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Genetic variability and character association studies for yield and yield related, floral and quality traits in maintainer lines of rice (*Oryza sativa* L.)

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Abstract
A study was conducted to evaluate the genetic variability parameters, correlation and path coefficient analysis for yield and yield related, floral and grain quality traits in twenty- nine rice maintainer lines at Rice Research Centre, ARI, Hyderabad during *rabi*, 2020-21. The results indicated that stigma length, number of grains per panicle, gel consistency, 1000-grain and grain yield per plant showed high PCV and GCV. High heritability coupled with high genetic advance as per cent of mean was observed for days to 50% flowering, stigma length, stigma exsertion, plant height, number of grains per panicle, 1000-grain weight, kernel length, kernel breadth, kernel L/B, amylose content, gel consistency and kernel length after cooking which indicates simple selection would be effective for enhancement of these traits. Correlation studies indicated that grain yield per plant showed significant and positive association with amylose content, plant height, panicle length, number of grains per panicle, number of productive tillers per plant and angle of flower opening. High positive direct effect on grain yield per plant was recorded by kernel breadth, amylose content, plant height, number of productive tillers per plant and stigma length.

Keywords: Rice, variability, correlation, path analysis

Introduction
Rice (*Oryza sativa* L.) is a major cereal food crop which serves as a pillar for food security in many developing countries. It occupies a pivotal place in Indian agriculture, as it forms staple food for two-thirds of the population. In view of the growing population, the main objective of the plant breeders would always be towards yield improvement in staple food crops. It is estimated that by 2040 the rice requirement should be around 140 million tonnes in India. Thus, production of rice has to be improved and maintained for global food security. Plateauing trend in the yield of HYVs, decreasing and degrading natural resources and acute labour shortage make the mission of increasing rice production quite challenging. Apart from crop management, the innovative genetic option of hybrid rice technology provides a practical and readily adoptable choice (Sadvi *et al*., 2017) [30]. Threeline system (CGMS) is widely being followed in rice to develop hybrids. To develop a new CMS line, the genotypes showing maintainer reaction need to be backcrossed for 5-6 generations on to its sterile line in order to transfer nuclear genes of maintainer line (fertile) to cytoplasmic sterile line. The sterile lines need to be crossed with suitable restorer line to get commercial hybrid seed. The knowledge on the nature and magnitude of genetic variation in respect of quantitative characters like yield and its components is essential for crop improvement. Variability for yield and its related traits are the basic factors to be focussed during selection. Generally, environment role is estimated by phenotypic coefficient of variation while, heritable variability is estimated by the genotypic coefficient of variation. During selection, the traits to be taken into consideration are determined by using the estimates of heritability. For predicting the grain under selection and for selecting superior varieties the parameters to be considered are estimates of heritability and genetic advance (Ali *et al*., 2002) [2]. Correlation measure degree of association among the traits and aids the breeder in defining selection criteria for grain yield in parental lines. However, it does not provide an exact picture of the proportional degree of direct and indirect effects of each of the component character on seed yield. Considering this, Wright (1921) [39] proposed estimation of path coefficient analysis which measures the direct and indirect causes of association. In addition to that, path coefficient analysis plays a role in planning effective breeding methods for superior plant development.

