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Anil Kumar
Department of Agricultural Botany, R.M.P. (P.G.) College, Gurukul Narsan, Haridwar, Uttarakhand, India

Shiv Kumar
Department of Agricultural Botany, R.M.P. (P.G.) College, Gurukul Narsan, Haridwar, Uttarakhand, India

Sarvendra Singh
Department of Agricultural Entomology, R.M.P. (P.G.) College, Gurukul Narsan, Haridwar, Uttarakhand, India

Janeshwar Prasad
Department of Agricultural Botany, R.M.P. (P.G.) College, Gurukul Narsan, Haridwar, Uttarakhand, India

AS Jeena
Department of Genetics and Plant Breeding, G B Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

MC Upreti
Department of Genetics and Plant Breeding, G B Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Corresponding Author:
AS Jeena
Department of Genetics and Plant Breeding, G B Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Character association studies for morphological and quality characters in basmati rice (*Oryza sativa* L.)

Anil Kumar, Shiv Kumar, Sarvendra Singh, Janeshwar Prasad, AS Jeena and MC Upreti

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Abstract
The present study was undertaken to estimate correlation coefficients among 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. Highest significant positive genotypic as well as phenotypic correlation was found between traits 100 kernel weight and 100 grain weight whereas, highest significant negative genotypic correlation was found between characters water absorbed by 10gm kernel and 100 grain weight, whereas, highest significant negative phenotypic correlation was found between characters grain weight per plant and days to maturity. Highest significant positive phenotypic correlation was found between traits 100 kernel weight and 100 grain weight. Grain weight per plant showed highly significant positive correlation with hulling %, kernel breadth before cooking, kernel breadth after cooking, breadth increase ratio after cooking and water absorbed by 10 gm kernel; significant positive association with peduncle length and flag leaf length. These characters could be utilized as indices of selection for future breeding programme.

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

Introduction
Rice (*Oryza sativa* L.), a staple cereal crops,occupies an important place in the Indian agriculture and has been grown under diverse ecological conditions and gets exposed to different environmental stresses like salinity, alkalinity, drought, cold etc. Fiyaz *et al.* (2011) [5]. Among the rice growing countries in the world, India has the largest area under rice crop and ranks second in production next to China. 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) [11]. Information on correlation coefficients between grain yield and its component characters is essential since grain yield in rice is a complex character and is highly influenced by several component characters (Hossain *et al.* 2015) [6]. So, it becomes important to understand correlation between yield and its components for making the best use of these relationships in selection. 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. While selecting the suitable plant type, correlation studies would provide reliable information in natural extent and the direction of the selection, especially when the breeder needs to combine high yield potentials with desirable agronomic traits and grain quality characters. 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. The correlations among the characters give the plant breeder an idea about the direct or indirect effect of one character on the other characters. Keeping the above facts in mind, the objective of this study is to elucidate correlation among the various morphological and quality traits of aromatic rice grown under rainfed environments in order to aid the effective selection for successful breeding program.

Materials and Methods

The present investigation was conducted at Research farm of R.M.P. P.G. College, Gurukul Narsan, Haridwar (Uttarakhand) with 30 improved genotypes of aromatic 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 m^2 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) [10] 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 [12]. The estimated values were compared with table values of correlation coefficient to test the significance of correlation coefficient prescribed by Fisher and Yates (1967) [4].

Results and Discussion

Correlation coefficient is another fundamental tool showing relationships among independent characteristics (Sravan *et al*. 2012) [13]. The values of genotypic and phenotypic correlation coefficients are presented in the Table1.

