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Research Note

Genetic variability, correlation and path-coefficient analysis for yield and yield attributing traits in aerobic rice (*Oryza sativa* L.)

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Abstract
The present research was conducted to examine different parameters of variability, correlations, and path coefficients associated with yield and yield-related traits in aerobic rice. The analysis of variance indicated noteworthy variations among the genotypes for all the traits investigated. Among them, flag leaf area and alkali spreading value showed high PCV and GCV. Except for days to fifty per cent flowering, days to maturity, and amylose content, the remaining traits demonstrated substantial heritability combined with high genetic advance as percentage of mean. The correlation analysis revealed significant positive association between grain yield per plant and several traits, namely effective tillers per plant, test weight, chlorophyll content, and length breadth ratio. Traits such as test weight, effective tillers per plant, and flag leaf area showed a positive direct effect on grain yield per plant. Therefore, it is crucial to give priority to traits that exhibit significant positive correlations and substantial direct effects during selection process. This approach will yield rewarding results in the development of high-yielding cultivars suitable for aerobic conditions.

Keywords: Aerobic rice, PCV, GCV, Heritability, Correlation coefficient, Path analysis

Rice (*Oryza sativa* L.) holds a crucial position as a major stable crop globally, contributing substantially to the daily caloric consumption of over half of the global population. It is an essential component of many cuisines worldwide. It is a cereal grain that belongs to the family Poaceae and is grown in a wide range of environments, Rice is grown in diverse climates and soil conditions, ranging from high-altitude mountain regions to lowland areas with hot and humid tropical climates. Rice is not only a vital source of carbohydrates but also contains dietary fibre, more than 12 essential vitamins and minerals, including iron, folate, and potassium (Fulgoni *et al*., 2010). Despite its widespread use and importance, rice production faces several challenges, including water scarcity, climate change, and the need for sustainable farming practices. As a result, there is ongoing research and innovation in rice cultivation to develop new varieties, technologies, and approaches to meet these challenges and ensure a sustainable and secure food supply for future generations. In this context, cultivation of aerobic rice may offer a promising alternative and making it a more sustainable option to traditional flooded rice cultivation, particularly in areas with water scarcity or where reducing greenhouse gas emissions is a priority. Aerobic rice presents numerous advantages over flooded rice, including significant water-saving of 30 to 56% compared to conventional flooded irrigation. In case of aerobic rice, only 470 to 644 mm of water is required (Anon, 2021). Aerobic rice exhibits enhanced tolerance to extreme weather events such as droughts and floods, which are increasingly frequent as a result of climate change.

To develop a suitable cultivar for aerobic cultivation, identifying superior genotypes with desirable traits is crucial. This can be achieved by establishment of appropriate selection criteria for various traits. In this context, in order to evaluate various metric traits of interest to the breeder, it is essential to separate the total variability into heritable and non-heritable components. This can be achieved by computing the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV), as well as determining the heritability and genetic advances. The correlation coefficient serves as a statistical measure to evaluate the nature, magnitude, and direction of the association between variables or traits, including yield. However, relying solely on correlation-based selection without considering the various types of interactions among the component traits that affect yield can lead to misleading results. Furthermore, it fails to offer a comprehensive understanding of the significance of both direct and indirect influences of different component traits on crop yield. To address this limitation, path coefficient analysis can be employed to assess the relative contributions of a specific trait to any dependent component. By examining the interrelationship between traits and quantifying their direct and indirect effect on yield, plant breeders can obtain valuable insights for establishing effective selection criteria in the pursuit of desirable genotypes.

Taking into consideration the aforementioned points, the present study aimed to evaluate the variability for yield and various quality traits under aerobic conditions, as well as to assess the association and direct and indirect effects of various morpho-physiological traits on yield in aerobic rice.

