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Deciphering correlation studies for yield and quality traits in basmati rice (*Oryza sativa* L.) mated through line × tester mating design

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Abstract
Nine lines, 3 testers and 27 F_1 crosses of basmati rice (*Oryza sativa* L.) mated through Line × Tester mating Design to decipher the extent and nature of correlation between yield and yield contributing characters moreover quality traits were also included in the study. At the end of the experiment and subsequent statistical analysis it was deciphered that grain yield per plant has positive significant correlation with number of effective tillers per plant and hulling recovery which pointed that the number of effective tillers is an important trait that can be targeted as a selection criteria in yield improvement programmes in breeding of Basmati rice moreover quality traits like hulling recovery and milling recovery should also be emphasized specially in long-grained rice.

Keywords: basmati rice, correlation and yield

Introduction
Rice (*Oryza sativa* L.) is one of the most premiere cereal crop grown in Indian Sub-Continent and is consumed as staple diet by 2/3rd of the country's total population. Basmati, the unique scented rice of the sub-continent, derives its name from *Bas* meaning aroma and *mati* meaning already ingrained and among the handful varieties of rice that are traded internationally. Basmati is also acknowledged as "Crown Jewel", "Prince of Rice" and "Queen of Fragrance" among the South-Asian rice and often romanticized as the gift of nature to the sub-continent and for hundreds of years being favored by emperors and praised by poets [1].
Attempts that have been undertaken to improve the yield of Basmati rice through hybridization to make it dwarf and non-lodging type has been partly successful. Basmati rice has a narrow genetic base lacking donor parents for grain quality. Poor combining ability attributed to the mutation on the *BADH* gene having impact an on pollen tube growth leading to chaffiness. The local landraces of these areas thus need to be incorporated into breeding programmes for their enhancement and hence developing NPT i.e., new plant types out of them. Hence the need of the hour is to explore parents which would be great combiners and which can be effectively used in hybridization to produce excellent genotypes without having lost any of the traditional Basmati quality.
The yield of the grain is somewhat complex trait and is proved to be dependent on various component traits and hence its response to direct selection is poor. The knowledge on the association between grain yield and its component characters is thus essential to improve the grain yield. The present Investigation was thus undertaken to decipher the association among grain yield and its component characters.

Materials and Methods
The research material for the present study performed at Norman E. Borlaug Crop Research Centre, GBPUAT, Pantnagar (figure 1), comprises 27 F_1 crosses involving 12 parents. Out of 12 parents, 9 are being used as lines (Female) namely., Pant Basmati 1, UPR-3716-27-1-1, UPR-3709-11-1-1, Pant Sugandh Dhan 17, Basmati 370, Pant Sugandh 4, Hariyana Basmati, 2110-Kharif-2017, UPR-3506-7-1-1and 3 as testers (Male) namely., Taraouri Basmati, Sugandhmati, Lal Basmati. Line × tester mating system was used to cross 9 lines with 3 testers to generate 27 F_1 hybrids for quantitative and qualitative traits for evaluation in rice. In the first Season, 27 F_1s of rice were produced with the help of 9 lines and 3 testers which were crossed in a line×tester fashion (figure 2). The F_1 seeds that were produced were harvested in the month of November and then the F_1 seeds were counted and kept in packets. Some insecticides and fungicides were

also put in the packets to avoid any damage. Out of all the crosses made some actually failed to produce seeds, those parents were planted again in a greenhouse in off-season nursery. Crosses were made and simultaneously seeds were harvested. The nursery was sown using total seeds harvested in the first season and from off-season crosses. All F_1s are planted along with parents in the second year in Randomized Block Design having 3 replications with a plot size of two meter length. Observations on different morphological, yield contributing and quality traits were recorded. The experimental material which consisted of 39 genotypes i.e., 9 lines, 3 testers, 27 F_1's was laid out in a Randomized Block Design (RBD) with 3 replications during *kharif* 2018. The seeds of all 39 genotypes were sown in rice nursery at Norman E. Borlaug Crop Research Centre. Twenty-one days old seedling was transplanted in the main field in a single row of 2 m length maintaining a spacing of 30 cm between two entries. The plant to plant spacing of 15 cm was kept for better evaluation and recording of data. Observations in respect to days to 50% flowering were recorded on the whole plot basis whereas five randomly selected competitive plants from the F1 crosses, lines and the testers were used to record the observations for some of the characters like plant height, number of tillers plant^{-1}, panicle length, grain length, grain breadth, l/b ratio,1000 grain weight, grain yield plant^{-1}, hulling recovery, milling recovery, amylose content, gel consistency (figure 4) and alkali digestion value (figure 3). The calculation of average values for these plants were used for statistical and genetic analysis.

