The Andhra Agric. J 68 (2): 172-181, 2021

Correlation Coefficient Analysis for Yield Enhancing Traits and Lodging Parameters in Rice (*Oryza sativa* L.) Genotypes

Bincy Babu Thomas, M Girija Rani, J Dayal Prasad Babu and Sk Nafeez Umar
Andhra Pradesh Rice Research Institute, Maruteru, A. P.

ABSTRACT

Thirty two elite rice lines (*Oryza sativa* L.) were evaluated during *Kharif* 2017-18 to study the nature and extent of correlation among yield enhancing and lodging related traits like plant height, tiller angle, ear bearing tillers per plant, flag leaf width, flag leaf length, days to 50 % flowering, number of grains per panicle, spikelet fertility, 1000 grain weight, panicle length, grain yield per plant, staygreenness of flag leaf, harvest index, culm diameter, culm thickness, basal internodal length, per cent of lodging, culm strength, bending strength. Character association studies revealed that the character grain yield per plant showed significant positive association with plant height, tiller angle, 1000-grain weight, harvest index, basal internodal length at both phenotypic and genotypic levels. Percent of lodging expressed positive significant genotypic association with plant height and basal internodal length. This indicated that simultaneous selection of all these characters was important for yield enhancement and lodging tolerance.

Keywords: *correlation,Grain yield, yield components, lodging,*

Rice being a staple food crop worldwide, several attempts are being carried out for breaking the yield saturation points in rice breeding. In the present scenario where the environmental constraints play a major role, the traits that enhance yield should be prioritized along with the lodging parameters as in the coastal areas unpredicted cyclonic rains at reproductive phase lead to drastic reduction of yield. As crop yield is the end product of the interaction of a number of other interrelated attributes, a thorough understanding of the interaction of characters among themselves had been of great use in plant breeding. If the selection is considering yield alone, high genotype and environment interaction will restrict improvement. The effective improvement in yield may be brought about through selection on yield component characters. With the help of correlation studies, it is possible to have a correct idea of the association between any two characters considered, particularly the strength of relationship and if there are any possible connections between the traits. The aim of correlation studies is primarily to know the suitability of various characters for indirect selection because any particular trait may bring about undesirable changes in other associated characters (Singh, 1998). It is important in plant breeding as it can be useful in indirect selection (Maxwell *et al*., 2019).

Yield is a complex character influenced by adverse weather parameters. Selection of high yielding, lodging resistant genotypes is a major challenge in the present scenario of climatic changed conditions. Understanding the relationship between yield and lodging related traits is of paramount importance for making the best use of these relationships in selection of non lodging high yielding genotypes. The present study was, therefore, undertaken to understand the character association for yield and lodging related parameters among 32 entries of rice.

MATERIAL AND METHODS

The present study comprised of 32 genetically diverse genotypes of rice (*Oryza sativa* L.). The experiment was carried out at Regional Agricultural Research Station (RARS), Maruteru, West Godavari district of Andhra Pradesh during *Kharif* 2017-18. The experimental trial was laid out in Randomized Complete Block design with two replications under irrigated conditions. Data on the basis of 5 randomly taken plants excluding borders were recorded on plant height, tiller angle, ear bearing tillers per plant, flag leaf width, flag leaf length, days to 50 % flowering, number of grains per panicle, spikelet fertility, 1000-grain weight, panicle length, grain yield per plant, staygreenness of flag leaf, harvest index, culm diameter, culm thickness, basal internodal length, per cent of lodging, culm strength, bending strength were recorded on plot basis. Culm diameter and thickness was measured at 4^{th} internode from the top at 20 days after heading using vernier calipers and expressed in millimeters (mm). Basal internodal length between 4 and 5 nodes from the top was measured and expressed in cm. Culm strength at the maturity stage was rated based on the inclination of the tillers as per the SES of IRRI, 2013 by pushing hill forward and back for few times at maturity.

Scale (plants lodged)

1 Strong (no bending)

3 Moderately strong (most plants bending)

5 Intermediate (Most plants moderately bending)

7 Weak (most plants nearly flat)

9 very weak (all plants are flat)

It was measured by pushing hill at 20 cm above the ground at 45^0 angle using Prostrate tester and it was expressed in g/stem using the following formula as per Bhagat *et al*. (2011).

