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Variability, correlation and path studies in coloured rice

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Abstract
The present investigation was undertaken with 33 coloured and white rice genotypes to study the variability and genetic parameters in addition to character associations and path effects for yield and quality parameters. The study involved seven red pericarp, eight black pericarp and 17 white rice genotypes, in addition to the check, BPT 5204. The results revealed high genotypic and phenotypic coefficient of variability, heritability and genetic advance as per cent mean for grains per panicle, grain yield per plant, alkali spreading value, protein content, total phenol content, total antioxidant activity, zinc and iron content indicating the effectiveness of selection for these traits. The results on character associations revealed positive and significant association of grain yield with panicle length, grains per panicle and test weight; and the quality traits, namely, alkali spreading value, protein content, total antioxidant activity, zinc and iron content, indicating scope for simultaneous improvement of yield and quality traits through selection. Among these, grains per panicle, protein content and zinc content had also recorded high and positive direct effects on grain yield per plant, indicating the effectiveness of these traits in improvement of grain yield per plant towards development of high yielding genotypes with good nutritional quality.

Keywords: Variability, Correlations, coloured rice, grain yield, nutritional quality, path effects

Introduction
Rice is the most important grain and staple food for more than 100 countries of the world and has been referred to as "Global Grain". It is the primary source of food and protein for about half of the mankind with an enormous nutritional and economic impact. It is the crucial dietary and food security source of many Asian countries. Increased health consciousness among the rice consumers has resulted in greater attention to genotypes containing higher levels of bioactive compounds, such as antioxidants. In this context, rice genotypes with red and black pericarp color containing high levels of antioxidants as reported by Tian *et al.* (2004) [39], are in increasing demand. Assessment of variability for grain yield, yield attributes and quality characters in these coloured rice genotypes is essential for their successful yield improvement through breeding. Further, since grain yield depends on various component characters, the knowledge of correlation among yield, yield components and quality traits, in addition to identification of direct and indirect effects of the yield and quality traits on grain yield would help in effective yield improvement. The present investigation was undertaken in this context to elucidate information on variability, heritability, genetic advance, character associations and path coefficients in coloured rice genotypes to identify effective selection criteria for grain yield and quality improvement of coloured rice genotypes.

Material and Methods
The experimental material consisted of 33 white and coloured rice genotypes obtained from Agricultural Research Station, Bapatla, Andhra Pradesh state in addition to collections from Telangana and Tamil Nadu states. Among the 33 genotypes, 15 genotypes were coloured, of which, seven were with red pericarp (Apputhokal, Asandi, BPT 3111, BPT 3139, BPT 3178, Chittiga and Hallabhatta) and eight genotypes were with black pericarp (BPT 2841, BPT 2848, BPT 3136, BPT 3140, BPT 3141, BPT 3145, BPT 3165 and Kakirekalu), while remaining 17 genotypes had brown pericarp and were white rice genotypes (ADT 49, BPT 2411, BPT 2507,

BPT 2595, BPT 2615, BPT 2660, BPT 2766, BPT 2776, BPT 2782, BPT 2846, BPT 3173, JKRH 3333, PHI 17108, MTU 1281, US 301, WGL 14 and 27P63) in addition to BPT 5204, a popular high yielding white rice genotype with excellent cooking quality traits, which was used as check variety in the present study.

All the 33 genotypes were sown at Agricultural College Farm, Bapatla during *Kharif* 2019 on separate raised nursery beds. All recommended package of practices were adopted to raise a healthy nursery and thirty days old seedlings were transplanted in the main field laid out in Randomized Block Design (RBD) with three replications. Each genotype was transplanted separately in 5 rows of 4.5 m length by adopting a spacing of 20 cm between rows and 15 cm between plants. All the recommended package of practices was adopted throughout the crop growth period and need based plant protection measures were taken up to raise a healthy crop. Observations were recorded on five randomly selected plants for grain yield per plant; yield component traits, namely, days to 50 per cent flowering, days to maturity, plant height, productive tillers per plant, panicle length, grains per panicle and test weight; and quality characters, namely, kernel length, kernel breadth, length/breadth ratio, hulling per cent, milling per cent, head rice recovery per cent, amylose content, alkali spreading value, protein content, total phenol content, total antioxidant activity, zinc and iron content in addition to grain type were recorded. However, days to 50 per cent flowering was recorded on plot basis. In contrast, observations for test weight and all the quality traits studied were obtained from a random grain sample drawn from each plot in each genotype and replication using standard procedures. The data collected was subjected to standard statistical procedures given by Panse and Sukhatme (1967) [21]. Correlation was worked out using the formulae suggested by Falconer (1964) [11]. Partitioning of the correlation coefficients into direct and indirect effects was carried out using the procedure suggested by Wright (1921) [41] and elaborated by Dewey and Lu (1959) [7]. Characterization of path coefficients was carried out as suggested by Lenka and Mishra (1973) [17].