The results revealed that the extent of genotypic correlation coefficients was higher than their phenotypic correlation coefficients indicating absence of environmental effects that enhanced genetic inherent associations (Sravan *et al*. 2012 and Hossain *et al*. 2015) [13, 6]. Hence here we are discussing the association of the morphological and quality characters of aromatic rice at genotypic level only. Grain weight per plant showed highly significant positive correlation with hulling %, kernel breadth before cooking, kernel breadth after cooking, breadth increase ratio after cooking and water absorbed by 10 gm kernel; significant positive association with peduncle length and flag leaf length and significantly negative correlation with days to flowering and 100 grain weight. Days to flowering exhibited highly significant positive correlations with days to maturity and number of tillers per plant; highly significant negative correlations with grain weight per panicle, 100 kernel weight, hulling % and 100 kernel weight after cooking; and significantly negative correlation with number of grains per panicle, grain weight per plant, 100 grain weight kernel length before cooking and kernel length after cooking. Days to maturity shared significant positive correlation with flag leaf width; highly significant negative correlation with water absorbed by 10 gm kernel; and significantly negative correlation with flag leaf length, hulling % and 100 kernel weight after cooking. Plant height showed significantly positive correlation with number of tillers per plant, flag leaf width and grain weight per panicle; highly significant negative correlation with hulling %, kernel breadth before cooking, kernel breadth after cooking and 100 kernel weight after cooking; and significantly negative correlation with L.B. Ratio. Number of tillers per plant showed highly significant positive correlation with100 grain weight, 100 kernel weight, kernel length after cooking and kernel elongation ratio; highly significant negative correlation with peduncle length, flag leaf length, number of grains per panicle, hulling %, kernel breadth after cooking, breadth increase ratio after cooking and water absorbed by 10 gm kernel. Peduncle length exhibited highly significant positive correlation with flag leaf width, hulling % and water absorbed by 10gm kernel; significantly positive correlations with grain weight per plant, kernel breadth after cooking, breadth increase ratio after cooking; and highly significant negative with 100 grain weight and 100 kernel weight. Flag leaf length accrued highly significant positive correlation with number of grains per panicle and kernel breadth before cooking; significantly positive correlations with grain weight per panicle and grain weight per plant; highly significant negative correlations with kernel length after cooking, L.B. Ratio and kernel elongation ratio; and significantly negative with 100 kernel weight, hulling %, breadth increase ratio after cooking and 100 kernel weight after cooking. Flag leaf width showed highly significant positive correlation with kernel elongation ratio; significantly positive correlation with number of grains per panicle and hulling %; highly significant negative correlation with 100 grain weight, kernel length before cooking and kernel breadth before cooking and 100 kernel weight after cooking; and significantly negative with 100 kernel weight and L.B. Ratio.

Number of grains per panicle showed highly significant positive correlation with grain weight per panicle; significantly positive correlation with water absorbed by 10 gm kernel; highly significant negative with 100 grain weight, 100 kernel weight, kernel length before cooking, kernel length after cooking and 100 kernel weight after cooking; and significantly negative with L.B. Ratio. Grain weight per panicle exhibited highly significant negative correlation with hulling %, kernel breadth after cooking, breadth increase ratio after cooking and water absorbed by 10 gm kernel; and significantly negative correlation with kernel length after cooking. Grain weight per plant showed highly significant positive correlation with hulling %, kernel breadth before cooking, kernel breadth after cooking, breadth increase ratio after cooking and water absorbed by 10 gm kernel; significant positive association with peduncle length and flag leaf length and significantly negative correlation with days to flowering and 100 grain weight. 100 grain weight exhibited highly significant positive correlation with 100 kernel weight, kernel length before cooking, kernel length after cooking, kernel breadth before cooking and 100 kernel weight after cooking; highly significant negative correlation with hulling %, kernel breadth after cooking, breadth increase ratio after cooking and water absorbed by 10gm kernel; and significantly positive correlation with kernel elongation ratio. 100 kernel weight showed highly significant positive correlation with kernel length before cooking, kernel length after cooking, kernel elongation ratio and 100 kernel weight after cooking; and highly significant negative correlation with hulling %.

Hulling % accrued highly significant positive correlation with kernel breadth after cooking, breadth increase ratio after cooking, 100 kernel weight after cooking and water absorbed by 10gm kernel. Kernel length before cooking showed highly significant positive correlation with kernel length after cooking, L.B. ratio and 100 kernel weight after cooking; and highly significant negative correlation with kernel elongation ratio. Kernel breadth before cooking exhibited highly significant correlation with 100 kernel weight after cooking; highly significant negative correlation with L.B. ratio and breadth increase ratio after cooking; and significantly negative correlation with kernel elongation ratio. Kernel length after cooking shared highly significant positive correlation with L.B. ratio, kernel elongation ratio and 100 kernel weight after cooking; highly significant negative correlation with water absorbed by 10 gm kernel; and significantly negative correlation with kernel breadth after cooking. Kernel breadth after cooking showed highly positive correlation with breadth increase ratio after cooking and water absorbed by 10 gm kernel; and significantly negative correlation with kernel elongation ratio. L.B. ratio exhibited highly significant positive correlation with breadth increase ratio after cooking; significantly positive correlation with 100 kernel weight after cooking; and significantly negative correlation with kernel elongation ratio. Kernel elongation ratio showed highly significant negative correlation with water absorbed by 10 gm kernel. Breadth increase ratio after cooking exhibited highly significant positive correlation with water absorbed by 10gm kernel; and significantly positive correlation with 100 kernel weight after cooking. Similar findings were also reported by Kumar and Verma (2015) [8], Sravan *et al.* (2016) [14], Devi *et al*. 2017 [3] and Tripathi *et al.* (2018) [15].