Bending strength = [(Test reading/40) X (1000/ number of tillers)]

Lodging incidence was determined as per cent ratio of plants lodged as per IRRI, 2013 standard evaluation system (SES) under natural conditions at maturity stage. Genotypic and phenotypic correlation coefficients for all the possible comparisons were computed as per the formulae suggested by Falconer (1964).

RESULTS AND DISCUSSION

Grain yield per plant showed significant and positive genotypic association with plant height (0.258*), tiller angle (0.323**), 1000-grain weight (0.267*), harvest index (0.360**), basal internodal length (0.285*). Indirect selection for genotypes with moderate plant height (120-130 cm), moderate tiller angle, greater harvest index would help in realization of higher yield by virtue of its positive genotypic association with grain yield plant^{-1}. The results were in similarity with Budak *et al*. (1999), Islam *et al.* (2016) for harvest index and Ramesh *et al.* (2018), Reddy *et al*. (2018) for plant height.

Plant height showed positive significant genotypic association with days to 50 % flowering (0.455**), flag leaf width (0.382**), flag leaf length (0.283*), panicle length (0.271*), 1000-grain weight (0.377), grain yield per plant (0.258*), culm diameter (0.522**), culm thickness (0.536**), basal internodal length (0.934*), per cent of lodging (-0.498**) and culm strength (0.413**) and significant negative association with spikelet fertility (-0.512**). These results indicated that increase in plant height results in large source for photosynthesis and sink in terms of large panicles, grain yield, wider and thicker culms but lowered the spikelet fertility rates. Resistance to lodging is entirely influenced by plant height and basal internodal length. Semi-dwarf varieties in rice decreased their internode length, which then improved their tolerance to lodging (Shah *et al.,* 2019). Indirect selection for genotypes with moderate plant height (120-130 cm), lesser basal internodal length, wider and thicker culm results in realization of lodging resistant plants with higher yield and this was reflected in terms of its positive association with per cent of lodging, basal internodal length, culm thickness. Thus lower per cent of lodging is desirable for selection of lodging resistant lines. These results were in accordance with Ramesh *et al.* (2018) for panicle length, Pandey *et al.* (2018) for 1000 grain weight, Sanju *et al.* (2019) for grain yield per plant.

Per cent of lodging expressed positive significant genotypic association with plant height (0.453**), basal internodal length (0.478**) and negative significant genotypic association with spikelet fertility (-0.0387**). Results as per the correlation matrix attribute that the lodging tendency of genotypes is associated with increased basal internodal length, taller plant height and ultimately affecting the spikelet fertility percentage. Careful Selection for non lodging genotypes with minimal basal internode and moderate plant height would be effective for crop improvement as it would contribute to more number of fertile spikelets. The results were in accordance with Girijarani and Satyanarayana (2018), Laza *et al.* (2014) and Liang *et al.* (2014) for plant height.

Tiller angle exhibited positive significant association with days to 50 % flowering (0.255*), grain yield plant^{-1} (0.323**) and harvest index (0.407**) and negative significant association with bending strength (-0.377**) at both genotypic and phenotypic levels. The above results revealed that increase in tiller angle evolve genotypes with higher duration of crop, grain yield plant^{-1} and harvest index but may lead to reduction in bending strength. Optimizing the tiller angle *ie*., to produce a moderately compact growth habit in rice lines is indeed needed in the breeding programs (Yang *et al.,* 2008) . Indirect selection of genotypes with moderate tiller angle can be considered for crop improvement programme by virtue of its positive association with yield.

Days to 50% flowering exhibited positive significant association with ear bearing tillers plant^{-1} (0.259**), culm diameter (0.300*), culm thickness (0.559**), basal internodal length (0.411**) and negative significant association with spikelet fertility % (-0.376**). Selection of long duration lines would be desirable as it increased the number of ear bearing tillers plant^{-1}, spikelet fertility. Above pattern of results were identical to the reports of Afrin *et al.* (2017), Ramesh *et al.* (2018) for ear bearing tillers plant^{-1} and spikelet fertility.

