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Character Association Studies for Yield, Nutritional and Cooking Quality Characters in Coloured Rice (*Oryza Sativa* L.)

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Abstract

In the present study 35 coloured rice genotypes along with three checks were evaluated in Randomized Complete Block Design for yield, nutritional and cooking quality traits to study association between the yield, nutritional and cooking quality traits. Correlation studies showed positive and significant correlation of grain yield per plant with yield contributing characters like ear bearing tillers per plant, panicle length, test weight, number of filled grains per panicle and some nutritional characters like protein content and anthocyanin content. The path analysis revealed that traits like ear bearing tillers per panicle, test weight, number of filled grains per panicle, alkali spreading value and anthocyanin content showed not only positive direct effect but also positive correlation with grain yield suggesting the importance of direct selection for above characters. The residual effect in the present study was 0.3696 and 0.2348 at phenotypic and genotypic levels respectively, indicating that the characters included in the present study clearly explained the direct and indirect effects on the dependent variable to some extent.

Keywords: Correlation coefficient, Direct selection, Path analysis, Nutritional and Cooking Quality, Residual effect

Introduction

Rice (*Oryza sativa* L.) is the predominant staple food crop for more than half of the world's population and is playing a pivotal role in providing human nutrition, energy supply and food security. It is not only the major source of carbohydrates, but also source of essential micronutrients. It is the only cereal, cooked and consumed as a whole grain. Hence quality considerations are much more important in rice than for any other food crops (Hossain *et al*., 2009). India is the second largest producer of rice but pigmented rice is restricted to some parts of Northeast and in Western Uttar Pradesh, Punjab and Gujarat. India produces majorly three different pigmented rice - black rice, red rice and purple rice. All three are unique in their functional properties. Eleven different colours of rice varieties are known to exist ranging from the commonly seen white to dark purple or black coloured rice. (Richa Sati and Shweta Singh, 2019). Currently, demand for highly nutritious and healthier food is the norm as people today are more concerned about maintaining a healthy lifestyle. In this regard, coloured rice genotypes have higher content of antioxidant compounds, such as polyphenols, tocochromanols and oryzanols, which have been shown to have a significant effect on human health. Furthermore,

these genotypes also contain high micronutrient content, such as iron and zinc. The iron and zinc content of red rice is 2 - 3 times higher than that of white rice. Hence, rice consumers are showing great interest for coloured rice varieties due to their potential health benefits.

To carry out any breeding programme, it is necessary to understand the genetic variability of yield contributing characters, along with their interaction with yield. The genotypic correlation coefficient indicates the genetic proportion of a character that is heritable in nature and hence is used to assist breeding programmes. The existence of this association may be attributed due to linkage, pleiotropic effects of genes, physiological and developmental relationships or due to environmental impacts (Oad *et al*., 2002). Path analysis along with correlation provides a better understanding of the cause and effect link between various pairs of characters (Jayasudha and Sharma, 2010). The association between predictor factors and responder variables has been established using path analysis and this imparts profound knowledge to plant breeders in increasing yield *via* direct and indirect effects (Meena *et al*., 2020).

Materials and Methods

The present investigation was carried out using 35 coloured rice genotypes grown in Randomized Complete Block Design with two replications during *kharif*, 2022 at Agricultural College Farm, Bapatla (**Table 1**). Each genotype was grown in a five rows of 3.0 m length with a spacing of 20 cm between rows and 15 cm between plants, within the row. The data was recorded on ten competitive plants taken from each replication on 18 traits *viz.,* days to 50 per cent flowering, plant height (cm), ear bearing tillers per plant, panicle length (cm), test weight (g), number of filled grains per panicle, grain yield/plant (g), L/B ratio, water uptake, alkali spreading value, amylose content (%), protein content (%), Zn content (ppm), Fe content (ppm), total phenol content (mg/100 g), antioxidant activity (mgAAE/100 g), flavonoid content (mg QE/100 g) and anthocyanin content (mg/100 g). Correlations were worked out using the Formula suggested by Falconer (1964) and partitioning of correlation coefficients into direct and indirect effects was carried out by procedure suggested by Wright (1921) and elaborated as suggested by Dewey and Lu (1959).