Highest significant positive genotypic andphenotypic correlation was found between traits 100 kernel weight and 100 grain weight, whereas, highest significant negative genotypic correlation was found between characters water absorbed by 10gm kernel and 100 grain weight while highest significant negative phenotypic correlation was found between characters grain weight per plant and days to maturity. Similar studies were conducted by Cyprien and Kumar (2011); Debnath *et al*. (2015) [2] etc. The negative and significant correlation between grain weight per plant and 100-grain weight was in accordance with the previous findings by Islam *et al*. 2016. Improvement in 100-grain weight character will lead to reduction of the grain weight per plant (yield) or alteration in the days to flowering. The above statement is fully supported by report from Newell and Eberhart (1961) [9], who described the situation when two characters show negative genotypic correlation it would be hard to apply simultaneous selection for these characters for development of a new variety. Therefore, judicious selection programme might be designed for simultaneous improvement of such component characters. The significant and positive correlation of the traits reflected that selection for one trait would directly affect the expression of other trait facilitating the selection and progress on breeding program. We found very similar findings in this study very consistent with the results from previous works in rice Hossain *et al.* 2015 [6].

Table 1: Phenotypic (Upper diagonal) and Genotypic (Lower Diagonal) Correlation coefficients among yield and different yield components and quality parameters in aromatic rice.