Ear bearing tillers plant^{-1} exhibited positive genotypic significant association with days to 50 % flowering (0.259*), flag leaf width (0.390**), culm thickness (0.282*) and negative significant association with flag leaf length (-0.323**), panicle length (-0.253*), bending strength (-0.924**). These results revealed that the genotypes with more ear bearing tillers plant^{-1} had longer duration, more flag leaf width, culm thickness and less flag leaf length, panicle length and bending strength. Above pattern of results were identical to the findings of Ashok *et al.* (2016) for days to 50 % flowering and panicle length.

Flag leaf width showed positive significant genotypic association with plant height (0.382**), ear bearing tillers (0.390**), filled grains per panicle (0.462**), culm diameter (0.386**), culm thickness (0.364**), basal internodal length (0.399**) and negative significant genotypic association with stay-greenness of flag leaf (-0.307*). Selection of genotypes with broader leaf may attribute to enhanced productive tiller number and maximum grain filling.

Similar results were revealed by earlier workers Akinwale *et al.* (2012) for plant height, Gautam *et al.* (2018) for 1000 grain weight.

Flag leaf length showed positive significant genotypic association with plant height (0.283**), panicle length (0.521**), bending strength (0.349**) and exhibited negative significant genotypic association with ear bearing tillers plant^{-1} (-0.323**) and stay-greenness of flag leaf (-0.258*). Results imply that selection of genotypes with greater flag leaf length increases more surface area of leaf for photosynthesis to occur resulting in higher yields by increasing plant height, panicle length. Similar trend of results were reported by Aditya *et al.* (2013) for panicle length, plant height in normal situations. Seesang *et al.* (2013) and Reddy *et al.* (2013) reported similar results for panicle length.

Panicle length exhibited positive genotypic significant association with plant height (0.0.271*), flag leaf length (0.521**), 1000-grain weight (0.246*), bending strength (0.252*), basal internodal length (0.267*) and negative significant association with harvest index (-0.353**). Results revealed that exploitation of lines with longer panicles would be useful as it would evolve genotypes with greater flag leaf length, 1000-grain weight reflecting finally on the yield. Above pattern of results were similar to the reports of Aparajita *et al.* (2015), Islam *et al.* (2016), Bharadwaj *et al.* (2017), Ramesh *et al.* (2018) for 1000-grain weight.

Number of filled grains panicle^{-1} exhibited positive significant genotypic association with harvest index (0.323**), flag leaf width (0.462**). Bharadwaj *et al.* (2012) worked out the importance of flag leaf in providing photosynthates to the filling grain. Selection for genotypes with wider flag leaf would contribute more filled grains panicle^{-1} inturn rewarding improved harvest index.

Spikelet fertility showed negative significant association with plant height (-0512**), days to 50 % flowering (-0.376**), grain yield (-0.362**), staygreenness of flag leaf (-0.393**), culm diameter (-0.401**), culm thickness (-0.592**), percent of lodging (-0.387**). The results can be attributed as increased plant height, greater percent of lodging, more number of days to 50 % flowering may reduce the spikelet fertility %. Indirect selection of non lodging genotypes of short to medium duration with moderate plant height may lead to increased spikelet fertility %. Similar reports were observed by Sravan *et al.* (2012) for days to 50 % flowering, Aparajita *et al.* (2015) for plant height.

1000 grain weight showed positive significant association with grain yield plant^{-1} (0.267*). Results imply that an increase in 1000 grain weight increases grain yield plant^{-1}. Indirect selection of genotypes with high 1000 grain weight would be rewarding as it may give rise to higher grain yields. Above pattern of results were revealed by Ramesh *et al.* (2018), Pandey *et al.* (2018), Ganapati *et al.* (2014), Seesang *et al.* (2013) for grain yield plant^{-1}.