Material and Methods

The research was carried out at Rice Research Centre, ARI, Rajendranagar, Hyderabad, Telangana during *rabi* 2020-21. For the present genetic study, the experimental material consists of 29 maintainer lines along with 4 standard checks of rice. Twenty-five days old seedlings were transplanted with 15 × 20 cm spacing between the plants and rows, respectively in randomized complete block design. Phenotypic data was recorded for seven yield and attributing traits *viz*., days to 50% flowering, plant height (cm), number of productive tillers per plant, panicle length (cm), number of grains per panicle, grain yield per plant (g) and 1000-grain weight (g), three floral traits *viz*., angle of flower opening (%), stigma length (µM) and stigma exsertion %, six grain quality characters *viz*., kernel length (mm), kernel breadth (mm), kernel L/B ratio, amylose content (%), gel consistency (mm) and kernel length after cooking. During the experiment for raising a healthy nursery and main crop recommended cultural practices and crop protection measures were taken up. Table 1 represents the list of maintainer lines employed for study. Statistical analysis was done for the data recorded on yield and related traits, floral traits and quality traits *viz*., Phenotypic Co- efficient of Variation (PCV), Genotypic Co-efficient of Variation (GCV), broad sense heritability and genetic advance as per cent of mean. GCV and PCV were calculated by adopting the technique given by Burton and Devane (1953) [9]. Range of variation were classified as high (> 20%), moderate (10- 20%) and low (< 10%) as proposed by Sivasubramanian and Madhavamenon (1973) [37]. Allard (1960) [4] proposed that broad sense heritability h2 (bs) was estimated by taking the ratio of genotypic variance to the total observed variance and expressed in per cent. According to Johnson *et al*. (1955) [18] the estimates of heritability were categorized as high (> 60%), moderate (30-60%) and low (0-30%). Genetic advance was calculated and classified as high (> 20%), moderate (10-20%) and low (< 10%) as given by Johnson *et al*. (1955) [18]. The formula given by Falconer (1964) [15] was used for computation of simple correlations and the one given by Dewey and Lu (1959) [13] is used for computation of path analysis.

Table 1: List of maintainer lines used for the present study

S. No.	Genotypes	Origin	S. No.	Genotypes	Origin
1.	CMS 11B	Philippines	16.	CMS 69B	Philippines
2.	CMS 23B	Philippines	17.	CMS 70B	Philippines
3.	CMS 46B	Philippines	18.	CMS 71B	Philippines
4.	CMS 52B	Philippines	19.	CMS 72B	Philippines
5.	CMS 59B	Philippines	20.	CMS 74B	Philippines
6.	CMS 64B	Philippines	21.	CMS 75B	Philippines
7.	JMS 13B	Jagityal	22.	CMS 77B	Philippines
8.	JMS 17B	Jagityal	23.	BCN 1112	Rajendranagar
9.	JMS 18B	Jagityal	24.	BCN 1146	Rajendranagar
10.	JMS 20B	Jagityal	25.	BCN 1206	Rajendranagar
11.	CMS 65B	Philippines	26.	RNR 15048	Rajendranagar
12.	CMS 66B	Philippines	27.	MTU1010	Maruteru
13.	CMS 67B	Philippines	28.	JGL 1798	Jagityal
14.	CMS 68B	Philippines	29.	IR 64	Philippines
15.	CMS 68B	Philippines			

Results and Discussion

To uncover the role of environmental effect on different traits GCV and PCV values are vital (Akinwale *et al*., 2011) [1]. Table 2 indicates the variability parameters calculated in the present study for seven yield and its related traits, 3 floral traits and 6 quality traits. For all the traits studied it was observed that PCV values in comparison with GCV values were slightly higher which indicates that the expression of traits was influenced less by the environmental factors. PCV and GCV estimates were recorded high for stigma length (47.80 and 46.44 respectively), number of grains per panicle (45.99 and 43.83 respectively), gel consistency (31.69 and 31.20 respectively), 1000- grain weight (23.41 and 22.98 respectively and grain yield per plant (22.48 and 21.03 respectively). The above-mentioned traits exhibited high estimates of PCV and GCV which indicates that these traits showed high degree of variability, so for crop improvement direct selection of these traits would be fruitful. Similar results of high PCV and GCV was reported by Gampala *et al*. (2015) [16] for 1000-grain weight, Edukondalu *et al*. (2017) [14] for grain yield per plant, Sahu *et al*. (2017)31 for gel consistency and Sandeep *et al*. (2018) [32] for number of grains per panicle.

The moderate level of PCV and GCV was recorded for the traits *viz*., days to 50% flowering, plant height, number of productive tillers per plant, stigma exsertion %, kernel length, kernel breadth, kernel L/B ratio, amylose content and kernel length after cooking. Similar results were reported by Rathi *et al*. (2010) [27] for amylose content, Singh *et al*. (2013) [36] for panicle length, Pathak *et al*. (2015) [24] for kernel length after cooking, Chandra Mohan *et al*. (2016) [11] for days to 50% flowering, Edukondalu *et al*. (2017) [14] for number of productive tillers per plant, Sahu *et al*. (2017) [31] for kernel length, kernel breadth and kernel L/B ratio and Kumar *et al*. (2018a) [19] for plant height. Whereas angle of flower opening recorded low level of PCV and GCV, which suggests that the trait exhibited less variability so, the selection may not be fruitful based on these traits.

