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CHARACTER ASSOCIATION AND PATH ANALYSIS FOR SEED YIELD AND LODGING TRAITS IN RICE (*Oryza sativa* L.) GENOTYPES

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ABSTRACT

The present study was carried out among 21 rice genotypes. Seeds for the study was collected from Rice Research Stations of Kerala Agricultural University (KAU). These genotypes were raised in RBD with two replications. The direct and indirect effects of seventeen traits including lodging and yield were estimated. The results from the correlation studies showed that grain yield plant^{-1} recorded positive correlation at high significance at both genotypic and phenotypic levels with number of panicles plant^{-1} (rp = 0.806, rg = 0.822) followed by number of tillers plant^{-1} (rp = 0.753, rg = 0.773), test weight and silicon content. Lodging% exhibited highly significant and positive correlation at both phenotypic and genotypic levels with days to 50% flowering, plant height, flag leaf length, internodal length, culm diameter, days to maturity and panicle length. Path analysis revealed that panicles plant^{-1} (1.064) had very high positive direct effect on yield followed by flag leaf length (0.824), seeds panicle-1 (0.785), test weight (0.607) and panicle weight. Among these traits, number of panicles plant^{-1} and test weight possessed both positive association and high direct effects. Meanwhile, plant height, internodal length and culm diameter possessed negative effects. Hence, selection for these traits could bring improvement in yield and yield components along with lodging resistance.

INTRODUCTION

Rice is the most important food and second most widely cultivated cereal in the world. Even though we are having a number of high yielding varieties, lodging of rice tillers create problems during harvesting as well as it affects the quality of grains in wet lands. There are certain high yielding varieties in rice which lodge at maturity due to which their cultivation was tremendously affected over the years like, Swetha. So it was right time to fix this problem along with keeping crop improvement to meet the global food demand. When we consider resistance to lodging, it is a complex trait having interactions between many agro-morphological traits such as, plant height (Yang *et al*., 2000), diameter and length of basal internode (Wan and Ma, 2003), silicon content (Ma and Yamaji, 2006) and cultivation condition (Cuo *et al*., 2003). Seed yield is also a complex trait the expression of which depends upon various yield contributing traits such as test weight, number of seeds per panicle, panicle weight, number of panicles, number of tillers and lodging resistance (Keerthiraj *et al*., 2020) *etc*.

Correlation studies provide information on the nature and extent of association between yield and its component traits and thus can help the breeder in deciding the magnitude and direction of selection for the improvement of the character. Path coefficient analysis further partitions the correlation coefficients into direct and indirect effects enabling plant breeders to rank the genetic attributes according to their contribution. Hence, Correlation and path analysis provides information to the plant breeders to explore and evaluate a lot of germplasm for understanding the association of yield with its component traits to use it in future hybridization programme for improving a combination of characters along with yield.

Hence this study was undertaken with the objective to determine the nature of the relationship of seed yield and lodging resistance with its yield components, direct and indirect contribution of these components towards the same and to identify better combinations of such yield components as selection criteria for developing high yielding, lodging resistant rice genotypes.

MATERIALS AND METHODS

The present investigation was carried at Agricultural Research Station, Mannuthy under Kerala Agricultural University (KAU). Materials for this study comprises of twenty-one high yielding rice genotypes collected from different rice research stations under KAU (Table-1). The genotypes were raised in Randomized Block Design (RBD) with two replications. The seedlings were raised in nursery and transplanted to the main field with spacing of 20 x 15 cm. General agronomic practices were carried out as per recommendations given in package of practices, KAU (2011).

Seventeen observations including qualitative, quantitative and biochemical parameters were recorded. Lodging was measured in percentage and all other observations recorded as per scales given by Standard Evaluation System- International Rice Research Institute (SES-IRRI, 2014). Observation recorded for traits, days to fifty per cent flowering, plant height, flag leaf width, flag leaf length, tillers per plant, internodal length, culm diameter, culm wall thickness, days to maturity, panicle length, panicles per plant, panicle weight, seeds per panicle, test weight, silicon content, potassium content, seed yield per plant, and lodging per cent. Silicon content in plant sample (culm) was estimated by digestion of sample in micro-digester with HNO_3, HF and H_2O_2 acids and determined by using ICP-OES (Ma *et al*., 2002). Potassium content in plant sample (culm) was estimated by digesting the sample with diacid mixture of HNO_3 and $HClO_4$ in the ratio of 9:4 and determined by using the Flame-photometer (Jackson, 1958).

