

Original Research Article

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Character Association and Path Analysis of Grain Yield and its Components in Maize (*Zea mays* L.) under Heat Stress

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ABSTRACT

Maize (*Zea mays* L.) is one of the most diversified and versatile crop grown worldwide under varied agro-climatic condition. However, a significant amount of reduction in grain yield has been reported because of heat stress. Being a complicated character that depends on multiple component traits, direct selection is ineffective for grain yield. Considering these aspects, a study was conducted to determine the magnitude and extent of trait interdependency among yield and yield attributing characters under heat stress condition using forty five maize hybrids. The hybrids were evaluated by following randomized block design with two replications at EB-II section of the Department of Plant Breeding and Genetics, College of Agriculture, OUAT, Bhubaneswar during Summer 2018. Association studies revealed that, six characters viz., plant height, ear height, cob diameter, number of grain rows per cob, number of grains per row and 100 seed weight exhibited significantly positive correlation at both genotypic and phenotypic level, while anthesis to silking interval was the only trait that attained negative significant correlation at genotypic level with grain yield per plant. Path analysis indicated that plant height, ear height, number of rows per cob and 100 grain weight have positive direct effect while, anthesis to silking interval has negative direct effect on grain yield per plant. Hence, these traits in desirable direction could be relied upon for selection of genotypes in order to improve genetic yield potential of maize under heat stress condition.

Keywords

Maize, correlation, path analysis, grain yield and heat stress

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Introduction

Globally, maize (*Zea mays* L.) is the third most important cereal crop, which is cultivated on nearly 197.19 million hectare of land with wider diversity of soil, climate, biodiversity and management practices with

production of 1134.75 million tonnes and productivity of 5.76 tonnes per hectare (FAOSTAT, 2017). India is the sixth largest producer and the fifth largest consumer of maize in the world, grown on an area of 9.22 million hectare with production of 28.72 million tonnes and productivity of 3.12 tonnes

per hectare (FAOSTAT, 2017). It is one of the most widely distributed crops and its expansion to new areas and environment still continues owing to its adaptability to diverse environmental conditions.

Forecasts indicate that by the year 2050, the demand for maize in the developing countries will double (Rosegrant *et al.*, 2009 and Prasanna 2014) owing to the newly emerging food habits, livestock products as well as enhanced industrial requirements of rapidly expanding human population. Thus, in order to meet this demand, intensification of cropping system and increased productivity is the only way. However, this goal of increasing maize production and productivity has been hindered by the global climate change that includes rising temperatures, frequent heat waves, drought, floods, desertification and weather extremes (IPCC, 2009). A record drop in maize production due to heat waves has already been reported globally (Ciais *et al.*, 2005; Van der Velde *et al.*, 2010). It has been anticipated that growing season temperature in the tropics and subtropics will exceed even the most extreme seasonal temperatures so far, while in temperate regions, the hottest seasons on record will become the normal temperature (Battisti and Naylor, 2009). Thus a huge loss in corn production can be expected in the near future. Hence, development of heat stress tolerant maize germplasm is the need of the hour.

Selection based on grain yield is quite not reliable as yield is a complex quantitative trait that is governed by poly genes and also highly influenced by environmental factors in which the crop is grown. So selection of secondary traits associated with this complex trait is a way to achieve higher grain yield. Correlation analysis used as effective tool to determine the relationship among different traits in genetic diverse population for enhancement of

crop improvement process. As more variables are included in the correlation study, the associations become more complex. In such a situation, the path coefficient analysis provides an effective means of finding out direct and indirect causes and effects of association and permits a critical examination of the specific forces acting to produce a given correlation and measures the relative importance of each factor. Thus aim of this study was to find out potential secondary traits associated with grain yield under heat stress condition in maize hybrids through correlation and path analysis.

Materials and Methods

Experimental details

The experimental material for the present study comprised of forty five maize F_1 s (Table 1) generated by crossing previously identified 15 heat tolerant double haploid lines with 3 double haploid testers collected from International Maize and Wheat Improvement Center (CIMMYT), Hyderabad, India. The F_1 s were evaluated in a randomized block design with two replications during spring, 2018 at EB-II section of the Department of Plant Breeding and Genetics, College of Agriculture, OUAT, Bhubaneswar. Each entry was sown in two rows of 4 meter length spaced at 60cm with a plant to plant spacing of 30 cm. Two seeds per hill were sown followed by thinning to maintain single plant per hill. In order to avoid the influence of moisture stress on the plants, proper care was taken by mulching the soil with paddy straw along with need based irrigation. Fertilizers were applied at the rate of 120 kg N, 60 kg P_2O_5 and 60 kg K_2O per hectare in the form of Urea, SSP and MOP respectively along with FYM 12 cart loads/ha and Zinc Sulphate 25kg/ha. Normal agronomic practices and plant protection measures were followed to raise a successful crop.