The present research involving 30 different rice genotypes (**Table 1**) was conducted during *Kharif*- 2022 at research farm of Lovely Professional University, Phagwara, Punjab. The accessions were raised in a Randomized Block Design (RBD) with three replications. The entries were direct seeded, with a spacing of 22 X 10 cm with three rows per entry. The seeds were carefully sown to maintain 1-2 seedlings per hill. To ensure a high-quality crop, all recommended standard agronomic practices were implemented, and the necessary preventive plant protection measures were taken. Observations on 13 different traits namely, Days to 50 per cent flowering(DFF), Days to maturity (DM), Panicle Length (PL), Plant height (PH), Flag leaf area(FLA), Effective tillers per plant (ETPP), Grains per Panicle(GPP), Chlorophyll content(CC), Grain yield per plant(GYPP), 1000 Grain weight(TW), Grain L/B ratio(LBR), Alkali spreading values (ASV), and Amylose content(AC%) were recorded. The data were collected for five plants chosen at random in each genotype, following the Standard Evaluation System (IRRI, 2013) for rice. The method proposed by Juliano (1971) was used to estimate the amylose content, while the method described by Little *et al*. (1958) was employed to determine the alkali spreading value (ASV). The mean values were subjected to statistical analysis using various methods. The analysis of variance (ANOVA) was performed for each trait as per Panse and Sukhatme (1985). The GCV and PCV were estimated using the method proposed by Burton and Devane (1953). The estimates of GCV and PCV were classified as high, medium, or low based on the values provided by Sivasubramanian and Menon (1973). The genetic advance was also estimated using the method proposed by Johnson *et al*. (1955). Broad-sense heritability was computed using the ratio of genotypic variance to the total variance, following the method suggested by Lush (1949) and Hanson *et al*. (1956). The correlation coefficients at the phenotypic levels were calculated using Falconer's (1964) formula. Path analysis was carried out as per the method proposed by Dewey and Lu (1959). INDOSTAT 9.2 and R-software were used to conduct the statistical analysis.

ANOVA (**Table 2**) showed significant variations among genotypes for all traits examined. The PCV values were higher than the GCV values for all the traits (**Table 3**), indicating that environmental factors have a significant impact on these traits. Flag leaf area and Alkali spreading value showed high PCV and GCV values (>20%), indicating that these traits have high variability and can be directly selected for crop improvement. Days to fifty per cent flowering, panicle length, plant height, effective tillers per plant, grains per panicle, test weight, chlorophyll content, length breadth ratio and grain yield per plant showed moderate PCV and GCV values (10-20%), while days to maturity and amylose content had the lowest value (<10%). These results are in accordance with the findings of Dhanwani *et al*. (2013) for the traits flag leaf area and Alkali spreading value, Chakraborty and Chakraborty (2010) for grain yield per plant, Ravikanth *et al*. (2018) for plant height, Tummuti *et al*. (2016) for Chlorophyll content, panicle length, days to 50% flowering. In conclusion, the results indicate that some traits have higher genetic variability than others, which could be useful for crop improvement through selective breeding. However, environmental factors should also be taken into consideration when selecting for traits with high variability. All of the traits except days to fifty percent flowering, days to maturity and amylose content, exhibited substantial heritability and demonstrated a high genetic advance over percentage of mean. This suggests the prominent influence of additive gene effects, indicating that direct selection can be employed effectively for improvement of these trait.

Similar findings have been reported earlier by Bhargava, *et al*. (2021), Edukondalu *et al*. (2017) for the traits viz., plant height, flag leaf area, number of grains per panicle, Lalitha. *et al*. (2019) for grains per panicle, Singh and Verma (2018) for plant height and flag leaf area. High heritability coupled with high genetic advance as

Table 1. List of rice genotypes

S. No.	Genotype Name	Percentage
1	Phule Samruddhi	Indrayani x Sonsali
2	PR 126	HuanGhuazhan ; IET 24721
3	Indrayani	Ambemohar 157 X IR 8
4	HUR-105	BHU 2009 Mutation Breeding Derived from MPR7-2 with EMS treatments consisting of 0.01 to 0.05 M doses
5	HKR-127	PAU 21-93-1 / HKR 120
6	Samba Mahsuri (BPT-5204)	(GEB24 x TN1) X Mahsuri
7	Karjat-7	Patel 3 × KJT 9-333
8	PR-128	Improved version of PAU 201
9	Sarjoo-52	T(N) 1 × kashi
10	HUR-2-1	HBR92/Pusa Basmati/Kasturi
11	Karjat-184	T(N)1 X Kolamba 540
12	DRR Dhan -50	BPT 5204 / IR 81896-B-B-195
13	HKR-47	12193-1/HKR-120
14	IR-82635-B-B-72-2 (BRR Dhan 66)	line released by IRRI
15	PR 130	PR121 / HKR 47
16	Swarna sub-1	Swarna 3/IR 49830-7-1-2-3 (FR13A)
17	PB-1509	Pusa 1301 / Pusa 1121
18	RTN -6 (Ratnagiri- 6)	IR 64 / Paras Sona
19	PB-7	Basmati 386 / Pusa Basmati 1121
20	Pusa-44	IARI 5901-2 / IR8
21	PB-1692	Pusa Basmati 1509/ Pusa 1601
22	PR-124	PR 116//PAU 3075-3-38/PR 106-P_3
23	PR-122	PR 108/IRRI-76//PR 106-P_1
24	HKR-126	Namsagui-19 x IR-4215-301-2-2-6 x IR-5853-162-1-2
25	IR-64-Sub1	IR 64 / IR 49830-7-1-2-3 (FR13A)
26	CR Dhan 800	Swarna*4/IRBB60
27	HUR-36	Mahsuri by mutation breeding
28	Kalajeera	Landrace
29	Ambemohar	Landrace (Local Cultivar)
30	PhuleMaval	Pawana x Indrayani