According to Johnson *et al*. (1955) [18] for selection of component traits in improving yield, estimates of PCV and GCV alone is not sufficient, combination of genetic gain and heritability estimates has to be taken together for more reliable results. Johnson et al. (1955) [18] suggested that the heritability in narrow sense includes additive components only whereas, Hanson et al. (1956) [17] suggested that broad sense heritability comprises of additive and non-additive components of gene effects. In this study, broad sense heritability was estimated and it was observed that all the studied traits exhibited high heritability.

Days to 50% flowering, stigma length, stigma exsertion %, plant height, number of grains per panicle, 1000- grain weight, kernel length, kernel breadth, kernel L/B ratio, amylose content, gel consistency and kernel length after cooking recorded high heritability and high genetic advance, which favours additive gene action. Earlier researchers, Sandeep *et al*. (2018) [32] for days to 50% flowering and Singh and Verma *et al*. (2018) [35] for plant height and number of grains per panicle reported similar findings. Panicle length recorded high heritability with moderate genetic advance. Sandeep *et al*. (2018) [32] reported similar findings.

Number of productive tillers per plant recorded moderate heritability and genetic advance which is similar to findings of Chakraborty and Chakraborty (2010) [10]. The trait grain yield per plant showed moderate heritability with high genetic advance. Similar finding reported by Bhargavi *et al*. (2021) [8]. Angle of flower opening showed moderate heritability but genetic advance was low which limits further improvement through direct selection. Ali *et al*. (2013) [3]. reported similar findings. Fig. 1 and 2 represents histogram of PCV, GCV, broad sense heritability (h2) and genetic advance as per cent of mean.

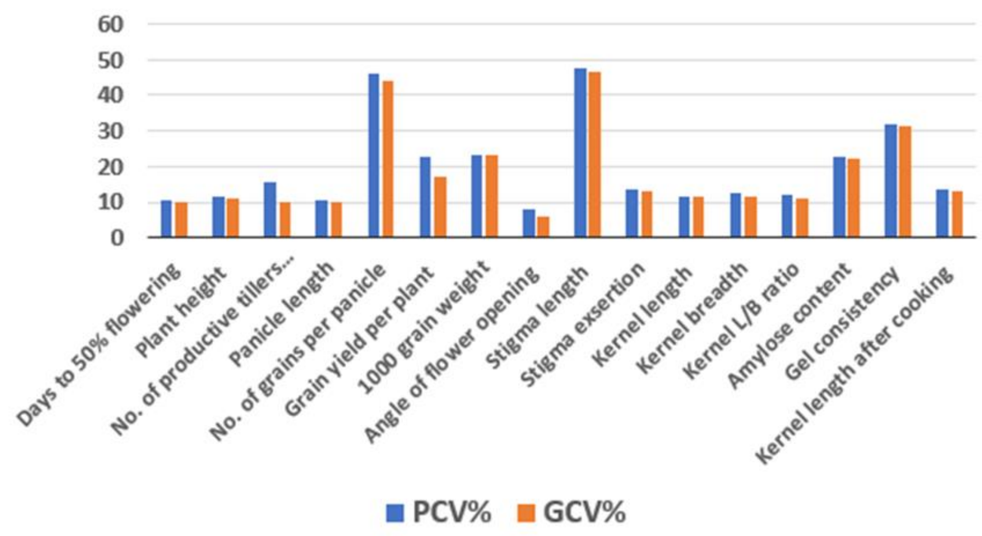

Fig 1: Histogram of Phenotypic Coefficient of Variation and Genotypic Coefficient of Variation

