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Genetic variability, correlation and path analysis for selection in elite breeding materials of Aromatic rice (*Oryza sativa* L.)

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Abstract
The presence of sufficient genetic variability, the knowledge of nature of association among different characters and relative contribution of different characters to yield is a prerequisite to any breeding programme. The aim of the present study was to estimate genetic parameters of thirty two yield, yield attributing and quality traits in 36 aromatic rice genotypes with a view to select better yield attributes in aromatic rice. The higher value of phenotypic co-efficient of variation (PCV) compared to the corresponding genotypic coefficient of variation (GCV) for all the studied traits indicated that there was an influence of the environment. High estimates of PCV and GCV were noticed for number of tillers per hill, leaf width of blade, stem length excluding panicle, panicle number per plant, total number of spikelet's per panicle, number of fertile grain per panicle, thousand seed weight, biological yield, grain yield per plant, harvest index, ratio of grain length/width and ratio of kernel length/width. High heritability coupled with high genetic advance was observed in number of tillers per hill, plant height, leaf length of blade, leaf width of blade, stem length excluding panicle, panicle number per plant, total number of spikelet per panicle, number of fertile grain per panicle, thousand seed weight, biological yield, grain yield per plant, harvest index, grain length, grain width, kernel length, ratio of grain length/width, ratio of kernel length/width, cooked rice length, cooked rice width, cooked rice length/width ratio, length expansion ratio, volume expansion ratio and iron content. Which reflected that the direct selection of these characters based on phenotypic expression by simple selection method for yield improvement would be more reliable. Grain yield per plant showed significant and positive association with numbers of tillers per hill, leaf length of blade, leaf width of blade, panicle length of main axis, panicle number per plant, total number of spikelet's per panicle, number of fertile grain per panicle, 1000 seed weight, biological yield, harvest index % and cooked rice width indicating selection of these characters for yield improvement in aromatic may be rewarding. Path coefficient analysis revealed that biological yield, harvest index, grain length and width expansion ratio and cooked rice length/width ratio had a high direct positive effect on grain yield have moderate direct effect on yield had direct positive effect on yield per plant indicating their importance during selection in yield improvement programme. Moreover, the information generated from this study, can be exploited in future breeding programme of aromatic rice.

Keywords: Aromatic rice, genetic variability, correlation, path analysis, quality and grain yield

Introduction

Rice (*Oryza sativa* L.), a staple food for more than half of the world's population. It is grown in more than 111 nations, from Bangladeshi plains to Nepal's Himalayan slopes and from ndonesia's rain forest to Australia's sandy plains (Khakwani *et al*., 2006) [3]. The finest aromatic rice in the world, known as Basmati rice are traditionally grown in India's northwestern region and are exported in higher amount from India. Due to the hot climate, which includes high humidity, the occurrence of illnesses, and insect pests, the Basmati cultivars from the mentioned zone do not produce well in the Eastern part of India. Farmers from the eastern part of India typically grow aromatic tall *indica* rice types that are focused on the local environment. These types typically exhibit lodging susceptibility and have low yields because to an inadequate biomass distribution. Due to its superior quality, basmati rice is widely valued by consumers and commands a premium price both in the domestic and international markets. In comparison to non-basmati rice varieties, it has the potential to contribute more foreign currency and improve the economic situation of rural people and their families. Though, we know that the demand of aromatic rice is increasing day by day. So, to make the continuity in demand of aromatic rice, the breeders should have to develop those varieties which have high yielding ability. During the course of developing varieties breeder should know the importance of each and every yield attributing characters. Whether the selected character have positive or negative effect on yield and also whether the character is exerting direct or indirect effect on yield. Hence with the help of correlation and path analysis they can select the traits in order to improve yield.

Genetic variability in a population can be partitioned into heritable and non-heritable variation with the aid of genetic parameters such as variance, genotypic coefficient of variation, heritability and genetic advance, which serve as a basis for selection of some outstanding genotypes from existing ones. Choice of parents is not only based on desirable agronomic traits, components of yield and extent of variability but also on heritability of yield contributing traits. The environment, in which selection is made, is also important because heritability and genetic advance vary with change in environment. The study of genetic variability reveals about the presence of variation in their genetic constitution and it is outmost important as it provide the basis of effective selection.

Grain yield is a complex trait and highly influenced by many genetic factors and environmental fluctuations. In plant breeding programme, direct selection for yield as such could be misleading. A successful selection depends upon the information on the genetic variability and association of morpho-agronomic traits with grain yield. Kumar *et al*. (2007) [21] reported high heritability coupled with high genetic advance for plant height, number of spikelets per panicle and 1000- grain weight. Correlation studies along with path analysis provide a better understanding of the association of different characters with grain yield. The grain yield was significantly and positively correlated with 1000 seed weight and the number of grains per spike (Kamana *et al*. 2019) [19]. Path coefficient analysis separates the direct effects from the indirect effects through other related characters by partitioning the correlation coefficient (Dixet and Dubey, 1984) [15]. Therefore, the present investigation was undertaken to study genetic variability, heritability, genetic advance, character association and path coefficient analysis in a set of thirty six aromatic rice genotypes to be used as suitable breeding materials for developing high yielding aromatic rice with desirable quality traits.