percentage of mean for the traits suggests that additive gene effects play a significant role in the expression of these trait. In such cases, direct selection of these traits can prove to be beneficial for crop improvement programs in aerobic rice. The traits days to 50% flowering and days to maturity showed moderate genetic advance with high heritability. Similar findings were reported by Singh *et al*. (2007). This demonstrates the involvement of both additive and non-additive gene effects in the expression of these traits on that restrict their use in future crop improvement programme.

By analysing the correlation between various traits, we can determine the nature and strength of their relationship and identify the key component traits that can be genetically selected to increase grain yield. Study of correlation among different traits (**Table 4**) revealed significant positive association of the grain yield per plant with various traits *viz*., effective tillers per plant (0.636**), test weight (0.657**), chlorophyll content (0.548**), and length breadth ratio (0.225*). Similar findings have been earlier reported by Seneega *et al*. (2019) Vengatesh *et al*. (2018) and Madakemohekar *et al*. (2015). Various other traits *viz*., days to 50% flowering (-0.338**), days to maturity (-0.214*), and amylose content (-0.272**) shown significantly negative correlation with grain yield per plant. These findings are in accordance with the findings of Patel *et al*. (2014) for days to maturity, Anil Kumar *et. al*. (2015) for days to 50% flowering and Sadhana *et al*. (2022) for amylose content. Thus, selecting traits such as effective tillers per plant, test weight, chlorophyll content, and length breadth ratio, which contribute to yield, will be having a substantial impact on enhancing grain yield in aerobic rice.

Table 2. ANOVA for yield and its contributing traits in rice genotypes

S.No.	Traits	MSS		
		Replication (df=2)	Treatment(df=29)	Error(df=58)
1	DFF	5.06	253.61**	19.97
2	DM	19.26	322.33**	31.70
3	PL (cm)	7.65	25.31**	2.55
4	PH	35.47	673.91**	53.62
5	FLA (cm^2)	2.84	520.08**	30.71
6	ETPP	3.80	10.73**	1.29
7	GPP	9.02	1682.75**	358.59
8	TW (g)	13.00	67.41**	5.53
9	CC (SPAD)	8.17	79.92**	19.27
10	LBR	0.00	1.12**	0.02
11	ASV	0.08	2.27**	0.03
12	AC%	1.52	12.44**	0.67
13	GYPP	8.23	74.01**	15.58

* and ** indicates significance at 0.01% and 0.05% respectively

Abbreviation-DFF- Days to 50% Flowering, DM- Days to Maturity, PL- Panicle length, FLA- Flag leaf area, ETPP- Effective tiller per plant, GPP- Grains per panicle, TW- Test weight, CC- Chlorophyll content, LBR- Length-Breadth ratio, ASV- Alkali spreading value, AC- Amylose content, GYPP- Grain yield per plant

Table 3. Genetic variability parameters for yield and its contributing traits in rice genotypes