The flowering occurred during the month of May, wherein the maximum and minimum temperature ranged between 35–39°C and 20–28°C respectively, while the mean relative humidity during the flowering period was 74%. Data was recorded on five randomly selected plants from each F₁s for twelve traits *viz.*, days to 50% tasseling (DT), days to 50% silking (DS), anthesis to silking interval (ASI), days to 75% dry husk (DDH), plant height (PH), ear height (EH), cob length (CL), cob diameter (CD), number of grain rows per cob (R/C), Number of grains per row (G/R), 100 seed weight (SW) and grain yield per plant (GY/P). The data was analyzed for estimating the correlation coefficients as described by Snedecor and Cochran, (1965) and path co-efficient analysis was carried out at the genotypic level by taking grain yield per plant as dependent variable against other measured traits as independent variables as suggested by Wright (1921) and discussed by Dewey and Lu (1959).

Results and Discussion

The phenotypic, genotypic correlation and path coefficients of twelve agro-economic traits of forty five maize hybrids were depicted in table 2 and table 3 respectively. The correlation coefficients were found to be significant at both genotypic and phenotypic level for most of the character combinations. In majority of the cases, genotypic correlation coefficient was higher than phenotypic correlation coefficients. Grain yield per plant was observed to have significant positive genotypic and phenotypic correlation with plant height (0.642 & 0.558), ear height (0.451 & 0.395), cob diameter (0.620 & 0.574), number of grain rows per cob (0.254 & 0.272), number of grains per row (0.686 & 0.701) and 100 seed weight (0.469 & 0.459). All these component traits except number of grain rows per cob at genotypic level recorded significant genotypic and phenotypic

correlation coefficient at even 1% level of significance. A negative significant genotypic correlation (-0.305) was observed between anthesis to silking interval and grain yield per plant. Four characters *viz.*, days to 50% tasseling, days to 50% silking, days to 75% dry husk and plant height exhibited non-significant negative correlation coefficient with grain yield per plant at both genotypic and phenotypic level.

Perusal of table 3 showed a residual effect of 0.028 from the path analysis. The analysis revealed that five out of eleven traits had positive direct effect on grain yield. The highest direct effect on grain yield was exhibited by days to 50% silking (3.309) followed by plant height (0.647), number of grain rows per cob (0.634) and 100 seed weight (0.318). However, days to 50% tasselling had the largest negative direct effect on grain yield per plant (-3.684) followed by anthesis to silking interval (-1.027) and cob length (-0.247). In general days to 50% tasseling was found to have negative indirect effect, whereas days to 50% silking was found to have positive indirect effect on grain yield per plant through other component characters.

Character association is a helping hand to study the interdependence among traits and quite useful to chalk out the component traits in connection with the target descriptor *i.e.* grain yield per plant. The genotypic and phenotypic correlations among the traits studied pointed out the existence of statistically significant relationships among them. The higher value of genotypic correlation coefficients than that of phenotypic correlation coefficients for most of the character combinations indicated the strong inherent association between the characters, which is largely governed by genetic causes and less affected by the environment. Such findings are in close

conformity with the results of Ghosh *et al.*, (2014) and Alake *et al.*, (2008). The component traits; plant height, ear height, cob diameter, number of grain rows per cob, number of grains per row and 100 seed weight displaying positive and significant association with grain yield per plant suggested that grain yield can be improved through simultaneous selection for these traits. These associations are partly in accordance with the earlier results observed by Jodage *et al.*, (2017), Al-Tabbal and Al-Fraihat (2012), Rani *et al.*, (2017), Ghosh *et al.*, (2014), Rafiq *et al.*, (2010) and Wali *et al.*, (2012), Seyedzavar *et al.*, (2015), Palta *et al.*, (2011); Khazaei *et al.*, (2010), Alvi *et al.*, (2003), Najeeb *et al.*, (2009) and Nemati *et*

al., (2009). Anthesis to silking interval was the only character that exhibited significant negative association with grain yield per plant suggesting that the genotypes with less gap between anthesis and silking will give higher grain yield per plant under heat stress condition. Magorokosho *et al.*, (2003) reported that selection for genotypes with reduced ASI was more effective than grain yield alone under drought stress. Days to 50% tasselling, days to 50% silking and days to 75% dry husk were positively correlated with each other whereas each one of them exhibited a non-significant negative correlation with yield per plant indicating the reverse relationship among the maturity related traits and grain yield per plant.