Materials and Methods

The experimental material comprised of 36 aromatic rice genotypes including three checks (RajendraKasturi, ShobiniandBadshabhog) grown in randomized block design with three replications at the rice experimentation farm, Department of Genetics and Plant Breeding, Bihar Agricultural University, Sabour (Bhagalpur) during *Kharif* 2020-21. Each plot consisted of eight rows of 5.0 metre length spaced at 20 cm plant and within a row at 20 m. All the recommended package of practices for wheat was followed to raise a healthy crop. Data were recorded on five randomly and competitive plants of each genotype from each replication for different quantitative characters *viz*. number of tillers per hill, plant height (cm), panicle length (cm), number of fertile grains per panicle, total number of spikelet's per panicle, thousand grains weight (g), grain yield/plant (g), biological yield (g), harvest index (%), leaf length of blade (cm), leaf width of blade (cm), panicle number per plant, stem length excluding panicle (cm), grain length (mm), hulling %, grain breadth (mm), grain length/breadth ratio, kernel length (mm), kernel breadth (mm), kernel length/ breadth ratio, cooking time, kernel dimension, Elongation ratio, volume expansion ratio, zinc content and iron content and the rest two characters *viz*., days to 50% flowering and days to maturity were recorded on plot basis. Mean values were subjected to analysis of variance to test the significance for each character as per methodology advocated by Panse and Sukhatme (1967) [29]. GCV and PCV were calculated by the formula given by Burton (1952) [7], heritability in broad sense (h^2) by Burton and De Vane (1953) [8] and genetic advance i.e. the expected genetic gain were calculated by using the procedure given by Johnson *et al*. (1955) [18]. Correlation coefficients were computed according to the method suggested by Singh and Chaudhary (1985) [34]. Dewey and Lu (1959) [16] was used to perform the path analysis for grain yield and its components keeping grain yield as resultant variable and its components as causal variables.

Results and Discussion

Analysis of variance revealed significant differences among the genotypes for all the characters under study which indicated that considerable amount of variability were present in the genotypes included in the study (Table 1). Hence, there is an ample scope for inclusion of promising genotypes in breeding programme for yield and its component characters in aromatic rice. Bitew (2016) [6] and Chakravorty *et al*. (2016) [13] also reported considerable genetic variability for grain yield and its component characters in aromatic rice. As a result, it was inferred that the study's material had a respectable amount of variability, giving the plant breeder plenty of room to choose superior genotypes for advancement. All of the studied traits had higher phenotypic variations than genotypic variances which may be due to higher degree of interaction of genotypes with the environment. These values alone are not helpful in determining the heritable portion of variation. The proportion of genetic variability which is transmitted from parents to offspring is reflected by heritability. Genotypic variances, phenotypic variances, heritability, genotypic co-efficient of variation (GCV), phenotypic co-efficient of variation (PCV), genetic advance (GA) and genetic advance as percentage of mean, GA (%) for all the yield contributing traits are shown in Table 2. All the characteristics under investigation showed substantial phenotypic and genotypic variance in the experimental material. A broad range of PCV was observed varies from 2.521 (Zinc content) to 43.984 (grains yield per plant). The GCV ranges from 1.25 (Zinc content) to 42.761 (grains yield per plant). Higher magnitudes of PCV were recorded for number of tillers per hill, leaf width of blade, stem length excluding panicle, panicle number per plant, total number of spikelet's per panicle, number of fertile grain per panicle, thousand seed weight, biological yield, grain yield per plant, harvest index, ratio of grain length/width and ratio of kernel length/width. A higher estimate of genotypic coefficient of variation was noticed for grain yield per plant, number of fertile grains per panicle, total number of spikelet's per panicle, panicle number per plant, number of tillers per hill, biological yield, harvest index, thousand seed weight and ratio of grain length/width. While lowest magnitude of GCV was recorded for zinc content. This is an indicative of less amenability of these traits to environmental fluctuations and hence, greater emphasis should be given to these characters, while breeding cultivars from the present material. These findings are in accordance with the result of Lalitha *et al*. (1999) [23], Verma *et al*. (2000) [40], Chaudhary *et al*. (2004) [14], Singh *et al*. (2010), Chakravorty *et al*. (2013) [13], Sarawgi *et al*. (2014) [38], Bitew (2016) [6], Bhati *et al*. (2015) [10], Nayak *et al*. (2016) [25], Abebe *et al*. (2017) [2], Kamana *et al*. (2019) [19] and Sharma Shishir *et al*. (2020) [33]. High heritability were observed for the characters like days to 50% flowering, days to maturity, number of tillers per hill, plant height, leaf length of blade, leaf width of blade, stem length excluding panicle, panicle length of main axis, panicle number per plant, total number of spikelet's per panicle, number of fertile grains per panicle, thousand seed weight, biological yield, grain yield per plant, harvest index, grain length, grain breadth, kernel length, ratio of grain length/width, ratio of kernel length/width, cooked rice length, cooked rice width, cooked rice length/width, length expansion ratio, volume expansion ratio and iron content. High genetic advance as percent of mean were observed for the character number of tillers per hill, plant height, leaf length of blade, leaf width of blade, stem length excluding panicle, panicle number per plant, total number of spikelet per panicle, number of fertile grain per panicle, thousand seed weight, biological yield, grain yield per plant, harvest index, grain length, grain breadth, kernel length, ratio of grain length/breadth, ratio of kernel length/width, cooked rice length, cooked rice width, cooked rice length/width ratio, length expansion ratio, volume expansion ratio and iron content. These results are in accordance to Verma *et al*. (2000) [40], Chaudhary *et al*. (2004) [14], Babu *et al*. (2012) [9] and Bitew (2016) [6]. This implied that these features may be thought of as advantageous traits for selection-based enhancement, possibly as a result of the presence of additive genetic effects, and that they could be enhanced by modifying selection without progeny testing.