Traits	Range			CV (%)	PCV (%)	GCV (%)	H^2 (%)	GA (5%)	GAM (5%)
	Mean	Max	Min						
DFF	87.63	105.69	74.95	5.10	10.49	10.07	0.92	17.45	19.91
DM	129.59	149.31	114.17	4.34	8.00	7.60	0.90	19.25	14.86
PL (cm)	26.02	30.93	21.44	6.14	11.16	10.59	0.90	5.38	20.68
PH	109.04	163.46	82.42	6.72	13.75	13.19	0.92	28.42	26.06
FLA (cm^2)	60.77	101.27	40.91	9.12	21.67	21.02	0.94	25.52	42.00
ETPP	11.12	13.85	7.38	10.22	17.01	15.95	0.88	3.43	30.82
GPP	153.20	191.91	109.18	12.36	15.46	13.71	0.79	38.39	25.06
TW (g)	25.59	32.61	15.24	9.19	18.53	17.75	0.92	8.96	35.04
CC (SPAD)	37.01	47.04	29.42	11.86	13.95	12.15	0.76	8.07	21.80
LBR	3.19	4.64	1.87	4.05	19.18	19.03	0.99	1.24	38.92
ASV	3.59	5.00	2.00	4.97	24.23	24.06	0.99	1.77	49.21
AC%	22.66	26.30	18.37	3.62	8.98	8.74	0.95	3.97	17.50
GYPP	32.65	42.54	24.07	12.09	15.21	13.52	0.79	8.08	24.74

Abbreviation-DFF- Days to 50% Flowering, DM- Days to Maturity, PL- Panicle length, FLA- Flag leaf area, ETPP- Effective tiller per plant, GPP- Grains per panicle, TW- Test weight, CC- Chlorophyll content, LBR- Length-Breadth ratio, ASV- Alkali spreading value, AC- Amylose content, GYPP- Grain yield per plant

Path analysis (**Table 5**) indicated that test weight exhibited high positive direct effect on grain yield per plant (0.5100) followed by effective tillers per plant (0.3302) and flag leaf area (0.2202) exerted moderate positive direct effect, indicating that selection for these characters is likely to bring about on overall improvement in grain yield directly. Similar result was reported by Gawai *et al.* (2006) and Jayasudha and Sharma (2010).The indirect effects observed among the other traits demonstrated that effective tillers per plant (0.4010) and chlorophyll content (0.3110) exerted a significant positive indirect impact on grain yield through test weight, aligning with the findings reported by Kishore *et al*. (2018). Consequently, for enhancing grain yield, it is advisable to consider

Table 4. Phenotypic correlation for yield and its contributing traits in rice genotypes

Traits	DFF	DM	PL	PH	FLA	ETP	NGP	TGW	CC	LBR	ASV	AC
DFF	1											
DM	0.739**	1										
PL	-0.419**	-0.408**	1									
PH	0.339**	0.365**	-0.04	1								
FLA	0.076	0.164	0.047	0.235*	1							
ETP	-0.174	-0.064	0.175	-0.011	-0.1247	1						
NGP	-0.117	-0.072	-0.147	0.013	-0.0208	-0.022	1					
TGW	-0.352**	-0.269*	0.139	-0.117	-0.220*	0.655**	0.086	1				
CC	-0.088	-0.029	-0.029	-0.16	0.027	0.529**	0.044	0.412	1			
LBR	-0.459**	-0.477**	0.365**	-0.195	-0.1908	0.296**	-0.145	0.347**	0.09	1		
ASV	-0.285**	-0.294**	0.093	-0.177	0.082	-0.077	-0.083	0.0073	-0.372**	0.085	1	
AC	0.181	-0.014	-0.096	-0.039	-0.0071	-0.317**	0.014	-0.282**	-0.223*	-0.287**	0.0023	1
GYPP	-0.338**	-0.214*	0.093	-0.136	-0.041	0.636**	0.133	0.657**	0.548**	0.225*	-0.135	-0.272**

* and ** indicates significance at 0.01% and 0.05% respectively
Abbreviation- DFF- Days to 50% Flowering, DM- Days to Maturity, PL- Panicle length, FLA- Flag leaf area, ETPP- Effective tiller per plant, GPP- Grains per panicle, TW- Test weight, CC- Chlorophyll content, LBR- Length-Breadth ratio, ASV- Alkali spreading value, AC- Amylose content, GYPP- Grain yield per plant

Table 5. Phenotypic path coefficient for yield and its contributing traits in rice genotypes