Table 1: List of landraces including checks used in the study

S. No.	Black pericarp genotypes	S. No	Red pericarp genotypes
1.	Baasalamaati black	15	Talangur
2.	Ikaladas	16	Aasudhi
3.	Burma black	17	Apputhokalu
4.	Chakhaoamubi	18	Baaludhudiya
5.	Chattisgarh black	19	Bairodlu
6.	**Kalabatti (check)**	20	Barhanaahi
7.	Krishna vrihi	21	Budamalu
8.	Karapukavuni	22	Chittiga
9.	Manipur black	23	Dasumali
10.	Safari	24	Ganga red
11.	SS-56	25	Rakthasaali
12.	Taiwan black	26	Hallabatti
13.	Nalladhanyam	27	Jaajudaan
14.	**BPT 2841 (check)**	28	Talangur
		29	Basumathi
		30	Jethu
		31	Kaantamaguni
		32	Mapilai Samba
		33	Kempusanna
		34.	Poohali
White rice genotype			
35.	**BPT 5204 (check)**		

Results and Discussions

The correlation study (**Table 2**) revealed that grain yield per plant had strong positive association

with ear bearing tillers per plant (r_g=0.7601** and r_p=0.5941**), panicle length (r_g=0.8863** and r_p=0.7596**), test weight (r_g=0.7218** and r_p=0.6854**) and number of filled grains per panicle (r_g=0.3832* and r_p=0.3681**) at both genotypic and phenotypic levels. The results are in accordance with the previous findings of Bhargavi *et al.,* (2022), Deepthi *et al*., (2022), Kiran *et al*., (2023), Teja *et al.,* (2023) and Heera *et al*., (2023). Protein content (r_p=0.2937*) and anthocyanin content (r_p=0.3271**) were positively correlated with grain yield per plant at phenotypic level only.

From the correlation studies it can be concluded that yield contributing characters like ear bearing tillers per plant, panicle length, test weight, number of filled grains per panicle and some nutritional characters like protein content and anthocyanin content were positively correlated with grain yield/plant indicating that the above traits can be considered for selection process. Characters like L/B ratio and plant height are correlated negatively with grain yield. It was also observed from the present study that simultaneous selection for all yield and quality traits may not be possible and balanced selection criteria has to be followed. Further breeding programmes should be refined in such a way to break undesirable linkages between traits for simultaneous improvement of both yield and quality traits.

The path coefficient analysis (**Tables 3 and 4**) revealed that traits like ear bearing tillers per panicle (G= 0.1913 and P= 0.2197), test weight (G= 1.2128 and P= 0.6667), number of filled grains per panicle (G= 0.6574 and P= 0.3123), alkali spreading value (G= 0.0873 and P= 0.0370) and anthocyanin content (G=0.5541 and P=0.3829) showed not only positive direct effect but also positive correlation with grain yield suggesting the importance of direct selection for above characters. Traits like plant height, water uptake, amylose content, Zn content, Fe content, total phenol content and flavonoid content showed negative direct effect with positive correlation indicating indirect effects can be the cause of positive correlation. In such situations, the indirect causal factors are to be considered simultaneously for selection. These results were similar with the previous findings of Archana *et al*., (2018), Deepthi *et al*., (2022) and Heera *et al*., (2023).

Further, the residual effect in the present study was 0.3696 and 0.2348 at phenotypic and genotypic levels respectively, indicating that the characters included in the present study clearly explained the direct and indirect effects on the dependent variable to some extent. The residual effect permits precise explanation about the pattern of interaction of other possible components with yield.