The information on the magnitude of the inheritance of characters from parents to offspring is provided from heritability estimation, while genetic advance is helpful in finding out the actual gain expected under selection. In the present study, genetic advance as percent of mean estimated the highest for number of tillers per hill, plant height, leaf length of blade, leaf width of blade, stem length excluding panicle, panicle number per plant, total number of spikelet per panicle, number of fertile grain per panicle, thousand seed weight, biological yield, grain yield per plant, harvest index, grain length, grain breadth, kernel length, ratio of grain length/breadth, ratio of kernel length/width, cooked rice length, cooked rice width, cooked rice length/width ratio, length expansion ratio, volume expansion ratio and iron content.

Heritability and genetic advance are important selection parameters. Heritability estimates along with genetic advance are normally more helpful in predicting the gain under selection than heritability estimates alone (Johnson *et al*., 1955) [18]. High heritability accompanied with high genetic advance as percent of mean were observed for number of tillers per hill, plant height, leaf length of blade, leaf width of blade, stem length excluding panicle, panicle number per plant, total number of spikelet per panicle, number of fertile grain per panicle, thousand seed weight, biological yield, grain yield per plant, harvest index, grain length, grain width, kernel length, ratio of grain length/width, ratio of kernel length/width, cooked rice length, cooked rice width, cooked rice length/width ratio, length expansion ratio, volume expansion ratio and iron content. This suggested that these characters can be considered as favourable attributes for the improvement through selection and this may be due to presence of additive genes effect and thus, could be improved upon by adapting selection without progeny testing. Hence, direct selection can be done through these characters for future improvement of aromatic rice genotypes for higher grain yield with superior quality.

The correlation for morpho-agronomic traits are presented in Table 3. Grain yield per plant showed highly significant and positive association with numbers of tillers per hill, leaf length of blade, leaf width of blade, panicle length of main axis, panicle number per plant, total number of spikelets per panicle, number of fertile grain per panicle, 1000 seed weight, biological yield, harvest index % and cooked rice width while it also displayed significant and positive association with days to maturity. However, it exhibited highly significant and negative correlation with zinc content and also significant and negative correlation with cooking time. These results are in accordance to Chakraborty *et al*. (2013), Nagarju *et al*. (2013), Solomon *et al*. (2016) [36], Limbani *et al*. (2017) [22], Kalyan *et al*. (2017) [20], Parween *et al*. (2020) and Sharma Shishir *et al*. (2020) [33]. Therefore, it is suggested that these traits should be used as selection criteria for yield improvement in aromatic rice.

Path coefficient analysis provides an effective way of finding out of direct and indirect sources of correlations. The results of the path coefficient analysis are shown in Table 4. Path coefficient analysis revealed that biological yield, harvest index, grain length and width expansion ratio had a high direct positive effect on seed yield while cooked rice length/width ratio have moderate direct effect on yield. These results are in accordance to Nandan *et al*. (2010) [27], Selvaraj *et al*. (2011) [37], RavindraBabu *et al*. (2012) [9], Naseem *et al*. (2014) [28], Prem kumar *et al*. (2016) [30] and Shrestha *et al*. (2018) [39].These characters should form selection criterion in breeding programme. Direct selection based on these traits could result in simultaneous improvement of seed yield had high positive direct effect on seed yield per plant, indicating true relationship of these characters with seed yield and direct selection for these characters will be rewarding.

Table 1: Analysis of variance for thirty-two different characters in thirty-six rice genotypes

Sl. No.	Characters	MSS		
		Replication DF =2)	Genotypes(DF=32)	Error(DF=70)
1	Days to 50% flowering	16.00	137.89 **	4.62
2	Days to maturity	4.70	88.136 **	5.40
3	Number of tillers per hill	45.56	57.01 **	2.57
4	Plant height (cm)	192.44	1462.04 **	63.86
5	Leaf length of blade (cm)	70.14	99.61 **	8.67
6	Leaf width of blade (cm)	0.071	0.18 **	0.014

7	Stem length excluding Panicle (cm)	8.51	1248.17 **	26.67
8	Panicle length of main axis (cm)	4.58	33.32 **	3.65
9	Panicle number per plant	39.10	47.55 **	2.46
10	Total number of spikelet's per panicle	1943.08	17257.37 **	367.79
11	Number of fertile grains per panicle	2649.59	17533.98 **	336.44
12	Thousand seed weight (g)	11.47	50.48 **	1.39
13	Biological yield (g)	225.60	1356.06 **	77.05
14	Grain yield per plant (g)	3.32	554.46 **	10.51
15	Harvest Index (%)	57.48	267.69 **	27.49
16	Grain length (mm)	0.07	2.85 **	0.14
17	Grain breadth (mm)	0.076	0.20 **	0.03
18	Kernel length (mm)	0.564	7.023 **	0.172
19	Kernel breadth (mm)	0.009	0.059 **	0.028
20	Ratio of grain L/W	0.112	1.467 **	0.172
21	Ratio of kernel L/W	0.109	2.525 **	0.289
22	Hulling percentage	35.820	18.714 *	11.056
23	Milling percentage	6.760	24.643 **	10.152
24	Coocked rice length (mm)	1.036	3.006 **	0.278
25	Cooked rice width (mm)	0.014	0.411 **	0.052
26	Cooked rice length / Width ratio	0.068	0.669 **	0.074
27	Cooking time	0.507	18.502 **	3.720
28	Length expansion Ratio=L cooked/L Raw	0.011	0.165 **	0.029
29	Width expansion ratio=W cooked/W raw	0.040	0.128 **	0.044
30	Volume Expansion ratio	0.002	0.196 **	0.002
31	Zinc content (PPM)	0.073	0.387 **	0.196
32	Iron content (PPM)	0.070	2.918 **	0.035