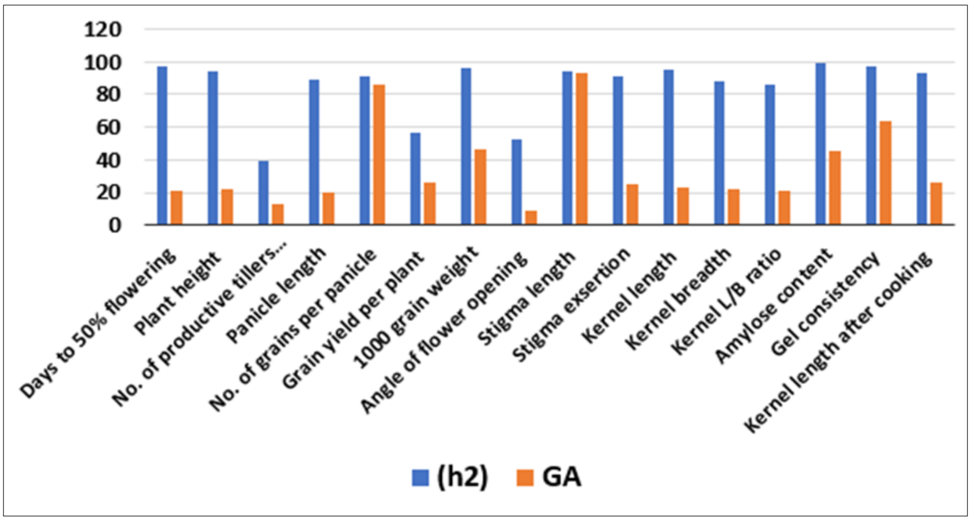

Fig 2: Histogram of h2 (broad sense) and Genetic advance as per cent of mean

Table 2: Estimates of variability, heritability and genetic advance for yield, its component characters, floral and quality parameters

S. No.	Characters	Mean	Range		PCV (%)	GCV (%)	Heritability in broad sense (h2) (%)	Genetic Advance as % mean
			Min	Max				
	Yield and its related traits							
1.	Days to 50% flowering	119	95	140	10.36	10.22	97.3	20.76
2.	Plant height (cm)	79.6	59.3	100.1	11.55	11.23	94.5	22.50
3.	No. of productive tillers per plant	15	11	19	15.67	10.00	39.6	12.79
4.	Panicle length (cm)	21.8	16.4	25.2	10.68	10.08	89.0	19.58
5.	No. of grains per panicle	165	89	355	45.99	43.83	90.8	86.06
6.	Grain yield per plant (g)	27.9	15.0	36.7	22.48	21.03	56.5	26.17
7.	1000 grain weight (g)	17.26	10.54	23.10	23.41	22.98	96.4	46.48
	Floral traits							

1.	Angle of flower opening (º)	27.3	22.9	29.5	7.98	5.80	52.8	8.68
2.	Stigma length (µM)	369.9	177.9	749.2	47.80	46.44	94.4	92.96
3.	Stigma exertion (%)	48.9	38.9	64.4	13.50	12.90	91.3	25.39
Grain quality traits								
1.	Kernel length (mm)	6.03	4.58	7.10	11.71	11.42	95.1	22.94
2.	Kernel breadth (mm)	1.70	1.40	2.13	12.39	11.63	88.2	22.50
3.	Kernel L/B ratio	3.57	2.82	4.38	11.80	10.93	85.8	20.86
4.	Amylose content (%)	17.77	8.34	25.92	22.54	22.40	98.8	45.87
5.	Gel consistency (mm)	71.57	42.00	106.00	31.69	31.20	97.0	63.29
6.	Kernel length after cooking (mm)	8.86	7.14	12.44	13.46	12.97	92.7	25.73

Table 3: Correlation analysis among yield and related traits, floral and quality traits among 29 genotypes