Stay-greenness of flag leaf (SPAD value) exhibited positive significant genotypic association with harvest index (0.279*) and negative significant association with flag leaf width (-0.307**), flag leaf length (0.258**), spikelet fertility % (-0.393**) and 1000 grain weight (-0.387**). The above results revealed that increase in stay-greenness of flag leaf (SPAD value) improves the harvest index. Selection of genotypes with greater SPAD value would be effective as it had expressed a positive significant genotypic association with harvest index. Similar pattern of results were noticed by Rathore *et al.* (2016) for flag leaf length and Jing *et al.* (2000) for harvest index.

Table 1. Estimates of phenotypic and genotypic correlation coefficients among yield and lodging related traits in rice

		PH	TA	DFF	EBT	FLW	FLL	PL	FG	SF	TGW	GY	STG	HI	CD	CT	BIL	LOD	CS	BS
PH	P	1.000																		
	G	1.000																		
TA	P	0.007^{NS}	1.000																	
	G	-0.001^{NS}	1.000																	
DFF	P	0.441^{**}	0.247^{*}	1.000																
	G	0.455^{**}	0.255^{*}	1.000																
EBT	P	0.123^{NS}	0.195^{NS}	0.252^{*}	1.000															
	G	0.126^{NS}	0.198^{NS}	0.259^{*}	1.000															
FLW	P	0.378^{**}	0.036^{NS}	0.232^{NS}	0.378^{**}	1.000														
	G	0.382^{**}	0.039^{NS}	0.230^{NS}	0.390^{**}	1.000														
FLL	P	0.282^{*}	-0.064^{NS}	0.184^{NS}	-0.287^{*}	0.095^{NS}	1.000													
	G	0.283^{*}	-0.069^{NS}	0.181^{NS}	-0.323^{**}	0.094^{NS}	1.000													
PL	P	0.264^{*}	-0.110^{NS}	0.133^{NS}	-0.247^{*}	0.051^{NS}	0.454^{**}	1.000												
	G	0.271^{*}	-0.121^{NS}	0.144^{NS}	-0.253^{*}	0.061^{NS}	0.521^{**}	1.000												
FG	P	0.115^{NS}	0.167^{NS}	0.153^{NS}	0.046^{NS}	0.437^{**}	-	-0.019^{NS}	1.000											
	G	0.109^{NS}	0.186^{NS}	0.152^{NS}	0.046^{NS}	0.462^{**}	-	-0.014^{NS}	1.000											
SF	P	-0.454^{**}	-0.057^{NS}	-0.327^{**}	0.078^{NS}	0.094^{NS}	-	-0.160^{NS}	0.157^{NS}	1.000										
	G	-0.512^{**}	-0.051^{NS}	-0.376^{**}	0.107^{NS}	0.113^{NS}	-	-0.228^{NS}	0.168^{NS}	1.000										
TGW	P	0.366^{**}	0.098^{NS}	0.018^{NS}	0.035^{NS}	0.227^{NS}	0.235^{NS}	0.223^{NS}	-0.220^{NS}	-0.111^{NS}	1.000									
	G	0.377^{**}	0.100^{NS}	0.018^{NS}	0.031^{NS}	0.227^{NS}	0.242^{NS}	0.246^{*}	-0.245^{NS}	-0.119^{NS}	1.000									
GY	P	0.250^{*}	0.308^{*}	0.229^{NS}	0.065^{NS}	0.209^{NS}	0.008^{NS}	-0.135^{NS}	0.114^{NS}	-0.243^{NS}	0.249^{*}	1.000								
	G	0.258^{*}	0.323^{**}	0.229^{NS}	0.057^{NS}	0.223^{NS}	0.020^{NS}	-0.155^{NS}	0.132^{NS}	-0.362^{**}	0.267^{*}	1.000								

Note: *- Significant at 5% level of significance, **- Significant at 1% level of significance.