** = Significant at 1% probability level

Table 2: Estimation of genetic parameters for quantitative traits related to grain yield, its contributing and quality traits of thirty six aromatic rice genotypes

S. No.	Characters	σ^2g	σ^2p	GCV	PCV	h² (BroadSense)	GeneticAdvance	Genetic Adv. as % ofMean
1	Days to 50% flowering	44.421	49.049	6.34	6.66	90.6	13.066	12.428
2	Days to maturity	27.576	32.984	3.891	4.26	83.6	9.891	7.329
3	Number of tillers per hill	18.146	20.719	27.458	29.34	87.6	8.212	52.934
4	Plant height (cm)	466.06	529.928	16.456	17.55	87.9	41.706	31.791
5	Leaf length of blade (cm)	30.313	38.989	15.834	17.96	77.7	10	28.761
6	Leaf width of blade (cm)	0.056	0.069	18.541	20.69	80.3	0.435	34.228
7	Stem length excluding Panicle (cm)	407.169	433.839	19.399	20.02	93.9	40.27	38.714
8	Panicle length of main axis (cm)	9.889	13.543	11.34	13.27	73	5.535	19.961
9	Panicle number per plant	15.033	17.493	28.524	30.77	85.9	7.404	54.471
10	Total number of spikelet's per panicle	5629.858	5997.656	32.435	33.48	93.9	149.752	64.735
11	Number of fertile grains per panicle	5732.514	6068.955	38.644	39.762	94.5	151.585	77.368
12	Thousand seed weight (g)	16.363	17.757	23.517	24.50	92.1	7.999	46.505
13	Biological yield (g)	426.336	503.394	24.599	26.73	84.7	39.144	46.634
14	Grain yield per plant (g)	181.316	191.833	42.761	43.98	94.5	26.967	85.638
15	Harvest Index (%)	80.068	107.56	24.106	27.94	74.4	15.904	42.844
16	Grain length (mm)	0.903	1.047	17.972	19.36	86.2	1.817	34.376
17	Grain breadth (mm)	0.056	0.093	12.642	16.30	60.1	0.378	20.192
18	Kernel length (mm)	2.284	2.455	19.015	19.72	93	3.002	37.778
19	Kernel breadth (mm)	0.01	0.038	5.616	10.87	26.7	0.108	5.978
20	Ratio of grain L/W	0.432	0.603	22.609	26.73	71.6	1.145	39.398
21	Ratio of kernel L/W	0.745	1.034	19.338	22.78	72.1	1.51	33.822
22	Hulling percentage	2.553	13.609	2.022	4.67	18.8	1.425	1.804
23	Milling percentage	4.83	14.982	2.875	5.06	32.2	2.571	3.363
24	Coocked rice length (mm)	0.909	1.187	12.75	14.57	76.6	1.719	22.985
25	Cooked rice width (mm)	0.12	0.172	12.708	15.22	69.8	0.595	21.863
26	Cooked rice length / Width ratio	0.198	0.273	15.905	18.66	72.7	0.782	27.935
27	Cooking time	4.927	8.647	10.45	13.84	57	3.452	16.25
28	Length expansion Ratio=L cooked/L Raw	0.046	0.074	14.72	18.78	61.4	0.345	23.767
29	Width expansion ratio=W cooked/W raw	0.028	0.072	11.315	18.17	38.8	0.215	14.514
30	Volume Expansion ratio	0.064	0.067	16.819	17.13	96.4	0.514	34.022
31	Zinc content (µg/g)	0.064	0.26	1.25	2.521	24.6	0.258	1.276
32	Iron content (µg/g)	0.961	0.996	15.386	15.67	96.5	1.983	31.13

Table3: Correlation corfficient between yield and other characters in Aromatic eice

