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Research Note

Association and path analysis for grain yield and its attributing traits under heat stress condition in tropical maize (*Zea mays* L.)

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Abstract

A study was undertaken to analyze grain yield and its component traits, and their relationships among themselves under heat stress conditions. A set of hybrids were evaluated during summer (mid-March sowing). Association analysis revealed that plant height, ear height, ear girth, number of kernels per cob and shelling per cent had significant positive association with grain yield per plant at both genotypic and phenotypic levels but ASI showed negative association with grain yield per plant while leaf firing and tassel blast were positively associated. Path coefficient analysis revealed that shelling per cent and number of kernels per cob showed high direct effect on grain yield. Number of kernels per cob showed high indirect effect on yield per plant through leaf firing and ear length. Our study suggests that these traits could be considered while selecting the lines for improved grain yield under heat stress condition.

Key words

Zea mays L., heat stress, grain yield, correlation coefficient, path coefficient

Maize is called queen of cereal crops due to high yielding potential and enormous genetic diversity (Prasanna, 2012). Maize being nutritionally an important crop has multiple functions in the traditional farming system; being used as food and fuel for human beings and feed for livestock and poultry. Average world's maize yield has increased from 4.9 tons ha^{-1} in 2012 to 5.5 ton ha^{-1} in 2013 (FAOSTAT, 2015). In India, maize production stands at third position, next to rice and wheat with annual production of 23 m t cultivated in an area of 9.4 m h with productivity of 2.5 t h^{-1} (India maize summit, 2014).

It is highly productive crop under optimal environmental and crop management conditions. However, it is susceptible to weather extremes such as drought and heat. Each year, an average of 15 to 20 per cent of the potential world maize production is lost due to these stresses (FAO STAT, 2006-2008). The total yield loss depends on the occurrence of stress during crop growth, as well as the duration and the severity of the stress. Heat stress in maize is associated with shortened life cycle (Muchow *et al*., 1990), reduced light interception (Stone, 2001), increased respiration, reduced photosynthesis (Crafts-Brander and Salvucci, 2002) and pollen sterility (Schoper *et al.*, 1987a) resulting in poor seed set and eventually reduced grain yield (Johnson, 2000).

Intergovernmental Panel on Climate Change (IPPC) has projected that global mean temperature would rise 0.3^{o}C per decade reaching to approximately 1^{o}C and 3^{o}C above the present value by years 2025 and 2100, respectively. High temperature during day and night time reduces the maize yield significantly due to tassel blast, leaf firing and other physiological disturbances. In general, a transient elevation in temperature, usually 10 to 15 °C above ambience is considered heat shock or heat stress (Wahid *et al.,* 2007). Heat stress for maize crop can be defined as temperature beyond a threshold level (T_{max}-> 35^{o}C and T_{min}->23^{o}C) for a period of time sufficient to cause irreversible damage to crop growth and development. It has been estimated that 2^{o}C increases in the temperature above 30^{o}C reduces the maize yields by 13 per cent as compared to 20 per cent intra seasonal variation in the rainfall (Lobell *et al*., 2011).

Grain yield is a complex trait and is collectively influenced by various component characters, besides polygenically inherited and influenced by environmental variation. The appropriate knowledge of interrelationships between grain yield and its contributing components can significantly improve the efficiency of breeding programme through the use of appropriate selection indices (Mohammadia *et al*., 2011). The correlation studies measure the associations between yield and other traits. Path coefficient analysis permits the separation of correlation coefficient into direct and indirect effects (effects exerted through other variables).

The concerted efforts towards development of heat stress resilient hybrids and inbreds are not many. For the development and selection of inbred lines for heat stress in tropical maize, information on secondary traits associated with grain yield under heat stress would pay pivotal role. Therefore, the present investigation was carried out to determine the association of traits with grain yield through correlation coefficient and direct and indirect effect of a set of variables through path analysis under heat stress condition in tropical maize.

Study Site and Experiment Details: The investigation was carried out at Agriculture College Farm, Bheemarayanagudi (16°44' N latitude and 76°47' E longitude at an elevation of 458 m above mean sea level) during spring (mid-March sowing) 2015.

The experimental material consist 32 hybrids developed at CIMMYT- Asia regional programme-Hyderabad using eight tropical female lines which were crossed with four male lines (Table 1) in NCD-II design. These hybrids (without parents) were evaluated along with three checks *viz.*, 31Y45, BIO9544, D2244 in alpha lattice design with two replications. Each plot consisted of two rows of 4m length with spacing of 60 cm x 20 cm. Recommended agronomic practices were adopted to raise a healthy crop.

