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Association and path analysis for yield components and quality traits in rice (*Oryza Sativa* L.)

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Abstract
The present investigation was aimed at estimating correlation and path coefficients using observations on 22 yield components and quality characters in thirty rice (*Oriza sativa* L.) genotypes. The genotypes were evaluated in RBD and ANOVA results revealed the highly significant mean sum of squares among the genotypes for all the characters. Correlation analysis revealed that grain yield showed highly significant and positive correlation with flag leaf length, number of grains per panicle, 100 grain weight, 100 kernel weight, kernel length after cooking and kernel elongation ratio. Path coefficient analysis revealed that 100 grain weight, 100 kernel weight after cooking, hulling%, number of grains per panicle and flag leaf length exerted high positive direct effect on grain yield and 100 grain weight, grain weight per panicle had negative direct effect towards grain yield. These relationships may be helpful in crop improvement, if selection favours high grain yield then the remaining characters which are positively associated will be automatically improved. The path-coefficient analysis helps to understand the causal factor better, because it divides total effects of paired traits into direct and indirect effects via other characters. These characters could be utilized as indices of selection for future breeding programme.

Keywords: Paddy, *Oryza Sativa* L., correlation, yield, quality

Introduction
Rice is the most important cereal food crop of India. Among the rice growing countries in the world, India has the largest area under rice crop and ranks second in production next to China. During 2016-17, India produced 165 million tons of rice from 45 million hectares of land. Considering the ever-rising population, the basic objective of the plant breeders heads towards yield improvement in staple food crops**.** Usually the characters which are of interest to the plant breeder are complex and are the result of the interaction of a number of components (Sarawgi *et al.* 1996). Direct selection based on crop yield is often a paradox in breeding programmes because yield is a complex polygenically inherited character, influenced by its component traits. Rice quality is a complex trait comprising many physicochemical characteristics. Consumers base their concept of quality on the grain appearance, size and shape of the grain and behaviour upon cooking. The cooking and eating qualities of rice are valuable properties, especially in Asia, where it is the most important food. These qualities are largely determined by the properties of starch that makes up to 90% of milled rice. The development of high yielding rice cultivars is the main objective of any rice breeding programmes in the world. Identification of better genotypes with desirable traits and their subsequent use in breeding programme and establishment of suitable selection criterion can helpful for successful varietals improvement programme.

Yield is quantitative character and is governed by many genes having smaller effects i.e., polygenes. Thus, we can say that the yield is the final product of yield components. These components may affect the yield directly or indirectly. Therefore, yield can be maximized by improving the yield components provided there is no unfavourable association. The correlation coefficient gives an idea about the various associations existing between the yield components. The correlation study can show the magnitude of association between any two characters. Thus, the knowledge of character association is essential for simultaneous improvement of yield and yield components. Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement yield. A positive value of correlation shows at the changes of two variables are in the same direction, i.e. high value of one variable are associated with high values of other and vice-versa. When correlation is negative the movements are in opposite directions, i.e. high values of one variable are associated with low values of other. The use of correlation coefficient and path analysis is to establish the extent of association between yield and yield components and others characters and for fixing up the characters which are having decisive role in influencing the yield. Keeping in view the above perspectives, the present research work was taken up to assess phenotypic and genotypic associations between various components of grain yield and unveiled nature and magnitude of direct and indirect effect of component characters on grain yield.

Materials and methods

The present study was conducted at Research farm of R.M.P. P.G. College, Gurukul Narsan, Haridwar (Uttarakhand) with 30 improved genotype of basmati rice. The Gurukul Narsan is situated in the foothills of Shivalik range of Himalaya and falls in the humid sub-tropical climate Zone. The Material was planted in a randomized complete block design with three replications in the plot size of 2 m2 keeping 20x15 cm spacing. The observations were recorded on a random sample of 10 plants from each plot for 22 quantitative characters viz., Days to 50% flowering, days to maturity, plant height (cm), number of tillers per plant, panicle length (cm), flag leaf length (cm), flag leaf with (cm), number of grains per panicle, grain weight per panicle (g), 100 grain weight (g), 100 kernel weight (g), hulling (%), kernel length before cooking (mm), kernel breadth before cooking (mm), kernel length after cooking (mm), kernel breadth after cooking (mm), L:B ratio, kernel elongation ratio, breath increase ratio after cooking, 100 kernel weight after cooking (g), water absorb by 10 gm kernel (ml), grain weight per plant (g). Analysis of variance was carried out following Panse and Sukhatme (1967) [9] and correlation coefficients between all possible pairs of characters were estimated at genotypic and phenotypic level. The analysis of variance and covariance was used for the estimation of correlation coefficient as suggested by Searle, 1961 [11]. Path coefficient was worked out as per the method suggested by Dewey and Lu (1959) [4] using genotypic correlation matrix. The estimated values were compared with table values of correlation coefficient to test the significance of correlation coefficient prescribed by Fisher and Yates (1967) [5].