Characters	DFF	DM	Number of tillers perhill	Plant height(cm)	Leaf length of blade (cm)	Leaf width of blade (cm)	Stem length excluding Panicle (cm)	Panicle length of main axis (cm)	Panicle number per plant	Total number of spikelet per panicle	Number of fertile grain per panicle
Days to 50% flowering	1										
Days to maturity	0.5601**	1									
Number of tillers per hill	-0.3967**	-0.2097*	1								
Plant height (cm)	0.2434*	0.1073	-0.2059*	1							
Leaf length of blade (cm)	-0.0312	0.1044	0.0313	0.4211**	1						
Leaf width of blade (cm)	-0.0379	0.1976*	0.1882	-0.0311	0.2766**	1					
Stem length excluding Panicle	0.2618**	0.1082	-0.1979*	0.9644**	0.4343**	-0.0750	1				
Panicle length of main axis (c)	0.1226	0.1043	0.0094	0.1747	0.3182**	0.4355**	0.2059*	1			
Panicle number per plant	-0.3784**	-0.2162*	0.9681**	-0.1688	0.0677	0.1233	-0.1580	0.0230	1		
Total number of spikelet per p	0.1854	0.3202**	0.1587	0.0968	0.1978*	0.3624**	0.1255	0.5826**	0.1565	1	
Number of fertile grain per pa	0.1059	0.2434*	0.0514	0.2451*	0.4187**	0.3277**	0.2946**	0.5874**	0.0546	0.7802**	1
Thousand seed weight (g)	-0.0514	-0.1470	0.2496**	0.0989	0.3043**	0.5568**	0.1176	0.6195**	0.2237*	0.5112**	0.6193**
Biological yield (g)	-0.0492	0.1542	0.3757**	0.1220	0.5511**	0.5775**	0.1410	0.5975**	0.3527**	0.5108**	0.5376**
Harvest Index (%)	0.0634	0.2426*	0.2306*	-0.2846**	-0.0254	0.2720**	-0.2476**	0.3088**	0.2438*	0.5401**	0.5425**
Grain length (mm)	-0.4107**	-0.3191**	0.0542	-0.0357	0.1021	0.1359	-0.0515	0.0709	0.0046	-0.1576	-0.0456
Grain breadth (mm)	0.0040	0.0194	-0.1134	0.2201*	0.0280	0.2892**	0.1882	0.2802**	-0.0822	0.1074	0.1120
Kernel length (mm)	-0.3797**	-0.2990**	0.1629	-0.1019	0.0785	0.0901	-0.1201	-0.0166	0.1112	-0.2235*	-0.0923
Kernel breadth (mm)	-0.1232	-0.2149*	0.2527**	0.0193	0.0434	0.2090*	0.0500	0.1021	0.2705**	0.0352	0.0342
Ratio of grain L/W	-0.3094**	-0.2207*	0.0801	-0.1393	0.0831	-0.0195	-0.1308	-0.0616	0.0336	-0.1378	-0.0738
Ratio of kernel L/W	-0.2835**	-0.1833	0.0358	-0.0952	0.0251	-0.0396	-0.1245	-0.0724	-0.0168	-0.2082*	-0.0953
Hulling percentage	0.1639	0.0792	-0.0576	0.2028*	-0.0419	-0.1530	0.1445	-0.1374	0.0018	-0.0603	-0.0761
Milling percentage	0.2550**	0.1422	-0.0591	0.1975*	0.0156	-0.2523**	0.1628	-0.2083*	0.0161	-0.0152	-0.0898
Coocked rice length (mm)	-0.1443	-0.1584	0.1591	-0.0967	-0.1703	0.2563**	-0.1614	0.0218	0.0722	0.0536	0.0194
Cooked rice width (mm)	-0.0234	-0.0373	0.2373*	-0.0517	-0.0719	0.3457**	-0.0434	0.2598**	0.2220*	0.1059	-0.0025
Cooked rice length / Width rat	-0.0711	-0.0646	-0.1015	-0.0462	-0.0598	-0.0621	-0.0999	-0.1479	-0.1472	-0.0017	0.0537
Cooking time	0.0890	-0.0189	-0.1939*	0.2949**	-0.1337	-0.3137**	0.3310**	-0.1101	-0.1679	-0.0061	0.0861
Length expansion Ratio=L cooke	0.2964**	0.2115*	0.0939	-0.0936	-0.2699**	0.0316	-0.1308	-0.1085	0.0768	0.1446	-0.0194
Width expansion ratio=W cooked	-0.0488	-0.0436	0.2952**	-0.2246*	-0.0898	0.0288	-0.1880	-0.0060	0.2679**	0.0087	-0.0854
Volume Expansion ratio	-0.1800	-0.2066*	0.3686**	-0.1405	-0.0789	-0.0938	-0.1208	0.0400	0.3577**	-0.1688	-0.1292
Zinc content (PPM)	-0.1946*	-0.2546**	-0.1198	-0.0179	-0.2472**	-0.2936**	-0.0475	-0.2095*	-0.0907	-0.2809**	-0.2929**
Iron content (PPM)	-0.0043	-0.1180	-0.0179	-0.1621	-0.1313	-0.1669	-0.1558	0.0810	0.0645	-0.0305	-0.0819
Grain yield per plant (g)	0.0423	0.2355*	0.3852**	-0.0917	0.3144**	0.548**	-0.0508	0.6404**	0.3855**	0.696**	0.704**

Characters	Thousand seed weight (g)	Biological yield (g)	Harvest Index (%)	Grain length (mm)	Grain breadth (mm)	Kernel length (mm)	Kernel breadth (mm)	Ratio of grain L/W	Ratio of kernel L/W	Hulling percentage	Milling percentage
Days to 50% flowering											
Days to maturity											
Number of tillers per hill											
Plant height (cm)											
Leaf length of blade (cm)											
Leaf width of blade (cm)											
Stem length excluding Panicle											
Panicle length of main axis (c)											
Panicle number per plant											
Total number of spikelet per p											
Number of fertile grain per pa											
Thousand seed weight (g)	1										
Biological yield (g)	0.6420**	1									
Harvest Index (%)	0.4327**	0.1644	1								
Grain length (mm)	0.2411*	0.1237	-0.1567	1							