The replicated data were subjected to statistical analysis; the mean values over replications were used for finding correlation coefficient following Singh and Chaudhary (1979). The estimates of correlation coefficients were then used in path analysis studies for finding the direct and indirect effects following the method suggested by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Correlation refers to the degree as well as the direction of association between two or more than two variables. It estimates the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement of yield. Resistance to lodging and grain yield are complex traits resulting from interaction of many yield attributes. Since almost all the characters are highly influenced by the environment, selection based on knowledge of association between the dependent variables and their component traits could accentuate the progress in breeding efforts.

Hence, the present study was undertaken to understand the magnitude and nature of the association among different yield contributing characters and their association with grain yield per plant. The results are listed in Table 2.

Correlation

Knowledge of correlation among different plant characters are important for indirect selection of a secondary character for the improvement of primary trait of interest. It plays an important role in case of complex characters such as yield

Table 1: Rice genotypes used for the present investigation

Sl. No.	Genotype	Parentage	Developed at
1	Aathira	BR 51-46-1 X Culture 23332-2	RARS, Pattambi, KAU
2	Akshaya	BPT 4358 X IR64	RARS, Pattambi, KAU
3	Aishwarya	Jyothi x BR 51-46-1	RARS, Pattambi, KAU
4	Gouri	MO 4 x Cul. 25331	RRS, Moncompu, KAU
5	Harsha	M. 210 X PTB 28	RARS, Pattambi, KAU
6	Jyothi	Ptb-10 x IR-8 (HS)	RARS, Pattambi, KAU
7	Kairali	IR 36 x Jyothi (HS)	RARS, Pattambi, KAU
8	Kanchana	IR 36 X Pavizham	RARS, Pattambi, KAU
9	Karishma	MO 1 x MO 6	RRS, Moncompu, KAU
10	Karuna	CO-25 X H4	RARS, Pattambi, KAU
11	Kunjukunju Varna	Reselection from Kunjukunju	RARS, Pattambi, KAU
12	Mangala Mahsuri	Reselection from Mashuri	RARS, Pattambi, KAU
13	Manupriya	PK3355-5-1-4 x Bhadra	ARS, Mannuthy, KAU
14	Prathyasa	IET 4786 x Aruna	RRS, Moncompu, KAU
15	Ponmani	Pankaj X Jagannnath	TNAU
16	Pournami	NHTA8 X Aruna	RARS, Pattambi, KAU
17	Samyuktha	Pureline selection from Cul. C2	RARS, Pattambi, KAU
18	Swetha	IR 50 X C 14-8	RARS, Pattambi, KAU
19	Uma	MO 6 x Pokkali	RRS, Moncompu, KAU
20	Vaishak	Pureline selection from Swarnaprabha	RARS, Pattambi, KAU
21	Varsha	M 210 X Harsha	RARS, Pattambi, KAU

Table 2: Genotypic (rg) and Phenotypic (rp) correlation coefficient of 21 rice genotypes between grain yield and yield attributes influenced by lodging.

		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
A	r_g	1																	
	r_p	1																	
B	r_g	0.277	1																
	r_p	0.275	1																
C	r_g	0.081	0.857**	1															
	r_p	0.081	0.848**	1															
D	r_g	0.299	0.771**	0.787**	1														
	r_p	0.3	0.761**	0.777**	1														
E	r_g	-0.122	0.034	0.041	0.047	1													
	r_p	-0.13	0.035	0.037	0.046	1													
F	r_g	0.25	0.909**	0.915**	0.829**	-0.036	1												
	r_p	0.25	0.898**	0.905**	0.824**	-0.039	1												
G	r_g	0.740**	0.202	0.133	0.194	-0.078	0.202	1											
	r_p	0.725**	0.199	0.126	0.185	-0.081	0.198	1											
H	r_g	0.406**	0.236	0.133	0.129	0.278	0.214	0.745**	1										
	r_p	0.400**	0.23	0.133	0.133	0.272	0.212	0.736**	1										
I	r_g	0.963**	0.232	0.028	0.238	0.007	0.188	0.764**	0.508**	1									
	r_p	0.947**	0.232	0.026	0.229	0.007	0.183	0.755**	0.495**	1									
J	r_g	-0.186	-0.055	-0.045	-0.027	0.981**	-0.113	-0.162	0.2	-0.068	1								
	r_p	-0.19	-0.05	-0.053	-0.034	0.970**	-0.117	-0.147	0.194	-0.057	1								

Table 2 : Continue..