Results and discussion

Complete knowledge on interrelation of plant characters like grain yield with other characters is of paramount importance to the breeder for making improvement in complex quantitative character like grain yield for which direct selection is not much effective. Hence, association analysis was undertaken to determine the direction and number of characters to be considered in improving grain yield.

Correlation studies

Sravan *et al.* 2012 [12] suggested correlation coefficient as another fundamental tool showing relationships among independent characteristics. The values of genotypic and phenotypic correlation coefficients are presented in the Table1.

Table 1: Genotypic Correlation coefficients exhibiting interrelationship among yield and different yield components in basmati rice

Character	DM	PLH	TM	PL	FLL	FLW	G/PE	GW/PE	GW/P	100GW	100KW	H%	KLBC	KBBC	KLAC	KBAC	LBR	KER	BIRAC	KWAC	WA
DF	-0.161NS	-0.145NS	0.174NS	-0.046NS	-0.282**	0.340**	-0.157NS	-0.322**	-0.133NS	-0.343**	-0.367**	-0.145NS	-0.394**	0.048NS	-0.262*	0.079NS	-0.269*	0.143NS	0.050NS	-0.170NS	0.247*
DM		-0.084NS	0.211*	0.011NS	-0.427**	0.147NS	0.105NS	0.209*	-0.226*	-0.108NS	-0.090NS	0.111NS	0.051NS	-0.215*	-0.014NS	-0.111NS	0.178NS	-0.096NS	-0.016NS	0.152NS	0.243*
PLH			0.173NS	0.124NS	0.142NS	-0.037NS	0.262*	0.326**	-0.185NS	-0.064NS	-0.123NS	-0.039NS	-0.345**	0.185NS	-0.486**	-0.475**	-0.423**	-0.268*	-0.348**	-0.402**	-0.183NS
TM				-0.157NS	-0.154NS	-0.037NS	0.191NS	0.171NS	0.118NS	-0.142NS	-0.130NS	0.111NS	-0.176NS	0.039NS	-0.218*	-0.205NS	-0.111NS	-0.067NS	-0.072NS	0.023NS	0.134NS
PL					0.069NS	-0.099NS	-0.337**	-0.224*	0.018NS	0.081NS	0.067NS	-0.021NS	0.082NS	-0.006NS	0.050NS	-0.150NS	0.058NS	-0.035NS	-0.166NS	-0.306**	-0.287**
FLL						-0.172NS	-0.046NS	-0.189NS	0.434**	0.056NS	0.063NS	0.014NS	0.132NS	0.173NS	0.012NS	-0.013NS	-0.067NS	-0.169NS	-0.144NS	-0.357**	-0.347**
FLW							0.235*	0.212*	0.153NS	0.135NS	0.168NS	0.166NS	-0.076NS	0.296**	0.081NS	0.355**	-0.103NS	0.273**	-0.263*	-0.027NS	-0.227*
G/PE								0.882**	0.224*	0.100NS	0.082NS	-0.014NS	-0.048NS	0.456**	-0.033NS	0.013NS	-0.243*	0.080NS	-0.204NS	0.098NS	-0.080NS
GW/PE									0.216*	0.435**	0.370**	-0.082NS	0.207*	0.231*	0.153NS	0.015NS	0.030NS	-0.003NS	-0.057NS	0.302**	-0.206NS
GW/P										0.404**	0.380**	-0.024NS	0.364**	0.099NS	0.406**	0.325**	0.317**	0.222*	0.168NS	0.078NS	-0.366**
100GW											0.923**	-0.135NS	0.756**	-0.005NS	0.704**	0.221*	0.582**	0.109NS	0.198NS	0.439**	-0.640**
100KW												0.243*	0.766**	0.095NS	0.797**	0.329**	0.537**	0.236*	0.185NS	0.477**	-0.691**
H%													0.076NS	0.223*	0.265*	0.236*	-0.057N	0.312**	-0.117N	0.024NS	-0.247

