Morpho-physiological characterization of aromatic rice (Oryza sativa) genotypes for grain yield under timely sown irrigated condition of upper IGPs

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Morpho-physiological characterization of aromatic rice (*Oryza sativa*) genotypes for grain yield under timely sown irrigated condition of upper IGPs

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ABSTRACT

The study was carried out to evaluate the morpho-physiological traits of eight aromatic genotypes of rice and their association with yield. The results indicated that highest genetic variability was observed in days to panicle initiation (PI), flowering (FL) and physiological maturity (PM), plant height, panicle length, grains per panicle, total dry matter (TDM) and grain yield. The highest grain yield was observed in Vallabh 21 (4.82 t ha^{-1}) whereas; Taroari Basmati produced lowest (2.07 t ha^{-1}). Total dry matter (TDM) at harvest varied from 11.44 to 14.69 t ha^{-1} and genotypes proved their photosynthetic radiation use efficiency (PRUE) in the rangeof 10.1 to 15.3(m mole CO_2 $mole^{-1}$ photon). PRUE showed a highly significant ($p<0.05$) and positive relation with TDM (r = 0.80**) and grain yield (r = 0.66**). Strong correlation between photosynthetic rate and grain yield suggest that higher leaf photosynthesis rate should be considered for improving potential productivity of aromatic rice. Highly significant correlation for yield was also noticed with panicle length (r= 0.421**), grains per panicle (r=0.50**), 1000 grains weight (r=0.58**), TDM at harvest (r=0.486**) and photosynthesis rate (r=0.386**). A negative correlation was established between TDM with harvest index and LAI with plant height. The principal component analysis (PCA) was performed for all the morpho-physiological traits of rice genotypes. Out of 28 variables under study, eight PC's exhibited more than one 'Eigen value' explaining 74.6 per cent variability among the traits. The highest variability was observed in TDM at harvest, flowering days, test weight, plant height, physiological maturity days, grains per panicle, panicle initiation days and panicle length which highly emphasized that these parameters are very vital for crop simulation models.

Keywords: Aromatic rice, Phenology, Leaf area index, Photosynthesis, Transpiration

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for one-third of the world population (Singh *et al.*, 2000). The world population is expected to reach 8 billion by 2030 and rice production must be increased by 50% in order to meet the growing demand (Khush and Brar, 2002). India is very rich in rice genetic resources in general and aromatic rice in particular cultivated over an area of about 0.7 to 0.8 million hectares with an average productivity of about 1.5 to 1.8 t ha^{-1} (Subudhi *et al.*, 2005). In recent past, there has been substantial gain in the area of aromatic (Basmati) rice cultivation owing to preferred demand and price in international market. Each state of India has its own specialty rice which has been maintained by a small group of farmers mainly for their subsistence requirements and for sustaining certain religious rituals and social ceremonies (Das *et al.*, 2012). The aromatic land races possess immense potential targeting gene of specific interest which can be effectively utilized in the present day breeding programme to evolve varieties with higher yield potential. Present work gives an account of growth and yield performance of some aromatic fine rice varieties and describes the relationship between grain yields and morpho-physiological characters under timely transplanted conditions in western plain zone of Upper Indo-Gangetic Plains.

MATERIALS AND METHODS

Field experiments were conducted at Modipuram (29.6^0 N, 77.7^0 E) at 237 m msl, during kharif 2008-2010. The soil of the experimental field is typic Ustochrepts, sandy loam, deep and mildly alkaline (pH 8.2) with low to medium fertility (OC– 0.40%, available P_2O_5– 32.5 kg and K_2O– 125 kg ha^{-1}).The climate is categorized as hot, dry and semi–arid subtropical with moderate summer and severe cold winters. The average annual rainfall of the region is about 800 mm and potential evapo-transpiration is 1600 mm. The experiments were laid out in a Randomized Complete Block Design (RCBD) with three replications comprising of 8 improved genotypes of basmati rice *viz*., Pusa Sugandha 4, Pusa Sugandha 5, Vallabh 21, Pusa Basmati 1460, Pusa Basmati 1, Pusa Sugandha 15, Basmati 370 and Taroari Basmati. Twenty five days old rice seedlings were manually transplanted in the main field (puddled) at a hill spacing of 0.2 × 0.2 m^2 with 2 plants/hill on July 2^{nd}, June 18^{th} and July 7^{th} during 2008, 2009 and 2010, respectively. The N-P–K–S–Zn fertilizers were applied @ 120-25–35–10–3 kg/ha in the form of urea, diammonium phosphate, muriate of potash, gypsum and zinc sulphate, respectively. The full dose of P–K–S–Zn and $1/3^{rd}$ of N was applied as basal dose at final land preparation. The remaining N was top-dressed as urea in two equal splits at 30 and 45 DAT.