		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
K	r_g	0.522**	0.698**	0.534**	0.369*	-0.161	0.631**	0.441**	-0.364*	0.464**	-0.249	1							
	r_p	0.514**	0.688**	0.531**	0.367*	-0.153	0.627**	0.431**	-0.357*	0.461**	-0.235	1							
L	r_g	0.526**	0.605**	0.473**	0.470**	0.034	0.482**	0.499**	0.265	0.497**	-0.031	0.582**	1						
	r_p	0.516**	0.601**	0.468**	0.460**	0.039	0.475**	0.498**	0.26	0.494**	-0.023	0.573**	1						
M	r_g	0.590**	0.195	0.073	0.312*	-0.043	0.22	0.576**	0.384*	0.626**	-0.028	0.301	0.330*	1					
	r_p	0.547**	0.193	0.072	0.298	-0.014	0.206	0.548**	0.363*	0.594**	-0.001	0.298	0.327*	1					
N	r_g	0.594**	0.103	-0.06	0.202	-0.282	0.089	0.462**	0.141	0.571**	-0.223	0.165	0.308*	0.850**	1				
	r_p	0.587**	0.104	-0.062	0.194	-0.278	0.089	0.458**	0.131	0.573**	-0.21	0.165	0.308*	0.803**	1				
O	r_g	-0.315*	0.244	0.316*	0.145	0.502**	0.181	-0.523**	-0.276	-0.303	0.474**	-0.195	-0.024	-0.511**	-0.495**	1			
	r_p	-0.313*	0.242	0.312*	0.143	0.491**	0.175	-0.512**	-0.271	-0.302	0.460**	-0.191	-0.025	-0.483**	-0.491**	1			
P	r_g	0.041	0.059	0.04	0.145	0.773**	-0.015	-0.116	0.036	0.121	0.822**	-0.263	0.095	0.277	0.245	0.513**	1		
	r_p	0.032	0.061	0.023	0.136	0.753**	-0.02	-0.103	0.042	0.111	0.806**	-0.269	0.09	0.252	0.228	0.494**	1		
Q	r_g	-0.293	-0.368*	-0.362*	-0.015	0.415**	-0.378*	-0.446**	-0.332*	-0.282	0.470**	-0.797**	-0.368*	-0.233	-0.107	0.318*	0.512**	1	
	r_p	-0.286	-0.362*	-0.353*	-0.017	0.405**	-0.368*	-0.435**	-0.322*	-0.276	0.457**	-0.771**	-0.363*	-0.213	-0.112	0.314*	0.492**	1	
R	r_g	-0.404**	-0.354*	-0.202	-0.012	-0.043	-0.263	-0.491**	-0.409**	-0.480**	-0.027	-0.602**	-0.606**	-0.246	-0.117	0.029	0.028	0.646**	1
	r_p	-0.401**	-0.353*	-0.201	-0.014	-0.046	-0.262	-0.484**	-0.407**	-0.475**	-0.028	-0.598**	-0.603**	-0.24	-0.115	0.029	0.028	0.630**	1

(*significance at 5% level; **significance at 1% level) (rg - Genotypic correlation, rp- Phenotypic correlation)

A -Days to 50 per cent flowering;B -Plant height (cm);C -Flag leaf length (cm);D -Flag leaf width (cm);E -Tillers per plant (no.); F -Internodal length (cm);G -Culm diameter (mm);H -Culm wall thickness (mm);I -Days to maturity;J -Panicles per Plant (no.);K -Lodging %;L -Panicle length (cm);M -Panicle weight (g);N -Seeds per panicle (no.);O -Test weight (g);P -Seed yield per plant (g);Q -Silicon content (%);R -Potassium content (%)

and lodging resistance. Among the correlation coefficients of seventeen traits under investigation, the genotypic correlation coefficients were found higher than phenotypic correlation coefficients, indicating the less influence of environment on these traits (Table 2).