		PH	TA	DH	EBT	FLW	FLL	PL	FG	SF	TGW	GY	STG	HI	CD	CT	BIL	LOD	CS	BS
STG	P	-0.100^{NS}	0.064^{NS}	0.160^{NS}	-0.068^{NS}	-0.301*	-0.260*	-0.185^{NS}	0.022^{NS}	-0.331**	-0.368**	-0.126^{NS}	1.000							
	G	-0.133^{NS}	0.062^{NS}	0.181^{NS}	-0.069^{NS}	-0.307*	-0.258*	-0.242^{NS}	0.047^{NS}	-0.393**	-0.387**	-0.166^{NS}	1.000							
HI	P	-0.016^{NS}	0.303*	-0.006^{NS}	0.130^{NS}	0.028^{NS}	-0.152^{NS}	-0.259*	0.198^{NS}	0.099^{NS}	-0.235^{NS}	0.379**	0.210^{NS}	1.000						
	G	0.003^{NS}	0.407**	-0.030^{NS}	0.176^{NS}	0.052^{NS}	-0.211^{NS}	-0.353**	0.323**	0.027^{NS}	-0.308*	0.360**	0.279*	1.000						
CD	P	0.506**	0.132^{NS}	0.290*	0.046^{NS}	0.377**	0.161^{NS}	0.108^{NS}	0.134^{NS}	-0.353**	0.321**	0.148^{NS}	0.068^{NS}	-0.035^{NS}	1.000					
	G	0.522**	0.143^{NS}	0.300*	0.067^{NS}	0.386**	0.183^{NS}	0.132^{NS}	0.142^{NS}	-0.384**	0.328**	0.151^{NS}	0.071^{NS}	-0.062^{NS}	1.000					
CT	P	0.504**	0.077^{NS}	0.539**	0.250*	0.353**	0.095^{NS}	0.059^{NS}	0.058^{NS}	-0.372**	0.206^{NS}	0.167^{NS}	0.118^{NS}	-0.142^{NS}	0.829**	1.000				
	G	0.536**	0.077^{NS}	0.559**	0.282*	0.364**	0.121^{NS}	0.064^{NS}	0.074^{NS}	-0.401**	0.211^{NS}	0.192^{NS}	0.139^{NS}	-0.164^{NS}	0.845**	1.000				
BIL	P	0.893**	-0.001^{NS}	0.408**	-0.093^{NS}	0.388**	0.223^{NS}	0.245^{NS}	0.136^{NS}	-0.530**	0.264*	0.271*	0.002^{NS}	-0.019^{NS}	0.487**	0.461**	1.000			
	G	0.934**	-0.006^{NS}	0.411**	-0.110^{NS}	0.399**	0.241^{NS}	0.267*	0.154^{NS}	-0.592**	0.270*	0.285*	0.001^{NS}	-0.036^{NS}	0.518**	0.485**	1.000			
LOD	P	0.440**	-0.062^{NS}	-0.032^{NS}	0.006^{NS}	-0.040^{NS}	-0.002^{NS}	0.185^{NS}	-0.079^{NS}	-0.348**	0.010^{NS}	0.028^{NS}	0.084^{NS}	-0.111^{NS}	-0.171^{NS}	-0.108^{NS}	0.469**	1.000		
	G	0.453**	-0.062^{NS}	-0.032^{NS}	0.008^{NS}	-0.040^{NS}	-0.005^{NS}	0.196^{NS}	-0.088^{NS}	-0.387**	0.009^{NS}	0.037^{NS}	0.096^{NS}	-0.140^{NS}	-0.177^{NS}	-0.111^{NS}	0.478**	1.000		
CS	P	0.409**	0.057^{NS}	0.012^{NS}	0.146^{NS}	-0.079^{NS}	0.007^{NS}	0.176^{NS}	-0.185^{NS}	-0.211^{NS}	0.018^{NS}	0.112^{NS}	-0.065^{NS}	0.055^{NS}	-0.196^{NS}	-0.142^{NS}	0.321**	0.810**	1.000	
	G	0.413**	0.058^{NS}	0.015^{NS}	0.142^{NS}	-0.081^{NS}	-0.011^{NS}	0.197^{NS}	-0.232^{NS}	-0.242^{NS}	0.018^{NS}	0.141^{NS}	-0.068^{NS}	0.095^{NS}	-0.203^{NS}	-0.137^{NS}	0.331**	0.821**	1.000	
BS	P	-0.070^{NS}	-0.370**	-0.192^{NS}	-0.909**	-0.392**	0.322**	0.239^{NS}	-0.180^{NS}	-0.040^{NS}	-0.080^{NS}	-0.087^{NS}	0.005^{NS}	-0.104^{NS}	-0.065^{NS}	-0.208^{NS}	0.072^{NS}	0.025^{NS}	-0.018^{NS}	1.000
	G	-0.060^{NS}	-0.377**	-0.211^{NS}	-0.924**	-0.414**	0.349**	0.252*	-0.220^{NS}	-0.049^{NS}	-0.081^{NS}	-0.080^{NS}	0.006^{NS}	-0.145^{NS}	-0.084^{NS}	-0.237^{NS}	0.085^{NS}	0.024^{NS}	0.002^{NS}	1.000

