777	1.081	2
46.	CRR 451-15-B-A1	112.53	21.20	21.00	8.24	0.502	0.670	3
47.	PBNR-03–20	117.26	14.93	24.30	21.32	1.299*	1.900	0
48.	Basmati-370 (ch)	69.36	51.03	20.46	7.29	0.357	1.479	2
49.	Parag (ch)	154.13	11.73	28.53	21.21	1.086	2.724	0
50.	Avishkar (ch)	179.23	12.46	28.53	30.18	1.052	1.601	0
Mean		115.51	23.01	20.05	12.59	0.758	1.391	--
SE±		5.71	2.32	0.62	0.97	0.062	0.067	--
CD 5%		16.04	6.51	1.76	2.72	0.174	0.188	--
CV %		8.57	17.48	5.42	14.09	14.25	8.37	--

Table 6: Mean values of genotypes for grain quality characters of rice

S. No.	Genotypes	ER	EI	L/B	VE	WA	RD	PC (%)	GC	AC (%)	GT	WB	AR
1.	NDR 1143	1.27	0.98	2.50	1.55	1.32	0.87	10.83**	78.66	22.33	Intermediate	Absent	Absent
2.	CR 3693-1-1	1.29	0.96	2.57	0.67	1.53	0.94	9.99*	73.33	27.93*	Intermediate	Present	Strong
3.	OR 2172-7-1	1.17	0.90	2.93	2.57	1.55	0.99	7.99	82.66	22.43	Intermediate	Present	Mild
4.	CR 3635-1-1	1.26	0.93	2.98	1.68	2.52**	1.06	8.67	78.66	27.96*	Intermediate	Present	Mild
5.	RP 5214-18-6-2-1-1-1-B	1.21	0.95	2.94	2.44	2.39**	1.17	10.99**	65.33	23.56	High	Absent	Mild
6.	PBNR-03-10	1.27	0.93	2.61	1.38	1.65	1.13	8.26	55.66	20.81	Intermediate	Absent	Mild
7.	GK 5022	1.32	0.85	3.12	2.00	1.75	1.18	9.33	62.66	19.40	Intermediate	Absent	Strong
8.	Rewa 1207-15	1.36	0.87	3.26	1.63	2.60**	0.89	7.17	75.33	22.32	Intermediate	Absent	Mild
9.	PBNR-04-28	1.20	0.75	3.60	0.72	1.45	1.23	6.84	64.66	24.53	Intermediate	Absent	Strong
10.	CR 3632-1-2	1.17	0.79	3.22	1.22	2.32**	0.92	8.16	75.66	25.37	Intermediate	Absent	Mild
11.	CRR 599-4-1	1.19	0.89	2.82	2.87*	1.46	1.74	7.66	71.00	20.17	Intermediate	Absent	Mild
12.	CR 2991-1-2-1-1-1	1.21	0.98	2.39	1.44	1.34	1.13	7.04	73.00	19.87	High	Present	Mild
13.	R 2212-RF-75	1.16	1.04	3.10	1.80	1.83*	1.19	10.16**	45.66	21.23	Intermediate	Present	Strong
14.	CRR 452-23-1-1-1-1	1.25	0.87	2.99	2.06	2.77**	0.99	7.35	78.66	27.79	Intermediate	Absent	Strong
15.	CRR 596-8-1	1.68	1.13	3.28	2.63	2.91**	1.06	7.04	58.66	25.33	Intermediate	Present	Mild
16.	CR 3692-1-1	1.29	0.99	2.50	1.35	1.66	1.07	8.99	65.66	30.24**	Intermediate	Present	Strong
17.	CB 09 516	1.19	0.99	3.16	1.85	2.59	0.94	11.32**	46.66	32.51**	Intermediate	Absent	Mild
18.	TJP 148	1.31	0.92	3.13	2.00	1.62	1.35	7.33	65.33	28.46**	Intermediate	Absent	Strong
19.	CB 10-504	1.26	0.89	2.84	2.89**	2.59**	1.36	9.83*	62.33	27.05	High	Present	Mild
20.	OR 1946-2-1	1.15	0.87	2.77	1.44	1.22	1.27	9.63*	74.66	30.63**	High	Absent	Mild
21.	MAS 946 (RC 2)	1.15	0.81	2.93	1.28	1.91*	0.95	10.32**	54.33	23.39	Intermediate	Absent	Mild
22.	RP Bio 4918-166-9	1.37	0.99	2.70	2.33	2.47**	1.07	6.67	68.33	20.62	Intermediate	Absent	Mild
23.	CR 3695-1-1	1.29	0.92	3.49	2.67	1.45	1.78	7.03	28.33	29.86**	Intermediate	Present	Mild
24.	BAU 408-05	1.28	0.96	2.80	0.93	1.22	1.08	10.16**	59.33	21.64	Intermediate	Absent	Mild
25.	CR 3634-1-3	1.17	0.90	3.06	0.67	1.07	0.85	7.50	74.66	26.65	Intermediate	Absent	Strong
26.	CR 3690-1-1	1.44	0.96	3.68	1.56	2.61**	0.93	6.83	77.33	24.62	Intermediate	Absent	Absent
27.	CR 3630-1-3	1.32	0.90	3.04	0.53	0.78	1.10	7.54	76.33	26.73	Intermediate	Present	Mild

