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Heritability, Correlation and Path Coefficient Analysis of Grain Yield and Yield Components in Maize (*Zea mays* L.)

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The present study was carried out on maize (*Zea mays* L.) to study the gene action, narrow sense heritability, interrelationships among traits and path coefficient analysis for grain yield and its components at Agricultural Research Station, Karimnagar, PJTSAU, India during rainy season, 2012. Results indicated that the magnitude of additive variance was consistently greater than that of dominance variance for days to 50% pollen shed, days to 50% silk emergence, plant height, kernel rows ear^{-1}, 100 seed weight and grain yield plant^{-1}. High narrow sense heritability estimate was detected for days to pollen shed and moderate narrow sense heritability estimates were found for days to silk emergence, plant height, ear height, ear girth, kernel rows ear^{-1}, 100 seed weight and grain yield plant^{-1}. This implies that the additive genetic variance was the major component of genetic variation in the inheritance of these traits and the effectiveness of selection for improving these traits. Positive and significant phenotypic and genotypic correlations were recorded for plant height and ear height with ear length, ear girth, 100 seed weight and grain yield plant^{-1}. The path analysis revealed that, ear girth had the highest direct effect on grain yield followed by days to 50% silk emergence, while both the traits recorded high moderate indirect effects on grain yield via days to 50% pollen shed, no. of grains per plant, 100 seeds weight, plant height and ear height. Hence days to 50% silk emergence and number of ears per the selection for ear girth plant will be highly effective for improvement of grain yield.

Key words: Maize, Narrow sense heritability, Correlation and path coefficient analysis.

Grain yield is a complex character and is influenced by a number of inter related traits. Plant breeders are interested in developing cultivars with improved yield and other desirable agronomic characters. Breeding for yield improvement require information on the nature and magnitude of variation available in the material, relationship of yield with other agronomic characters and the degree of environmental influence on the expression of these component characters. Since, grain yield in maize is quantitative in nature and polygenically controlled, effective yield improvement and simultaneous improvement in yield components are imperative. Direct selection for yield *per se* may not be the most efficient method for yield improvement but indirect selection for other yield related characters which are closely associated with yield and high heritability estimate will be more effective. Knowledge of association between yield and its component traits and among component traits can improve the efficiency of selection in plant breeding. Correlation coefficient measures the mutual relationship between a pair of variables independent of other variables to be considered. Where more than two variables are involved, correlation coefficient alone does not give complete picture of interrelationship. Hence, information based on correlation coefficients is only partial, whereas the path coefficient analysis permits the partition of correlation coefficients into direct and indirect effects and gives a more realistic relationship of the characters and helps in identifying the effective components. The present study was undertaken to estimate genetic variance, heritability, correlation and path coefficients for yield and its components in single crosses of maize.

Materials and Methods

The experimental material comprised of a set of maize crosses obtained through line x tester mating design. The experimental work was conducted at Agricultural Research Station, Karimnagar. During *rabi* 2011-12, fifteen lines viz., KMLD-3, KMLD-5, KMLD-6, KMLD-11, KMLD-18, KMLD-19, KMLD-21, KMLD-61, KMLD-65, KMLD-66, KMLD-68, KMLD-70, KMLD-71, KMLD-73 and KMLD-82 were crossed with nine testers viz., BML-7, KML-9, KML-29, KML-36, KML-55, KML-99, KML-224, KML-801 and KML-802 in line x tester design. Lines were derived from CIMMYT ‘Tuxpeno Sequia’ population through recurrent selection and testers were developed by pedigree breeding. During rainy (*kharif*) season,

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2012 the resultant 135 crosses were evaluated in a randomized block design with two replications with row-to-row and plant-to-plant spacing of 75 cm × 20 cm, respectively. The data was recorded on five selected plants for days to 50% pollen shed, days to 50% silk emergence, plant height, ear height, number of ears plant^{-1}, ear length, ear girth, kernel rows ear^{-1}, number of kernels row^{-1}, 100 grain weight and grain yield plant^{-1}. Narrow sense heritability and variances were estimated according to standard statistical procedures. Path coefficient analysis was done following the method of Dewey and Lu (1959).