Fig 1: All Materials were Planted at Rice Breeding Block, Pantnagar

Fig 2: Emasculation of Rice plants by Suction Method

Fig 3: Experimental setup for finding alkali digestion value

Fig 4: Experimental setup for finding gel consistency

Results and Discussion

In table 1 the phenotypic and genotypic correlations are presented and generally as phenotypic correlations are affected by environmental effects the value of their coefficients are normally higher than genotypic correlation coefficients. In table 2 phenotypic and genotypic direct (diagonal) and indirect effects (off-diagonal) are shown although results of table 2 are not discussed elaborately but just been attached for futher reference. In the present study, days to 50 per cent flowering exhibited a positive and significant association with panicle length [2] which indicates that there is a scope for improving the trait simultaneously. Similar results were reported by [3, 4]. However, negative and significant association was noticed with Number of tillers per plant, Number of grains per panicle, Kernel length (mm), Length-breadth ratio. Such negative correlations arise primarily from competition for a common possibility, such as nutrient supply and whenever one component gets an additional edge or upper-hand over the other, a negative correlation generally arises [5]. Plant height had registered positive and significant associations with panicle length [6, 7]. It had also recorded positive and significant association with Hulling recovery and Milling recovery. However, non-significant associations were noticed for the trait with amylose content. Negative and significant associations were recorded for number of effective tillers per plant with panicle length, number of grains per panicle, Length-breadth ratio and Hulling recovery. However, it had recorded positive and significant association with grain yield per plant, similar to the results of [3, 7]**.** Significant negative association was noticed for panicle length with alkali digestion value at genotypic and phenotypic level, while positive and significant association was recorded with 1000 grain weight, Number of grains per panicle, Hulling recovery, Milling recovery, Head rice recovery, Amylose content.

Table 1: Estimation of phenotypic (P) and genotypic (G) correlation coefficients for fifteen characters in rice

Parents		Plant height (cm)	Number of tillers per plant	Panicle length (cm)	1000 grain weight (gm)	Number of grains per panicle	Kernel length (mm)	Kernel breadth (mm)	Length-breadth ratio	Hulling recovery (%)	Milling recovery (%)	Head rice recovery	Alkali digestion value	Gel consistency (mm)	Amylose content	Yield per plant
Days to 50% flowering	G	0.057	-0.261**	0.264**	-0.131	-0.210*	-0.212*	0.037	-0.258**	-0.087	-0.078	0.176	-0.001	0.178	-0.034	0.132
	P	-0.019	-0.147	0.145	-0.068	-0.085	-0.169	0.016	-0.181	-0.042	-0.036	0.108	0.012	0.112	-0.015	0.083
Plant height (cm)	G		-0.125	0.579**	0.032	0.079	-0.296**	-0.133	-0.066	0.260**	0.484**	-0.042	0.022	0.069	-0.193*	0.008
	P		-0.106	0.306**	0.024	0.070	-0.148	-0.133	0.018	0.192*	0.376**	-0.046	0.008	0.030	-0.134	0.005
Number of tillers per plant	G			0.199*	0.108	0.256**	0.106	-0.102	0.198*	0.253**	-0.042	0.014	-0.088	0.087	-0.093	0.432**
	P			0.146	0.092	0.169	0.065	-0.097	0.140	0.229*	-0.041	0.012	-0.088	0.084	-0.088	0.424**
Panicle length (cm)	G				0.272**	0.307**	0.023	-0.108	0.115	0.266**	0.417**	0.299**	-0.295**	-0.067	0.258**	0.103
	P				0.200*	0.124	-0.153	-0.123	-0.031	0.186*	0.275**	0.218*	-0.214*	-0.039	0.154	0.079
1000 grain weight (gm)	G					0.144	0.500**	-0.064	0.385**	-0.078	-0.291**	0.423**	-0.078	-0.495**	0.172	0.169
	P					0.061	0.304**	-0.054	0.245**	-0.057	-0.240**	0.356**	-0.075	-0.403**	0.109	0.141
Number of grains/ panicle	G						0.025	-0.001	0.013	-0.012	-0.030	0.194*	-0.145	-0.036	-0.038	0.166
	P						0.052	-0.062	0.093	0.000	0.000	0.122	-0.104	0.017	-0.008	0.103
Kernel length (mm)	G							0.454**	0.205*	-0.075	-0.479**	0.518**	-0.192*	-0.480**	-0.249**	0.046
	P							0.337**	0.469**	-0.078	-0.262**	0.375**	-0.141	-0.262**	-0.167	0.040
Kernel breadth (mm)	G								-0.746**	-0.163	-0.152	0.280**	0.021	0.178	0.087	0.025
	P								-0.649**	-0.116	-0.100	0.248**	0.017	0.125	0.054	0.022
Length-breadth ratio	G									0.153	-0.149	-0.028	-0.143	-0.541**	-0.245**	-0.004
	P									0.062	-0.082	-0.011	-0.107	-0.303**	-0.145	0.004
Hulling recovery (%)	G										0.603**	0.112	-0.342**	-0.142	0.056	0.483**
	P										0.570**	0.107	-0.325**	-0.137	0.042	0.453**
Milling recovery (%)	G											-0.143	-0.231*	0.220*	0.045	0.069
	P											-0.137	-0.225*	0.211*	0.034	0.071
Head rice recovery	G												-0.201*	-0.172	-0.075	0.174
	P												-0.197*	-0.144	-0.074	0.171
Alkali digestion value	G													0.119	-0.061	-0.247**
	P													0.097	-0.061	-0.243**
Gel consistency (mm)	G														0.045	-0.229*
	P														0.033	-0.198*
Amylose content	G															-0.109
	P															-0.106
Yield per plant	G															1.000
	P															1.000