Results and Discussion

The estimates of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2 broad sense) and genetic advance as per cent of mean (GAM) are presented in Table 1 and Figs. 1-2. Higher PCV, compared to GCV was recorded for all the traits studied in the present investigation, indicating the influence of environment. Similar finding was reported earlier by Sudeepthi *et al.* (2020) [35]. The results also revealed high GCV, PCV, heritability and genetic advance as per cent mean for grains per panicle, grain yield per plant, alkali spreading value, protein content, total phenol content, total antioxidant activity, zinc and iron content indicating the pre-dominant role of additive gene action in the inheritance of the traits and hence, the effectiveness of direct selection for these traits. The results are in accordance with the reports of Saha *et al.* (2019) [25] for grains per panicle; Nithya *et al.* (2020) [19] for grain yield per plant; Sundaram *et al.* (2019) [36] for alkali spreading value, zinc and iron content; and Sangamithra *et al.* (2018) [28] for protein content, total phenol content and total antioxidant activity.

In contrast, productive tillers per plant had recorded moderate GCV, PCV, heritability and genetic advance as per cent mean. The findings are in agreement with the reports of Singh *et al.* (2018) [33]. Further, the traits, namely, plant height, panicle length, test weight, kernel breadth, L/B ratio and amylose content had recorded moderate GCV and PCV along with high heritability and genetic advance as per cent mean suggesting the role of both additive and non-additive gene effects in governing the trait. The findings are in conformity with the reports of Nithya *et al.* (2020) [19] for plant height; Sandeep *et al.* (2018) [27] for panicle length; Amegan *et al.* (2020) [3] for test weight; Meena *et al.* (2015) [18] for kernel breadth; Supriya *et al.* (2017) [37] for L/B ratio; and Hari *et al.* (2018) [13] for amylose content.

The GCV and PCV were however, observed to be low for days to 50 per cent flowering, days to maturity, kernel length, hulling and milling per cent coupled with high heritability and moderate genetic advance as per cent mean, with the exception of genetic advance as per cent mean for milling per cent which had recorded low value. The findings are in agreement with the reports of Osman *et al.* (2012) [20] for days to 50 per cent flowering and days to maturity; Tejaswini (2016) [38] for kernel length; Sahu *et al.* (2017) [26] for hulling per cent; and Hari *et al.* (2018) [13] for milling per cent. Head rice recovery had recorded moderate GCV and PCV along with high heritability and moderate genetic advance as per cent mean in the present study, indicating the role of both additive and non-additive gene action in the inheritance of the trait. The results are in agreement with the reports of Parvathi *et al.* (2011) [22].

The results on character associations between yield, yield components and quality characters are presented in Table 2. A perusal of these results revealed positive and significant association of grain yield with the yield component traits, namely, panicle length, grains per panicle and test weight; and the nutritional quality traits, namely, alkali spreading value, protein content, total antioxidant activity, zinc and iron content, indicating scope for simultaneous improvement of yield and quality traits through selection. The results are in agreement with the reports of Umarani *et al.* (2019) [40] for panicle length and test weight; Saha *et al.* (2019) [25] for grains per panicle; and Sridevi (2018) [34] for protein content, total antioxidant activity, zinc and iron content.