Table 2: Correlation coefficients (Phenotypic and Genotypic) for grain yield and yield contributing characters in 35 genotypes of rice (*Oryza sativa* L.)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
D50%F	**G**	1.0000	-0.1691	0.2428	-0.1121	-0.3843*	0.5520**	-0.1376	0.5878**	0.2677	0.1490	0.0644	-0.0957	-0.1548	-0.0207	-0.6524**	0.0605	0.1503	-0.0686
	P	1.0000	-0.1280	0.1792	0.0428	-0.330**	0.4258**	-0.0124	0.4158**	0.2386*	0.1463	0.0575	-0.0433	-0.1394	-0.0257	-0.5001**	0.0562	0.1169	-0.0460
PH	**G**		1.0000	0.0602	0.0709	0.3293	-0.0915	-0.0069	-0.1707	0.1097	-0.1303	0.3546*	0.1492	0.2635	-0.0299	0.2897	0.1341	0.1049	0.1717
	P		1.0000	-0.0069	0.0780	0.2881*	-0.0805	-0.0801	-0.1463	0.0762	-0.1205	0.3184**	0.1247	0.2316	-0.0279	0.2654*	0.1226	0.0974	0.1642
EBT	**G**			1.0000	0.6737**	0.2326	0.7242**	0.2259	0.3303**	0.1526	0.0433	0.4254*	0.2843	0.1290	0.1308	-0.1291	0.3338	0.5636**	0.7601**
	P			1.0000	0.5733**	0.1284	0.5307**	0.3169**	0.2817*	0.1260	0.0468	0.3230**	0.2275	0.1051	0.1091	-0.1038	0.2641*	0.4598**	0.5941**
PL	**G**				1.0000	0.5747**	0.4202*	0.0666	0.1413	0.2351	0.1111	0.3954*	0.0924	-0.0514	0.0486	0.1153	0.2710	0.3676*	0.8863**
	P				1.0000	0.4573**	0.3530**	0.0605	0.1567	0.2037	0.0994	0.3517**	0.0830	-0.0320	0.0374	0.0945	0.2346	0.3196**	0.7596**
TW	**G**					1.0000	-0.1937	-0.2884	-0.0104	-0.0065	-0.1102	0.1653	0.0406	0.1272	-0.1110	0.1043	-0.0460	-0.0590	0.7218**
	P					1.0000	-0.1809	-0.2797*	-0.0064	-0.0149	-0.1074	0.1723	0.0484	0.1196	-0.1082	0.0967	-0.0465	-0.0556	0.6854**
NFGPP	**G**						1.0000	0.0705	0.4032**	0.2976	0.2029	0.3669*	0.2560	0.1943	0.3913*	-0.2708	0.4845**	0.6423**	0.3832*
	P						1.0000	0.0372	0.3563**	0.2786**	0.2115	0.3432**	0.2182	0.1923	0.3728**	-0.2496*	0.4616**	0.6131**	0.3681**
L/B R	**G**							1.0000	-0.0350	-0.0166	-0.1654	0.0940	0.2809	0.3260	0.0341	0.1754	0.0150	0.1027	-0.0927
	P							1.0000	-0.0495	-0.0291	-0.1382	0.0550	0.2109	0.2431*	0.0262	0.1274	0.0057	0.0832	-0.0925
WU	**G**								1.0000	0.3745*	0.0327	0.1531	0.3347*	0.0064	0.0738	-0.2364	0.1614	0.2077	0.1412
	P								1.0000	0.3649**	0.0307	0.1619	0.3066**	0.0053	0.0711	-0.2335	0.1570	0.2052	0.1399
ASV	**G**									1.0000	0.0920	0.2487	0.3173	-0.1785	0.2373	-0.1598	0.3453*	0.3683*	0.1512
	P									1.0000	0.0953	0.2488*	0.2931*	-0.1764	0.2311	-0.1539	0.3389**	0.3613**	0.1467
AC	**G**										1.0000	0.0348	0.0710	-0.0133	0.0180	0.2402	-0.0014	0.0973	0.0151
	P										1.0000	0.0343	0.0684	-0.0085	0.0177	0.2311	-0.0053	0.0959	0.0170
PC	**G**											1.0000	0.2609	0.2191	0.5878**	0.1594	0.6310**	0.7099**	0.2959
	P											1.0000	0.2451*	0.2018	0.5761**	0.1527	0.6137**	0.6993**	0.2937*
Zn	**G**												1.0000	0.1440	0.2718	0.2998	0.3272	0.3570*	0.1020
	P												1.0000	0.1252	0.2603*	0.2890*	0.3116**	0.3409**	0.1081
Fe	**G**													1.0000	0.2136	0.3150	0.1665	0.1929	0.1195
	P													1.0000	0.2094	0.3048	0.1622	0.1867	0.1120
TPC	**G**														1.0000	0.0468	0.7488**	0.7882**	0.0503
	P														1.0000	0.0481	0.7441**	0.7872**	0.0498
AA	**G**															1.0000	0.1415	0.0001	0.0138
	P															1.0000	0.1432	0.00001	0.0188
FC	**G**																1.0000	0.8825**	0.2251
	P																1.0000	0.8786**	0.2196
ANC	**G**																	1.0000	0.3315
	P																	1.0000	0.3271**
GY/P	**G**																		1.0000
	P																		1.0000