The date of occurrence of different phenological events *viz.*, panicle initiation (PI) 50% flowering (FL) and physiological maturity (PM) were recorded when 50% of plants in each plot reached the respective stage. For dry weight, plant samples were oven dried at 70.0°C to reach constant dry weight. Leaf area index as described by Watson (1947) was estimated using leaf area meter (Model LI-3100) Photosynthesis and transpiration rate of the fully opened top flag leaf were measured at flowering using portable Photosynthesis System (Model LI-6400). The photosynthetic water use efficiency and physiological radiation use efficiency (PRUE) were calculated following Singh *et al.* (2012).

To reduce the multidimensionality, the entire data set was subjected to principal component analysis (PCA) to identify the important morpho-physiological parameters causing maximum variation in the grain yield under field condition. Two way correlation coefficients were calculated at $P<0.01$ and $P<0.05$ to established relationship between two traits with the use of statistical package 'Statistica' (trial version 10). Three years replicated pooled data were analyzed by one-way analysis of variance (ANOVA) using 'Statistical Package for Agricultural Workers' (OPSTAT) for comparing the treatment means at 5% level of significance.

RESULTS AND DISCUSSION

Phenological characters and their interrelationship

Among different genotypes, the days to panicle initiation ranged from 49-73 DAT, while it varied from 58-87 DAT for 50% flowering (Fl) and 95-123 DAT in

Table 1: The periodical variations in plant height (cm) and tillers m^{-2} among the different rice genotypes (Pooled data over 2008-2010)

Rice genotypes	Plant height (cm) at				Tillers m^{-2} at			
	21 DAT	42 DAT	63 DAT	84 DAT	20 DAT	30 DAT	40 DAT	50 DAT
Pusa Sugandha - 4	41.3	59.2	80.4	106.5	173.4	253.1	280.9	284.1
Pusa Sugandha - 5	45.2	59.4	73.5	107.0	165.7	246.1	316.8	263.7
Vallabh - 21	34.1	63.6	94.6	117.2	185.8	261.8	325.0	288.0
Pusa basmati -1460	35.3	53.5	86.1	111.4	163.6	265.6	303.7	289.8
Pusa basmati - 1	48.0	57.3	90.1	105.9	152.9	254.1	320.0	294.4
Pusa Sugandha - 15	42.7	64.0	88.3	121.4	179.2	285.2	299.0	280.9
Basmati - 370	43.7	68.6	103.9	128.3	167.3	254.6	282.3	267.1
Taroari Basmati	45.9	62.2	105.3	139.1	153.8	269.6	320.3	312.1
CD (p=0.05)	3.4	5.0	10.0	6.6	16.8	19.8	20.5	22.4

Table 2: The periodical variations in leaf area index (LAI) and total dry matter (TDM) among different rice genotypes (pooled data over 2008-2010)