Character		DFF	AFO	SL	SE	PH	NPT	PL	NGP	GW	KL	KB	AC	GC	KLAC	GYP
DFF	G	1.00	0.37**	0.23*	-0.06	0.79**	0.65**	0.58**	0.44**	-0.31**	-0.16	-0.24*	0.43**	-0.15	-0.04	0.52**
	P	1.00	0.28**	0.21*	-0.05	0.76**	0.39**	0.53**	0.41**	-0.29**	-0.15	-0.22*	0.41**	-0.14	-0.54**	0.39**
AFO	G		1.00	0.42**	0.29*	0.33**	-0.15	0.14	0.45**	-0.48**	-0.29**	0.16	0.56**	-0.54**	-0.32**	0.45**
	P		1.00	0.29**	0.24*	0.25*	-0.05	0.10	0.31**	-0.32**	-0.16	0.11	0.42**	-0.42**	-0.22*	0.24*
SL	G			1.00	0.38**	0.04	0.18	-0.037	0.17	-0.09	-0.06	0.14	-0.17	-0.27*	-0.17	0.10
	P			1.00	0.35**	0.05	0.13	0.02	0.15	-0.08	-0.05	0.16	-0.17	-0.26*	-0.18	0.07
SE	G				1.00	-0.18	-0.16	-0.13	-0.24*	0.31**	0.31**	0.33**	-0.15	-0.09	0.27*	-0.12
	P				1.00	-0.16	-0.03	-0.11	-0.24*	0.30**	0.29**	0.31**	-0.14	-0.09	-0.23*	-0.09
PH	G					1.00	0.67**	0.74**	0.46**	-0.28**	-0.18	-0.29**	0.57**	-0.19	-0.05	0.75**
	P					1.00	0.42**	0.68**	0.42**	-0.26*	-0.16	-0.28**	0.55**	-0.18	-0.06	0.53**
NPT	G						1.00	0.68**	0.05	-0.013	0.004	0.05	0.07	-0.07	0.26**	0.22*
	P						1.00	0.33**	0.02	-0.01	0.02	0.02	0.05	-0.06	0.13	0.26*
PL	G							1.00	0.26*	-0.04	-0.01	0.09	0.41**	-0.20	0.09	0.63**
	P							1.00	0.23*	-0.03	-0.009	0.09	0.38**	-0.17	0.09	0.41**
NGP	G								1.00	-0.85**	-0.85**	-0.48**	0.59**	-0.50**	-0.61**	0.58**
	P								1.00	-0.79**	-0.80**	-0.41**	0.56**	-0.47**	-0.56**	0.41**
GW	G									1.00	0.89**	0.72**	-0.55**	0.48**	0.68**	-0.40**
	P									1.00	0.86**	0.67**	-0.54**	0.47**	0.64**	-0.30**
KL	G										1.00	0.52**	-0.47**	0.48**	0.71**	-0.42**
	P										1.00	0.49**	-0.45**	0.46**	0.67**	-0.31**
KB	G											1.00	-0.22*	0.14	0.51**	-0.01
	P											1.00	-0.21*	0.13	0.46**	0.04
AC	G												1.00	-0.31**	-0.19	0.82**
	P												1.00	-0.31**	-0.18	0.63**
GC	G													1.00	0.48**	-0.32**
	P													1.00	0.46**	-0.24*
KLAC	G*														1.00	-0.08
	P														1.00	-0.08

* Significant at 5 per cent level; ** Significant at 1 per cent level

DFF: Days to 50% flowering, AFO: Angle of flower opening, SL: Stigma length, SE: Stigma exsertion %, PH: Plant height, NPT: Number of Productive Tillers per plant, PL: Panicle length, NGP: Number of grains per panicle, GW: 1000-grain weight, KL: Kernel length, KB: Kernel breadth, AC: Amylose content, GC: Gel consistency, KLAC: kernel length after cooking, GYP: Grain yield per plant.

Table 4: Phenotypic path coefficient analysis representing direct and indirect effects on grain yield by its related traits, floral and quality traits