Table.1 Forty five hybrids generated from crossing programme

1	ZL155069 × ZL155828	16	ZL155132 × ZL155828	31	ZL155201 × ZL155828
2	ZL155069 × ZL154230	17	ZL155132 × ZL154230	32	ZL155201 × ZL154230
3	ZL155069 × CML 451	18	ZL155132 × CML 451	33	ZL155201 × CML 451
4	ZL155085 × ZL155828	19	ZL155136 × ZL155828	34	ZL155219 × ZL155828
5	ZL155085 × ZL154230	20	ZL155136 × ZL154230	35	ZL155219 × ZL154230
6	ZL155085 × CML 451	21	ZL155136 × CML 451	36	ZL155219 × CML 451
7	ZL155110 × ZL155828	22	ZL155181 × ZL155828	37	ZL155235 × ZL155828
8	ZL155110 × ZL154230	23	ZL155181 × ZL154230	38	ZL155235 × ZL154230
9	ZL155110 × CML 451	24	ZL155181 × CML451	39	ZL155235 × CML451
10	ZL155115 × ZL155828	25	ZL155187 × ZL155828	40	ZL155246 × ZL155828
11	ZL155115 × ZL154230	26	ZL155187 × ZL154230	41	ZL155246 × ZL154230
12	ZL155115 × CML 451	27	ZL155187 × CML 451	42	ZL155246 × CML 451
13	ZL155122 × ZL155828	28	ZL155199 × ZL155828	43	ZL155247 × ZL155828
14	ZL155122 × ZL154230	29	ZL155199 × ZL154230	44	ZL155247 × ZL154230
15	ZL155122 × CML 451	30	ZL155199 × CML 451	45	ZL155247 × CML 451

Table.2 Phenotypic (r_p) and genotypic (r_g) correlation coefficients among twelve agro-economic traits of 45 maize hybrids

Characters	Correlation coefficient	Days to 50% tasselling	Days to 50% silking	ASI	Days to 75% dry husk	Plant height (cm)	Ear height (cm)	Cob length (cm)	Cob diameter (cm)	No. of grain rows/ cob	No. of grains/row	100- Seed weight (g)
Days to 50% silking	r_g	0.991**										
	r_p	0.942**										
ASI	r_g	-0.236*	-0.104									
	r_p	-0.168	0.172									
Days to 75% dry husk	r_g	0.703**	0.691**	-0.202								
	r_p	0.691**	0.708**	0.052								
Plant height (cm)	r_g	0.513**	0.518**	-0.054	0.255*							
	r_p	0.444**	0.464**	0.060	0.235*							
Ear height (cm)	r_g	0.639**	0.624**	-0.212*	0.419**	0.753**						
	r_p	0.558**	0.543**	-0.044	0.368**	0.720**						
Cob length (cm)	r_g	-0.232*	-0.225*	0.094	-0.282**	-0.247*	-0.272**					
	r_p	-0.200	-0.182	0.052	-0.255*	-0.192	-0.193					
Cob diameter (cm)	r_g	0.003	-0.013	-0.120	-0.271**	0.355**	0.210*	-0.012				
	r_p	-0.049	-0.027	0.064	-0.193	0.284**	0.161	0.036				
No. of grain rows/ cob	r_g	-0.461**	-0.431**	0.294**	-0.472**	-0.247*	-0.362**	0.416**	0.351**			
	r_p	-0.380**	-0.322**	0.171	-0.371**	-0.234*	-0.344**	0.347**	0.367**			
No. of grains/row	r_g	0.501**	0.475**	-0.272**	0.292**	0.752**	0.711**	-0.218*	0.521**	0.007		
	r_p	0.395**	0.360**	-0.103	0.218*	0.658**	0.637**	-0.059	0.436**	0.040		
100- Seed weight (g)	r_g	0.210*	0.240*	0.180	0.080	0.631**	0.524**	-0.237*	0.300**	-0.267*	0.451**	
	r_p	0.130	0.155	0.074	0.029	0.576**	0.487**	-0.110	0.320**	-0.232*	0.437**	
Grain yield/ plant (g)	r_g	-0.018	-0.061	-0.305**	-0.185	0.642**	0.451**	-0.196	0.620**	0.254*	0.686**	0.469**
	r_p	-0.023	-0.040	-0.052	-0.144	0.558**	0.395**	-0.061	0.574**	0.272**	0.701**	0.459**

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

Table.2 Genotypic (Pg) path-coefficient analysis showing direct and indirect effects of different traits on grain yield per plant