A number of positive genotypic correlations were recorded for seed yield per plant at 1% level of significance including number of tillers per plant (0.773), number of panicles per plant (0.822), test weight (0.513) and silicon content (0.512). Same results were also reported by Reddy *et al*. (2013), Chuanren *et al*. (2004), Devi *et al*. (2017), Akter *et al*. (2018) and Kumari *et al*. (2019) in rice. Lodging per cent exhibited positive genotypic correlation at 1% level of significance with days to fifty per cent flowering (0.522), plant height (0.698), flag leaf length (0.534), internodal length (0.631), culm diameter (0.441), days to maturity (0.464) and panicle length (0.582) and a significant correlation with flag leaf width (0.369). A high negative significant association was observed with silicon content (0.797) and potassium content (0.602). Sinniah *et al*. (2012), Dhanwani *et al*. (2013), Broomand *et al*. (2016) and Abebe *et al*. (2017) also reported a similar kind of results in their work. A similar trend was also observed for phenotypic correlation among these characters. When we consider crop yield, all those characters having positive correlation with the same Should be considered for getting an added advantage of indirect effect and for lodging resistance characters having negative association should be considered since we are looking for reduced lodging.

Path Analysis

The correlation studies are helpful in measuring the association between yield and yield components but they do not provide the accurate result of the direct and indirect cause of such association which, can be obtained through path analysis (Wright, 1923). Path analysis is very useful to identify the cause of the association between the dependent variable like yield and independent variables like yield components and of their indirect effect via some other traits which can be utilized as selection parameters for crop improvement.

In the present study, phenotypic correlation coefficients were used for carrying out path coefficient analysis for finding the direct and indirect effects of component characters on grain yield (Table-3). A low residual effect obtained in the path analysis indicates that the component characters had contributed adequate variability to yield. Similar trends were also stated by Manjunatha *et al*. (2017) and Nanda *et al*. (2019). Path coefficient analysis revealed that the highest positive direct effect exhibited by Seeds per panicle (0.5975) followed by Panicles per plant (0.5535), Test weight (0.3961), Days to 50 % flowering (0.3104), Tillers per plant (0.2042), Flag leaf length (0.1354), Plant height (0.0723) and Panicle weight (0.0540) on seed yield per plant. These results are in agreement with the findings of Kumar and Nilanjaya, (2014), Roy *et al*. (2015), Manjunatha *et al*. (2017) and Nanda *et al*. (2019).

The highest negative direct effect was exhibited by Days to maturity (-0.2734), Lodging % (-0.1897) and Internodal length (-0.1428). Similar results have been reported by Zahid *et al*. (2006). Negative direct effect was also exhibited by the traits namely, Flag leaf width (-0.0225), Culm diameter (-0.0264), Culm wall thickness (-0.0149), Panicle length (-0.0386), Silicon

Table 3 : Estimation of direct and indirect effect of growth parameters on yield of 21 rice genotypes