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KLBC														-0.232*	0.845**	0.332**	0.817**	-0.061NS	0.252*	0.345**	-0.553**
KBBC															0.023NS	0.247*	-0.721**	0.453**	-0.308**	0.070NS	-0.090NS
KLAC																0.532**	0.640**	0.482**	0.187NS	0.527**	-0.463**
KBAC																	0.120NS	0.405**	0.471**	0.346**	-0.068NS
LBR																		-0.145NS	0.346**	0.290**	-0.332**
KER																			-0.113NS	0.373**	-0.005NS
BIRAC																				0.477**	0.271**
KWAC																					0.291**

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

DF: Days to 50% flowering, DM: Days to Maturity, PLH: Plant Height (cm), TM: Number of Tillers per Plant, PL: Panicle Length (cm), FLL: Flag Leaf Length (cm), FLW: Flag Leaf With (cm), G/PE: Number of Grains per Panicle, GW/PE: Grain Weight Per Panicle (g), GW/P: Grain Weight Per Plant (g), 100GW: 100 Grain Weight (g), 100 KW: 100 Kernel Weight (g), H%: Hulling (%), KLBC: Kernel Breadth Before Cooking (mm), KBBC: Kernel Breadth Before Cooking (mm), KLAC: Kernel Length After Cooking (mm), KBAC: Kernel Breadth After Cooking (mm),LBR: L:B Ratio, KER: Kernel Elongation Ratios, BIRAC: Breath Increase Ratio After Cooking, KWAC: 100 Kernel Weight After Cooking (g), WA: Water Absorb by 10 g kernel (ml).

Genotypic correlation coefficients between grain yield per plant and other quantitative characters attributing to yield showed that grain yield was significantly and positively associated with flag leaf length, 100 grain weight, 100 Kernel weight, kernel length before cooking, kernel length after cooking, kernel breadth after cooking and L:B ratio. Similar studies were conducted by Cyprien and Kumar (2011) [1]; Debnath *et al.* (2015) [2] etc. It showed significant and positive correlation with number of grains per panicle, grain weight per panicle and kernel elongation ratio while it showed significant and negative correlation with Days to maturity, hulling per cent and water observe by 10g kernel. Days to flowering exhibited highly significant and positive correlation with flag leaf breadth. Whereas days to flowering showed highly significant and negative correlation with flag leaf length, 100 grain weight and kernel length before cooking. It showed significant negative correlation with kernel length after cooking and L:B ratio. The days to maturity exhibited significant and positive correlation with number of tillers per plant, grain weight per panicle. However, it showed significant and negative correlation with flag leaf length, grain weight per plant, kernel breadth before cooking. Plant height showed significant and positive correlation with number of grains per panicle and grain weight per panicle. While it showed highly significant negative correlation with kernel length before cooking, kernel length after cooking, kernel breadth after cooking, L:B ratio, kernel elongation ratio, kernel weight after cooking and breadth increase ratio. Tillers per plant showed significant and negative correlation with kernel length after cooking. Panicle length showed highly significant and negation correlation with number of grains per panicle, kernel weight after cooking water observe by 10g kernel. It showed significant correlation with grain weight per panicle. Flag leaf length showed highly significant and positive correlation with grain weight per plant, however, it showed significant and negative correlation with kernel weight after cooking and water observe by 10g kernel. Flag leaf breadth showed highly significant positive correlation with kernel breadth before cooking, kernel breadth after cooking and kernel elongation ratio and significant and positive correlation with number of grains per panicle and grain weight per panicle. it showed significant and negative correlation with 100 water observe by kernel. Grains per panicle showed highly significant and positive correlation with grain weight per panicle, grain weight per plant and kernel breadth before cooking. While it showed highly significant and negative correlation with kernel breadth before cooking, kernel length after cooking, L:B ratio and breath increase ratio after cooking. It showed significant and negative correlation with 100 grain weight. Grain weight per panicle showed highly significant positive correlation with 100 kernel weight and kernel weight after cooking. It showed signification and positive correlation with grain yield per plant, kernel length before cooking and kernel breadth before cooking.