Characters	Days to 50% tasselling	Days to 50% silking	ASI	Days to 75% dry husk	Plant height (cm)	Ear height (cm)	Cob length (cm)	Cob diameter (cm)	No. of grain rows/ cob	No. of grains/ row	100-Seed weight (g)	Correlation with Grain yield/ plant (g)
Days to 50% tasselling	-3.684	3.279	0.242	-0.061	0.332	0.063	0.057	0.000	-0.292	-0.023	0.067	-0.018
Days to 50% silking	-3.651	3.309	0.107	-0.060	0.335	0.062	0.056	0.000	-0.274	-0.022	0.076	-0.061
ASI	0.870	-0.345	-1.027	0.017	-0.035	-0.021	-0.023	0.002	0.186	0.013	0.057	-0.305**
Days to 75% dry husk	-2.589	2.288	0.208	-0.086	0.165	0.042	0.070	0.005	-0.299	-0.013	0.026	-0.185
Plant height (cm)	-1.889	1.713	0.055	-0.022	0.647	0.075	0.061	-0.006	-0.157	-0.035	0.201	0.642**
Ear height (cm)	-2.352	2.066	0.218	-0.036	0.487	0.099	0.067	-0.004	-0.229	-0.033	0.166	0.451**
Cob length (cm)	0.856	-0.744	-0.097	0.024	-0.160	-0.027	-0.247	0.000	0.264	0.010	-0.076	-0.196
Cob diameter (cm)	-0.013	-0.043	0.123	0.023	0.229	0.021	0.003	-0.018	0.223	-0.024	0.095	0.620**
No. of grain rows/ cob	1.698	-1.427	-0.302	0.041	-0.160	-0.036	-0.103	-0.006	0.634	0.000	-0.085	0.254*
No. of grains/row	-1.845	1.572	0.279	-0.025	0.487	0.071	0.054	-0.009	0.005	-0.046	0.143	0.686**
100- Seed weight (g)	-0.775	0.795	-0.185	-0.007	0.408	0.052	0.059	-0.005	-0.169	-0.021	0.318	0.469**

Genotypic residual effect = 0.028 *Significant at 5% level ** Significant at 1% level

Correlation analysis is not sufficient to explain the true association as it does not indicate the cause and effect relationship, hence the correlated traits have to be further analysed to determine the direct and indirect effects of individual yield components on grain yield per plant through path analysis.

According to Pavan *et al.*, (2011), traits having high positive correlation along with high direct effects are expected to be useful as selection criteria in improvement program. The residual effect of 0.028 indicated that the studied characters were almost sufficient to determine the dependent variable *i.e.* grain yield per plant in maize under heat stress condition. Days to 50% tasselling exhibited highest negative direct effect, whereas days to 50 % silking recorded highest positive direct effect among all the traits under study. Both the traits were complementing each other as days to 50 % silking contributed highest positive indirect effect on days to 50 % tasselling while days to 50 % tasselling put highest indirect effect on days to 50% silking. Therefore, these two traits nullified their effects with each other leading to a non-significant correlation with yield per plant. Such finding was earlier reported by Omprakash *et al.*, (2017).

The characters; plant height, number of grain rows per cob and 100 seed weight exhibiting high positive direct effect on grain yield per plant were also reported with high positive correlation with the same. Hence, selection for these component traits could be considered as important criteria in improving grain yield per plant in maize under heat stress condition. These results are mostly in accordance with the earlier findings of Azhar *et al.*, (2016), Dinesh *et al.*, (2016a), Khodarahmpour and Choukan, (2011), Pavan *et al.*, (2011) and Begu *et al.*, (2016). It is worth to note that cob diameter and number of grains per row recorded negative direct

effect, but positive correlation with grain yield per plant. The positive correlation might arise due to high positive indirect effects via plant height. Thus in maize hybrids, tall stature was associated with better yield and might be taken into consideration for further studies under heat stress. This finding is in accordance with Al-Tabbal and Al-Fraihat (2012). Ear height possessed very less positive direct effect but significantly high positive correlation with grain yield per plant. This result is supported by Khodarahmpour (2012), who suggested that tall plants with high ear placement gave better yield under heat stress. Anthesis to silking interval is the only character that exhibited negative correlation and also negative direct effect on grain yield per plant. Such finding was also reported by Magorokosho *et al.*, (2003). Hence, for improving grain yield, emphasis must be given for selecting genotypes with minimum anthesis to silking interval.

The results obtained from this research of character association and path coefficient analysis revealed that plant height, ear height, number of rows per cob, and 100 seed weight in positive direction and anthesis to silking interval in negative direction have significant influence on grain yield per plant in maize under heat stress condition. Thus selection for these characters can be considered as important criteria in improving grain yield of maize under heat stress.

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