Rice genotypes	LAI at				TDM (t ha^{-1}) at				
	21 DAT	42 DAT	63 DAT	84 DAT	21 DAT	42 DAT	63 DAT	84 DAT	Harvest
Pusa Sugandha - 4	1.17	3.38	4.22	3.08	0.818	3.862	7.840	11.395	11.820
Pusa Sugandha - 5	0.92	3.33	4.38	2.80	0.717	3.747	9.091	11.032	11.745
Vallabh - 21	1.20	3.64	5.13	3.95	0.920	4.111	9.921	11.353	14.688
Pusa basmati -1460	0.81	3.93	4.73	3.34	0.779	4.167	8.867	11.799	13.618
Pusa basmati - 1	0.71	3.69	5.11	2.89	0.503	4.479	9.066	12.014	12.287
Pusa Sugandha - 15	0.92	3.94	5.16	4.17	0.765	3.970	8.714	13.728	14.602
Basmati - 370	0.77	4.34	5.23	3.56	0.538	5.229	9.686	11.217	12.332
Taroari Basmati	0.84	4.30	4.70	2.96	0.633	6.821	11.278	12.838	11.444
CD(p=0.05)	0.10	N.S.	N.S.	N.S.	0.058	1.611	1.598	NS	1.396

physiological maturity (Fig. 1). Shorter flowering length ensures the visible uniformity of a crop field which is always preferred by farmers. Maturity duration is the final and cumulative result of all phenological responses which was started with Pusa Sugandha 4 at 95 DAT and ended with Taroari Basmati at 123 DAT.

Plant height and number of tillers

At 84 DAT, significant genotypic variation in plant height was reported which ranged between 105.9 cm (Pusa Basmati1) to139.1 cm (Taroari Basmati) (Table 1). The shorter plant height in Pusa Basmati 1 was due to shorter internode length and vice- versa.

Periodical variation in number of tillers (m^{-2}) showed an S-shaped growth curve with significant increase was noticed from 20 DAT to 40 DAT (active tillering stage) irrespective of genotypes and thereafter it decreased at 50 DAT as all number of tillers did not converted into effective tillers. Among genotypes, significantly lower number of tillers m^{-2} was reported in Pusa Sugandha 5 (263.7) and highest in Taroari Basmati (312.1) (Table 1). Duration, required for attaining maximum tillering stage, varied in a wide range. Pusa Sugandha 4 required longest period. This indicates that there was great genetic variation in number of tillers among the rice genotypes (Wu *et al.*, 1999).

Leaf area index and total dry matter

Leaf area index increased with the advancement of plant age from 21 DAT to 63 DAT and thereafter it declined (Table 2). Maximum LAI was notice at 63 DAT ranging from 4.22 (Pusa Sugandha) to 5.13 (Vallabh-21). Maximum LAI was correlated positively and strongly with grain yield (r=0.58,) which might be cause by the increasing nitrogen absorption during vegetative phase of the crop. Significant difference in mean value of TDM accumulation between genotypes at harvest was in the range of 11.4 t ha^{-1} (Taroari Basmati) to14.7 t ha^{-1} (Vallabh-21) (Table 2). TDM at harvest had positive correlation with grain yield (r=0.486**) (Fig. 2).

Physiological characters

Significantly lower rate of photosynthesis (µ mole CO_2 m^{-2} s^{-1}) was reported in Pusa Sugandha 15, Basmati 370 and Taroari Basmati in comparison to Pusa Sugandha 5,Vallabh 21 and Pusa Basmati1. Vallabh 21 recorded the highest rate of transpiration (m mole H_2O m^{-2} s^{-1}) in comparison to others. Significantly higher positive correlation was observed between photosynthetic (r =0.386**) and transpiration rate (r=0.298*) with grain yield (Fig. 2). Genotypes differed significantly for photosynthetic radiation use efficiency ((PRUE (m mole CO_2 $mole^{-1}$ photon)) and Pusa Basmati1460 followed by Pusa Basmati 1 recorded highest PRUE while the lowest PRUE was recorded with Pusa Sugandha15 (Table 3).