PH- Plant height, TA- Tiller angle, DFF- Days to 50% flowering, EBT- Ear bearing tillers, FLW- Flag leaf width, FLL- Flag leaf length, PL- Panicle length, FG- No. of filled grains per panicle, SF- Spikelet fertility, TGW- 1000 grain weight, GY- Grain yield per plant, STG- Stay-greenness of flag leaf, HI- Harvest index, CD- Culm diameter, CT- Culm thickness, BIL- Basal internodal length, LOD- Percent of lodging, CS- Culm strength, BS- Bending strength.

Note: *- Significant at 5% level of significance, **- Significant at 1% level of significance.

Harvest index showed positive significant genotypic association with tiller angle (0.407**), filled grains per panicle (0.323), stay-greenness (0.279*), grain yield plant^{-1} (0.360*) and negative significant genotypic association with 1000-grain weight (-0.308*) and panicle length (-0.353*). These results indicate that increase in harvest index results in large source for photosynthesis and sink in terms of more filled grains per panicle, stay-greenness of flag leaf ultimately higher grain yields. An increase in the harvest index result in an increase in grain yield (Qin *et al*., 2013). Indirect selection of genotypes with higher harvest index would give rise to higher grain yields. The results were in accordance with Jing *et al.* (2000) for stay-greenness of flag leaf and Budak *et al*. (1999), Islam *et al.* (2016) for grain yield.

Culm diameter exhibited positive significant genotypic association with plant height (0.522**), days to 50 % flowering (0.300*), flag leaf width (0.386**), 1000 grain weight (0.328**), culm thickness (0.845**), basal internodal length (0.518**) and negative significant genotypic association with spikelet fertility (-0.384**). The above results unveiled that plants with wider culm possess taller plant height, longer duration, flag leaf width, basal internodal length and more test weight. Shah *et al.* (2019) reported that greater culm diameter is strongly associated with culm wall thickness thereby improving resistance to lodging. Selection for strong culm genotypes with moderate elongation is essential to minimize the risk of lodging for realizing higher yields.The trends of results are identical to the reports by Islam *et al.* (2016) for plant height, days to 50 % flowering and Girijarani and Satyanarayana (2018) for plant height and culm thickness.

Culm thickness showed positive significant genotypic association with plant height (0.536), days to 50 % flowering (0.559**), ear bearing tillers plant^{-1} (0.282), flag leaf width (0.364**), culm diameter (0.0845**), basal internodal length (0.485) and negative significant genotypic association with spikelet fertility % (-0.401**). Similar pattern of results were reported by Girijarani and Satyanarayana (2018) for culm diameter. Culm strength expressed positive significant genotypic association with percent of lodging (0.821**), plant height (0.413**), basal internodal length (0.331**). This implies that higher values of culm strength leads to increased basal internodal length and therefore enhances per cent of lodging owing to tall plants. Lines with lower values of culm strength (a score of 1 to 3) coupled with lower percent of lodging is essential to achieve better yields. Above trend of results are in compliance with earlier reports of Girijarani and Satyanarayana (2018) for percent of lodging and Yadav *et al.* (2017) for grain yield per plant.