* Significant at 5% level; ** Significant at 1% level

D 50%F -Days to 50 per cent flowering, **PH** -Plant height (cm), **EBT** -Ear bearing tillers per plant, **PL**-Panicle length (cm), **TW** -Test weight (g), **NFGPP**-Number of filled grains per panicle, **L/B R**-L/B ratio, **WU**-Water uptake, **ASV**-Alkali spreading value, **AC** -Amylose content (%), **PC**- Protein content, **Zn**-Zn content (ppm), **Fe**-Fe content(ppm), **TPC**-Total phenol content(mg/100g), **AA**-Antioxidant activity(mg AAE/100g), **FC**-Flavonoid content (mg QE/100g), **ANC**-Anthocyanincontent(mg/100g), **GY / P**-Grain yield/plant; **P**- Phenotypic; **G**-Genotypic

Table 3: Direct and indirect effects of different traits on grain yield at genotypic level in 35 genotypes of rice (*Oryza sativa* L.)

	D 50%F	PH (cm)	EBT	PL (cm)	TW (g)	NFGPP	L/B R	WU	ASV	AC (%)	PC (%)	Zn (ppm)	Fe (ppm)	TPC (mg/100g)	AA (mgAAE/100	FC (mgQ-E/100g)	ANC (mg/100g)	GY/P (g)
D 50% F	**0.2401**	-0.0406	0.0583	-0.0269	-0.0922	0.1325	-0.0330	0.1411	0.0643	0.0358	0.0155	-0.0230	-0.0372	-0.0050	-0.1566	0.0145	0.0361	-0.0686
PH	0.0214	**-0.1263**	-0.0076	-0.0089	-0.0416	0.0116	0.0009	0.0216	-0.0139	0.0165	-0.0448	-0.0188	-0.0333	0.0038	-0.0366	-0.0169	-0.0133	0.1717
EBT	0.0465	0.0115	**0.1913**	0.1289	0.0445	0.1385	0.0432	0.0632	0.0292	0.0083	0.0814	0.0544	0.0247	0.0250	-0.0247	0.0639	0.1078	0.7601**
PL	0.0324	-0.0204	-0.1944	**-0.2886**	-0.1699	-0.1213	-0.0192	-0.0408	-0.0679	-0.0321	-0.1141	-0.0267	0.0148	-0.0140	-0.0333	-0.0782	-0.1061	0.8863**
TW	-0.4660	0.3993	0.2821	0.6970	**1.2128**	-0.2349	-0.3497	-0.0126	-0.0079	-0.1337	0.2005	0.0493	0.1543	-0.1346	0.1265	-0.0558	-0.0715	0.7218**
NFGPP	0.3628	-0.0601	0.4761	0.2762	-0.1273	**0.6574**	0.0463	0.2651	0.1966	0.1334	0.2412	0.1683	0.1277	0.2573	-0.1780	0.3185	0.4222	0.3832*
L/B R	-0.0372	-0.0019	0.0610	0.0180	-0.0779	0.0190	**0.2701**	-0.0095	-0.0045	-0.0447	0.0254	0.0759	0.0881	0.0092	0.0474	0.0040	0.0277	-0.0927
WU	-0.0282	0.0082	-0.0159	-0.0068	0.0005	-0.0194	0.0017	**-0.0480**	-0.0163	0.0026	-0.0033	-0.0141	0.0036	0.0063	0.0174	0.0030	0.0001	0.1412
ASV	0.0234	0.0096	0.0133	0.0205	-0.0006	0.0260	-0.0014	0.0296	**0.0873**	0.0080	0.0217	0.0277	-0.0156	0.0207	-0.0139	0.0301	0.0321	0.1512
AC	-0.0215	0.0188	-0.0063	-0.0160	0.0159	-0.0293	0.0239	0.0077	-0.0133	**-0.1444**	-0.0050	-0.0102	0.0019	-0.0026	-0.0347	0.0002	-0.0141	0.0151
PC	-0.0154	-0.0846	-0.1015	-0.0943	-0.0394	-0.0875	-0.0224	-0.0163	-0.0593	-0.0083	**-0.2386**	-0.0622	-0.0523	-0.1402	-0.0380	-0.1505	-0.1694	0.2959
Zn	0.0324	-0.0505	-.0962	-0.0312	-0.0137	-0.0866	-0.0950	-0.0992	-0.1073	-0.0240	-0.0883	**-0.3382**	-0.0487	-0.0919	-0.1014	-0.1107	-0.1207	0.1020
Fe	0.0526	-0.0895	-0.0438	0.0175	-0.0432	-0.0660	-0.1107	0.0254	0.0606	0.0045	-0.0744	-0.0489	**-0.3397**	-0.0726	-0.1070	-0.0565	-0.0655	0.1195
TPC	0.0019	0.0028	-0.0123	-0.0046	0.0104	-0.0368	-0.0032	0.0123	-0.0223	-0.0017	-0.0552	-0.0255	-0.0201	**-0.0939**	-0.0044	-0.0703	-0.0740	0.0503
AA	-0.3822	0.1697	-0.0756	0.0675	0.0611	-0.1587	0.1027	-0.2121	-0.0936	0.1407	0.0934	0.1756	0.1845	0.0274	**0.5859**	0.0829	-0.0005	0.0138
FC	-0.0147	-0.0325	-0.0808	-0.0656	0.0111	-0.1173	-0.0036	0.0153	-0.0836	0.0003	-0.1528	-0.0792	-0.0403	-0.1813	-0.0343	**-0.2421**	-0.2136	0.2251
ANC	0.0833	0.0581	0.3123	0.2037	-0.0327	0.3559	0.0569	-0.0015	0.2041	0.0539	0.3933	0.1978	0.1069	0.4367	-0.0004	0.4890	**0.5541**	0.3315
GY/P	-0.0686	0.1717	0.7601**	0.8863**	0.7218**	0.3832*	-0.0927	0.1412	0.1512	0.0151	0.2959	0.1020	0.1195	0.0503	0.0138	0.2251	0.3315	1.0000
Partial R^2	-0.0165	-0.0217	0.1454	-0.2558	0.8754	0.2519	-0.0250	-0.0068	0.0132	-0.0022	-0.0706	-0.0345	-0.0406	-0.0047	0.0081	-0.0545	0.1837	