Grain yield and yield attributes

The highest panicle length was reported in Pusa Basmati 1460 (135.7 cm) whereas, it was shortest in Taroari Basmati (45.4 cm). Numbers of grains/panicle was reported significantly higher in Pusa Sugandha15 (135.7) and Basmati 370 (127.4) whereas, it was significantly lower in Taroari Basmati (45.4). Significantly higher 1000 grains weight (g) was recorded in Pusa Sugandha 4, Pusa Sugandha 5 and Vallabh 21 whereas; it was lower in Basmati370 and Taroari Basmati. Grain yield was significantly lower in Pusa Basmati1 (3.98 t ha^{-1}),

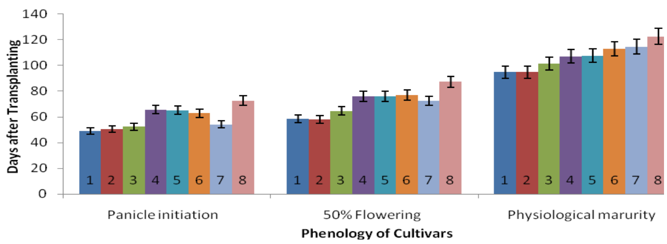

Fig. 1: Phenological mean variations with standard error at Panicle initiation (PI), 50% Flowering (Fl) and Physiological maturity (PM) of the rice genotypes (1-Pusa Sugandha 4, 2- Pusa Sugandha 5, 3-Vallabh 21, 4- Pusa basmati 1460, 5- Pusa basmati 1, 6- Pusa Sugandha 15, 7- Basmati 370, 8-Taroari)

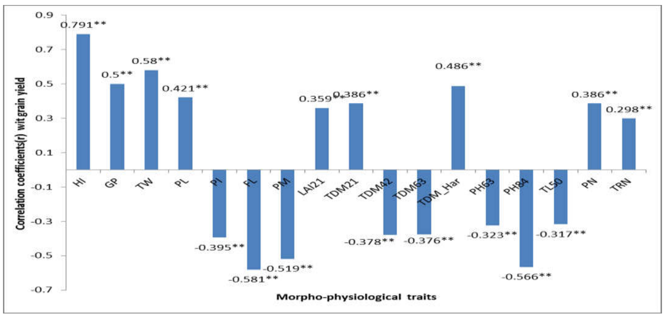

Fig. 2: Correlation coefficients of the various morpho-physiological traits with grain yield of aromatic rice (**correlation is significant at the 0.01 level). (HI= Harvest index, GP= grains per panicle, TW= test weight, PL= panicle length, PI= Days to Panicle initiation, FL= days to flowering, PM= days to physiological maturity, LAI= Leaf area Index, DAT= days after transplanting, TDM= Total dry matter, PH= Plant height, TL= tillers per m^2, PN= Photosynthesis, TRN= Transpiration)

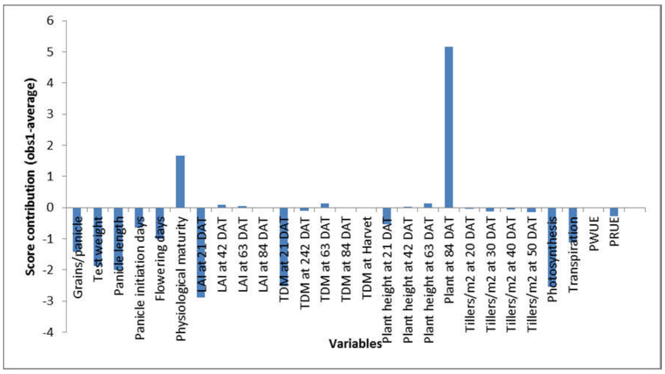

Fig. 3: Variable importance of the various traits in prediction of the variance in the grain yield of the rice genotypes

Basmati 370 (3.76 t ha^{-1}) and Taroari Basmati (2.7 t ha^{-1}) whereas, Vallabh21 (4.82 t ha^{-1}), Pusa Sugandha 4 (4.68 t ha^{-1}), Pusa Sugandha5 (4.68 t ha^{-1}) but Pusa Sugandha15 (4.57 t ha^{-1}) was yielded significantly higher among the genotypes. The highest harvest index was recorded from Pusa Sugandha15 (40.2%) and the lowest harvest index was obtained from Taroari Basmati (18.1%) (Table 4).

