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Genetic Variability and Cause-Effect Relationship in Aromatic Rice

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ABSTRACT

Twenty diverse rice genotypes, mostly aromatic landraces, were grown during warm wet season of 2022 to analyse the genetic variability, correlation and path coefficients for sixteen agro-morphological characters. The results of genotypic and phenotypic coefficients of variability, heritability, and genetic advance indicated that improvement through selection for flag leaf angle, panicle exertion, secondary branches per panicle, test weight, spikelet number, and number of filled grains would be effective. Correlation coefficients of grain yield with flag leaf area, spikelet fertility percentage, test weight and harvest index were positive and significant, while with flag leaf angle it was negative and significant indicating the importance of these characters on grain yield. Path analysis revealed that selection for larger flag leaf area, greater test weight and narrow flag leaf angle, reduced plant height and early flowering would increase grain yield. However, restrictions are required to be imposed on panicle number, panicle length and filled grain, so that a balance between morphological architecture and physiological rhythm is maintained to optimize source-sink relationship.

Keywords Aromatic rice, Variability, Correlation, Path coefficients, Morphological characters.

INTRODUCTION

Rice (*Oryza sativa* L., 2n=24) is one of the most important cereals and consumed widely as staple foods in the world. This cereal is native to Southeast Asia and has been cultivated for thousands of years. As of 2022, the top 10 producers of rice are in Asia. Globally, the top rice producing country is China (147 million tons), followed by India (124 million tons) (milled basis). Together, China and India account for more than the half of the rice produced globally (USDA December 2022).

There are many different types of rice available, each of which having its own unique flavor, texture, color, and cooking characteristics. Among them aromatic rice constitutes a special group of rice for its unique quality. It is believed that the unique fragrance and flavor of aromatic rice is due to exceeding the critical limit of some volatile compounds among which 2-acetyl-1-pyrroline is found to be the major compound (Pachauri *et al.* 2010).

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Any plant breeding programs ultimate objective is to create improved genotypes that outperform the existing ones and are sold in the market with premium price. The knowledge on germplasm evaluation, genotypic and phenotypic coefficients of variability, heritability, character associations and path analysis in the available germplasm lines or genotypes offers useful assistance to the breeding program. The present study was undertaken in a population of 20 rice germplasm, mostly aromatic, with a view to assessing variability and identifying important characters for improvement through correlations and path coefficients analysis.

MATERIALS AND METHODS

The field experiment was conducted at the NE Borlaug Crop Research Center of GB Pant University of Agriculture and Technology, Pantnagar. A set of 20 diverse rice genotypes mostly aromatic non-basmati landraces except PB1121 and Taraori Basmati being basmati type and Pusa 44 and Sambha Masuri nonaromatic was grown during *kharif* season (July-December) in 2022. The list of rice genotypes and the procedures of conducting field experiment have been described elsewhere (Kole and Deo 2023). Observations were recorded on following sixteen agro-morphological yield related characters viz. plant height, days to 50 % flowering, flag leaf area and angle, panicle number per hill, panicle exertion, panicle length, primary and secondary branches per panicle, number of spikelet and filled grain per panicle, fertility percentage, test weight, straw yield per hill, harvest index, grain yield per hill. Data on days to flowering were recorded on the whole plot basis. Biometrical analyses were done following procedures of Burton (1952) for phenotypic and genotypic coefficients of variability, Johnson *et al.* (1955) for heritability and genetic advance, Al-Jibouri *et al*. (1958) for correlation coefficients and Dewey and Lu (1959) for path coefficients.

RESULTS AND DISCUSSION

Analysis of variance reveals that the mean squares due to genotypes for all the characters were highly significant, indicating presence of sufficient amount of genetic variability among the genotypes. Considerable variations in different characters have been reported earlier (Sar and Kole 2023, Das *et al*. 2024). The estimates of GCV and PCV values (Table 1) were high for flag leaf and its angle, panicle exertion, secondary branches, spikelet number and filled grains per panicle, test weight, straw weight, harvest index and grain yield indicating scope for selection. High values of GCV and PCV indicates that the traits are under genetic control and the information is helpful for practising selection. Similar results were reported

Table 1. Phenotypic and genotypic coefficients of variability, heritability and genetic advance for sixteen quantitative characters in rice.