Results and Discussion

Variability and heritability estimates

Variance components for general (Vgca) and specific (Vsca) combining abilities calculated for each trait were translated into additive (VA) and dominance (VD) genetic variances and are presented in Table 1. Results indicated that all estimates of VA and VD were significant for plant height, ear height, 100 grain weight and grain yield plant^{-1} and VD for number of kernels row^{-1}. The trait ear length was non-significant for VA and VD may be attributed to larger magnitude of error variance. However, the magnitude of VA was consistently larger than that of VD for days to 50% pollen shed, days to 50% silk emergence, plant height, kernel rows ear^{-1}, 100 grain weight and grain yield plant^{-1} and VD was higher in magnitude than VA for remaining traits. This indicated that the experimental materials may be more efficiently exploited by adopting any population improvement method for composite development to derive new inbred lines. Recurrent selection plays an important role in improvement of these traits. These findings were in close agreement with those of Singh *et al.* (1998) and Vasal *et al*. (1993) for days to 50% silk emergence and plant height.

Table 1. Heritability (h^2) and Variance of additive (VA), dominance (VD), environment (VE) and phenotypic (VP) for all studied traits

Parameter	Days to 50% pollen shed	Days to 50% silk emergence	Plant height	Ear height	No.of ears plant^{-1}	Ear length	Ear girth	Kernel rows ear^{-1}	No.of kernels row^{-1}	100 grain weight	Grain yield plant^{-1}
VA	1.73	1.35	83.52**	23.05**	0.0003	0.18	0.24	1.11	2.26	7.11*	96.75**
VD	0.49	0.44	65.06**	35.96**	0.0017	0.47	0.26	0.38	5.03**	6.84*	64.54**
VP	2.84	2.48	211.06**	88.51**	0.0052	1.75**	0.69	2.17	16.20**	18.13**	404.33**
VE	0.62	0.70	62.48**	29.50**	0.0032	1.11**	0.19	0.68	8.90**	4.19	243.03**
h^2	60.91	54.25	39.57	26.04	4.83	10.23	34.74	51.10	13.97	39.18	23.93

*, ** significant at 5% and 1%, respectively.

Results showed that high narrow sense heritability estimates were detected for days to 50% pollen shed (61%), days to 50% silk emergence (54%) and kernel rows ear^{-1} (51%). However, moderate narrow sense heritability estimates were obtained for plant height (40%), ear height (26%), ear girth (35%), 100 grain weight (39%) and grain yield plant^{-1} (24%), while such estimates were low for number of ears plant^{-1} (5%), ear length (10%) and number of kernels row^{-1} (14%). Similar result of high narrow sense heritability for kernel rows ear^{-1} and medium narrow sense heritability for 100 grain weight was reported by Wannows *et al.* (2010). Narrow sense heritability estimates emphasized the portion of additive genetic variance that will be useful in choosing suitable segregating generations for best expression of genes of different characters in the studied hybrids for improving such traits.

Correlation among characters

Correlation studies give reliable information on the nature, extent and direction of selection. The knowledge on correlation coefficients between different yield attributes helps in finding out the nature and magnitude of the association between these traits to get good yields. Phenotypic and genotypic correlation coefficients estimated for all pairs of studied characters including grain yield plant^{-1} are presented (Table 2).The data showed that significant and positive phenotypic correlation coefficients were found between grain yield and all the characters except days to 50% pollen shed, days to 50% silk emergence and kernel rows ear^{-1}. It helps the breeder to select for high grain yield through selection of one or more of these characters. This indicates that selection for increased plant height, ear height, long ears, increased ear girth, more number of kernels row^{-1} and more 100 grain weight may be accompanied by increasing grain yield of maize. High correlation of grain yield with plant height was reported by Gautam *et al*. (1999). Other inter-character correlations revealed that plant height and ear height had significant and positive phenotypic correlations with ear length, ear girth and 100 grain weight. Ear length had significant and positive correlation with ear girth, number of kernels row^{-1} and 100 grain weight, whereas ear girth had significant and positive correlation with number of kernels row^{-1} and 100 grain weight.