Table 2: Additional

Parents		Days to 50% flowering	Plant height (cm)	Number of tillers /plant	Panicle length (cm)	1000 grain weight (gm)	Number of grains /panicle	Kernel length (mm)	Kernel breadth (mm)	Length-breadth ratio	Hulling recovery (%)	Milling recovery (%)	Head rice recovery	Alkali digestion value	Gel consistency (mm)	Amylose content	R with Yield per plant
Days to 50% flowering	G	0.466	0.005	-0.140	-0.148	-0.032	-0.027	0.086	0.018	-0.005	-0.026	-0.008	0.010	0.002	-0.076	0.001	0.132
	P	0.198	-0.001	-0.061	-0.016	-0.009	-0.007	0.048	0.028	-0.054	-0.027	0.006	0.005	-0.001	-0.017	0.002	0.083
Plant height (cm)	G	0.011	0.205	-0.078	-0.322	0.010	0.012	0.128	-0.054	-0.001	0.084	0.042	-0.002	-0.005	-0.032	0.010	0.008
	P	-0.005	0.021	-0.040	-0.035	0.003	0.005	0.050	-0.050	0.004	0.075	-0.032	-0.002	-0.001	-0.005	0.016	0.005
No of tillers/ plant	G	-0.105	-0.026	0.622	-0.111	0.033	0.040	-0.046	-0.042	0.004	0.082	-0.004	0.001	0.018	-0.040	0.005	0.432**
	P	-0.032	-0.002	0.376	-0.017	0.011	0.012	-0.022	-0.036	0.034	0.090	0.003	0.000	0.011	-0.015	0.010	0.424**
Panicle length (cm)	G	0.124	0.119	0.124	-0.556	0.082	0.048	-0.010	-0.044	0.002	0.086	0.036	0.014	0.061	0.031	-0.014	0.103
	P	0.027	0.007	0.055	-0.115	0.025	0.009	0.052	-0.046	-0.007	0.073	-0.023	0.008	0.026	0.007	-0.018	0.079
1000 grain weight (g)	G	-0.049	0.006	0.067	-0.151	0.301	0.023	-0.216	-0.026	0.007	-0.025	-0.025	0.020	0.016	0.230	-0.009	0.169
	P	-0.014	0.001	0.035	-0.023	0.124	0.004	-0.103	-0.020	0.059	-0.023	0.020	0.013	0.009	0.071	-0.013	0.141
No of grains/panicle	G	-0.080	0.016	0.159	-0.171	0.043	0.157	-0.011	0.000	0.000	-0.004	-0.003	0.009	0.030	0.017	0.002	0.166
	P	-0.021	0.002	0.064	-0.014	0.008	0.069	-0.018	-0.023	0.023	0.000	0.000	0.005	0.013	-0.003	0.001	0.103
Kernel length (mm)	G	-0.092	-0.061	0.066	-0.013	0.150	0.004	-0.432	0.186	0.004	-0.024	-0.042	0.025	0.039	0.223	0.013	0.046
	P	-0.028	-0.003	0.025	0.018	0.038	0.004	-0.340	0.126	0.114	-0.031	0.022	0.014	0.017	0.046	0.019	0.040
Kernel breadth (mm)	G	0.020	-0.027	-0.063	0.060	-0.019	0.000	-0.196	0.409	-0.014	-0.053	-0.013	0.013	-0.004	-0.083	-0.005	0.025
	P	0.015	-0.003	-0.036	0.014	-0.007	-0.004	-0.114	0.373	-0.157	-0.045	0.008	0.009	-0.002	-0.022	-0.006	0.022
Length-breadth ratio	G	-0.121	-0.013	0.123	-0.064	0.116	0.002	-0.089	-0.305	0.019	0.049	-0.013	-0.001	0.029	0.251	0.013	-0.004
	P	-0.044	0.000	0.053	0.004	0.030	0.006	-0.159	-0.242	0.242	0.024	0.007	0.000	0.013	0.053	0.017	0.004
Hulling recovery (%)	G	-0.037	0.053	0.157	-0.148	-0.024	-0.002	0.032	-0.067	0.003	0.323	0.053	0.005	0.070	0.066	-0.003	0.483**
	P	-0.013	0.004	0.086	-0.021	-0.007	0.000	0.026	-0.043	0.015	0.393	-0.048	0.004	0.039	0.024	-0.005	0.453**
Milling recovery (%)	G	-0.040	0.099	-0.026	-0.232	-0.088	-0.005	0.207	-0.062	-0.003	0.195	0.087	-0.007	0.048	-0.102	-0.002	0.069
	P	-0.013	0.008	-0.016	-0.032	-0.030	0.000	0.089	-0.037	-0.020	0.224	-0.084	-0.005	0.027	-0.037	-0.004	0.071
Head rice recovery	G	0.096	-0.009	0.009	-0.166	0.127	0.031	-0.224	0.115	-0.001	0.036	-0.012	0.048	0.041	0.080	0.004	0.174
	P	0.029	-0.001	0.005	-0.025	0.044	0.008	-0.127	0.092	-0.003	0.042	0.012	0.037	0.024	0.025	0.009	0.171
Alkali digestion value	G	-0.006	0.005	-0.055	0.164	-0.024	-0.023	0.083	0.009	-0.003	-0.111	-0.020	-0.010	-0.206	-0.055	0.003	-0.247**
	P	0.001	0.000	-0.033	0.025	-0.009	-0.007	0.048	0.006	-0.026	-0.127	0.019	-0.007	-0.122	-0.017	0.007	-0.243**
Gel consistency (mm)	G	0.076	0.014	0.054	0.037	-0.149	-0.006	0.207	0.073	-0.010	-0.046	0.019	-0.008	-0.024	-0.465	-0.002	-0.229*
	P	0.020	0.001	0.032	0.004	-0.050	0.001	0.089	0.046	-0.073	-0.054	-0.018	-0.005	-0.012	-0.175	-0.004	-0.198*
Amylose content	G	-0.011	-0.040	-0.058	-0.144	0.052	-0.006	0.108	0.036	-0.005	0.018	0.004	-0.004	0.013	-0.021	-0.052	-0.109
	P	-0.004	-0.003	-0.033	-0.018	0.014	-0.001	0.057	0.020	-0.035	0.017	-0.003	-0.003	0.007	-0.006	-0.116	-0.106