Principal Component (PC) analysis

The principal component analysis (PCA) was performed for all the morphological traits of rice genotypes. Out of 28 variables under study, eight PC's exhibited more than one 'Eigen value' explaining 74.6 per cent variability among the traits (Table 5). The highly weighted variables under PC-1 were Test weight, panicle initiation days, flowering days, physiological maturity, LAI at 21, TDM at DAT 21, plant height at 63 and 84 DAT; PC-2: LAI at 42 DAT, plant height at 21 DAT, plant height at 42 DAT, tillers/m^2 at 20 DAT, tillers/m^2 at 50 DAT; PC-3: panicle initiation days, LAI at 42 DAT, TDM at 42 DAT; PC-4: tillers/m^2 at 40 DAT, Photosynthesis and transpiration; PC-5: grains/panicle and TDM at Harvest; PC-6: Transpiration and PWUE; PC-7 number of tillers at 30 DAT;PC-8: LAI at 63 DAT (Table 6). Correlation analyses among the above highly weighted variables were done to remove the redundant variables, accordingly HI%, test weight, rate of photosynthesis, transpiration, TDM at 21, 42 DAT and at harvest, LAI at 21, 42 and 63 DAT number of tillers at 20,30,40 and 50 DAT were highly correlated, and finally days to PM, HI, TDM at harvest, number of tillers at 60 DAT, plant height at 21,42,63and 84 DAT, transpiration rate and LAI at 84 DAT were retained owing to their high factor loading .

Variable Importance in Projection (VIP) scores

Variable Importance in Projection (VIP) scores estimate the importance of each variable in the projection

Table 3: Photosynthesis, transpiration rate, photosynthetic water use efficiency (PWUE) photosynthetic radiation use efficiency (PRUE) of the rice genotypes (pooled data over 2008-2010)

Rice genotypes	Photosynthesis (μ mole CO_2 m^{-2} s-1)	Transpiration (m mole H_2O m^{-2} s^{-1})	PWUE (m mole CO_2 $mole^{-1}$ H_2O)	PRUE (m mole CO_2 $mole^{-1}$ photon)
Pusa Sugandha - 4	19.89	7.93	2.52	12.17
Pusa Sugandha - 5	21.37	9.33	2.30	12.79
Vallabh - 21	21.21	9.83	2.18	13.82
Pusa basmati -1460	19.94	8.42	2.45	15.34
Pusa basmati - 1	21.10	9.30	2.30	15.27
Pusa Sugandha - 15	16.85	7.41	2.31	10.15
Basmati - 370	16.93	7.03	2.46	10.93
Taroari	16.95	7.34	2.33	11.17
CD(p=0.05)	2.51	1.23	N.S.	1.54

Table 4: Variation in yield and yield attributes among different rice genotypes

Rice genotypes	Panicle length (cm)	Grains $panicle^{-1}$	1000 grains weight (g)	Grain yield (t ha^{-1})	HI(%)
Pusa Sugandha - 4	27.67	106.83	24.02	4.78	39.78
Pusa Sugandha - 5	26.80	112.16	23.95	4.68	40.17
Vallabh - 21	28.46	96.67	22.75	4.82	33.06
Pusa basmati -1460	28.97	96.09	20.55	4.38	32.47
Pusa basmati - 1	27.90	89.52	19.76	3.97	32.58
Pusa Sugandha - 15	27.78	135.74	21.25	4.57	31.59
Basmati - 370	27.32	127.38	18.94	3.65	29.75
Taroari Basmati	24.17	45.44	18.94	2.06	18.09
CD(p=0.05)	2.03	20.87	1.67	0.496	3.50

Table 5: Eigen value (>1.0), % of variance and cumulative % of initial 8 extracted principal components from 27 morpho-physiological traits

Principal components	Initial Eigen values >1.0	Variance (%)	CumulativeEigen value	Cumulative variance (%)
1	5.4	20.0	5.4	20.0
2	3.3	12.1	8.7	32.1
3	2.8	10.5	11.5	42.6
4	2.3	8.6	13.8	51.2
5	2.1	7.7	15.9	58.9
6	1.7	6.1	17.6	65.1
7	1.4	5.2	19.0	70.2
8	1.2	4.3	20.1	74.6