Data Collection and Analysis: Data on days to 50% anthesis, days to 50% silking and ears per plot were recorded on plot basis. Whereas, plant height (cm), ear height (cm), number of kernels per cob, ear length (cm), ear girth (cm), test weight (g) and shelling per cent were recorded on five selected representative plants. The sample cobs were shelled, cleaned and grain weight and shank weight were recorded to calculate the shelling per cent. Test weight was measured by counting 100 grains from the bulk of each plot after shelling and weighed in grams after the moisture was adjusted to 12.5%. Anthesis to silking interval (ASI) was calculated by subtracting the number of days taken for 50% anthesis from the number of days taken to 50% silk emergence. Leaf firing was obtained by the counting the number of plants that showed leaf firing symptoms (younger leaves near tassel burnt or dried) in the total number of plants in a particular plot. Then the value was expressed in percentage. Tassel blast was obtained by the counting the number of plants that showed tassel blast symptoms (tassel dried with partial or no pollen shedding) in the total number of plants in particular plot. Grain yield per plant (g) was calculated by dividing the grain yield per plot by total number of plants in the plot and finally it was adjusted to the moisture content of 12.5%.

The phenotypic and genotypic correlation coefficients for various characters were calculated as per the method suggested by Al-Jibouri *et al.* (1958); partitioning correlation coefficients into direct and indirect effects at phenotypic level was made by determining path coefficients using the method proposed by Wright (1921) and Dewey and Lu (1959) by subjecting the data to Windostat 9.2.

For achieving rational improvement in grain yield and its components, knowledge on mechanism of correlation, cause and effect relationship provides a basis for formulating suitable selection methods for the grain yield. Association analysis revealed that shelling per cent (0.996, 0.651), ear girth (0.513, 0.519), number of kernels per cob (0.468, 0.511), test weight (0.892, 0.298) and plant height (0.501, 0.383) had high significant positive association with grain yield per plant at both genotypic and phenotypic levels but ear height (0.402) had significant positive association only at phenotypic level (Table 2). Whereas, ASI (-0.235) showed significant negative association with grain yield per plant at phenotypic level. Thus, lesser interval between anthesis and silking interval results in higher yields per plant under heat stress. Leaf firing showed significant negative association with plant height (-0.334,-0.260) and number of kernels per cob (-0.636,-0.242) and it showed significant positive association with tassel blast per cent (0.592, 0.268) at both phenotypic and genotypic levels. Hence, occurrence of tassel blast influences the occurrence leaf firing under heat stress condition. (Rupindarkaur *et al.*, 2010) also reported that leaf firing and tassel blast had positive association and both of these were negatively correlated with shelling percentage and yield under heat stress condition. Hence, it could be concluded that the selection for higher plant height, more number of kernels per cob, higher test weight and shelling per cent and plants with no tassel blast and leaf firing might result in improved grain yield.

Partitioning of the total correlation coefficient into direct and indirect effects for grain yield showed high direct effects from two traits *viz*., shelling per cent (0.361) and number of kernels per cob (0.319). However, ear height (0.166) and ear girth (0.185) registered moderate direct effect for grain yield. High indirect effect on yield per plant exhibited by number of kernels per cob through leaf firing (-0.755) and ear length (0.205) (Table 3). Angadi (2014) reported that in hybrids number of kernels per cob and 100 kernel weight showed high direct effect on grain yield per plant under heat stress condition.

The results of the present study indicated that the high direct effect of the shelling per cent, number of kernels per cob, ear height and ear girth were appeared to be the main factors for their strong association with grain yield per plant under heat stress. Hence, direct selection for these traits would be effective to improve grain yield under heat stress condition. Since, important heat tolerant traits *viz.*, tassel blast and leaf firing were negatively associated with grain yield, it is suggested to select plants which do not show these characters to get heat tolerant plants in subsequent generation.

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Table 1. List of parental lines used for crossing and their reaction to heat stress

Parental lines	Pedigree	Reaction to heat stress
L1	(CA14515/CA14502)-F2-10-2-B*9	Tolerant
L2	POOL16BNSEQC3F32x37-4-1-2-1-B*8	Tolerant
L3	POOL16BNSEQC3F37x3-2-2-3-2-B*5	Tolerant
L4	P31C4S5B-6-*-*-3-1-B*8-3-B*6	Tolerant
L5	DTPYC9-F46-3-9-1-2-2-1-3-B*9	Tolerant
L6	CA14514-8-3-2-B*6	Susceptible
L7	POOL16BNSEQC3F22x1-3-2-2-2-B*5	Susceptible
L8	DTPYC9-F46-1-7-1-2-1-2-2-B*7	Tolerant
T1	(DT/LN/EM-46-3-1xCML311-2-1-3)-B-F216-1-1-1-B*5	Tolerant
T2	WLS-F190-2-1-1-B-2-B*5	Tolerant
T3	(CML20xCML329)-17-3-3-1-B*11	Susceptible
T4	CA14514-9-6-3-B*4	Susceptible