100 grain weight showed highly significant and positive correlation with 100 kernel weight, kernel length before cooking and kernel length after cooking, L:B ratio and 100 kernel weight after cooking while it showed highly significant and negative correlation with water absorb by 10 g kernel.100 kernel weight showed highly significant and positive correlation with kernel length before cooking, kernel length after cooking, kernel breadth after cooking, L:B ratio and 100 kernel weight after cooking. However, it showed highly significant and negative correlation with water absorb by 10 g kernel. Hulling percent exhibited significant and positive correlation with kernel breadth before cooking, kernel length after cooking, kernel breadth after cooking and kernel elongation ratio. While it showed significant and negative correlation with water observe by 10g kernel. Kernel length before cooking exhibited highly significant and positive correlation with kernel breadth after cooking, L:B ratio and kernel weight after cooking. It showed significant and positive correlation with breadth increase ratio. While it showed highly significant and negative correlation with kernel breadth before cooking and water observe by 10g kernel. Kernel breadth before cooking showed highly significant and positive correlation with kernel breadth after

cooking. However, it showed highly signification and negative correlation with L:B ratio and breadth increase ratio after cooking. Kernel length after cooking showed highly significant and positive correlation with kernel breadth after cooking, lb ratio, kernel elongation ratio and kernel weight after cooking. However, it showed significant and negation correlation with water observe by kernel. Kernel breadth after cooking showed highly significant and positive correlation with kernel elongation ratio, kernel breadth increase ratio after cooking and kernel weight after cooking. L:B ratio exhibited highly significant and positive correlation with kernel breadth increase ratio after cooking and 100 kernel weight after cooking however, it showed highly significant and negative correlation with water absorb by 10g kernel. Kernel elongation ratio showed highly significant and positive correlation with 100 kernel weight after cooking. Kernel breadth increase ratio after cooking exhibited highly significant and positive correlation with kernel weight after cooking and significant correlation with water absorb by 10g kernel. Kernel weight after cooking showed highly significant and positive correlation with kernel weight after cooking and water absorb by 10g kernel.

Genotypic correlation coefficients were of higher in magnitude than the corresponding phenotypic correlation coefficients which might be due to masking or modifying effect of environment (Sravan *et al.* 2012 and Hossain *et al.* 2015) [12, 7]. Flag leaf length, grains per panicle, 100 grain weight, L:B ratio and kernel elongation ratio manifested significant positive correlation with grain yield. Indicating that simultaneous improvement of all the characters is possible, Kumar and Verma (2015) [8], Sravan *et al.,* (2016) [13], Devi *et al.* 2017 [3] and Tripathi *et al.* (2018) [14] also reported similar findings.

Path coefficient analysis

The correlation Coefficient is insufficient to explain true relationship for an effective manipulation of the character, so that path coefficient was work out. Path-coefficient analysis using correlation coefficients at genotypic level was undertaken and the direct and indirect effect of yield contributing character on yield have been presented in Table2. Higher positive direct effect on yield was recorded for 100 grain weight followed by kernel weight after cooking, hulling%, number of grains per panicle, L:B ratio, flag leaf length, panicle length and breadth increase ratio after cooking, while higher negative direct effect on yield was recorded for 100 kernel weight, water absorb by 10g kernel, grain weight per panicle and kernel length before cooking.