Positive and significant associations were also noticed for days to per cent flowering with days to maturity (Saha *et al*., 2019) [25], productive tillers per plant (Saha *et al*., 2019) [25], panicle length (Khare *et al*., 2014) [14], grains per panicle (Satheeshkumar and Saravanan, 2012) [31], length/breadth ratio (Sridevi, 2018) [34], hulling percentage, milling percentage (Ekka *et al*., 2015) [9] and head rice recovery (Ekka *et al*., 2015) [9]; days to maturity with productive tillers per plant (Ashok, 2015) [4], panicle length (Kumar *et al*., 2017) [15], grains per panicle (Saha *et al*., 2019) [25], length/breadth ratio (Allam *et al*., 2015) [1], milling percentage and head rice recovery; plant height with panicle length (Umarani *et al*., 2019) [40], test weight (Santhipriya *et al*., 2017) [30], kernel breadth (Santhipriya *et al*., 2017) [30], protein content (Sridevi, 2018) [34], total phenol content (Sridevi, 2018) [34], total antioxidant activity (Sridevi, 2018) [34], zinc content (Archana *et al*., 2018) [2] and iron content; productive tillers per plant with grains per panicle (Archana *et al*., 2018) [2], kernel length (Archana *et al*., 2018) [2], length/breadth ratio, milling percentage (Ashok, 2015) [4] and hulling percentage; panicle length with grains per panicle (Santhipriya *et al*., 2017) [30], length/breadth ratio (Archana *et al*., 2018) [2], protein content (Sridevi, 2018) [34], total antioxidant activity (Sridevi, 2018) [34], zinc content (Sridevi, 2018) [34] and iron content (Archana *et al*., 2018) [2]; grains per panicle with length/breadth ratio (Archana *et al*., 2018) [2] and head rice recovery (Ekka *et al*., 2015) [9]; test weight with kernel breadth (Edukondalu *et al*., 2017) [8], protein content, total phenol content (Sridevi, 2018) [34], total antioxidant activity (Sridevi, 2018) [34], zinc content (Sridevi, 2018) [34] and iron content; kernel length with length/breadth ratio (Archana *et al*., 2018) [2], total phenol content and iron content (Archana *et al*., 2018) [2]; kernel breadth with protein content and total antioxidant activity; length/breadth ratio with head rice recovery; hulling percentage with milling percentage (Edukondalu *et al*., 2017) [8], head rice recovery (Chowdhury *et al*., 2016) [6], amylose content (Binodh *et al*., 2007) [5] and alkali spreading value; milling percentage with head rice recovery (Pushpa *et al*., 2019) [23]; protein content with total phenol content, total antioxidant activity, zinc and iron content (Sridevi, 2018) [34]; total phenol content with total antioxidant activity, zinc and iron content (Sridevi, 2018) [34]; total antioxidant activity with zinc and iron content (Sridevi, 2018) [34]; and zinc with iron content (Kumar *et al*., 2019) [16], similar to the findings of earlier workers. The results thus indicated a scope for simultaneous improvement of the above traits.

Negative and significant associations were in contrast observed for days to 50 per cent flowering with plant height (Saha *et al*., 2019) [25], test weight (Sridevi, 2018) [34], kernel breadth (Sanghera *et al*., 2013) [29], protein content (Sridevi, 2018) [34], total phenol content (Sridevi, 2018) [34], total antioxidant activity (Sridevi, 2018) [34] and zinc content (Sridevi, 2018) [34]; days to maturity with plant height, test weight (Kumar *et al*., 2017) [15], kernel breadth (Sanghera *et al*., 2013) [29], total phenol content and total antioxidant activity; plant height with hulling percentage, milling percentage and head rice recovery; productive tillers per plant with test weight (Eradasappa *et al*., 2007) [10], amylose content, zinc content (Archana *et al*., 2018) [2] and iron content; panicle length with kernel breadth (Archana *et al*., 2018) [2]; grains per panicle with test weight (Archana *et al*., 2018) [2] and kernel breadth (Archana *et al*., 2018) [2]; test weight with length/breadth ratio (Sridevi, 2018) [34], hulling percentage, milling percentage and head rice recovery (Edukondalu *et al*., 2017) [8]; kernel length with hulling percentage, milling percentage and amylose content (Shankar *et al*., 2016) [32]; kernel breadth with length/breadth ratio (Archana *et al*., 2018) [2], hulling percentage, milling percentage (Edukondalu *et al*., 2017) [8] and head rice recovery; hulling percentage with protein content, total phenol content, total antioxidant activity, zinc content (Kumar *et al*., 2019) [16] and iron content (Kumar *et al*., 2019) [16]; milling percentage with protein content, total phenol content, total antioxidant activity, zinc and iron content (Kumar *et al*., 2019) [16]; head rice recovery with protein content, total phenol content, total antioxidant activity, zinc content (Kumar *et al*., 2019) [16] and iron content (Kumar *et al*., 2019) [16]; amylose content with total phenol content; and grain yield per plant with milling per cent, similar to the findings of earlier workers. A perusal of these results indicated the need for balanced selection while effecting simultaneous improvement for these traits.