Character	Grand mean	Min	Max	Coefficient of variation GCV%	PCV%	Heritability (%)	Genetic advance	Genetic advance as a percent mean (GAM)
Plant height (cm)	127.26	86.13	148.13	16.21	17.48	86	39.41	30.97
Days to flowering	124.98	75	149	18.44	18.49	99.4	47.33	37.87
Flag leaf area (cm^2)	26.84	18	40.63	21.95	28.19	60.7	9.45	35.25
Flag leaf angle (0)	30.01	6.83	52.67	49.54	54.19	83.6	28	93.33
Panicle number	13.88	10.53	18.8	16.01	19.41	68	3.78	27.23
Panicle exertion (cm)	3.75	-1.93	9.07	83.12	87.12	91	6.13	163.47
Panicle length (cm)	23.88	16.53	27.67	10.98	12.45	77.7	4.76	19.93
Primary branches	11.23	8.53	12.93	12.93	13.99	85.4	2.76	24.58
Secondary branches	34.2	10.13	55.13	39.01	40.27	93.9	26.63	77.87
Spikelet number	183.22	79.33	279	30.81	33.67	83.7	106.39	58.07
Spikelet fertility %	61.36	22.29	79.18	16.66	18.93	77.4	18.54	30.2
Filled grain number	112.21	30.47	209.23	45.12	48.79	85.5	96.43	85.94
Test weight (g)	13.83	7.6	24.83	35.95	36.75	95.7	10.02	72.45
Straw weight (g)	57.67	23	96.23	30.32	32.5	87.1	33.61	58.27
Harvest index (%)	19.32	4.2	39.46	31.60	34.04	86.2	11.68	60.45
Grain yield (g)	12.62	3.1	25.23	33.08	36.29	83.1	7.84	62.12

by Kole *et al*. (2008) and Challa *et al.* (2022). The traits like plant height, days to 50% flowering, panicle number per hill, panicle length, primary branches, and spikelet fertility % showed moderate estimates of PCV and GCV. Katkani *et al.* (2019) and Akhtar *et al.* (2022) also reported that PCV and GCV were moderate for plant height, number of active tillers and a low value for panicle length. The differences between PCV and GCV for days to 50% flowering and test weight were very small indicating greater role of genetic factor in the expression of these characters.

The estimates of heritability (Table 1), in the broad sense, reveals that days to 50% flowering, panicle exertion, secondary branches per panicle and test weight are greater than 90%, while flag leaf area and panicle number have less than 70% heritability. The rest of the characters have heritability estimates greater than 70% but less than 90%. Similar results were reported by Roy and Shil (2020), Keerthiraj and Biju (2020), Akhtar *et al.* (2022), Challa *et al.* (2022), Kulsum *et al.* (2022), Singh *et al.* (2022), Sadhu *et al.* (2023), Shanmugam *et al.* (2023).

The estimates of genetic advance as percent of mean (Table 1) were high (>50%) for flag leaf angle, panicle exertion, secondary branch, spikelet number per panicle, number of filled grain per panicle, test weight, straw weight, harvest index and grain yield. The value is moderate (25-50%) for plant height, days to 50% flowering, flag leaf area, panicle number per hill, spikelet fertility and low (<25%) for panicle length and primary branches. Similar results were found for days to 50 % flowering, panicle number per plant and harvest index by Khaire *et al.* (2022), plant height and grain yield per plant by Katkani *et al.* (2019), and test weight and grain yield by Nath and Kole (2021).

Table 2. Genotypic (G) and phenotypic (P) correlation coefficients among 16 quantitative characters in rice.