Table 2: Genotypic Path Coefficient analysis showing direct (bold) and indirect effects of yield components on grain yield in basmati rice

Character	DF	DM	PLH	TM	PL	FLL	FLW	G/PE	GW/PE	100GW	100KW	H%	KLBC	KBBC	KLAC	KBAC	LBR	KER	BIRAC	KWAC	WA	CGY
DF	0.090	-0.004	0.007	0.024	-0.018	-0.167	-0.017	-0.214	0.374	-1.484	1.961	-0.210	0.302	-0.001	0.024	0.025	-0.188	0.000	0.015	-0.264	-0.387	-0.133
DM	-0.014	0.022	0.004	0.029	0.004	-0.253	-0.007	0.143	-0.243	-0.466	0.483	0.162	-0.039	0.006	0.001	-0.035	0.125	0.000	-0.005	0.236	-0.379	-0.226
PLH	-0.013	-0.002	-0.049	0.024	0.048	0.085	0.002	0.357	-0.378	-0.277	0.658	-0.057	0.264	-0.005	0.045	-0.148	-0.296	0.001	-0.106	-0.622	0.286	-0.185
TM	0.016	0.005	-0.008	0.139	-0.061	-0.091	0.002	0.260	-0.198	-0.615	0.694	0.160	0.135	-0.001	0.020	-0.064	-0.078	0.000	-0.022	0.036	-0.210	0.118
PL	-0.004	0.000	-0.006	-0.022	0.389	0.041	0.005	-0.459	0.260	0.351	-0.357	-0.031	-0.063	0.000	-0.005	-0.047	0.040	0.000	-0.051	-0.474	0.448	0.018
FLL	-0.025	-0.009	-0.007	-0.021	0.027	0.594	0.009	-0.063	0.219	0.240	-0.339	0.021	-0.101	-0.005	-0.001	-0.004	-0.047	0.000	-0.044	-0.553	0.543	0.434
FLW	0.031	0.003	0.002	-0.005	-0.038	-0.102	-0.050	0.320	-0.247	0.586	-0.899	0.241	0.058	-0.009	-0.007	0.110	-0.072	-0.001	-0.080	-0.042	0.355	0.153
G/PE	-0.014	0.002	-0.013	0.027	-0.131	-0.028	-0.012	1.363	-1.025	0.434	-0.437	-0.020	0.037	-0.013	0.003	0.004	-0.170	0.000	-0.062	0.152	0.126	0.224
GW/PE	-0.029	0.005	-0.016	0.024	-0.087	-0.112	-0.011	1.202	-1.162	1.881	-1.981	-0.119	-0.159	-0.007	-0.014	0.005	0.021	0.000	-0.017	0.469	0.322	0.216
100GW	-0.031	-0.002	0.003	-0.020	0.032	0.033	-0.007	0.137	-0.505	4.326	-4.939	-0.195	-0.579	0.000	-0.065	0.069	0.407	0.000	0.061	0.680	1.001	0.404
100KW	-0.033	-0.002	0.006	-0.018	0.026	0.038	-0.008	0.111	-0.430	3.995	-5.349	0.352	-0.586	-0.003	-0.073	0.102	0.376	-0.001	0.057	0.740	1.081	0.380
H%	-0.013	0.002	0.002	0.015	-0.008	0.008	-0.008	-0.019	0.095	-0.582	-1.298	1.450	-0.059	-0.006	-0.024	0.073	-0.040	-0.001	-0.036	0.037	0.387	-0.024
KLBC	-0.035	0.001	0.017	-0.025	0.032	0.079	0.004	-0.066	-0.241	3.269	-4.096	0.111	-0.766	0.007	-0.077	0.103	0.571	0.000	0.077	0.535	0.864	0.364
KBBC	0.004	-0.005	-0.009	0.005	-0.002	0.103	-0.015	0.621	-0.268	-0.024	-0.508	0.323	0.178	-0.029	-0.002	0.077	-0.504	-0.001	-0.094	0.108	0.140	0.099
KLAC	-0.024	0.000	0.024	-0.030	0.019	0.007	-0.004	-0.045	-0.177	3.045	-4.262	0.384	-0.647	-0.001	-0.092	0.165	0.448	-0.001	0.057	0.816	0.723	0.406
KBAC	0.007	-0.002	0.023	-0.029	-0.058	-0.008	-0.018	0.018	-0.017	0.957	-1.762	0.343	-0.255	-0.007	-0.049	0.311	0.084	-0.001	0.144	0.537	0.106	0.325
LBR	-0.024	0.004	0.021	-0.016	0.022	-0.040	0.005	-0.331	-0.035	2.516	-2.872	-0.083	-0.625	0.021	-0.059	0.037	0.700	0.000	0.106	0.450	0.520	0.317
KER	0.013	-0.002	0.013	-0.009	-0.013	-0.100	-0.014	0.109	0.004	0.471	-1.264	0.452	0.047	-0.013	-0.044	0.126	-0.101	-0.002	-0.035	0.578	0.007	0.222
BIRAC	0.005	0.000	0.017	-0.010	-0.065	-0.086	0.013	-0.277	0.066	0.858	-0.992	-0.170	-0.193	0.009	-0.017	0.146	0.242	0.000	0.306	0.740	-0.423	0.168
KWAC	-0.015	0.003	0.020	0.003	-0.119	-0.212	0.001	0.134	-0.351	1.897	-2.553	0.034	-0.264	-0.002	-0.048	0.108	0.203	-0.001	0.146	1.549	-0.455	0.078
WA	0.022	0.005	0.009	0.019	-0.112	-0.207	0.011	-0.110	0.240	-2.769	3.698	-0.359	0.423	0.003	0.042	-0.021	-0.233	0.000	0.083	0.451	-1.563	-0.366