The results on path analysis of yield components and quality characters on grain yield per plant are presented in Table 3 and Fig. 3. A perusal of the results revealed a residual effect of 0.472 indicating that variables studied in the present investigation explained about 52.80 per cent of variability for grain yield per plant and therefore other attributes, besides the characters studied are contributing for grain yield per plant. High and positive direct effects of grains per panicle (Saha *et al*., 2019) [25], protein content (Sridevi, 2018) [34] and zinc content (Sridevi, 2018) [34] on grain yield per plant were noticed in the present study, similar to the results of earlier workers. These traits had also recorded high positive and significant association with grain yield per plant, indicating the effectiveness of direct selection for these traits in improvement of grain yield per plant. However, moderate to negligible or negative direct effects were noticed for days to maturity (Saha *et al*., 2019) [25], productive tillers per plant (Saha *et al*., 2019) [25], panicle length (Archana *et al*., 2018) [2], test weight (Umarani *et al*., 2019) [40], kernel length (Archana *et al*., 2018) [2], hulling percentage (Rathod, 2017) [24], head rice recovery (Ashok, 2015) [4], alkali spreading value (Sridevi, 2018) [34], total phenol content (Sridevi, 2018) [34], total antioxidant activity (Sridevi, 2018) [34] and iron content (Archana *et al*., 2018) [2], similar to the results of earlier workers, along with non-significant to significant associations with grain yield per plant, indicating indirect effects as the cause of correlation. Hence, consideration of indirect causal factors is suggested simultaneously for these traits. For days to 50 per cent flowering (Saha *et al*., 2019) [25], kernel breadth (Archana *et al*., 2018) [2], length/breadth ratio (Archana *et al*., 2018) [2], milling percent (Rathod, 2017) [24] and amylose content (Garg *et al*., 2010) [12] recorded high and positive direct effects, similar to the results of earlier workers. Further, non-significant association of the above traits was also noticed with grain yield per plant in general, indicating the need for use of restricted simultaneous selection model with restrictions imposed for nullifying the undesirable indirect effects in order to make use of the high positive direct effects observed for these traits on grain yield per plant.

In conclusion, the results revealed high genotypic and phenotypic coefficient of variation, heritability and genetic advance as per cent mean, in addition to siginificant positive associations and high direct effects for grains per panicle, protein content and zinc content indicating their importance as effective selection criteria for improvement of grain yield per plant towards development of high yielding coloured rice genotypes with good nutritional quality.

Table 1: Variability, heritability and genetic advance as per cent of mean for yield, yield components and quality characters in coloured rice

S. No.	Character	Coefficient of variation		Heritability (%)	Genetic advance as per cent of mean
		PCV (%)	GCV (%)		
1	Days to 50 per cent flowering	6.67	5.77	75.04	10.31
2	Days to maturity	5.18	4.12	63.21	6.75
3	Plant height (cm)	14.99	14.63	95.31	29.43
4	Productive tillers per plant	13.17	10.20	59.92	16.26
5	Panicle length (cm)	13.94	12.13	75.71	21.75
6	Grains per panicle	31.01	28.59	85.02	54.31
7	Test Weight (g)	19.52	19.12	95.92	38.58
8	Grain yield per plant (g)	27.64	25.60	85.77	48.84
9	Kernel length (mm)	8.62	8.33	93.30	16.58
10	Kernel breadth (mm)	14.17	13.42	89.61	26.17
11	Length/Breadth ratio	14.68	13.29	81.94	24.78
12	Hulling percentage	6.38	5.74	80.91	10.63
13	Milling percentage	5.61	5.13	83.64	9.67
14	Head Rice Recovery (%)	11.04	10.23	85.86	19.53

15	Amylose Content (%)	11.32	10.82	91.39	21.30
16	Alkali Spreading Value	27.77	26.35	90.07	51.52
17	Protein Content (%)	22.28	22.03	97.7	44.85
18	Total Phenol Content (mg/100g)	54.05	53.84	99.22	110.49
19	Total Antioxidant Activity (mg AAE/100g)	48.49	48.07	98.28	98.18
20	Zinc content (ppm)	27.38	26.85	96.22	54.27
21	Iron content (ppm)	28.20	26.67	89.43	51.96