		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
A	G	-0.118	-0.1891	0.067	-0.1059	-0.1303	-0.0553	-0.1004	0.0716	-0.201	0.1453	0.3827	-0.0429	0.2077	0.4665	-0.191	-0.3106	0.1449
	P	0.3104	0.0199	0.011	-0.0068	-0.0265	-0.0358	-0.0192	-0.0059	-0.2588	-0.1051	-0.0974	-0.02	0.0295	0.3506	-0.124	0.008	0.0022
B	G	-0.0327	-0.6825	0.7057	-0.2727	0.0361	-0.2009	-0.0275	0.0416	-0.0484	0.0427	0.5119	-0.0493	0.0687	0.0812	0.1478	-0.3901	0.1272
	P	0.0853	0.0723	0.1148	-0.0171	0.0071	-0.1282	-0.0053	-0.0034	-0.0634	-0.0277	-0.1305	-0.0232	0.0104	0.0624	0.0957	0.0101	0.0019
C	G	-0.0096	-0.5848	0.8236	-0.2786	0.0436	-0.2021	-0.018	0.0235	-0.0058	0.0349	0.3917	-0.0386	0.0257	-0.0467	0.1918	-0.3829	0.0724
	P	0.0252	0.0613	0.1354	-0.0175	0.0075	-0.1292	-0.0033	-0.002	-0.0072	-0.0296	-0.1007	-0.0181	0.0039	-0.0371	0.1236	0.0098	0.0011
D	G	-0.0353	-0.5259	0.6485	-0.3539	0.0504	-0.1832	-0.0263	0.0228	-0.0496	0.0208	0.2702	-0.0384	0.1099	0.1585	0.0882	-0.0162	0.0044
	P	0.0931	0.055	0.1053	-0.0225	0.0094	-0.1177	-0.0049	-0.002	-0.0625	-0.0187	-0.0696	-0.0178	0.0161	0.1159	0.0565	0.0005	0.0001
E	G	0.0145	-0.0232	0.0338	-0.0168	1.064	0.008	0.0106	0.049	-0.0015	-0.7669	-0.1181	-0.0028	-0.0152	-0.2214	0.3045	0.4391	0.0156
	P	-0.0403	0.0025	0.005	-0.001	0.2042	0.0055	0.0021	-0.004	-0.0019	0.5369	0.0291	-0.0015	-0.0007	-0.166	0.1944	-0.0113	0.0003
F	G	-0.0295	-0.6206	0.7533	-0.2934	-0.0384	-0.221	-0.0275	0.0376	-0.0392	0.0885	0.4627	-0.0393	0.0775	0.0699	0.1098	-0.4	0.0944
	P	0.0777	0.0649	0.1226	-0.0185	-0.0079	-0.1428	-0.0052	-0.0032	-0.05	-0.0649	-0.1189	-0.0184	0.0111	0.0529	0.0693	0.0103	0.0014
G	G	-0.0873	-0.1381	0.1092	-0.0686	-0.083	-0.0447	-0.1357	0.1313	-0.1595	0.1264	0.3235	-0.0407	0.2026	0.3624	-0.3176	-0.4719	0.1762
	P	0.225	0.0144	0.0171	-0.0042	-0.0165	-0.0283	-0.0264	-0.0109	-0.2065	-0.0812	-0.0818	-0.0192	0.0295	0.2738	-0.2028	0.0121	0.0026
H	G	-0.048	-0.1612	0.1098	-0.0458	0.2959	-0.0472	-0.1011	0.1763	-0.1061	-0.1559	0.2665	-0.0216	0.135	0.1107	-0.1673	-0.3511	0.1468
	P	0.1242	0.0166	0.018	-0.003	0.0555	-0.0303	-0.0195	-0.0149	-0.1354	0.1072	-0.0677	-0.0101	0.0196	0.0782	-0.1073	0.009	0.0022
I	G	-0.1137	-0.1584	0.0231	-0.0841	0.0075	-0.0415	-0.1037	0.0896	-0.2087	0.0533	0.34	-0.0405	0.2204	0.448	-0.1841	-0.2987	0.1722
	P	0.2938	0.0168	0.0036	-0.0052	0.0014	-0.0261	-0.02	-0.0074	-0.2734	-0.0313	-0.0874	-0.0191	0.0321	0.3425	-0.1195	0.0077	0.0026
J	G	0.0219	0.0373	-0.0367	0.0094	1.0442	0.025	0.0219	0.0352	0.0142	-0.7815	-0.1828	0.0026	-0.0097	-0.1749	0.2876	0.4981	0.0097
	P	-0.059	-0.0036	-0.0072	0.0008	0.198	0.0167	0.0039	-0.0029	0.0155	0.5535	0.0447	0.0009	0	-0.1253	0.1821	-0.0128	0.0002
K	G	-0.0616	-0.4767	0.4401	-0.1305	-0.1715	-0.1395	-0.0599	0.0641	-0.0968	0.195	0.7329	-0.0475	0.106	0.1293	-0.1184	-0.8441	0.216
	P	0.1594	0.0497	0.0719	-0.0083	-0.0313	-0.0895	-0.0114	-0.0053	-0.126	-0.1303	-0.1897	-0.0221	0.0161	0.0986	-0.0758	0.0215	0.0032
L	G	-0.062	-0.4127	0.3898	-0.1664	0.0365	-0.1065	-0.0678	0.0467	-0.1037	0.0245	0.4264	-0.0816	0.1162	0.2414	-0.0146	-0.3893	0.2175
	P	0.1603	0.0434	0.0634	-0.0103	0.0079	-0.0679	-0.0132	-0.0039	-0.135	-0.0127	-0.1086	-0.0386	0.0177	0.1838	-0.0099	0.0101	0.0033
M	G	-0.0697	-0.1332	0.0602	-0.1105	-0.0458	-0.0487	-0.0781	0.0677	-0.1308	0.0216	0.2207	-0.0269	0.3518	0.6672	-0.31	-0.2466	0.0883
	P	0.1697	0.014	0.0097	-0.0067	-0.0028	-0.0294	-0.0145	-0.0054	-0.1625	-0.0004	-0.0565	-0.0127	0.054	0.4799	-0.1914	0.0059	0.0013
N	G	-0.0701	-0.0706	-0.049	-0.0715	-0.3001	-0.0197	-0.0627	0.0249	-0.1191	0.1742	0.1208	-0.0251	0.2991	0.7848	-0.3003	-0.113	0.042
	P	0.1821	0.0076	-0.0084	-0.0044	-0.0567	-0.0126	-0.0121	-0.0019	-0.1567	-0.116	-0.0313	-0.0119	0.0433	0.5975	0.1945	0.0031	0.0006
O	G	0.0372	-0.1663	0.2603	-0.0515	0.5339	-0.04	0.071	-0.0486	0.0633	-0.3704	-0.143	0.002	-0.1798	-0.3884	0.6068	0.3366	-0.0106
	P	-0.0972	0.0175	0.0423	-0.0032	0.1002	-0.025	0.0135	0.004	0.0825	0.2545	0.0363	0.001	-0.0261	-0.2933	0.3961	-0.0087	-0.0002
P	G	0.0346	0.2514	-0.2977	0.0054	0.4412	0.0835	0.0605	-0.0584	0.0589	-0.3676	-0.5841	0.03	-0.0819	-0.0838	0.1929	1.059	-0.2319
	P	-0.0889	-0.0262	-0.0478	0.0004	0.0826	0.0525	0.0115	0.0048	0.0754	0.2532	0.1463	0.014	-0.0115	-0.0672	0.1243	-0.0279	-0.0034
Q	G	0.0476	0.2419	-0.1661	0.0043	-0.0462	0.0581	0.0666	-0.0721	0.1001	0.0211	-0.441	0.0494	-0.0866	-0.0917	0.0179	0.6841	-0.359
	P	-0.1246	-0.0255	-0.0273	0.0003	-0.0093	0.0374	0.0128	0.0061	0.13	-0.0156	0.1134	0.0233	-0.013	-0.0684	0.0117	-0.0176	-0.0054