Grain breadth (mm)	0.2018*	0.1363	-0.0775	-0.1968*	1						
Kernel length (mm)	0.1835	0.1327	-0.1654	0.8781**	-0.2952**	1					
Kernel breadth (mm)	0.2919**	0.1233	0.0261	0.1160	0.1326	0.0884	1				
Ratio of grain L/W	0.0841	0.0401	-0.0580	0.8195**	-0.6865**	0.7859**	0.0273	1			
Ratio of kernel L/W	0.0174	0.0455	-0.1743	0.6917**	-0.3016**	0.8256**	-0.4451**	0.6474**	1		
Hulling percentage	-0.1239	-0.0595	-0.1852	-0.2827**	0.1352	-0.3129**	0.0591	-0.2884**	-0.2882**	1	
Milling percentage	-0.1784	-0.0989	-0.1560	-0.3630**	0.0698	-0.3977**	-0.0259	-0.3175**	-0.3197**	0.7681**	1
Coocked rice length (mm)	0.2606**	0.0746	-0.0187	0.4791**	-0.0383	0.4668**	0.1190	0.3463**	0.3299**	-0.1494	-0.2285*
Cooked rice width (mm)	0.2864**	0.2966**	0.1099	-0.1726	0.3341**	-0.2386*	0.2507**	-0.3074**	-0.3390**	0.0327	-0.0689
Cooked rice length / Width rat	0.0088	-0.1538	-0.0542	0.4830**	-0.2792**	0.5084**	-0.1125	0.4944**	0.4980**	-0.1425	-0.1162
Cooking time	-0.0967	-0.2407*	-0.0741	-0.1257	-0.0283	-0.1023	0.0557	-0.0603	-0.0802	0.1972*	0.1492
Length expansion Ratio=L cooke	-0.1124	-0.1040	0.1114	-0.6879**	0.1705	-0.5395**	-0.0272	-0.5937**	-0.4565**	0.1625	0.1893*
Width expansion ratio=W cooked	0.0526	0.1041	0.1586	0.0084	-0.5847**	0.0339	0.1194	0.3469**	-0.0502	-0.0722	-0.1040
Volume Expansion ratio	0.0339	0.0210	0.0739	0.0419	-0.0137	0.1368	0.1364	0.0391	0.0365	-0.0177	-0.0818
Zinc content (PPM)	-0.2309*	-0.3365**	-0.1635	-0.0242	0.0934	-0.0942	-0.0364	-0.0712	-0.0629	0.0185	-0.0340
Iron content (PPM)	0.0606	-0.0998	0.1660	-0.0627	-0.0037	-0.1199	0.0620	-0.0500	-0.1379	-0.0307	0.0371
Grain yield per plant (g)	0.7351**	0.7574**	0.7456**	-0.0441	0.087	-0.0598	0.1102	-0.0599	-0.1163	-0.1368	-0.1439

Characters	**Coocked rice length (mm)**	**Cooked rice width (mm)**	**Cooked rice length / Width ratio**	**Cooking time**	**Length expansion Ratio=L cooked/L Raw**	**Width expansionratio=Wcooked/W raw**	**Volume Expansion ratio**	**Zinccontent (PPM)**	**Iron content (PPM)**
Days to 50% flowering									
Days to maturity									
Number of tillers per hill									
Plant height (cm)									
Leaf length of blade (cm)									
Leaf width of blade (cm)									
Stem length excluding Panicle									
Panicle length of main axis (c)									
Panicle number per plant									
Total number of spikelet per p									
Number of fertile grain per pa									
Thousand seed weight (g)									
Biological yield (g)									
Harvest Index (%)									
Grain length (mm)									
Grain breadth (mm)									
Kernel length (mm)									
Kernel breadth									

(mm)									
Ratio of grain L/W									
Ratio of kernel L/W									
Hulling percentage									
Milling percentage									
Coocked rice length (mm)	1								
Cooked rice width (mm)	0.1195	1							
Cooked rice length / Width rat	0.6164**	-0.6893**	1						
Cooking time	-0.1760	-0.2112*	-0.2112*	1					
Length expansion Ratio=L cooke	0.2733**	0.2888**	0.2888**	-0.0360	1				
Width expansion ratio=W cooked	0.1211	0.5453**	0.5453**	-0.1250	0.1062	1			
Volume Expansion ratio	0.0923	0.1726	0.1726	-0.1310	0.0620	0.1699	1		
Zinc content (PPM)	-0.0397	-0.0504	-0.0504	-0.0025	0.0214	-0.1176	0.0408	1	
Iron content (PPM)	-0.2581**	0.2001*	0.2001*	-0.1603	-0.1136	0.1915*	0.0058	0.2866**	1
Grain yield per plant (g)	0.0284	0.2989**	0.2989**	-0.2032*	0.0202	0.1642	0.0632	-0.3172**	0.0723

Table 5: Direct and indirect effect of different characters on grain yield in aromatic rice