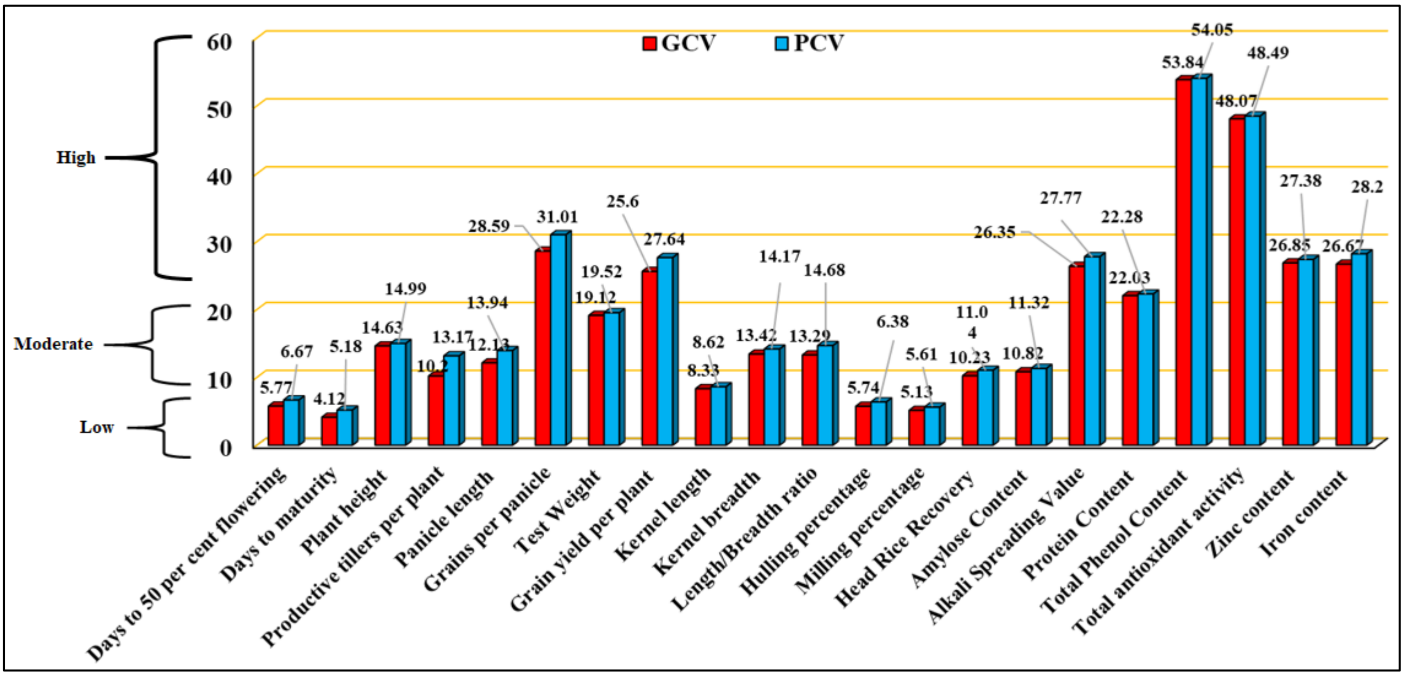


Fig 1: Variability parameters for yield, yield components and quality characters studied

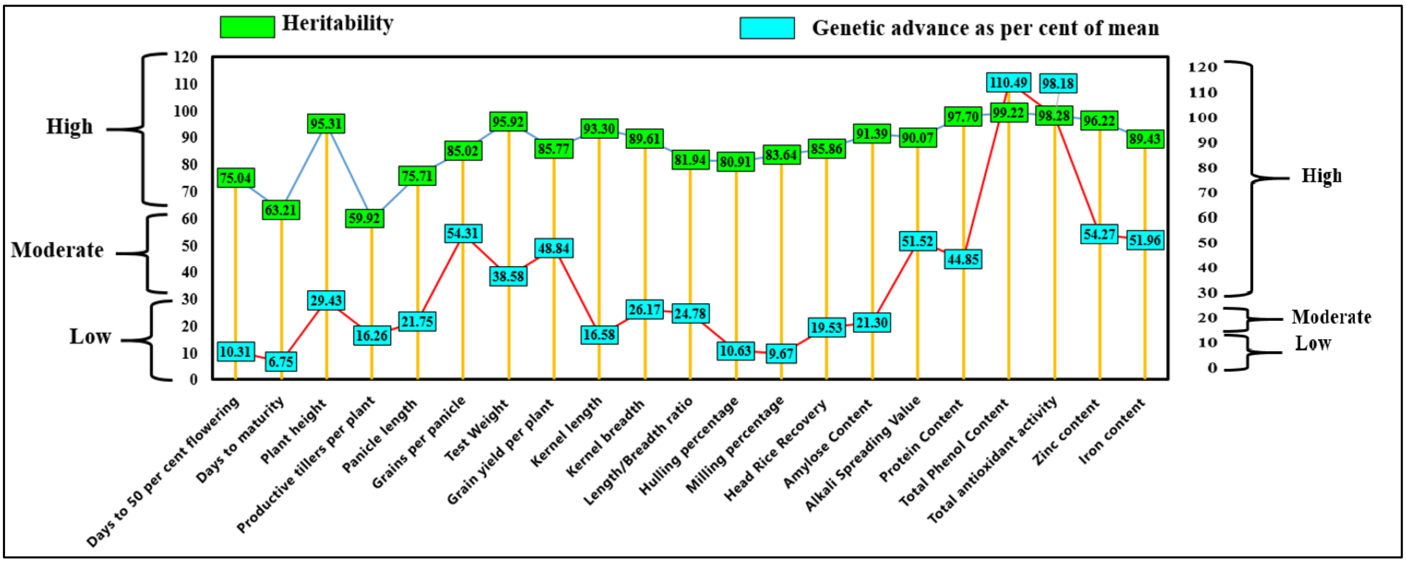


Fig 2: Heritability and genetic advance as per cent mean for yield, yield components and quality characters studied