(Residual effect (Genotypic) = 0.04931, Residual effect (Phenotypic) = 0.03215, Bold: Direct effects, Normal: Indirect effect)

A -Days to 50 per cent flowering; B -Plant height (cm);C -Flag leaf length (cm);D -Flag leaf width (cm);E -Tillers per plant (no.);F -Internodal length (cm);G -Culm diameter (mm);H -Culm wall thickness (mm);I -Days to maturity J -Panicles per Plant (no.);K -Lodging %;L -Panicle length (cm);M -Panicle weight (g);N -Seeds per panicle (no.);O -Test weight (g);P - Silicon content (%);Q - Potassium content (%)

content (-0.0279), Potassium content (-0.0054). Even though days to 50% flowering and plant height showed positive direct responses at phenotypic level, their genotypic direct effects were negative. This may be due to environmental effects, timely harvest at maturity and their management aspects. Otherwise plant height and days to 50% flowering has negative direct effect since tall varieties are susceptible to lodging. Negative direct effect of plant height was earlier reported by Ramakrishnan *et al*. (2006) and Sandhya *et al*. (2014).

The indirect effects of culm diameter recorded grain yield through seeds per panicle (0.2738) and panicle weight (0.0295). Seeds per panicle (0.1945) and panicle length (0.0021) expression through test weight for seed yield per plant. Days to 50% flowering (0.1594), days to maturity (0.1294), Plant height (0.0497) and internodal length (0.089) provided indirect effects through Lodging resistance are significant. Same results are in accordance with the findings of Nature N., (2014) and Soni A., (2018).

The seeds per panicle and panicles per plant displayed higher positive direct effect on single plant yield which implicated that direct selection of this trait would be rewarding for grain yield improvement. The overall conclusion is that reduction of plant height, internodal length, culm diameter, days to 50% flowering and days to maturity is important to achieve lodging resistance and earliness (Hema *et al*., 2019).

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