T: Tolerant to heat stress, S: Susceptible to heat stress

Table 2. Genotypic and phenotypic correlation coefficients between grain yield and its attributing traits in maize hybrids under heat stress condition at Bheemarayanagudi

		ASI	PH	EH	TB%	LF%	NKC	EL	EG	SP	TW	YPP
ASI	P	1.000	0.426**	-0.284*	0.067	-0.024	0.097	0.218	-0.147	-0.149	-0.208	-0.235*
	G	1.000	-0.197	-	0.120	-0.115	-	-0.781**	-	-	-0.296*	-
PH	P		1.000	0.796*	-0.138	-0.260*	0.576**	-0.138	-0.260*	0.284*	0.069	0.383**
	G		1.000	0.928**	-0.419**	-0.334**	0.820**	0.476**	0.406**	0.227*	-0.246*	0.501**
EH	P			1.000	-0.048	-0.139	0.468**	0.366**	0.348**	0.281*	0.068	0.402**
	G			1.000	-0.175	-0.181	-	0.647**	0.708**	0.507**	0.062	-
TB%	P				1.000	0.268*	-0.205	-0.201	0.019	-0.020	0.138	-0.190
	G				1.000	0.592**	-0.536**	-0.402**	0.178	-0.719**	0.195	-0.057
LF%	P					1.000	0.242*	-0.223	0.248*	0.029	0.348**	-0.103
	G					1.000	-0.636**	-0.382**	0.414**	0.097	0.679**	-0.0009
NKC	P						1.000	0.660**	0.492**	0.446**	-0.146	0.511**
	G						1.000	0.965**	0.053	0.359**	-0.254*	0.468**
EL	P							1.000	0.284*	0.092	0.092	0.170
	G							1.000	0.212	0.188	-0.342**	0.395**
EG	P								1.000	0.516**	0.477**	0.519**
	G								1.000	0.481**	0.974**	0.513**
SP	P									1.000	0.420**	0.651**
	G									1.000	0.583**	0.996**
TW	P										1.000	0.298*
	G										1.000	0.892**

*, ** Significant 5 and 1 per cent level, respectively

ASI: Anthesis to silking interval; PH: Plant height (cm); EH: Ear height (cm); EPP: Ears per plant; NKC: Number of kernels/ cob; EL: Ear length (cm); EG: Ear girth (cm); HKW: Hundred kernel weight (g); SP: Shelling per cent; YPP: Grain yield per plant (g); P = phenotypic; G = Genotypic Non-estimable at genotypic level;

Table 3. Direct and indirect effects between selected characters and grain yield at phenotypic level in maize hybrids under heat stress condition at Bheemarayanagudi

Traits	ASI	PH	EH	TB%	LF%	NKC	EL	EG	SP	TW	‘r^2 YPP
ASI	**-0.192**	0.11	0.02	-0.01	0.008	0.015	0.027	0.023	0.022	0.009	0.042
PH	-0.001	**-0.065**	-0.112	0.015	0.035	-0.064	-0.059	-0.033	-0.031	-0.01	-0.315
EH	-0.103	0.198	**0.166**	-0.01	-0.021	0.089	0.064	0.068	0.053	-0.008	0.506
TB%	-0.059	0.069	-0.014	**-0.138**	-0.032	0.03	0.023	0.001	0.003	-0.039	-0.146
LF%	-0.047	0.053	-0.002	-0.035	**-0.124**	0.033	0.024	-0.029	-0.002	-0.065	-0.184
NKC	-0.08	0.232	0.128	-0.066	-0.755	**0.319**	0.205	0.159	0.015	-0.066	0.101
EL	-0.005	-0.05	-0.096	0.041	0.051	-0.136	**-0.213**	-0.056	-0.018	-0.019	-0.491
EG	-0.076	0.108	0.043	0.002	0.05	0.091	0.047	**0.185**	0.093	0.067	0.622
SP	-0.103	0.152	0.081	-0.008	0.015	0.162	0.029	0.189	**0.361**	-0.005	0.883
TW	-0.067	0.045	-0.015	0.01	0.034	-0.01	-0.018	0.042	0.036	**0.063**	0.135

Residual value – 0.644

*, ** Significant 5 and 1 per cent level, respectively

ASI: Anthesis to silking interval; PH: Plant height (cm); EH: Ear height (cm); EPP: Ears per plant; NKC: Number of kernels/ cob; EL: Ear length (cm); EG: Ear girth (cm); TW: Test weight (g); SP: Shelling per cent; YPP: Grain yield per plant (g).