Table 2: Correlation coefficients for yield, yield components and quality characters in coloured rice

Character	DM	PH	PTPP	PL	GPP	TW	KL	KB	L/B	HULL	MILL	HRR	AMY	ASV	PRO	TPC	TAA	Zn	Fe	GYPP
DFF	0.996**	-0.259**	0.347**	0.521**	0.767**	-0.565**	-0.095	-0.743**	0.539**	0.217*	0.589**	0.588**	0.113	0.041	-0.326**	-0.351**	-0.318**	-0.203*	-0.180	-0.177
DM		-0.205*	0.320**	0.543**	0.709**	-0.459**	-0.104	-0.646**	0.458**	0.139	0.508**	0.500**	0.060	0.036	-0.197	-0.318**	-0.246**	-0.127	-0.107	-0.195
PH			-0.107	0.429**	0.111	0.594**	0.188	0.487**	-0.194	-0.197*	-0.340**	-0.541**	0.050	0.007	0.493**	0.447**	0.607**	0.620**	0.606**	0.531**
PTPP				0.142	0.212*	-0.224*	0.223*	-0.194	0.279**	0.137	0.310**	0.276**	-0.277**	0.019	-0.196	-0.036	-0.167	-0.231*	-0.239*	-0.135
PL					0.836**	0.099	0.155	-0.286**	0.351**	-0.185	-0.183	0.057	-0.015	0.090	0.345**	0.185	0.361**	0.480**	0.412**	0.434**
GPP						-0.403**	0.070	-0.663**	0.597**	0.153	0.178	0.293**	0.072	0.195	-0.050	0.069	0.098	0.188	0.197	0.228*
TW							0.087	0.748**	-0.482**	-0.294**	-0.344**	-0.607**	-0.167	-0.127	0.471**	0.307**	0.444**	0.426**	0.308**	0.212*
KL								-0.098	0.672**	-0.214*	-0.197*	0.145	-0.241**	-0.154	0.181	0.424**	0.174	0.114	0.209*	0.197*
KB									-0.845**	-0.211*	-0.226**	-0.602**	-0.009	-0.071	0.237**	0.092	0.241*	0.174	0.077	0.115
L/B										0.038	0.058	0.527**	-0.121	-0.047	-0.053	0.180	-0.033	-0.035	0.081	0.044
HULL											0.711**	0.416**	0.297**	0.203*	-0.528**	-0.365**	-0.245*	-0.488**	-0.576**	0.012
MILL												0.566**	0.003	0.092	-0.635**	-0.467**	-0.471**	-0.611**	-0.654**	-0.275**
HRR													0.023	-0.068	-0.446**	-0.481**	-0.500**	-0.553**	-0.510**	-0.129
AMY														-0.006	-0.076	-0.199*	-0.020	-0.023	-0.100	-0.107
ASV															-0.157	-0.094	-0.072	-0.116	-0.127	0.209*

Character	DFF	DM	PH	PTPP	PL	GPP	TW	KL	KB	L/B	HULL	MILL	HRR	AMY	ASV	PRO	TPC	TAA	Zn	Fe	GYPP
PRO																	0.723**	0.760**	0.820**	0.750**	0.265**
TPC																		0.689**	0.709**	0.708**	0.168
TAA																			0.851**	0.738**	0.323**
Zn																				0.959**	0.311**
Fe																					0.285**