Character		DFF	AFO	SL	SE	PH	NPT	PL	NGP	GW	KL	KB	AC	GC	KLAC	GYP
DFF	G	-0.6976	-0.2596	-0.1629	0.0437	-0.5542	-0.4557	-0.4042	-0.3064	0.2170	0.1117	0.1725	-0.2970	0.1052	0.0334	0.5231
	P	-0.0700	-0.0200	-0.0149	0.0039	-0.0532	-0.0276	-0.0374	-0.0287	0.0209	0.0108	0.0154	-0.0293	0.0102	0.0038	0.3921
AFO	G	0.2534	-0.6809	-0.2875	-0.1981	-0.2247	0.0988	-0.0983	-0.3062	0.3247	0.1950	0.1139	-0.3826	0.3662	0.2180	0.4455
	P	0.0128	-0.0447	-0.0129	-0.0108	-0.0110	0.0023	-0.0045	-0.0138	0.0147	0.0072	0.0047	-0.0189	0.0188	0.0097	0.2441
SL	G	0.0174	0.0314	0.0743	0.0282	0.0032	0.0138	-0.0028	0.0128	-0.0071	-0.0045	0.0105	-0.0131	-0.0203	-0.0128	0.1043
	P	0.0282	0.0382	0.1322	0.0458	0.0070	0.0174	-0.0022	0.0201	-0.0109	-0.0067	0.0152	-0.0226	-0.0344	-0.0234	0.0721
SE	G	-0.0488	0.2267	0.2954	0.7793	-0.1411	-0.1237	-0.0992	-0.1872	0.2449	0.2405	0.2582	-0.1139	-0.0762	0.2123	-0.1168
	P	0.0029	-0.0127	-0.0183	-0.0527	0.0085	0.0017	0.0060	0.0124	-0.0157	-0.0155	-0.0163	0.0072	0.0050	-0.0123	-0.0924
PH	G	-0.1063	-0.0442	-0.0058	0.0242	-0.1338	-0.0895	-0.0986	-0.0610	0.0379	0.0236	0.0382	-0.0761	0.0250	0.0071	0.7494
	P	0.2263	0.0729	0.0158	-0.0480	0.2975	0.1264	0.2037	0.1245	-0.0772	0.0464	-0.0827	0.1640	-0.0538	-0.0192	0.5272
NPT	G	0.8633	-0.1918	0.2455	-0.2098	0.8843	1.3218	0.8951	0.0624	-0.0184	0.0054	0.0708	0.0954	-0.0981	0.3502	0.2154
	P	0.0531	-0.0068	0.0177	-0.0044	0.0573	0.1347	0.0450	0.0004	-0.0015	0.003	-0.0031	0.0078	-0.0081	0.0178	0.2620
PL	G	0.1513	-0.0377	0.0097	0.0332	-0.1925	-0.1768	-0.2611	-0.0679	0.0122	0.0029	-0.0223	-0.1084	0.0511	-0.0250	0.6309
	P	-0.0057	-0.0011	0.0002	0.0012	-0.0073	-0.0036	-0.0106	-0.0024	0.0004	0.0001	-0.0009	-0.0041	0.0018	-0.0009	0.4075
NGP	G	0.3832	0.3923	0.1499	-0.2095	0.3979	0.0412	0.2267	0.8724	-0.7390	-0.7452	-0.4178	0.5130	-0.4370	-0.5328	0.5814
	P	0.0042	0.0032	0.0016	-0.0024	0.0043	0.0000	0.0024	0.0103	-0.0081	-0.0082	-0.0042	0.0058	-0.0049	-0.0057	0.4119
GW	G	0.7931	1.2160	0.2443	-0.8014	0.7230	0.0355	0.1195	2.1599	-2.5498	-2.2861	-1.8398	1.4160	-1.2304	-1.7415	-0.4044
	P	-0.0015	-0.0017	-0.0004	0.0015	-0.0013	-0.0001	-0.0002	-0.0040	0.0051	0.0044	0.0034	-0.0027	0.0024	0.0033	-0.2967

KL	G	-1.0861	-1.9431	-0.4147	2.0931	-1.1948	0.0277	-0.0745	-5.7944	6.0817	6.7834	3.5480	-3.2143	3.2824	4.8461	-0.4177
	P	0.1050	0.1092	0.0347	-0.2004	0.1062	-0.0168	0.0061	0.5449	-0.5867	-0.6815	-0.3305	0.3099	-0.3165	-0.4543	-0.3148
KB	G	0.6231	0.4215	-0.3553	-0.8351	0.7193	0.1350	-0.2157	1.2071	-1.8185	-1.3183	-2.5204	0.5631	-0.3652	-1.2976	-0.0069
	P	-0.1752	-0.0834	0.0913	0.2454	-0.2206	-0.0184	0.0703	-0.3237	0.5320	0.3850	0.7938	-0.1637	0.1025	0.3614	0.0395
AC	G	0.4479	0.5912	-0.1854	-0.1537	0.5984	0.0759	0.4367	0.6187	-0.5843	-0.4985	-0.2351	1.0521	-0.3295	-0.1981	0.8213
	P	0.2188	0.2208	-0.0895	-0.0716	0.2881	0.0302	0.2017	0.2928	-0.2829	-0.2376	-0.1078	0.5226	-0.1625	-0.0949	0.6283
GC	G	-0.1241	-0.4429	-0.2251	-0.0805	-0.1536	-0.0611	-0.1612	-0.4125	0.3974	0.3985	0.1193	-0.2579	0.8235	0.3964	-0.3165
	P	-0.0085	-0.0245	-0.0151	-0.0055	-0.0105	-0.0035	-0.0100	-0.0275	0.0272	0.0270	0.0075	-0.0181	0.0582	0.0270	-0.2449
KLAC	G	0.0576	0.3854	0.2066	-0.3280	0.0636	-0.3189	-0.1150	0.7352	-0.8222	-0.8600	0.6198	0.2266	-0.5795	-1.2038	-0.0823
	P	0.0031	-0.0122	-0.0099	0.0131	-0.0036	0.0074	0.0049	-0.0312	0.0360	0.0374	0.0255	-0.0102	0.0260	0.0561	-0.0775
Genotypic Residual effect = 0.5150 Phenotypic Residual effect = 0.6645 Bold values are direct effects																