	DF	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	1.00	0.24*	0.12	0.29**	-0.02	0.45**	0.09	-0.19*	-0.32**	-0.22*	-0.22*	-0.33**	-0.21*	-0.24*	-0.32**	-0.24*	-0.14	0.13	-0.07	-0.13	-0.53**	0.00
DM	0.25**	1.00	0.12	0.05	0.18	-0.21*	0.21*	-0.17	-0.03	-0.86**	0.13	0.07	-0.13	-0.17	0.02	-0.07	0.00	-0.11	0.09	-0.13	-0.21*	-0.26**
PLH	0.12	0.12	1.00	0.21*	0.17	0.18	0.21*	0.18	0.20*	0.03	-0.04	-0.15	-0.25**	-0.02	-0.26**	-0.10	-0.36**	0.21*	-0.06	-0.19*	-0.36**	-0.10
TM	0.31**	0.05	0.22*	1.00	-0.43**	-0.06	0.01	-0.36**	-0.03	-0.15	0.59**	0.45**	-0.53**	0.02	0.06	0.39**	-0.44**	-0.06	0.41**	-0.43**	-0.12	-0.58**
PL	-0.02	0.18	0.17	-0.43**	1.00	0.28**	0.11	0.04	0.21*	-0.35**	-0.34**	0.34**	0.19*	-0.13	-0.08	-0.15	0.19*	-0.05	0.01	0.19*	0.03	0.37**
FLL	0.04	-0.21*	0.18	-0.60**	0.11	1.00	0.04	0.33**	0.27**	0.23*	-0.12	-0.22*	-0.16	-0.15	0.23*	-0.34**	-0.09	-0.28**	-0.24*	-0.21*	-0.21*	0.13
FLW	0.10	0.22*	0.21*	-0.01	0.29**	0.04	1.00	0.26**	0.15	0.16	-0.23*	-0.19*	0.14	-0.53**	-0.21*	-0.17	-0.08	-0.19*	0.35**	0.00	-0.31**	-0.01
G/PE	-0.20*	-0.17	0.18	-0.37**	0.11	0.33**	0.28*	1.00	0.82**	0.10	-0.35**	-0.37**	-0.09	-0.38**	-0.01	-0.52**	-0.18	-0.21*	-0.18	-0.15	-0.29**	0.26**
GW/PE	-0.33**	-0.03	0.21*	-0.04	0.03	0.28*	0.18	0.83**	1.00	0.09	0.16	0.77**	-0.16	-0.15	0.12	-0.19*	-0.32**	-0.17	-0.01	-0.32**	-0.06	-0.11
GW/P	-0.23*	-0.08	0.03	-0.15	0.22*	0.24*	0.17	0.12	0.09	1.00	-0.19*	-0.14	0.18	-0.12	0.06	0.09	0.39**	-0.12	0.07	0.29**	0.16	0.24*
100GW	-0.22*	0.13	-0.05	0.60**	-0.35**	-0.12	-0.25**	-0.36**	0.17	-0.20*	1.00	0.93**	-0.39**	0.35**	0.32**	0.51**	-0.32**	-0.03	0.23*	-0.41**	0.34**	-0.79**
100KW	-0.34**	-0.08	-0.16	0.49**	-0.36**	-0.22*	-0.24*	-0.40**	0.08	-0.15	0.97**	1.00	-0.06	0.35**	0.33**	0.52**	-0.12	-0.04	0.24*	-0.24*	0.47**	-0.79**
H%	-0.34**	-0.19*	-0.41**	-0.82**	0.33**	-0.22*	0.19*	0.15	-0.26**	0.31**	-0.66**	-0.47**	1.00	-0.06	-0.06	-0.11	0.49**	0.00	-0.05	0.48**	0.23*	0.19*
KLBC	-0.24*	-0.17	-0.02	0.02	-0.13	-0.15	-0.55**	-0.38**	-0.16	-0.12	0.35**	0.35**	-0.14	1.00	0.04	0.53**	-0.01	0.64**	-0.40**	-0.01	0.57**	-0.01
KBBC	-0.03	0.03	-0.29**	0.06	-0.08	0.27**	-0.26**	-0.01	0.12	0.63**	0.34**	0.36**	-0.11	0.04	1.00	-0.14	0.05	-0.72**	-0.21*	-0.45**	0.26**	-0.17
KLAC	-0.24*	-0.07	-0.11	0.40**	-0.15	-0.35**	-0.18	-0.53**	-0.19*	-0.09	0.52**	0.55**	-0.17	0.55**	-0.16	1.00	-0.22*	0.41**	0.54**	-0.13	0.48**	-0.21*
KBAC	-0.14	0.00	-0.37**	-0.47**	0.19*	-0.10	-0.08	-0.17	-0.33**	0.39**	-0.33**	-0.14	0.79**	-0.01	0.05	-0.22*	1.00	-0.03	-0.19*	0.86**	0.36**	0.35**
LBR	-0.15	-0.12	-0.22*	-0.06	-0.06	-0.32**	-0.22*	-0.22*	-0.16	-0.13	-0.03	-0.04	-0.14	0.69**	-0.69**	0.44**	-0.04	1.00	-0.17	0.34**	0.18	0.14
KER	-0.07	0.09	-0.06	0.42**	0.01	-0.25**	0.36**	-0.18	-0.01	0.07	0.23*	0.27**	-0.05	-0.40**	-0.23*	0.55**	-0.19*	-0.19*	1.00	-0.09	-0.01	-0.30**
BIRAC	-0.13	-0.01	-0.19	-0.47**	0.19*	-0.23*	0.01	-0.14	-0.33**	0.31**	-0.43**	-0.27**	0.77**	-0.01	-0.41**	-0.14	0.88**	0.29**	-0.09	1.00	0.19*	0.36**
KWAC	-0.55**	-0.21*	-0.37**	-0.13	0.03	-0.22*	-0.34**	-0.31**	-0.07	0.17	0.35**	0.49**	0.36**	0.59**	0.29**	0.49**	0.36**	0.19*	0.00	0.19*	1.00	0.15
WA	-0.01	-0.28**	-0.11	-0.67**	0.39**	0.13	0.02	0.28*	-0.30**	0.26**	-0.85**	-0.71	0.77**	0.00	-0.17	-0.31**	0.39**	0.15	-0.34**	0.40**	0.14	1.00

* 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 (gm), 100 KW: 100 Kernel Weight (gm), 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:BRatio, KER: Kernel Elongation Rations, BIRAC: Breath Increase Ratio After Cooking, KWAC: 100 Kernel Weight After Cooking (g), WA: Water Absorb by 10 gm kernel (ml).

Conclusion

Grain weight per plant showed highly significant positive correlation with hulling %, kernel breadth before cooking, kernel breadth after cooking, breadth increase ratio after cooking and water absorbed by 10 gm kernel. Moreover, these quality parameters are significantly and positively associated with each other and 100 kernel weight after cooking. Grain weight per plant further exhibited significant positive association with morphological characters such as peduncle length and flag leaf length and these characters showed significant positive correlation with flag leaf width, grains per panicle and grain weight per panicle. These findings suggest that selection based on morphological characters such as peduncle length, flag leaf length, flag leaf width, grains per panicle and grain weight per panicle will resulted in enhancement of grain weight per plant (yield) and quality parameters *viz*., hulling %, kernel breadth before cooking, kernel breadth after cooking, breadth increase ratio after cooking,100 kernel weight after cooking and water absorbed by 10 gm kernel. Therefore, It could be concluded from present investigation that these morphological characters would be utilized as selection indices for enhancement of yield and quality in aromatic rice.

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