	Characters		DF	FLA	FLANG	PN	PE	PL	PB	SB
1	Plant height	G	0.223	-0.612**	0.499*	0.417	0.281	0.403	-0.075	0.129
		P	0.2	-0.424	0.415	0.247	0.253	0.275	-0.05	0.094
2	Days to flowering (DF)	G		-0.280	-0.011	-0.404	-0.575**	-0.174	0.749**	0.513*
		P		-0.221	-0.002	-0.335	-0.545*	-0.154	0.691**	0.494*
3	Flag leaf area (FLA)	G			-0.597**	-0.156	-0.067	-0.412	-0.082	-0.357
		P			-0.390	-0.036	-0.023	-0.238	0.027	0.214
4	Flag leaf angle	G				-0.002	0.609**	0.404	-0.311	0.002
		P				0.006	0.519*	0.312	0.259	0.009
5	Panicle number (PN)	G					0.183	0.102	-0.667**	-0.566**
		P					0.145	0.192	-0.466*	0.403
6	Panicle exertion (PE)	G						0.573**	-0.701**	-0.445*
		P						0.506*	-0.616**	-0.418
7	Panicle length (PL)	G							-0.356	-0.172
		P							-0.281	-0.126
8	Primary branches (PB)	G								0.779**
		P								0.736**
9	Secondary branches (SB)	G								
		P								
10	Total spikelet no. (TSN)	G\								
		P								
11	Fertility % (FERT)	G								
		P								
12	Filled grain no. (FGN)	G								
		P								
13	Test weight (TW)	G								
		P								
14	Straw weight (SW)	G								
		P								
15	Harvest index (HI)	G								
		P								

Table 2. Continued.

	Characters		TSN	FERT	FG	TW	SW	HI	Grain Yield
1	Plant height	G	0.236	0.172	0.144	-0.369	0.503*	-0.477*	-0.379
		P	0.184	0.121	0.117	-0.342	0.407	-0.391	-0.310
2	Days to flowering (DF)	G	0.236	0.507*	-0.266	-0.681**	0.776**	-0.844**	-0.437
		P	0.215	0.459*	-0.236	-0.666**	0.723**	-0.783**	-0.403
3	Flag leaf area (FLA)	G	-0.257	-0.382	0.093	0.509*	-0.310	0.448*	0.451*
		P	0.152	-0.209	0.044	0.383	0.274	0.396	0.397
4	Flag leaf angle	G	0.056	-0.001	0.015	-0.036	0.090	-0.364	-0.567**
		P	0.062	0.003	0.033	-0.277	0.07	-0.279	-0.434
5	Panicle number (PN)`	G	-0.574**	-0.570**	-0.204	0.440	-0.321	0.211	-0.058
		P	-0.391	-0.340	0.154	0.343	0.228	0.169	-0.029
6	Panicle exertion (PE)	G	-0.039	-0.385	0.430	0.329	-0.401	0.411	0.193
		P	-0.042	-0.344	0.372	0.292	-0.347	0.348	0.150
7	Panicle length (PL)	G	0.244	-0.084	0.551	0.093	0.034	0.218	0.432
		P	0.224	0.065	0.465*	0.094	0.037	0.16	0.344
8	Primary branches (PB)	G	0.579**	0.766**	-0.026	-0.586**	0.658**	0.471*	0.078
		P	0.491*	0.711**	-0.082	-0.516*	0.549*	-0.401	-0.077
9	Secondary branches (SB)	G	0.808**	0.979**	-0.061	-0.773**	0.581**	-0.389	-0.127
		P	0.728**	0.930**	0.006	-0.718**	0.509*	-0.331	-0.095
10	Total spikelet no. (TSN)	G		0.039	0.799**	-0.784**	0.650**	-0.399	-0.069
		P		-0.018	0.753**	-0.688**	0.525*	-0.293	-0.023
11	Fertility % (FERT)	G			0.621**	0.165	-0.021	0.448**	0.649**
		P			0.620**	0.093	-0.015	0.404	0.575**
12	Filled grain no. (FGN	G				-0.552	0.488	-0.081	0.263
		P				-0.525	0.405	-0.010	0.291
13	Test weight (TW)	G					-0.604**	0.686**	0.494*
		P					-0.556**	0.611**	0.423
14	Straw weight (SW)	G						-0.791	0.273
		P						-0.776**	-0.256
15	Harvest index (HI)	G							0.771**
		P							0.772**

*,** : Significant at p=0.05 and 0.01, respectively.