DFF: Days to 50% flowering, AFO: Angle of flower opening, SL: Stigma length, SE: Stigma exsertion %, PH: Plant height, NPT: Number of Productive Tillers per plant, PL: Panicle length, NGP: Number of grains per panicle, GW: 1000-grain weight, KL: Kernel length, KB: Kernel breadth, AC: Amylose content, GC: Gel consistency, KLAC: kernel length after cooking, GYP: Grain yield per plant.

Correlation analysis provides information regarding nature and degree of relationship among various traits and decides the component traits, on the basis of which traits can be chosen to improve grain yield genetically. In this study, correlations between seven yield and its related traits namely days to 50% flowering, plant height, number of productive tillers per plant, panicle length, number of grains per panicle and 1000 grain-weight, three floral traits namely angle of flower opening, stigma length and stigma exsertion, five quality traits namely kernel length, kernel breadth, amylose content, gel consistency and kernel length after cooking were computed. Correlation coefficient results were represented in Table 3 which was done by considering plant yield as dependent variable. The trait days to 50% flowering exhibited significantly positive correlation with amylose content, number of grains per panicle, number of productive tillers per plant, grain yield per plant, angle of flower opening and stigma length. Similar results were reported by Padmaja *et al.* (2010) [21] and Kumar *et al*. (2018b) [20] for number of grains per panicle, Patel *et al.* (2017) [23] for amylose content, Vanisree *et al.* (2013) [38] and Rachana *et al.* (2018) [26] for grain yield per plant. Plant height showed a significantly positive correlation with panicle length, grain yield per plant, number of grains per panicle, number of productive tillers and angle of flower opening. It indicates that plant height plays crucial role in increasing the yield potential in rice as it is positive and significantly associated with number of productive tillers, panicle length and grain yield. The results are in confirmity with Vanisree *et al*. (2013) [38], Panigrahi *et al*. (2018) [22] and Rachana *et al*. (2018) [26]. Number of productive tillers per plant showed a significantly positive correlation with plant height, panicle length and grain yield. Earlier researchers, Seneega *et al*. (2019) [34] and Prasanna Kumari *et al*. (2020) [25] reported similar positive association between number of productive tillers and grain yield. Panicle length exhibited a significantly positive correlation with grain yield, amylose content, number of productive tillers and number of grains per panicle which indicates improvement in panicle length would improve grain number per panicle and grain yield. The trait number of grains per panicle exhibited a positively significant association with amylose content, grain yield per plant and panicle length and it exhibited a negatively significant association with 1000-grain weight, kernel length, kernel breadth and gel consistency. It was evident that lesser the grain weight more would be number of grains per panicle and vice-versa. Rukmini *et al*. (2014) [29] reported similar results for 1000- grain weight and grain yield per plant. Edukondalu *et al*. (2017) [14] for kernel length and kernel breadth. 1000-grain weight exhibited significant positive correlation with kernel length, kernel breadth, gel consistency and stigma exsertion.

