Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(5): 1374-1377
Received: 27-07-2018
Accepted: 28-08-2018

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Studies on phenotypic correlation and path coefficient analysis of grain yield and its component traits in maize (*Zea mays* L.) hybrids

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Abstract
Maize is one of the most important grown plants in the world. Superior position of maize is due to his very wide and variety utilisation and because of that, the main goal of all maize breeding programs is to obtain new inbred lines and hybrids that will outperform the existing hybrids with respect to a number of traits. The present study was carried out to access correlation coefficient and path analysis among 50 developed maize hybrids for ten characters. Highly significant mean sum of squares due to genotypes and wide range of variability were noticed among the genotypes for all the characters except number of kernels per row. Grain yield per plant was significant and positively association with cob height, cob girth and number of kernels per row. Path analysis was used to partition the genetic correlations between grain yield and related characters. Path coefficient analysis revealed that days to 50 percent flowering exhibited the largest direct effect on grain yield per plant at phenotypic level followed by cob height indicating the effectiveness of direct selection. The information generated by this study could be useful for researchers who need to develop high yielding maize hybrids.

Keywords: Maize, correlation, hybrids, and path analysis

Introduction
Maize (*Zea mays* L.; 2n=20) the sole cultivated member of genus *Zea* and tribe *Maydeae*, ranks as one of the three important cereal crops in the world after wheat and rice. It is the principal staple food in many developing countries contributing to food security and income in tropical and sub-tropical environments. Maize is a versatile crop grown with a latitude 58° N to 40° S and height of cultivation ranges from sea level to more than 3000 meters altitude and can withstand rainfall from 250 mm to 5000 mm of precipitation per annum. However, most of the area under this crop is in the warmer parts of temperate regions and in humid-subtropical climate. Highest production is in area having the warmest month isotherms from 21 °C to 27 °C and a frost free season of 120 to 180 days duration. It can be grown in soils ranging from 5.5 to 8.0 p^H, but it is sensitive to salinity.

Globally, maize is cultivated in an area of 183.24 million hectare with the production of 1036.07 million tonnes and productivity of 5.65 t ha^{-1}. Among the maize growing countries, USA stands first followed by Brazil, China, Mexico. India stands sixth among the maize producing countries in the globe with an area, production and productivity of 9.6 million hectare, 27.15 million tonnes and 2.83 t ha^{-1}, respectively. Further, 2.83 t ha^{-1} productivity is lower than world average, may be due to 70-75 percent area is under rainfed condition, where, crop suffers from heat and drought stress. Karnataka is one of the major maize producing states in the country with an area of 1.18 million hectare, production 3.27 million tonnes and productivity 2773 kg ha^{-1}. Nutritionally it has highest crude protein of about 9.9 percent at early and at full bloom stages which decreases to percent at milking stage and 6 percent at maturity. It has high nutritive value as it contains 72 percent starch, 10 percent protein, 4.80 percent oil, 9.50 percent fiber, 3.0 percent sugar, 1.70 percent ash, 82 percent endosperm, 12 percent embryo, 5 percent bran testa and 1 percent tip cap.

The efficiency of breeding programme depends mainly on the direction and magnitude of association between yield and its components and also the relative importance of each factor involved in contributing to grain yield. Grain yield is a complex quantitative trait that depends on plant genetics and its interaction with environmental conditions. To determine such relationships, correlation analyses are used such that the values of two characters are analyzed on a paired basis, results of which may be either positive or negative. The result of correlation is of great value in the evaluation of the most effective procedures for selection of superior genotypes. When there is positive association of major yield characters, component breeding would be very effective but when these characters are negatively associated, it would be difficult to exercise simultaneous selection for such characters in varietal development. Phenotypic correlation indicates the extent of the observation having relation between two traits while genotypic correlation provides an estimate of inherent association between the genes controlling any two traits. For formulating selection indices for genetic improvement of yield, the cause and effect of the trait is very essential and can be done by path analysis.

Path analysis showed direct and indirect effects of cause variables on effect variables. In this method, the correlation coefficient between two traits is separated into the components which measure the direct and indirect effects. Generally, this method provides more information among variables than do correlation coefficients since this analysis provides the direct effects of specific yield components on yield, and indirect effects via other yield components.

In order to obtain new inbred and hybrids that will outperform the existing hybrids with respect to a number of traits, the breeders had the option of selecting desirable genotypes in early generations or delaying intense selection until advanced generations. For full understanding of the complex relationships between grain yield and other characters, the computation of direct and indirect effects of these traits on grain yield is essential. Therefore, before embarking on grain yield improvement it is necessary to understand the relationships existing between grain yield and other metric traits of the crop to improve the efficiency of breeding programs through the use of appropriate selection indices. Therefore, the present study was conducted to determine trait association and direct and indirect effects of yield related traits on grain yield of elite maize hybrids.

Materials and Methods

Sixteen best promising inbred lines were selected from two different populations and these selected 16 inbred lines were crossed with three different testers *viz.*, CI-4, KDMI-15, NEI-9202B, using line × tester mating design during *kharif* 2012 and generated 48 single cross hybrids which were evaluated during *rabi/*summer 2012-13 along with two commercial checks *viz.*, Bio-9681 and 900M for their performance. These were grown in randomised complete block design with three replications of 4 m length with inter row spacing of 60 cm and intra row spacing of 20 cm at Agriculture College Bheemarayanagudi during *rabi/*summer 2012-13. The data on Days to 50 percent flowering, Days to 50 percent silking, Plant height (cm), Ear height (cm,) Ear length (cm), Ear girth (cm), Number of kernel rows per cob, Number of kernels per row, 100 kernel weight (g) and Grain yield per plant (g) were recorded. The standardized traits mean values were pooled and used to investigate correlation and path using Indostat version 9.2.