Genotypic correlation coefficients showed that grain yield had positive and significant correlation with all the characters except ear height, ear length and number of kernels row^{-1}.There were positive and significant genotypic correlations of days to 50% pollen shed and days to 50% silk emergence with plant height, ear height, number of ears plant^{-1}, ear

Table 2. Phenotypic (rp), genotypic (rg) and environmental (re) correlation coefficients between studied traits

Characters	Correlation coefficient	Days to 50% pollen shed	Days to 50% silk emergence	Plant height	Ear height	No.of ears plant^{-1}	Ear length	Ear girth	Kernel rows ear^{-1}	No.of kernels row^{-1}	100 grain weight
Days to 50% pollen shed	rp	1.00									
	rg	1.00									
	re	1.00									
Days to 50% silk emergence	rp	0.89**	1.00								
	rg	0.95**	1.00								
	re	0.80**	1.00								
Plant height	rp	0.04	-0.01	1.00							
	rg	0.22**	0.22**	1.00							
	re	-0.23**	-0.30**	1.00							
Ear height	rp	0.10	0.08	0.74**	1.00						
	rg	0.28**	0.32**	0.80**	1.00						
	re	-0.14*	-0.19**	0.67**	1.00						
No.of ears plant^{-1}	rp	0.09	-0.02	0.16 **	0.11	1.00					
	rg	0.32**	0.37**	0.05	-0.01	1.00					
	re	-0.07	-0.26**	0.25**	0.18**	1.00					
Ear length	rp	-0.08	-0.17**	0.32 **	0.22**	0.15*	1.00				
	rg	0.03	-0.07	0.31**	0.12*	-0.05	1.00				
	re	-0.17**	-0.25**	0.35**	0.30**	0.21**	1.00				
Ear girth	rp	0.17 **	0.10	0.35 **	0.22 **	0.10	0.31 **	1.00			
	rg	0.39**	0.36**	0.55**	0.28**	0.13*	0.32**	1.00			
	re	-0.16**	-0.24**	0.09	0.15*	0.09	0.33**	1.00			
Kernel rows ear^{-1}	rp	-0.03	-0.04	-0.09	-0.07	0.00	0.01	0.38 **	1.00		
	rg	-0.03	-0.03	-0.17**	-0.14*	-0.07	-0.08	0.48**	1.00		
	re	-0.04	-0.05	0.00	0.01	0.04	0.05	0.26**	1.00		
No.of kernels row^{-1}	rp	-0.14*	-0.21**	0.05	0.01	0.13*	0.57**	0.09	0.03	1.00	
	rg	-0.15*	-0.21**	-0.18**	-0.20**	0.02	0.37**	-0.11	0.12*	1.00	
	re	-0.16**	-0.22**	0.23**	0.15*	0.16**	0.64**	0.26**	-0.03	1.00	
100 grain weight	rp	0.13*	0.09	0.28 **	0.25 **	0.10	0.18 **	0.23**	-0.29 **	-0.04	1.00
	rg	0.27**	0.25**	0.44**	0.42**	0.25**	0.34**	0.33**	-0.46**	-0.18**	1.00
	re	-0.11	-0.13*	0.07	0.03	0.00	0.10	0.09	-0.06	0.08	1.00
Grain yield plant^{-1}	rp	0.11	0.01	0.32**	0.19**	0.41**	0.29**	0.37**	0.10	0.17**	0.30**
	rg	0.66**	0.73**	0.21**	0.07	0.44**	-0.13*	0.73**	0.22**	-0.32**	0.40**
	re	-0.30**	-0.46**	0.42**	0.27**	0.40**	0.43**	0.16**	0.04	0.36**	0.26**

*, ** significant at 5% and 1%, respectively.

girth, 100 grain weight and grain yield plant^{-1}. Troyer and Larkins (1985) observed that plant height was positively correlated with days to flowering morphologically as internode's formation stops at floral initiation and that early flowering maize varieties are usually short in height. This suggests that genetic factors are responsible for these associations. For majority of the traits, genotypic correlations are higher in magnitude than the corresponding phenotypic correlations, indicating a strong inherent relationship among traits studied.