Characters	**DFF**	**DM**	**Number of tillers per hill**	**Plant height (cm)**	**Leaf length of blade (cm)**	**Leaf width of blade (cm)**	**Stem length excluding Panicle (cm)**	**Panicle length of main axis (cm)**	**Panicle number per plant**	**Total number of spikelet per panicle**	**Number of fertile grain per panicle**
Days to 50% flowering	0.0375	0.021	-0.0149	0.0091	-0.0012	-0.0014	0.0098	0.0046	-0.0142	0.007	0.004
Days to maturity	-0.0103	-0.0184	0.0039	-0.002	-0.0019	-0.0036	-0.002	-0.0019	0.004	-0.0059	-0.0045
Number of tillers per hill	0.0245	0.0129	-0.0617	0.0127	-0.0019	-0.0116	0.0122	-0.0006	-0.0598	-0.0098	-0.0032
Plant height (cm)	-0.0178	-0.0078	0.015	-0.0729	-0.0307	0.0023	-0.0703	-0.0127	0.0123	-0.0071	-0.0179
Leaf length of blade (cm)	0.0011	-0.0038	-0.0011	-0.0152	-0.0361	-0.01	-0.0157	-0.0115	-0.0024	-0.0071	-0.0151
Leaf width of blade (cm)	0	-0.0001	-0.0001	0	-0.0002	-0.0007	0.0001	-0.0003	-0.0001	-0.0002	-0.0002
Stem length excluding Panicle	0.0199	0.0082	-0.0151	0.0734	0.0331	-0.0057	0.0762	0.0157	-0.012	0.0096	0.0224
Panicle length of main axis (c)	0.0062	0.0053	0.0005	0.0088	0.016	0.0219	0.0104	0.0504	0.0012	0.0293	0.0296
Panicle number per plant	-0.0258	-0.0147	0.0659	-0.0115	0.0046	0.0084	-0.0108	0.0016	0.0681	0.0107	0.0037
Total number of spikelet per p	0.0023	0.004	0.002	0.0012	0.0024	0.0045	0.0016	0.0072	0.0019	0.0124	0.0097
Number of fertile grain per pa	-0.0063	-0.0144	-0.003	-0.0145	-0.0247	-0.0193	-0.0174	-0.0347	-0.0032	-0.046	-0.059
Thousand seed weight (g)	-0.0046	-0.0131	0.0223	0.0088	0.0272	0.0497	0.0105	0.0553	0.02	0.0456	0.0553
Biological yield (g)	-0.0315	0.0987	0.2404	0.0781	0.3526	0.3695	0.0902	0.3823	0.2257	0.3268	0.344
Harvest Index (%)	0.0384	0.1469	0.1396	-0.1723	-0.0154	0.1647	-0.1499	0.1869	0.1476	0.327	0.3284
Grain length (mm)	-0.1349	-0.1048	0.0178	-0.0117	0.0335	0.0446	-0.0169	0.0233	0.0015	-0.0518	-0.015
Grain breadth (mm)	0.0005	0.0026	-0.015	0.0291	0.0037	0.0382	0.0249	0.037	-0.0109	0.0142	0.0148
Kernel length (mm)	0.0281	0.0221	-0.012	0.0075	-0.0058	-0.0067	0.0089	0.0012	-0.0082	0.0165	0.0068
Kernel breadth (mm)	-0.0009	-0.0015	0.0017	0.0001	0.0003	0.0014	0.0003	0.0007	0.0019	0.0002	0.0002
Ratio of grain L/W	0.1359	0.0969	-0.0352	0.0612	-0.0365	0.0086	0.0575	0.0271	-0.0147	0.0605	0.0324
Ratio of kernel L/W	-0.0111	-0.0072	0.0014	-0.0037	0.001	-0.0015	-0.0049	-0.0028	-0.0007	-0.0082	-0.0037
Hulling percentage	0.0004	0.0002	-0.0001	0.0005	-0.0001	-0.0004	0.0003	-0.0003	0	-0.0001	-0.0002
Milling percentage	-0.001	-0.0005	0.0002	-0.0008	-0.0001	0.001	-0.0006	0.0008	-0.0001	0.0001	0.0003
Coocked rice length (mm)	0.0253	0.0278	-0.0279	0.017	0.0299	-0.045	0.0283	-0.0038	-0.0127	-0.0094	-0.0034
Cooked rice width (mm)	0.0043	0.0069	-0.0441	0.0096	0.0134	-0.0643	0.0081	-0.0483	-0.0413	-0.0197	0.0005
Cooked rice length / Width rat	-0.0154	-0.014	-0.0219	-0.01	-0.0129	-0.0134	-0.0216	-0.032	-0.0318	-0.0004	0.0116
Cooking time	-0.001	0.0002	0.0022	-0.0034	0.0015	0.0036	-0.0038	0.0013	0.0019	0.0001	-0.001
Length expansion Ratio=L cooke	0.0007	0.0005	0.0002	-0.0002	-0.0006	0.0001	-0.0003	-0.0003	0.0002	0.0003	0
Width expansion ratio=W cooked	-0.0204	-0.0182	0.1232	-0.0937	-0.0375	0.012	-0.0785	-0.0025	0.1118	0.0036	-0.0357
Volume Expansion ratio	-0.0008	-0.0009	0.0017	-0.0006	-0.0004	-0.0004	-0.0005	0.0002	0.0016	-0.0008	-0.0006
Zinc content (PPM)	-0.0014	-0.0019	-0.0009	-0.0001	-0.0018	-0.0022	-0.0004	-0.0016	-0.0007	-0.0021	-0.0022
Iron content (PPM)	0.0001	0.0027	0.0004	0.0037	0.003	0.0038	0.0036	-0.0019	-0.0015	0.0007	0.0019

Characters	**Thousand seed weight (g)**	**Biological yield (g)**	**Harvest Index (%)**	**Grain length (mm)**	**Grain breadth (mm)**	**Kernel length (mm)**	**Kernel breadth (mm)**	**Ratio of grain L/W**	**Ratio of kernel L/W**	**Hulling percentage**	**Milling percentage**
Days to 50% flowering	-0.0019	-0.0018	0.0024	-0.0154	0.0002	-0.0142	-0.0046	-0.0116	-0.0106	0.0061	0.0096
Days to maturity	0.0027	-0.0028	-0.0045	0.0059	-0.0004	0.0055	0.004	0.0041	0.0034	-0.0015	-0.0026
Number of tillers per hill	-0.0154	-0.0232	-0.0142	-0.0033	0.007	-0.0101	-0.0156	-0.0049	-0.0022	0.0036	0.0036
Plant height (cm)	-0.0072	-0.0089	0.0208	0.0026	-0.0161	0.0074	-0.0014	0.0102	0.0069	-0.0148	-0.0144