S.No.	Name										GT	WB	AR
28.	CRR 617-B-47-3	1.18	0.91	3.00	1.80	0.61	1.87*	10.33**	26.66	25.68	Intermediate	Absent	Mild
29.	CR 3633-1-3	1.28	0.80	2.58	2.54	1.47	1.56	10.16**	71.33	18.53	Intermediate	Present	Mild
30.	PBNR-03-07	1.41	0.80	3.15	1.00	1.22	1.19	6.54	61.33	24.30	Intermediate	Absent	Strong
31.	R-RF-48	1.15	0.86	3.22	1.67	1.65	1.17	11.03**	76.33	29.38**	Intermediate	Present	Mild
32.	MAULS-15	1.19	0.94	3.11	0.50	0.75	0.94	10.32**	58.33	25.83	High	Absent	Mild
33.	PBNR-08–07	1.40	0.86	3.27	1.81	1.88**	1.13	7.22	44.33	19.39	High	Absent	Mild
34.	CRR 635-3-2	1.09	0.92	3.37	2.38	2.20**	1.34	7.13	52.36	30.24**	High	Absent	Strong
35.	BAU 389-02	1.09	0.86	3.20	0.62	0.52	1.26	9.99*	96.33	27.33*	Intermediate	Absent	Absent
36.	CR 3616-2-1-2-1-1	1.32	0.94	2.82	0.60	1.39	0.71	9.66*	69.66	24.33	High	Present	Mild
37.	PAU 3832-79-4-3-1	1.22	0.90	3.15	2.60	1.42	1.74	11.82**	57.66	29.50**	Intermediate	Absent	Strong
38.	RP 5216-13-7-2-1-1-1	1.15	0.88	3.52	3.00**	2.29**	1.24	10.83**	58.33	28.40**	Intermediate	Present	Strong
39.	R 1700-2240-4-2295-1	1.13	0.87	3.70	2.17	1.27	1.12	7.21	52.66	20.56	Intermediate	Absent	Mild
40.	CRR 499-11-2-12-1	1.17	0.90	3.15	2.00	2.16**	1.25	8.31	78.33	21.99	High	Absent	Mild
41.	UPRI 2012-16	1.23	1.05	2.43	2.00	1.16	1.76	11.59**	88.66	29.33**	Intermediate	Present	Mild
42.	Tulasi	1.62	1.07	3.34	0.33	1.05	0.57	7.54	24.33	25.63	Intermediate	Present	Strong
43.	CRR 614-4-1	1.26	0.89	3.56	0.60	1.15	0.94	7.66	83.66	19.70	Intermediate	Absent	Mild
44.	PBNR–08–04	1.21	0.96	3.47	1.55	1.49	1.24	8.09	68.33	20.53	Intermediate	Absent	Mild
45.	RP 5125-17-6-3-2-1	1.27	0.94	2.47	1.88	2.15**	1.06	11.16**	73.66	29.03**	High	Present	Mild
46.	CRR 451-15-B-A1	1.36	0.91	3.19	1.71	1.68	1.26	7.38	54.33	25.80	High	Absent	Strong
47.	PBNR-03–20	1.19	0.81	2.55	0.90	1.47	1.16	7.42	46.33	24.83	Intermediate	Absent	Strong
48.	Basmati-370 (ch)	1.67	1.09	3.63	2.60	1.31	1.7	8.33	61.33	20.35	Intermediate	Absent	Strong
49.	Parag (ch)	1.34	0.92	3.24	1.60	1.41	1.28	7.37	72.66	21.14	Intermediate	Absent	Mild
50.	Avishkar (ch)	1.64	1.00	4.61	2.57	1.55	1.53	7.45	65.33	24.80	High	Absent	Strong
	Mean	1.27	0.92	3.08	1.69	1.677	1.18	8.70	64.72	24.80	--	--	--
	SE±	0.03	0.04	0.08	0.07	0.08	0.05	0.45	1.84	0.87	--	--	--
	CD 5%	0.09	0.13	0.24	0.22	0.22	0.14	1.26	5.17	2.44	--	--	--
	CV %	4.62	8.66	4.87	7.94	8.05	7.52	8.98	4.93	6.06	--	--	--

* and ** indicates significant at 5 and 1 per cent level, respectively, ER-elongation ratio, EI-elongation index, L/B-length breadth ratio, WA-water absorption, VE-volume expansion, PC-protein content, RD-relative density, GC-gel consistency, AC-amylose content, GT-gelatinization temperature, WB-chalkiness, AR-aroma.