Diagonal bold values indicate direct effect, Off-diagonal values-indirect values * Significant at 5% level, ** Significant at 1% level

Residual Effect= 0.2348 R^2=0.9449

D 50%F -Days to 50% flowering, **PH** -Plant height (cm), **EBT** -Ear bearing tillers per plant, **PL**-Panicle length (cm), **TW** -Test weight (g), **NFGPP**-Number of filled grains per panicle, **L/B R**-L/B ratio, **WU**-Water uptake, **ASV**-Alkali spreading value, **AC** -Amylose content (%), **PC** -Protein content, **Zn**-Zn content (ppm), **Fe**-Fe content(ppm), **TPC**-Total phenol content(mg/100g), **AA**-Antioxidant activity (mgAAE/100g), **FC**-Flavonoid content (mgQE/100g), **ANC**-Anthocyanin content(mg/100g), **GY / P**-Grain yield/plant.

Table 4: Direct and indirect effects of different traits on grain yield at phenotypic level in 35 genotypes of rice (*Oryza sativa* L.)

	D 50% F	PH (cm)	EBT	PL (cm)	TW (g)	NFGPP	L/B R	WU	ASV	AC (%)	PC (%)	Zn (ppm)	Fe (ppm)	TPC (mg/100g)	AA (mgAAE/100	FC (mgQE/100g)	ANC (mg/100g)	GY/P(g)
D50%F	**0.0679**	-0.0087	0.0122	0.0029	-0.0224	0.0289	-0.0008	0.0282	0.0162	0.0099	0.0039	-0.0029	-0.0095	-0.0017	-0.0340	0.0038	0.0079	-0.0460
PH	0.0014	**-0.0108**	0.0001	-0.0008	-0.0031	0.0009	0.0009	0.0016	-0.0008	0.0013	-0.0034	-0.0014	-0.0025	0.0003	-0.0029	-0.0013	-0.0011	0.1642
EBT	0.0394	-0.0015	**0.2197**	0.1259	0.0282	0.1166	0.0696	0.0619	0.0277	0.0103	0.0709	0.0500	0.0231	0.0240	-0.0228	0.0580	0.1010	0.5941**
PL	0.0084	0.0153	0.1127	**0.1965**	0.0899	0.0694	0.0119	0.0308	0.0400	0.0195	0.0691	0.0163	-0.0063	0.0073	0.0186	0.0461	0.0628	0.7596**
TW	-0.2200	0.1921	0.0856	0.3049	**0.6667**	-0.1206	-0.1865	0.0043	-0.0099	-0.0716	0.1148	0.0323	0.0798	-0.0721	0.0645	-0.0310	-0.0370	0.6854**
NFGPP	0.1330	-0.0251	0.1658	0.1103	-0.0565	**0.3123**	0.0116	0.1113	0.0870	0.0661	0.1072	0.0682	0.0601	0.1165	-0.0779	0.1442	0.1915	0.3681**
L/B R	0.0002	0.0014	-0.0055	-0.0011	0.0049	-0.0006	**-0.0174**	0.0009	0.0005	0.0024	-0.0010	-0.0037	-0.0042	-0.0005	-0.0022	-0.0001	-0.0014	-0.0925
WU	-0.0092	0.0032	-0.0062	-0.0035	-0.0001	-0.0079	0.0011	**-0.0221**	-0.0073	0.0012	-0.0019	-0.0058	0.0016	0.0028	0.0078	0.0014	0.0000	0.1399
ASV	0.0088	0.0028	0.0047	0.0075	-0.0006	0.0103	-0.0011	0.0121	**0.0370**	0.0035	0.0092	0.0108	-0.0065	0.0086	-0.0057	0.0125	0.0134	0.1467