Leaf length of blade (cm)	-0.011	-0.0199	0.0009	-0.0037	-0.001	-0.0028	-0.0016	-0.003	-0.0009	0.0015	-0.0006
Leaf width of blade (cm)	-0.0004	-0.0004	-0.0002	-0.0001	-0.0002	-0.0001	-0.0001	0	0	0.0001	0.0002
Stem length excluding Panicle	0.009	0.0107	-0.0189	-0.0039	0.0143	-0.0091	0.0038	-0.01	-0.0095	0.011	0.0124
Panicle length of main axis (c)	0.0312	0.0301	0.0155	0.0036	0.0141	-0.0008	0.0051	-0.0031	-0.0036	-0.0069	-0.0105
Panicle number per plant	0.0152	0.024	0.0166	0.0003	-0.0056	0.0076	0.0184	0.0023	-0.0011	0.0001	0.0011
Total number of spikelet per p	0.0063	0.0063	0.0067	-0.002	0.0013	-0.0028	0.0004	-0.0017	-0.0026	-0.0007	-0.0002
Number of fertile grain per pa	-0.0365	-0.0317	-0.032	0.0027	-0.0066	0.0054	-0.002	0.0044	0.0056	0.0045	0.0053
Thousand seed weight (g)	0.0893	0.0573	0.0386	0.0215	0.018	0.0164	0.0261	0.0075	0.0016	-0.0111	-0.0159
Biological yield (g)	0.4108	0.6398	0.1052	0.0791	0.0872	0.0849	0.0789	0.0257	0.0291	-0.0381	-0.0633
Harvest Index (%)	0.262	0.0995	0.6053	-0.0948	-0.0469	-0.1001	0.0158	-0.0351	-0.1055	-0.1121	-0.0945
Grain length (mm)	0.0792	0.0406	-0.0514	0.3284	-0.0646	0.2883	0.0381	0.2691	0.2271	-0.0928	-0.1192
Grain breadth (mm)	0.0267	0.018	-0.0102	-0.026	0.1321	-0.039	0.0175	-0.0907	-0.0398	0.0179	0.0092
Kernel length (mm)	-0.0136	-0.0098	0.0122	-0.0649	0.0218	-0.0739	-0.0065	-0.0581	-0.061	0.0231	0.0294
Kernel breadth (mm)	0.002	0.0009	0.0002	0.0008	0.0009	0.0006	0.0069	0.0002	-0.0031	0.0004	-0.0002
Ratio of grain L/W	-0.037	-0.0176	0.0255	-0.3599	0.3015	-0.3452	-0.012	-0.4392	-0.2843	0.1267	0.1394
Ratio of kernel L/W	0.0007	0.0018	-0.0068	0.0271	-0.0118	0.0323	-0.0174	0.0254	0.0392	-0.0113	-0.0125
Hulling percentage	-0.0003	-0.0001	-0.0004	-0.0007	0.0003	-0.0008	0.0001	-0.0007	-0.0007	0.0024	0.0019
Milling percentage	0.0007	0.0004	0.0006	0.0014	-0.0003	0.0015	0.0001	0.0012	0.0012	-0.0029	-0.0038
Coocked rice length (mm)	-0.0457	-0.0131	0.0033	-0.0841	0.0067	-0.0819	-0.0209	-0.0608	-0.0579	0.0262	0.0401
Cooked rice width (mm)	-0.0533	-0.0552	-0.0204	0.0321	-0.0621	0.0444	-0.0466	0.0572	0.0631	-0.0061	0.0128
Cooked rice length/Width rat	0.0019	-0.0333	-0.0117	0.1044	-0.0604	0.1099	-0.0243	0.1069	0.1077	-0.0308	-0.0251
Cooking time	0.0011	0.0028	0.0009	0.0014	0.0003	0.0012	-0.0006	0.0007	0.0009	-0.0023	-0.0017
Length expansion Ratio=L cooke	-0.0003	-0.0002	0.0003	-0.0016	0.0004	-0.0013	-0.0001	-0.0014	-0.0011	0.0004	0.0004
Width expansion ratio=W cooked	0.0219	0.0435	0.0662	0.0035	-0.2441	0.0142	0.0498	0.1448	-0.021	-0.0301	-0.0434
Volume Expansion ratio	0.0002	0.0001	0.0003	0.0002	-0.0001	0.0006	0.0006	0.0002	0.0002	-0.0001	-0.0004
Zinc content (PPM)	-0.0017	-0.0025	-0.0012	-0.0002	0.0007	-0.0007	-0.0003	-0.0005	-0.0005	0.0001	-0.0003
Iron content (PPM)	-0.0014	0.0023	-0.0038	0.0014	0.0001	0.0027	-0.0014	0.0011	0.0032	0.0007	-0.0008

Conclusion

Estimation of genetic parameters of variability, correlation analysis and path coefficient analysis revealed that the numbers of tillers per hill, leaf length of blade, leaf width of blade, panicle length of main axis, panicle number per plant, total number of spikelets per panicle, number of fertile grain per panicle, 1000 seed weight, biological yield, harvest index %, grain length and width expansion ratio, cooked rice width and cooked rice length/width ratio, were the most reliable traits for yield improvement in aromatic rice. So the utmost importance should be given to these characters during the selection for yield improvement in aromatic rice.

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