Table 7: Estimates of variability, broad sense heritability and genetic advance for grain yield and yield contributing characters

S. No.	Characteristics	Range	mean±SE	$\sigma^2 g$	$\sigma^2 p$	GCV	PCV	h² (broad sense)	G. A. as % of mean (5%)
1.	Days to 50% flowering	78.00–104.33	89.17±3.69	32.165	73.220	6.360	9.596	43.9	8.64
2.	Plant height (cm)	50.63–111.56	74.02±4.28	197.046	215.977	18.964	21.444	78.2	34.54
3.	Panicle Length (cm)	20.28–28.90	23.62±1.01	1.959	5.024	5.925	9.489	39.0	7.62
4.	No. of tiller/plant	2.90–8.40	4.91±0.22	1.735	1.891	26.811	27.992	91.7	52.89
5.	No. of tiller/meter	77.00–198.66	119.33±4.18	754.635	807.058	23.020	23.807	93.5	45.85
6.	Days to maturity	108.00-142.33	124.14±4.52	37.369	98.692	4.924	8.002	37.9	6.24
7.	Flag Leaf area (cm²)	19.32–45.91	29.38±1.28	38.992	43.976	21.249	22.566	88.7	41.21
8.	Filled	69.36–	151.51±5.71	483.139	581.173	19.028	20.869	83.1	35.73

S. No.	Characteristics	Range	mean±SE	$\sigma^2 g$	$\sigma^2 p$	GCV	PCV	h² (broad sense)	G. A. as % of mean
	grains/panicle	179.23							
9.	Unfilled grains/panicle	4.23–77.30	23.01±2.23	131.389	147.579	49.802	52.782	89.0	96.80
10.	Test weight (gm)	12.46–28.53	20.05±0.62	14.339	15.522	18.878	19.641	92.4	37.37
11.	Grain yield/plant (g)	4.49–30.18	12.59±0.972	39.295	42.132	52.465	54.326	93.3	99.05
12.	Grain yield/plot (kg)	0.357–1.418	0.754±0.062	0.065	0.076	33.723	36.612	84.8	63.98
13.	Straw yield/plot (kg)	0.598–2.724	1.391±0.067	0.209	0.222	33.893	33.880	93.9	65.56

Table 8: Estimates of variability, broad sense heritability and genetic advance for quality characters of rice grain

S. No.	Characteristics	Range	mean±SE	$\sigma^2 g$	$\sigma^2 p$	GCV	PCV	h² (broad sense)	G. A. as % of mean (5%)
1.	Length breadth ratio	2.39–4.61	3.08±0.088	0.343	0.36	18.700	19.32	93.6	37.27
2.	Elongation ratio	1.09-1.68	1.27±0.033	0.018	0.021	10.484	11.45	83.7	19.76
3.	Elongation index	0.75-1.09	0.92±0.046	0.004	0.01	6.96	11.11	39.2	8.98
4.	Volume expansion	0.33-3.00	1.69±0.078	0.530	0.54	43.011	43.73	96.7	87.12
5.	Water absorption	0.52–2.91	1.67±0.078	0.336	0.35	34.573	35.49	94.9	69.36
6.	Relative density (g/ml)	0.57-1.87	1.18±0.051	0.078	0.086	23.469	24.64	90.7	46.04
7.	Protein content (%)	6.54-11.82	8.70±0.451	2.317	2.92	17.491	19.66	79.1	32.05
8.	Gel consistency (mm)	24.33-96.33	64.72±1.84	220.017	230.20	22.918	23.44	95.6	46.15
9.	Amylose content (%)	18.53–32.52	24.80±1.01	12.767	15.03	14.405	15.63	84.9	27.34

Heritability and genetic advance

Heritability in broad sense estimates were highest for straw yield per plot (93.9%) followed by number of effective tillers per plant (93.5%),grain yield per plant (93.3%), 1000 grains weight (92.4%), number of effective tillers per plant (91.7%), number of unfilled grains per panicle (89.0%), flag leaf area (88.7%), grain yield per plot (84.8%), number of filled grains per panicle (83.1%) and plant height (78.2%) among yield contributing characters, whereas, among grain quality characters volume expansion (96.7%) had recorded highest estimate of broad sense heritability followed by gel consistency (95.6%), water absorption per unit rice (94.9%), L: B ratio (93.6%), relative density (90.7%), amylose content (84.9%) and elongation ratio (79.1%). The estimates of heritability were moderate for days to 50% flowering (43.9%) followed by elongation index (39.2%), panicle length (39.0%) and days to maturity (37.9%).