DF: Days to 50% flowering, DM: Days to Maturity, PLH: Plant Height (cm), TM: Number of Tillers per Plant, PL: Penicle Length (cm), FLL: Flag Leaf Length (cm), FLW: Flag Leaf With (cm), G/PE: Number of Grains per Penicle, GW/PE: Grain Weight Per Penicle (g), 100GW: 100 Grain Weight (g), 100 KW: 100 Kernel Weight (g), H%: Hulling (%), KLBC: Kernel Breadth Before Cooking (mm), KBBC: Kernel Breadth Before Cooking (mm), KLAC: Kernel Length After Cooking (mm), KBAC: Kernel Breadth After Cooking (mm),LBR: L:B Ratio, KER: Kernel

Elongation Ratios, BIRAC: Breath Increase Ratio After Cooking, KWAC: 100 Kernel Weight After Cooking (g), WA: Water Absorb by 10 g kernel (ml). GW/P: Grain Weight Per Plant (g), CGY: Correlation with Grain yield.

Genotypic indirect positive effects of days to flowering on yield were recorded via 100 kernel weight, grain weight per panicle and kernel length before cooking, while it showed indirect negative effect via 100 grain weight, water absorb by 10g kernel, 100 kernel weight after cooking and number of grains per panicle. Days to maturity exerted high positive indirect effect on grain yield through 100 kernel weight, 100 kernel weight after cooking, hulling% and number of grains per panicle. However, it showed indirect negative effect on grain yield via 100 grain weight, water absorb by 10g kernel and grain weight per panicle. Plant height made high positive contribution towards grain yield via 100 kernel weight, number of grains per panicle, water absorb by 10g kernel, kernel length before cooking and flag leaf length. However, it made indirect negative effect on grain yield by 100 kernel weight after cooking, grain weight per panicle and 100 grain weight. Number of tillers per plant made high positive contribution towards grain yield through 100 kernel weight, number of grains per panicle, hulling% and kernel length before cooking, however, it showed indirect negative effect on grain yield through 100 grain weight, water absorb by 10g kernel, grain weight per panicle, flag leaf length. Panicle length caused positive effect on grain yield through water absorb by kernel, 100 grain weight, grain weight per panicle, flag leaf length, while it showed negative effect on grain yield via 100 grain weight, number of grains per panicle, water absorb by 10g kernel and kernel breadth increase ratio. Flag leaf length made high positive contribution towards grain yield via water absorb by 10g kernel, 100 grain weight and grain weight per panicle, while it showed negative effect on grain yield via 100 kernel weight after cooking, 100 kernel weight, kernel length before cooking and number of grains per panicle. Flag leaf breadth made high positive contribution towards grain yield through 100 grain weight followed by water absorb by 10g kernel, number of grains per panicle, hulling% and kernel breadth after cooking, while it made negative effect on grain yield via grain weight per panicle, flag leaf length and panicle length. Number of grains per panicle showed high positive effect on grain yield through 100 grain weight, 100 kernel weight after cooking and water absorb by 10g kernel, while it showed negative effect on grain yield through 100 kernel weight, L:B ratio and panicle length. Grain weight per panicle caused positive effect on grain yield through 100 grain weight, number of grains per panicle, 100 kernel weight after cooking and water absorb by 10g kernel. It showed negative effect on grain yield via 100 kernel weight, kernel length before cooking, hulling % and flag leaf length.100 grain weight exerted high positive indirect effect on grain yield via water absorb by 10g kernel, 100 kernel weight after cooking, L:B ratio and number of grains per panicle, while it showed negative effect on grain yield via 100 kernel weight followed by kernel length before cooking, grain weight per panicle and hulling%.