* and ** Significant at 5% and 1% levels respectively

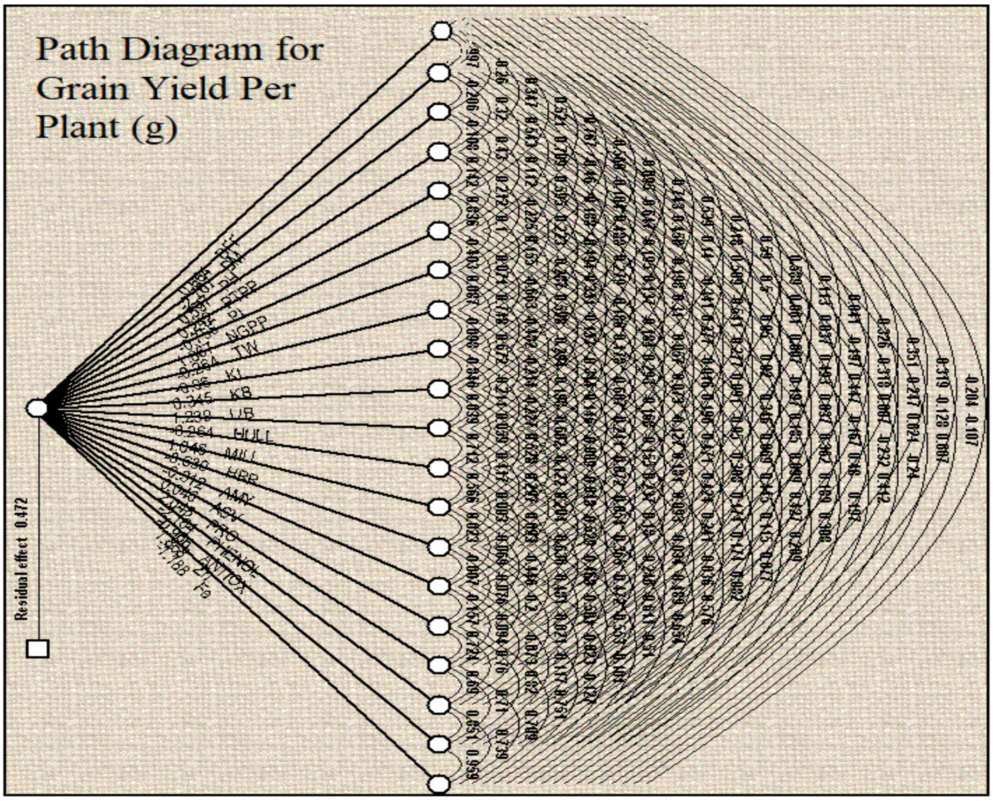
DFF=Days to 50 per cent flowering, DM=Days to maturity, PH=Plant height, PTPP=Productive tillers per plant, PL=Panicle length, GPP= Grains per panicle, TW=Test weight, KL=Kernel length, KB=Kernel breadth, L/B=Length/Breadth ratio, HULL=Hulling percentage, MILL= Milling percentage, HRR=Head rice recovery, AMY=Amylose content, ASV=Alkali spreading value, PRO=Protein content, TPC=Total phenol content, TAA=Total antioxidant activity, Zn=Zinc content, Fe=Iron content, GYPP=Grain yield per plant.

Table 3: Direct and indirect effects of yield components and quality characters on grain yield in coloured rice