Heritability combined with genetic advance, as suggested by Johnson *et al*. (1955) and Lerner (1958), gives more useful data for choosing the best plant. High to moderate values of both heritability and genetic advance for flag leaf angle, panicle exertion, secondary branch, spikelet and filled grain per panicle, test weight, straw weight, harvest index and grain yield are indicative of predominantly additive type of gene action and effectiveness of selection in this population.

The trends between the genotypic and the phenotypic correlation coefficients (Table 2) were similar, genotypic correlation being always greater than the corresponding phenotypic correlation coefficients due to modifying effect of the environment. Correlation coefficients of grain yield with flag leaf area, spikelet fertility percentage, grain weight and harvest index were positive and significant, while with flag leaf angle it was negative and significant indicating the influence of these characters on seed yield. Comparable results were made regarding the yield of grains, which showed a positive and significant correlation with test weight by Kumar *et al.* (2018), flag leaf area by Saha *et al.* (2019), spikelet fertility by Rahangdale *et al.* (2019) and Kujur *et al.* (2023), test weight by Gayathri and Padmalatha (2023), harvest index by Challa *et al.* (2022) and Kujur *et al.* (2023).

The results of both genotypic and phenotypic path analyses (Tables 3 - 4) of 12 characters (other characters being overlapping were excluded) on seed yield indicate that the direction and magnitude did not match in some cases. This is due to differences in the magnitude and dual nature of genotypic and phenotypic correlation coefficients (Falconer and Mackay

Table 3. Phenotypic path analysis of 12 quantitative character on grain yield.

	PH	DF	FLA	FANGL	PN	PE	PL
Plant height (PH)	**-0.091**	-0.019	-0.085	-0.162	-0.015	-0.002	0.101
Days to flowering (DF)	-0.018	**-0.097**	-0.044	0.001	0.02	0.004	-0.057
Flag leaf area (FLA)	0.039	0.022	**0.201**	0.153	0.002	0.0001	-0.088
Flag leaf angle (FANGL)	-0.038	0.0001	-0.078	**-0.392**	0.0001	-0.004	0.115
Panicle number (PN)	-0.022	0.033	-0.007	-0.004	**-0.06**	-0.001	0.071
Panicle exertion (PE)	-0.023	0.053	-0.005	-0.203	-0.009	**-0.007**	0.187
Panicle length (PL)	-0.025	0.015	-0.048	-0.122	-0.012	-0.004	**0.369**
Primary branches (PB)	0.005	-0.067	-0.006	0.102	0.028	0.004	-0.104
Secondary branches (SB)	-0.009	-0.048	-0.043	-0.004	0.024	0.003	-0.047
Filled grain no. (FGN)	-0.017	-0.021	-0.03	-0.024	0.024	0.0001	0.083
Test weight (TW)	0.03	0.064	0.076	0.109	-0.021	0.002	0.035
Straw weight (SW)	-0.037	-0.071	-0.055	-0.027	0.014	0.002	0.014

Table 3. Continued.

	PB	SB	FGN	TW	SW	Correlation with grain yield
Plant height (PH)	0.002	-0.008	0.101	-0.095	-0.037	-0.31
Days to flowering (DF)	-0.035	-0.044	0.118	-0.185	-0.066	-0.403
Flag leaf area (FLA)	0.001	0.019	-0.083	0.106	0.025	0.397
Flag leaf angle (FANGL)	0.013	-0.001	0.034	-0.077	-0.006	-0.434
Panicle number (PN)	0.023	0.036	-0.214	0.095	0.021	-0.029
Panicle exertion (PE)	0.03	0.038	-0.023	0.081	0.031	0.150
Panicle length (PL)	0.014	0.011	0.123	0.026	-0.003	0.344
Primary branches (PB)	**-0.049**	-0.066	0.269	-0.143	-0.05	-0.077
Secondary branches (SB)	-0.036	**-0.09**	0.399	-0.199	-0.045	-0.095
Filled grain no. (FGN)	-0.024	-0.065	**0.548**	-0.146	-0.037	0.291
Test weight (TW)	0.025	0.064	-0.288	**0.277**	0.05	0.423
Straw weight (SW)	-0.027	-0.046	0.222	-0.154	**-0.091**	-0.256

Bold figures indicate direct effects, Residual: 0.24.