100 kernel weight exerted high positive indirect effect on grain yield through water absorb by 10g kernel followed by 100 kernel weight after cooking, hulling% and number of grains per panicle, while it showed negative indirect effect on grain yield through kernel length before cooking and grain weight per panicle. Hulling% made high positive contribution towards grain yield via water absorb by 10g kernel, kernel breadth after cooking, grain weight per panicle, kernel weight after cooking, while it showed negative effect on grain yield via 100 kernel weight and 100 grain weight. Kernel length before cooking showed high positive contribution towards grain yield via 100 grain weight followed by water absorb by 10g kernel, L:B ratio, kernel weight after cooking and hulling%, while it exhibited negative contribution towards grain yield through 100 grain weight, grain weight per panicle and kernel length after cooking. Kernel breadth before cooking caused positive effect on grain yield through number of grains per panicle, hulling%, kernel length before cooking, water absorb by 10g kernel and 100 kernel weight after cooking, while it showed negative indirect effect on grain yield through L:B ratio and grain weight per panicle. Kernel length after cooking made high positive contribution towards grain yield through 100 grain weight followed by 100 kernel weight after cooking, water absorb by 10g kernel, L:B ratio, hulling% and kernel breadth after cooking, while it showed negative effect on grain yield through 100 grain weight followed by kernel length before cooking and grain weight per panicle. Kernel breadth after cooking had indirect positive effect on grain yield via 100 kernel weight after cooking, 100 grain weight, hulling% and water absorb by 10g kernel, while it showed negative effect on grain yield via 100 kernel weight and kernel before cooking. L:B ratio exerted high positive indirect effect on grain yield via 100 grain weight, water absorb by kernel, 100 kernel weight after cooking and breadth increase ratio, while it showed negative effect on grain yield via 100 kernel weight followed by kernel length before cooking and number of grains per panicle. Kernel elongation ratio exhibited positive effect on grain yield through 100 kernel weight after cooking followed by 100 grain weight, hulling% and number of grains per panicle, while it showed negative effect on grain yield through 100 kernel weight, L:B ratio and flag leaf length. Breadth elongation ratio made high positive contribution towards grain yield through 100 grain weight, 100 kernel weight after cooking and L:B ratio, while it showed negative contribution towards grain yield through 100 kernel weight, water absorb by 10g kernel, kernel length before cooking and hulling%.100 kernel weight after cooking made high positive contribution towards grain yield via 100 grain weight followed by L:B ratio, breadth increase ratio after cooking and kernel breadth after cooking, while it showed negative contribution towards grain yield through 100 kernel weight followed by water absorb by 10g kernel, grain weight per panicle and kernel length before cooking. Water absorb by 10g kernel caused positive effect on grain yield through 100 kernel weight followed by 100 kernel weight after cooking, kernel length before cooking and grain weight per panicle, while it showed negative effect on grain yield through 100 grain weight, hulling%, L:B ratio and flag leaf length. A perusal of data revealed that 100 grain weight, 100 kernel weight after cooking, hulling%, number of grains per panicle, L:B ratio, flag leaf length, panicle length and kernel breadth increase ratio showed direct effects on correlation with yield. The results were in agreement with the previous finding of Fiyaz *et al.* (2011) [6]. Earlier reports of Kumar and Verma (2015) [8], Sravan *et al.,* (2016) [13], Devi *et al.* 2017 [3] and Tripathi *et al.* (2018) [14] also reported similar findings.

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