The trait angle of flower opening exhibited positive significant correlation with amylose content, number of grains per panicle, stigma length, grain yield per plant and stigma exsertion. Stigma length showed positive significant correlation with stigma exsertion, angle of flower opening. Similar results reported by Banumathy *et al*. (2002) [7]. The trait stigma exsertion showed significant positive association with 1000-grain weight, kernel length and kernel breadth. Interestingly, all the three floral traits studied have positive correlation with each other and hence, simultaneous improvement of all these traits is possible to derive new female lines with good outcrossing ability.

The trait kernel length showed positive significant correlation with kernel breadth, kernel length after cooking and gel consistency. The results are in accordance with Vanisree *et al*. (2013) [38] for kernel breadth. Kernel breadth exhibited significant positive correlation with kernel length and kernel length after cooking. The trait amylose content showed significant positive correlation with grain yield per plant and number of grains per panicle and exhibited negative correlation with gel consistency. Similar results were reported by Chaudary *et al*. (2013) [12] for gel consistency. The trait kernel length after cooking has positive significant correlation with gel consistency.

The traits amylose content, plant height, panicle length, number of grains per panicle, number of productive tillers and angle of flower opening exhibited significant and positive association with grain yield per plant. The study of correlation suggests that ultimate increase in yield may be due to improvement of these traits. Atsedemariam (2018) [6] and Rachana *et al*. (2018) [26] reported such positive correlation with yield. Correlation measures the relation between two variables only, whereas path coefficient analysis explains the direct and indirect causes of association using other attributes by dividing the correlations for explaining the cause-and-effect relationship clearly (Wright, 1921) [39].

Table 4 depicts the path coefficient analysis estimates for yield and its related traits, floral traits and quality traits. Among yield related traits, plant height (0.2975) exerted maximum positive direct effect on grain yield per plant followed by number of productive tillers per plant (0.1347), number of grains per panicle (0.0103) and 1000-grain weight (0.0051). Similar results of direct positive effect on grain yield were reported by Archana *et al*. (2018) [5] for plant height and number of productive tillers. In contrast to positive direct effect, negative direct effect on grain yield was exhibited by days to 50% flowering and panicle length.

Similar results of negative direct results were reported by Ravindra Babu *et al*. (2012) [28] for days to 50% flowering and Patel *et al*. (2017) [23] for panicle length.

Among floral traits, stigma length (0.1322) exerted positive direct effect on grain yield per plant. Both angle of flower opening and stigma exsertion exhibited negative direct effect on grain yield per plant.

Among quality traits, Kernel breadth (0.7938) exerted maximum positive direct effect on grain yield per plant followed by amylose content (0.5226), gel consistency (0.0582) and kernel length after cooking (0.0561). Similar results of direct positive effect on grain yield were reported by Saxena and Suman (2017) [33] for amylose content. Kernel length exerted negative direct effect on grain yield. Similar results of negative direct results were reported by Edukondalu *et al*. (2017) [14] for kernel length.

At phenotypic level the residual effect was 0.6645. Path coefficient analysis revealed that traits kernel breadth, amylose content, plant height, number of productive tillers, stigma length, gel consistency, kernel length after cooking, number of grains per panicle and 1000-grain weight exhibited positive direct effect on grain yield per plant indicating that the selection for these characters was likely to bring about an overall improvement in grain yield per plant directly. Hence, it is suggested that preference should be given to these characters in the selection programme to isolate superior lines with genetic potentiality for higher yield in rice genotypes. Phenotypical path diagram for plant yield was represented in Fig. 3.

Conclusion

PCV and GCV estimates were high for number of grains per panicle, 1000-grain weight and grain yield per plant among yield related traits, stigma length among floral traits and gel consistency among quality traits implying that direct selection of these traits may lead to genetic improvement. It was observed that days to 50% flowering, plant height, number of grains per panicle, 1000-grain weight of yield related traits, stigma length, stigma exsertion of floral traits and kernel length, kernel breadth, kernel L/B, amylose content, gel consistency and kernel length after cooking of quality traits showed high genetic advance as per cent of mean and high heritability which signifies predominance of additive gene action in their genetic control. So, for improvement of these traits simple selection would be productive. Analysis of correlation and path coefficient together revealed that among the yield traits studied, plant height, number of productive tillers per plant, number of grains per panicle and among floral traits stigma length and angle of flower opening and among quality traits amylose content were considered as most critical ones as they exhibited higher correlation coefficients and direct effects in association to grain yield per plant.

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