1996). The greater per cent of variability in seed yield is determined by these 12 characters as revealed by the low residual effects. In both path analyses, straw yield, flag leaf area and primary branches per panicle have positive direct effects and these characters exerted positive effects in the pathway of other characters.

Table 4. Genotypic path analysis of 12 quantitative character on grain yield.

	PH	DF	FLA	FANGL	PN	PE	PL
Plant height (PH)	**1.954**	-0.024	0.061	-0.672	-0.953	-0.198	0.227
Days to flowering (DF)	0.436	**-0.098**	0.028	0.014	0.923	0.405	-0.098
Flag leaf area (FLA)	-1.196	0.027	**-0.099**	0.805	0.357	0.047	-0.231
Flag leaf angle (FANGL)	0.975	0.001	0.059	**-1.348**	-0.005	-0.428	0.227
Panicle number (PN)	0.815	0.039	0.016	-0.001	**-2.285**	-0.129	0.057
Panicle exertion (PE)	0.549	0.056	0.007	-0.821	-0.418	**-0.703**	0.323
Panicle length (PL)	0.788	0.017	0.041	-0.545	-0.233	-0.403	**0.561**
Primary branches (PB)	-0.146	-0.073	0.008	0.42	1.524	0.493	-0.2
Secondary branches (SB)	0.251	-0.05	0.035	-0.002	1.292	0.313	-0.096
Filled grain no. (TSN)	0.461	-0.023	0.025	-0.076	1.312	0.028	0.137
Test weight (TW)	-0.721	0.067	-0.05	0.413	-1.006	-0.231	0.051
Straw weight (SW)	0.984	-0.076	0.031	-0.121	0.733	0.282	0.019

Table 4. Continued.

	PB	SB	FGN	TW	SW	Correlation with grain yield
Plant height (PH)	0.099	0.139	-0.153	-0.421	-0.438	-0.379
Days to flowering (DF)	-0.993	0.553	-0.153	-0.778	-0.676	-0.437
Flag leaf area (FLA)	0.109	-0.385	0.167	0.581	0.269	0.451
Flag leaf angle (FANGL)	0.413	0.002	-0.036	-0.349	-0.078	-0.567
Panicle number (PN)	0.885	-0.609	0.372	0.503	0.279	-0.058
Panicle exertion (PE)	0.93	-0.479	0.025	0.375	0.349	0.193
Panicle length (PL)	0.472	-0.185	-0.159	0.107	-0.029	0.432
Primary branches (PB)	**-1.325**	0.84	-0.376	-0.67	-0.573	-0.078
Secondary branches (SB)	-1.034	**1.077**	-0.524	-0.883	-0.506	-0.127
Filled grain no. (TSN)	-0.768	0.871	**-0.649**	-0.63	-0.425	0.263
Test weight (TW)	0.778	-0.833	0.358	**1.142**	0.526	0.494
Straw weight (SW)	-0.874	0.626	-0.317	-0.69	**-0.87**	-0.273

Bold figures indicate direct effects, Residual: 0.14.

Their indirect effects were positive (except tiller number for flag leaf area and primary branches). Therefore, selection of these characters in positive direction will increase grain yield. Plant height, panicle length, test weight, tiller number and filled grain had either negative direct effects or negative indirect effects in the pathway of other characters or both. So, restriction is required to be imposed on these characters, so that a balance between morphological architecture and physiological rhythm is maintained to optimize source-sink relationship. Longkho and Kole (2022) reported direct selection of primary branches and restricted selection on panicle number, panicle length and 100-grain weight.

CONCLUSION

The overall results on the magnitude of variability, influence of environment on character expression, and cause-effect relationship indicated that the selection for larger flag leaf area, higher spikelet fertility, and greater grain weight with restricted selection for panicle number, plant height, flag leaf angle would increase the grain yield of rice in this population.

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