Traits	DFF	DM	PL	PH	FLA	ETPP	GPP	TGW	CC	LBR	ASV	AC
DFF	-0.0278	-0.0254	0.0138	-0.0119	-0.0017	0.0062	0.0041	0.0120	0.0047	0.0148	0.0094	-0.0065
DM	-0.3056	-0.3615	0.2220	-0.2000	-0.0769	0.0329	0.0720	0.1160	0.0121	0.2001	0.1290	0.0070
PL	0.1097	0.2060	-0.2217	0.0076	-0.0115	-0.0394	0.0101	-0.0419	0.0140	-0.0908	-0.0250	0.0229
PH	-0.0030	-0.0041	0.0013	-0.0089	-0.0021	0.0101	-0.0102	0.0017	0.0014	0.0018	0.0019	0.0102
FLA	0.0126	0.0440	0.0112	0.0430	0.2202	-0.0370	-0.0026	-0.0494	0.0007	-0.0551	0.0198	-0.0034
ETPP	-0.0750	-0.0340	0.0390	-0.0048	-0.0587	0.3302	-0.0106	0.2400	0.2910	0.1450	-0.0101	-0.0207
GPP	0.0046	0.0043	0.0061	-0.0107	0.0014	0.0015	-0.0334	-0.0042	-0.0019	0.0060	0.0030	0.0023
TGW	-0.2156	-0.1510	0.1107	-0.0789	-0.1130	0.4010	0.0610	0.5100	0.3110	0.2034	0.0064	-0.2456
CC	0.0191	0.0054	0.0077	0.0150	-0.0107	-0.0851	-0.0070	-0.0707	-0.1879	-0.0119	0.0398	0.0371
LBR	0.0945	0.0099	-0.0792	0.0398	0.0367	-0.0667	0.0243	-0.0842	-0.0390	-0.2049	-0.0160	0.0474
ASV	0.0806	0.0021	-0.0300	0.0705	-0.0259	0.0253	0.0154	-0.0031	0.1007	-0.0250	-0.3036	0.0104
AC	-0.0321	0.0908	0.0119	0.0033	0.0013	0.0568	0.0099	0.0310	0.0411	0.0410	0.0102	-0.1330
GYPP	-0.3380	-0.2135	0.0928	-0.1360	-0.0409	0.6358	0.1330	0.6572	0.5479	0.2244	-0.1352	-0.2719

Residual value (R)-0.3298
Abbreviation-DFF- Days to 50% Flowering, DM- Days to Maturity, PL- Panicle length, FLA- Flag leaf area, ETPP- Effective tiller per plant, GPP- Grains per panicle, TW- Test weight, CC- Chlorophyll content, LBR- Length-Breadth ratio, ASV- Alkali spreading value, AC- Amylose content, GYPP- Grain yield per plant

indirect selection in conjunction with these traits. Days to maturity (-0.3615) and alkali spreading value (-0.3036) had a high direct negative effect on a grain yield per plant. The negative direct effects showed that selection through these traits would be ineffective for enhancing rice productivity (Subudhi *et al*., 2011). Days to 50% flowering (-0.3056) had a high negative indirect effect and plant height (-0.2000) exerted moderate negative indirect effect *via* days to maturity on grain yield per plant. Days to 50% flowering and amylose content exerted moderate negative indirect effect via test weight on yield per plant. In present study the estimated residual effect was 0.3298, suggesting that approximately 73% of the variation in grain yield could be attributed to the traits examined in the study. However, it is apparent that additional factors, which were not taken into account in this analysis, need to be incorporated in order to fully account for the remaining variability in the yield.

In summary, the ANOVA revealed significant variations among all genotypes for every trait examined, suggesting the existence of intrinsic genetic variations within these genotypes. All the traits except days to fifty per cent flowering, days to maturity, and amylose content, all the traits displayed substantial heritability and genetic advance, indicating that their inheritance was primarily governed by additive gene action. Consequently, these traits can be improved through straight forward selection technique. Conversely, traits exhibiting low to moderate levels of genetic advance could be predominantly influenced by non-additive gene effects. Through correlation studies, it was determined that selecting plants based on their effective tillers per plant, test weight, chlorophyll content, and length-breadth ratio would enhance yield. The path coefficient analysis further revealed that traits like effective tillers per plant and test weight exerted a stronger positive direct impact on grain yield per plant. Consequently, it is recommended to prioritize these traits during the selection process in order to develop improved lines greater yield potential under aerobic conditions.

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