Basal internodal length exhibited positive significant genotypic association with plant height (0.934**), days to 50 % flowering (0.411**), flag leaf width (0.399**), panicle length (0.267*), 1000 grain weight (0.270*), grain yield plant^{-1} (0.285*), culm diameter (0.518**), culm strength (0.331**), culm thickness (0.485**), per cent of lodging (0.478**) and negative significant genotypic association with spikelet fertility (-0.592*). Hence careful selection for basal internodal length is desirable to minimize lodging risk and may also improve fertile grain count because of its negative association with spikelet fertility. Similar trend of results were revealed in earlier works of Zhu *et al.* (2016) for culm diameter and Shahidullah *et al.* (2009) for percent of lodging.

CONCLUSION

Yield enhancing traits like 1000 grain weight, plant height, tiller angle, harvest index were found to associate with grain yield in a positive manner revealing the indirect selection of these traits would be favourable. Present study also suggest that plant stature, basal internodal length and lodging traits like culm strength associating positiveley with one another and these traits could be effectively exploited in crop breeding programmes as these become decisive indirect factors in the development of non lodging elite rice lines with higher grain yields.

LITERATURE CITED

Abebe T, Alamerew S and Tulu L 2019 Traits association and path coefficient analysis of yield and related traits in rainfed lowland rice (*Oryza sativa* L.) genotypes in north western Ethiopia. *African Journal of Plant Science.* 13 (1): 1-8.

Aditya J P and Bhartiya A 2013 Genetic variability, correlation and path analysis for quantitative characters in rainfed upland rice of Uttarakhand hills. *Journal of Rice Research.* 6 (2): 24-34.

Afrin W, Hossain M A and Islam M M 2017 Evaluation of yield and yield contributing traits for submergence tolerance of rice. *Progressive Agriculture.* 28 (1): 7-11.

Akinwale M G, Akinyele B O, Odiyi A C, Nwilene F, Gregorio G and Oyetunji O E 2012 Phenotypic screening of Nigerian rainfed lowland mega rice varieties for submergence tolerance. *Proceedings of the world congress on Engineering.* 1: 4-6.

Aparajita S, Mukul J M, Ram M, Arya M and Singh P K 2015 Screening and evaluation of rice cultivars for submergence tolerance using SSR markers. *The Ecoscan.* 9 (2): 255-259.

Ashok S, Jyothula D P B and Ratnababu D 2016 Character association and path analysis for yield components and grain quality parameters of rice (*Oryza sativa* L.). *International Journal of Agricultural Science and Research (IJASR)*. 6 (6): 253-258.

Bharadwaj C, Mishra R C, Tara S C, Rao S K, Mishra D K, Upendra K, Suman J, Biswajit P, Srirama K and Sabyaschi K 2017 Genetic variability and character association for yield and yield components in submergence tolerant rice varieties. *Indian Journal of Agricultural Research.* 51 (3): 239-244.

Budak N and Metin B Y 1999 Correlations among the yield and yield components at segregating populations derived from selection based on harvest index in bread wheat. *Cereal Research Communications.* 27 (3): 267–272.

Falconer D S 1964 *An Introduction to Quantitative Genetics*. Oliver and Boyd, Edinburgh, London. Pp: 312-324.

Ganapati R K and Mak M 2014 Genetic variability and character association of T-aman rice (*Oryza sativa* L). *International Journal of Plant Biology and Research.* 2 (2): 1013.

Gautam A, Chetia S K, Modi M K and Ahmed T 2018 Phenotypic screening and evaluation of SUB1 introgressed lines in popular rice varieties Ranjit and Bahadur of Assam, India. *International Journal of Current Microbiology and Applied Sciences*. 7 (9): 1744-1755.

Girijarani M and Satyanarayana P V 2018 Selection of lodging resistant lines in early generations using linked molecular markers and phenotypic traits in rice International Journal of Current Microbiology and Applied Sciences. 7 (1): 1638-1650

I**slam M Z, Khalequzzaman M, Bashar M K Ivy N A, Haque M M and Mian M A K 2016** Variability assessment of aromatic and fine rice germplasm in Bangladesh based on quantitative traits. *The Scientific World Journal*. 1-14.

Jing C, Kusutani A, Toyota M and Asanuma K 2000 Studies on the varietal difference of harvest index in rice. Relationship between harvest index and morphological characteristics and leaf color. *Japanese journal of crop science*. 69. 359-364.