Positive significant association was noticed for 1000-grain weight with panicle length, Kernel length, Length-breadth ratio, Head rice recovery, while it registered negative and significant association with Milling recovery, Gel consistency. However, non-significant associations were recorded with grain yield per plant.Number of grains per panicle had recorded non-significant association with kernel length, kernel breadth, L/B ratio and grain yield per plant. Similar non-significant association of the trait with grain yield per plant was reported earlier by [8, 9]**.** Kernel length showed positive significant with Length-breadth ratio [10, 11] and Kernel breadth, Head rice recovery, while negative and significant association was recorded with Milling recovery, Alkali digestion value, Gel consistency and Amylose content.

Further, kernel breadth registered negative significant association with L/B ratio, while it showed non-significant association with grain yield per plant. L/B ratio had also recorded non-significant association with grain yield per plant. A perusal of the results on character associations for grain yield, yield components and quality characters revealed phenotypic and genotypic correlation to be of similar direction and significance. The genotypic correlation values were also in general higher than the phenotypic correlation values indicating the masking effects of environment on these traits (Table 1). Similar results were reported by Rajput *et al. (*1996) [12]. Grain yield per plant was observed to be positively and significantly associated with number of effective tillers per plant and hulling recovery indicating the importance of these traits as selection criterion in yield enhancement programmes although yield showed a negative significant association with alkali digestion value and gel consistency. The results are in line with the findings of Nayak *et al.,* 2001 and Nayak and Reddy, 2005). [10, 11]

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