Table 6: Principal component analysis of 27 morpho-physiological traits

Traits	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8
Grains/panicle	-0.298	0.332	0.239	-0.143	**0.590**	-0.266	0.017	-0.304
Test weight	**-0.702**	0.160	0.128	0.127	0.128	0.224	-0.043	0.148
Panicle length	-0.358	0.212	0.166	0.366	0.285	-0.210	-0.457	-0.182
Panicle initiation days	**0.724**	-0.010	**-0.544**	0.182	-0.119	-0.062	-0.015	0.050
Flowering days	**0.896**	-0.076	-0.203	0.207	0.026	-0.055	0.061	0.007
Physiological maturity	**0.785**	-0.152	-0.450	-0.048	0.107	-0.092	0.025	0.089
LAI at 21 DAT	**-0.632**	-0.248	-0.080	-0.099	0.265	0.191	0.303	0.401
LAI at 42 DAT	0.072	**-0.556**	**0.625**	0.129	0.008	-0.104	0.000	-0.229
LAI at 63 DAT	0.189	-0.196	-0.024	0.116	0.149	0.188	0.169	**-0.647**
LAI at 84 DAT	0.101	-0.157	-0.405	0.085	0.407	-0.090	-0.442	-0.013
TDM at 21 DAT	**-0.641**	-0.461	-0.200	0.060	0.311	0.055	0.143	0.234
TDM at 42 DAT	0.337	-0.235	**0.756**	0.202	0.055	0.121	0.040	0.075
TDM at 63 DAT	0.350	-0.398	0.447	0.202	-0.025	0.298	0.131	0.074
TDM at 84 DAT	0.120	-0.277	0.412	0.369	0.116	-0.114	-0.283	0.103
TDM at Harvest	-0.117	-0.057	-0.499	0.388	**0.551**	-0.023	-0.119	-0.017
Plant height at 21 DAT	0.448	**0.629**	0.105	-0.017	-0.054	0.169	0.344	-0.051
Plant height at 42 DAT	0.300	**0.719**	0.063	0.169	0.395	0.135	0.222	0.155
Plant height at 63 DAT	**0.598**	0.072	0.419	0.315	0.313	0.093	-0.064	0.218
Plant height at 84 DAT	**0.548**	-0.481	-0.061	-0.151	0.175	0.143	-0.261	0.278
Tillers/m2 at 20 DAT	-0.368	**-0.555**	-0.086	-0.198	0.251	-0.217	0.332	-0.113
Tillers/m2 at 30 DAT	0.284	-0.109	-0.123	0.281	0.464	-0.143	**0.554**	-0.107
Tillers/m2 at 40 DAT	0.038	-0.141	-0.120	**0.700**	-0.159	0.021	0.079	-0.025
Tillers/m2 at 50 DAT	0.032	**-0.770**	-0.176	-0.047	-0.215	-0.107	0.109	-0.118
Photosynthesis	-0.469	0.065	-0.080	**0.638**	-0.228	-0.066	0.159	0.128
Transpiration	-0.440	-0.008	-0.258	**0.533**	-0.162	**0.525**	-0.009	-0.110
PWUE	0.021	0.077	0.229	0.087	-0.022	**-0.785**	0.179	0.286
PRUE	-0.219	0.124	-0.117	0.450	-0.464	-0.466	0.043	-0.030

Highly weighted factors are bold faced.

used in a PLS model and is often used for variable selection. First 10 important variables on the basis of values of VIP were TDM at harvest, flowering days, test weight, plant height at 84 DAT, days to physiological maturity, grains/panicle, days to panicle initiation, panicle length and TDM at 63 DAT identified among the various traits by the PLS analysis. Among physiological parameters only rate of photosynthesis came forward in prediction of the variation in yield over the others (Fig. 3).

CONCLUSION

This study identifies better high yielding genotypes with strong yield sensitivity to grains per panicle, total dry matter and tillers per m^2. These genotypes can be successfully grown under irrigated ecosystem of IGPs to improve the profitability of the small and marginal farms. The identified important parameters must be taken in consideration for parameterization of any crop model.

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