Johnson H W, Robinson H F and Comstock R E 1955 Estimates of genetic and environmental variability in soybean. *Agronomy Journal*. 47: 314-318.

Laza M R, Shrestha S, Mendez KV, Dingkuhn M and Lopez M 2014 Morphological characterization of component traits for lodging resistance in rice. *Abstracts of International Rice Congress, Bangkok*. 1354.

Liang D M, Qiong G C, Yuan P and Su Z 2014 Principal component analysis of traits related to lodging resistance of plateau japonica rice. *Southwest China Journal of Agricultural Sciences*. 27: 919-924.

Maxwell D A, Kossi L A and Ebenezer A A 2019 Assessment of genetic diversity for grain yield and yield component traits in some genotypes of rice (*Oryza Sativa* L.). *Journal of Crop Science and Biotechnology*. 22: 123-130.

Pandey V K and Kar S 2018 Association analysis of native rice (*Oryza sativa* L.) of Bastar. *Electronic Journal of Plant Breeding.* 9 (1): 199-212.

Ramesh C, Raju C D, Raju S and Varma N R G 2018 Character association and path coefficient analysis for grain yield and yield components of parents and hybrids in rice (*Oryza sativa* L.). *International Journal of Current Microbiology and Applied Sciences*. 7 (4): 2692-2699.

Rathore M, Raghwendra S, Kumar B and Chauhan B S 2016 Characterization of functional trait diversity among Indian cultivated and weedy rice populations. *Scientific Reports*. 6: 241-255.

Reddy B S, Rani M G, Rao V S and Rao V S 2018 Character association studies for yield and lodging related parameters in rice (*Oryza sativa* L.). *The Andhra Agricultural Journal*. 65 (2): 320-325.

Reddy G E, Suresh B G and Sravan T 2013 Correlation and path analysis for yield and yield attributes in rice (*Oryza sativa* L.) genotypes. *International Journal of Plant Sciences*. 8 (2): 391-394.

Sanju K, S, Pawan K, Bisen P, Loitongbam B, Rai V, Sinha B 2019 Genetic diversity analysis of rice. *Germplasm through morphological markers*. 953-957.

Seesang J, Sripicchitt P, Sornchit P and Sreewongchai T 2013 Genotypic correlation and path coefficient for some agronomic traits of hybrid and inbred rice (*Oryza sativa* L.) cultivars. *Asian Journal of Crop Science*. 5 (3): 319-324.

SES IRRI 2013 *Standard evaluation system for rice*. International Rice Research Institute, Philippines.

Shah L, Yahya M and Shah S M 2019 Improving lodging resistance: using wheat and rice as classical examples. *International Journal of Molecular Sciences*. 20 (17): 4211.

Shahidullah S, Hanafi M M, Ashrafuzzaman M, Ismail M and Salam M A 2009 Tillering dynamics in aromatic rice genotypes. *International journal of agriculture and biology*. 11: 509-514.

Singh P 1998 *Cotton Breeding.* Kalyani Publishers, New Delhi, pp. 191-211.

Sravan T, Rangare N R, Surwesh B G and Ramesh Kumar S 2012 Genetic variability and character association in rainfed upland rice (*Oryza sativa* L.). *Journal of Rice Research*. 5 (1): 24-28.

Yadav S, Singh U M, Naik S M, Venkateshwarlu C, Ramayya P J, Raman K A, Sandhu N and Kumar A 2017 Molecular mapping of QTLs associated with lodging resistance in dry direct-seeded rice (*Oryza sativa* L.). *Frontiers in Plant Science.* 8: 1431.

Yang X C and Hwa C M 2008 Genetic modification of plant architecture and variety improvement in rice. *Heredity*. 101 (5): 396-404.

Zhu Y J, Huang D R, Fan Y Y, Zhang Z H, Ying J Z and Zhuang J Y 2016 Detection of QTLs for yield heterosis in rice using a RIL population and its testcross population. *International journal of genomics*. 2587823: 1-9.

Received on 23.04.2021 and Accepted on 26.06.2021