Character	DFF	DM	PH	PTPP	PL	GPP	TW	KL	KB	L/B	HULL	MILL	HRR	AMY	ASV	PRO	TPC	TAA	Zn	Fe	GYPP
DFF	**0.663**	-2.758	-0.155	0.083	-0.393	1.432	0.149	0.005	-0.256	0.668	-0.057	0.616	-0.376	-0.035	0.001	-0.668	0.76	0.307	-0.38	0.214	-0.177
DM	0.661	**-2.767**	-0.122	0.077	-0.41	1.323	0.121	0.006	-0.223	0.5677	-0.036	0.532	-0.319	-0.019	0.001	-0.403	0.688	0.238	-0.238	0.127	-0.195
PH	-0.172	569	**0.596**	-0.026	-0.324	0.208	-0.157	-0.011	0.168	-0.241	0.052	-0.356	0.345	-0.015	0.003	1.01	-0.967	-0.586	1.159	-0.721	0.531**
PTPP	0.23	-0.886	-0.064	**0.241**	-0.107	0.396	0.059	-0.013	-0.067	0.345	-0.036	0.324	-0.176	0.086	0.009	-0.403	-0.079	0.161	-0.433	0.285	-0.135
PL	0.345	-1.503	0.256	0.034	**-0.755**	1.561	-0.023	-0.009	-0.099	0.435	0.049	-0.192	-0.036	0.005	0.004	0.708	-0.4	-0.349	0.896	-0.489	0.434**
GPP	0.509	-1.962	0.066	0.051	-0.631	**1.866**	0.106	-0.004	-0.229	0.74	-0.04	0.186	-0.187	-0.022	0.008	-0.102	-0.15	-0.095	0.352	-0.234	0.228*
TW	-0.375	1.272	0.354	-0.054	-0.075	-0.753	**-0.264**	-0.005	0.258	-0.597	0.077	-0.359	0.388	0.052	-0.006	0.964	-0.666	-0.429	0.796	-0.366	0.213*
KL	-0.063	0.287	0.112	0.054	-0.117	0.132	-0.023	**-0.06**	-0.034	0.833	0.056	-0.206	-0.093	0.075	-0.007	0.371	-0.918	-0.168	0.214	-0.248	0.197*
KB	-0.493	1.789	0.291	-0.047	0.216	-1.237	-0.197	0.006	**0.345**	-1.047	0.055	-0.236	0.384	0.003	-0.003	0.486	-0.201	-0.233	0.325	-0.091	0.115
L/B	0.357	-1.268	-0.116	0.067	-0.265	1.115	0.127	-0.04	-0.292	**1.239**	-0.01	0.061	-0.337	0.038	-0.002	-0.109	-0.39	0.032	-0.066	-0.0969	0.0449
HULL	0.144	-0.387	-0.117	0.033	0.14	0.286	0.077	0.012	-0.073	0.048	**-0.263**	0.744	-0.266	-0.092	0.009	-1.082	0.79	0.237	-0.912	0.684	0.013
MILL	0.391	-1.408	-0.203	0.075	0.138	0.332	0.09	0.011	-0.078	0.072	-0.187	**1.045**	-0.361	-0.001	0.004	-1.301	1.012	0.455	-1.142	0.777	-0.275**
HRR	0.39	-1.384	-0.322	0.066	-0.043	0.547	0.16	-0.008	-0.208	0.654	-0.109	0.592	**-0.639**	-0.007	-0.003	-0.913	1.041	0.483	-1.033	0.606	-0.129
AMY	0.075	-0.168	0.03	-0.067	0.011	0.135	0.044	0.014	-0.003	-0.151	-0.078	0.003	-0.014	**0.312**	-0.003	-0.155	0.432	0.02	-0.042	0.119	-0.107
ASV	0.027	-0.102	0.004	0.004	-0.068	0.365	0.033	0.009	-0.024	-0.059	0.053	0.097	0.044	0.002	**0.045**	-0.322	0.203	0.07	-0.217	0.151	0.209*
PRO	-0.216	0.545	0.294	-0.047	-0.261	-0.093	-0.124	-0.011	0.082	-0.066	0.139	-0.664	0.285	0.023	-0.007	**2.047**	-1.566	-0.734	1.531	-0.891	0.265**
TPC	-0.233	0.88	0.266	0.008	-0.139	0.129	-0.081	-0.025	0.032	0.223	0.096	-0.489	0.307	0.062	-0.004	1.481	**-2.164**	-0.666	1.325	-0.842	0.168
TAA	-0.211	0.683	0.362	-0.04	-0.273	0.184	-0.117	-0.01	0.083	-0.042	0.064	-0.493	0.32	0.006	-0.003	1.556	-1.492	**-0.966**	1.589	-0.878	0.323**
Zn	-0.135	0.353	0.37	-0.056	-0.363	0.352	-0.112	-0.006	0.06	-0.044	0.128	-0.639	0.353	0.007	-0.005	1.679	-1.536	-0.822	**1.867**	-1.14	0.312**
Fe	-0.119	0.297	0.362	-0.058	-0.311	0.368	-0.081	-0.012	0.026	0.101	0.152	-0.684	0.326	0.031	-0.005	1.534	-1.533	-0.714	1.792	**-1.188**	0.285**

Residual Effect = 0.472; * and ** Significant at 5% and 1% levels respectively; Diagonal bold values indicate direct effects

DFF=Days to 50 per cent flowering, DM=Days to maturity, PH=Plant height, PTPP=Productive tillers per plant, PL=Panicle length, GPP= Grains per panicle, TW=Test weight, KL=Kernel length, KB=Kernel breadth, L/B=Length/Breadth ratio, HULL=Hulling percentage, MILL= Milling percentage, HRR=Head rice recovery, AMY=Amylose content, ASV=Alkali spreading value, PRO=Protein content, TPC=Total phenol content, TAA=Total antioxidant activity, Zn=Zinc content, Fe=Iron content, GYPP=Grain yield per plant



DFF=Days to 50 per cent flowering, DM=Days to maturity, PH=Plant height, PTPP=Productive tillers per plant, PL= Panicle length, GPP=Grains per panicle, TW=Test weight, KL=Kernel length, KB=Kernel breadth, L/B= Length/Breadth ratio, HULL=Hulling percentage, MILL=Milling percentage, HRR=Head rice recovery, AMY= Amylose content, ASV=Alkali spreading value, PRO=Protein content, PHENOL=Total phenol content, ANTIOX= Total antioxidant activity, Zn=Zinc content, Fe=Iron content.

Fig 3: Path diagram of yield components and quality characters for grain yield per plant in rice

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