Similarly, genetic advance as percent of mean were recorded for grain yield and quality traits. Among yield contributing characters, the high expected genetic advance were observed for the characters viz., grain yield per plant (99.05%), number of unfilled grains per panicle (96.80%), straw yield per plot (65.56%), grain yield per plot (63.98%), number of effective tillers per plant (52.89%), number of effective tillers per meter length (45.85%), flag leaf area (41.21%), test weight (37.37%), number of filled grains per panicle (35.73%) and plant height (34.54%).

However, lowest expected genetic advance was observed for days to maturity (6.24%), panicle length (7.62%) and days to 50% flowering (8.64%). Among the quality characters, moderate expected genetic advance was observed in elongation ratio (19.76%) and lowest in elongation index (8.98%).

Among the grain yield contributing characters, high estimates of GCV and heritability for grain yield per plant, number of effective tillers per plant and water absorption was observed. Similar, results were also reported earlier by Durai et al. [40] and Chaudhari et al. [41]. Parameters showed high estimates of PCV, high heritability with high genetic advance as percent of mean, indicated that role of additive gene effects in the inheritance of traits, these results are in conformity with the findings of Govindswami and Ghosh [42], Kumari et al. [43] and Selvaraj et al. [44]. Fukrei et al. [28] observed high PCV, high heritability and high genetic advance as percent of mean for flag leaf area, straw yield and gain yield while Bisne et al. [45] observed similar result for number of unfilled grains per panicle. Low genetic advance as percent of mean was recorded by panicle length, days to 50% flowering and days to maturity coupled with moderate heritability. Similar low genetic advance as percent of mean was noted by Babu et al. [46], Prajapati et al. [26] and Singh et al. [40] for panicle length; Pandey et al. [47] observed for days to 50% flowering, and days to % flowering and days to maturity.

Grain elongation without increase in girth is considered highly desirable in some high quality rice. Basmati rice elongates 100 per cent upon cooking. In the present study elongation ratio exhibited high heritability coupled with moderate EGA which was accordance with the findings of Vanaja and Babu [48] and Subbaiah *et al.* [30]. Likewise, gel consistency measures the tendency of the gelatinized starch to retrograde on cooking, varieties with soft gel consistency are preferred. High heritability with high EGA was observed for gel consistency indicating that character is controlled by additive gene action and thus selection would be effective for that character. Similar result was also reported by Babu *et al.* [19].

The high heritability coupled with high EGA was observed for water absorption, amylose content, relative density, protein content, volume expansion and L: B ratio. Similar findings were also reported by Chouhan and Nanda [49], Hussain *et al.* [50] and Nayak *et al.* [51] for water absorption and amylose content while Babu *et al.* [19] observed for L: B ratio and volume expansion ratio. Vanaja and Babu [48] observed similar results for L: B ratio, volume expansion, water uptake and amylose content. High heritability and high EGA was recorded for protein content, which was in contrary with the result observed by Shenoy *et al.* [52].

CONCLUSION

It is presumed that dwarf, high yielding and slender grain rice having quality traits viz., high protein, intermediate amylose and soft gel consistency are the characteristics of rice preferred by people in Maharashtra. The present investigation revealed that these genotypes possess better grain and cooking quality characters including good agronomic traits. The semi dwarf genotypes Tulasi, NDR 1143, CRR 599-4-1, PBNR 04-28, CRR 3630-1-3, CRR 6614-1-4, PBNR 08-07 and PBNR 03-10 possess maximum number of good attributes and higher grain yield per plant. These genotypes need to be improving for its cooking quality characters. Tall genotypes PBNR 03-07 seemed to be promising but need improvement in some of the quality characters. The genotype NDR 1143 had more yield and protein content than the checks and also possess some good quality characters. The genotypes PAU 3832-79-4-3-1 (11.82%) and UPRI (11.59%) recorded the highest protein content. The promising genotype for yield and grain cooking quality characters requires further study for its confirmation. In the present investigation, appreciable amount of GCV, heritability and EGA was observed for quantitative characters. The characters that showed high heritability coupled with high genetic advance are controlled by additive gene action which is coherent with the findings of Panse and Sukhatme [15]. Similarly, for the characters having high heritability along with moderate and low genetic advance has possibilities for improving by inter-mating with superior genotypes of segregating population.

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AUTHORS CONTRIBUTIONS

Rajeev Dhakal is the principal researcher who conducted the entire experiment and meticulously recorded the data. Ritesh Kumar Yadav helped the principal author in statistical analyses and interpretation of the results, and drafting this manuscript. Dr. D. B. Deosarkar is Professor, Department of Agricultural Botany, VNMKV who conceptualized, designed and supervised the research. D. P. Paudel guided the principal researcher during various stage of research and provided his critical suggestions and feedbacks for refinement of this manuscript.

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