Environmental correlation coefficients between studied traits revealed that highly significant and positive correlations of all the characters with grain yield plant^{-1} except days to 50% pollen shed, days to 50% silk emergence and number of kernel rows ear^{-1}. Bello *et al.* (2010) reported that plant height, ear height and ear weight had significant and positive correlations with grain yield. Grain yield plant^{-1} had significant and negative correlation with days to 50% pollen shed, days to 50% silk emergence and positive, non-significant correlation with number of kernels row^{-1}.Westermann and Crothers (1977) reported that changes in yield and yield components had been attributed to plant's response to its environment which may or may not permit full genetic expression of each character. Significant positive correlations between yield and other agronomic characters that can improve yield are quite desirable in plant breeding, because it facilitates selection process and gain from selection.

Table 3. Genotypic path analysis for grain yield plant^{-1}

Character	Means	Direct effects	Indirect effects										Total effects
			1	2	3	4	5	6	7	8	9	10	
Days to 50% pollen shed	52	-0.523		-0.495	-0.116	-0.147	-0.168	-0.016	-0.203	0.014	0.078	-0.141	0.661**
Days to 50% silk emergence	54	0.915	0.866		0.205	0.296	0.341	-0.065	0.328	-0.025	-0.196	0.226	0.732**
Plant height	162	-0.233	-0.052	-0.053		-0.187	-0.011	-0.073	-0.128	0.039	0.043	-0.102	0.210**
Ear height	64	-0.234	-0.066	-0.076	-0.187		0.002	-0.029	-0.067	0.034	0.045	-0.097	0.068
No.of ears plant^{-1}	1	0.072	0.023	0.027	0.003	-0.001		-0.004	0.009	-0.005	0.002	0.018	0.438**
Ear length	17	-0.319	-0.010	0.023	-0.099	-0.040	0.016		-0.101	0.024	-0.119	-0.108	-0.127*
Ear girth	14	0.935	0.363	0.335	0.513	0.266	0.123	0.297		0.448	-0.103	0.309	0.734**
Kernel rows ear^{-1}	14	-0.220	0.006	0.006	0.037	0.032	0.014	0.017	-0.105		-0.027	0.102	0.217**
No.of kernels row^{-1}	33	-0.005	0.001	0.001	0.001	0.001	0.000	-0.002	0.001	-0.001		0.001	-0.318**
100 grain weight	27	0.196	0.053	0.049	0.086	0.082	0.049	0.067	0.065	-0.091	-0.036		0.404**

*, ** significant at 5% and 1%, respectively.

Path coefficient analyses was also estimated to obtain further information on the inter relationships among traits and their effects on grain yield and are presented (Table 3). Ear girth exerted maximum direct effect on grain yield plant^{-1} followed by days to

50% silk emergence, 100 grain weight and number of ears plant^{-1}.Remaining characters had negative direct effects on grain yield plant^{-1}. Negative direct effect of plant height on grain yield plant^{-1} was reported by Geetha and Jayaraman (2000). Ear girth had high moderate positive indirect effects on grain yield plant^{-1} by days to 50% pollen shed, days to 50% silk emergence, plant height and number of kernel rows ear^{-1}. Days to 50% silk emergence had high positive indirect effects on grain yield plant^{-1} by days to 50% pollen shed followed by number of ears plant^{-1} and ear girth. In the present study, days to 50% pollen shed, days to 50% silk emergence, plant height, number of ears plant^{-1}, ear girth, kernel rows ear^{-1}and 100 grain weight appeared to be prominent characters that could be used in selecting for high yield, because of their highly significant genotypic correlation with grain yield plant^{-1}. Days to 50% silk emergence and ear girth had the highest direct and indirect effects on grain yield plant^{-1} through most of the other characters. Therefore, it is concluded that these agronomic parameters could be considered as an important criteria for improving the grain yield of maize.

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