AC	-0.0140	0.0115	-0.0045	-0.0095	0.0103	-0.0202	0.0132	0.0050	-0.0091	**-0.0955**	-0.0033	-0.0065	0.0008	-0.0017	-0.0221	0.0005	-0.0092	0.0170
PC	-0.0108	-0.0596	-0.0605	-0.0658	-0.0322	-0.0642	-0.0103	-0.0157	-0.0466	-0.0064	**-0.1872**	-0.0459	-0.0378	-0.1078	-0.0286	-0.1149	-0.1309	0.2937*
Zn	0.0050	-0.0143	-0.0261	-0.0095	-0.0055	-0.0250	-0.0242	-0.0299	-0.0336	-0.0078	-0.0281	**-0.1146**	-0.0143	-0.0298	-0.0331	-0.0357	-0.0391	0.1081
Fe	0.0089	-0.0149	-0.0068	0.0021	-0.0077	-0.0123	-0.0156	0.0046	0.0113	0.0005	-0.0130	-0.0080	**-0.0642**	-0.0134	-0.0196	-0.0104	-0.0120	0.1120
TPC	0.0018	0.0019	-0.0075	-0.0026	0.0074	-0.0257	-0.0018	0.0089	-0.0159	-0.0012	-0.0396	-0.0179	-0.0144	**-0.0688**	-0.0033	-0.0512	-0.0542	0.0498
AA	-0.1201	0.0542	-0.0212	0.0193	0.0198	-0.0510	0.0260	-0.0720	-0.0314	0.0472	0.0312	0.0590	0.0622	0.0098	**0.2042**	0.0293	0.0000	0.0188
FC	-0.0094	-0.0206	-0.0444	-0.0394	0.0078	-0.0775	-0.0010	0.0106	-0.0569	0.0009	-0.1031	-0.0523	-0.0272	-0.1250	-0.0241	**-0.1680**	-0.1476	0.2196
ANC	0.0448	0.0373	0.1761	0.1224	-0.0213	0.2348	0.0319	-0.0006	0.1384	0.0367	0.2678	0.1305	0.0715	0.3014	-0.0001	0.3364	**0.3829**	0.3271**
GY/P	-0.0460	0.1642	0.5941**	0.7596**	0.6854**	0.3681**	-0.0925	0.1399	0.1467	0.0170	0.2937*	0.1081	0.1120	0.0498	0.0188	0.2196	0.3271**	1.0000
Partial R^2	-0.0031	-0.0018	0.1305	0.1493	0.4570	0.1150	0.0016	-0.0031	0.0054	-0.0016	-0.0550	-0.0124	-0.0072	-0.0034	0.0038	-0.0369	0.1253	

*Diagonal bold values indicate direct effect, Off-diagonal values-indirect values * Significant at 5% level, ** Significant at 1% level*

Residual Effect= 0.3696 R^2=0.8634

D 50% F -Days to 50% flowering, **PH** -Plant height (cm), **EBT** -Ear bearing tillers per plant, **PL**-Panicle length (cm), **TW** -Test weight (g), **NFGPP**-Number of filled grains per panicle, **L/B R**-L/B ratio, **WU**-Water uptake, **ASV**-Alkali spreading value, **AC** -Amylose content (%), **PC**-Protein content, **Zn**-Zn content (ppm), **Fe**-Fe content(ppm), **TPC**-Total phenol content(mg/100g), **AA**-Antioxidant activity(mgAAE/100g), **FC**-Flavonoid content (mgQE/100g), **ANC**-Anthocyanin content(mg/100g), **GY / P**-Grain yield/plant

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