Results and Discussion

The analysis of variance showed a wide range of variation and significant differences for all the characters under study, indicating the presence of adequate variability for further improvement. The mean sum of squares due to genotypes showed highly significant differences for all the characters except for number of kernels per row (Table 1). This indicates the presence of substantial genetic variability among the genotypes, which could be exploited for the improvement of respective traits. Similar results were reported by for number of cobs per plant.

Table 1: Analysis of variance for grain yield and its component traits in maize hybrids.

Characters	Mean sum of square		
	Replication (Df= 2)	Genotypes (Df= 49)	Error (Df= 98)
Days to 50% flowering	1.64	7.94**	1.41
Days to 50% silking	6.40	11.01**	3.56
Plant height (cm)	8693.98**	444.71**	169.05
Cob height (cm)	2456.23**	362.25**	95.55
Cob length (cm)	88.02**	7.25**	3.48
Cob girth (cm)	9.15**	1.44**	0.68
Number of kernel rows per cob	1.96	5.10**	0.94
Number of kernels per row	423.75**	28.64	21.93
100 seed weight (g)	215.62**	18.10*	11.71
Grain yield per plant (g)	384.70	2153.64**	505.78

* Significant at P =0.05, ** Significant at P =0.01

Table 2: Phenotypic correlation coefficients of grain yield and its component traits in maize hybrids.

Character	Days to 50% flowering	Days to 50% silking	Plant height (cm)	Cob height (cm)	Cob length (cm)	Cob girth (cm)	No of kernel rows/cob	No of kernels/ row	100 seed weight (g)	Grain yield/plant (g)
Days to 50% flowering	1.000	0.844**	-0.160*	0.022	0.236**	0.028	-0.167*	0.207*	-0.103	0.022
Days to 50% silking		1.000	-0.084	0.022	0.074	-0.061	-0.106	0.069	-0.221**	0.003
Plant height(cm)			1.000	0.670**	0.391**	0.412**	0.212**	0.191*	0.303**	-0.012
Cob height(cm)				1.000	0.221**	0.240**	0.089	0.049	0.285**	0.186*
Cob length(cm)					1.000	0.489**	-0.088	0.772**	0.438**	-0.073
Cob girth (cm)						1.000	0.444**	0.373**	0.356**	0.208*
No of kernel rows/cob							1.000	-0.131	-0.094	-0.137
No of kernels/row								1.000	0.202*	0.188*
100 seed weight (g)									1.000	-0.032
Grain yield/plant (g)										1.000

Table 3: Direct (bold) and indirect effect of nine characters on grain yield per plant (g) at phenotypic level.

Character	Days to 50% flowering	Days to 50% silking	Plant height (cm)	Cob height (cm)	Cob length (cm)	Cob girth (cm)	No of kernel rows/cob	No of kernels/ row	100 seed weight (g)	Correlation with grain yield/plant (g)
Days to 50% flowering	0.142	0.120	-0.022	0.003	0.033	0.004	-0.021	0.021	-0.014	0.022
Days to 50% silking	-0.121	-0.143	0.012	-0.003	-0.016	0.008	0.015	-0.009	0.031	0.003
Plant height(cm)	-0.002	-0.001	0.012	0.008	0.004	0.005	0.002	0.002	0.003	-0.012
Cob height(cm)	0.002	0.002	0.088	0.131	0.029	0.031	0.011	0.006	0.037	0.186*
Cob length(cm)	0.024	0.006	0.033	0.019	0.086	0.042	-0.007	0.066	0.037	-0.073
Cob girth (cm)	-0.005	0.012	-0.085	-0.050	-0.101	-0.207	-0.092	-0.077	-0.074	-0.208*
No of kernel rows/cob	0.010	0.007	-0.014	-0.005	0.005	-0.029	-0.066	0.008	0.006	-0.137
No of kernels/row	-0.028	-0.009	-0.026	-0.006	-0.106	-0.051	0.018	-0.138	-0.027	0.188*
100 seed weight (g)	0.003	0.007	-0.010	-0.009	-0.014	-0.011	0.003	-0.006	-0.033	-0.032

Correlation analysis

The phenotypic correlation coefficients for all ten traits were presented (Table 2). Grain yield per plant had significant and positive association with cob height (0.186), cob girth (0.208) and number of kernels per row (0.188). The findings are in accordance with the reports of Rafiq *et al.* (2010) [10], vijay kumar *et al.* (2015) [14], Begum *et al*. (2016) [5]. Saha and Mukherjee (1993) [12] reported significant positive correlations between grain yield per plant with cob height, cob girth and number of grains per row. Positive and significant associations of grain yield with thousand kernel weight and number of kernels per row is reported earlier by Dagne (2008) [3] and Mesenbet *et al*. (2017) [7]. Studies on character associations for yield components revealed positive and highly significant association of days to 50 percent flowering with days to 50 percent silking (0.844). The result is supported by Nataraj *et al*. (2014) [6] and Begum *et al*. (2016) [2].

Positive and highly significant associations of plant height was observed with cob height (0.670), cob length (0.391), cob girth (0.412), number of kernel rows per cob (0.212), 100 seed weight (0.303). Pandey *et al*. (2017) reported plant height correlated significant and positively with cob length (0.471), kernel rows per cob (0.643) and 100-seed weight (0.449). Cob height showed highly significant positive association with cob length (0.221), cob girth (0.240) and 100 seed weight (0.285). Cob length showed highly significant and positive association with cob girth (0.489), number of kernels per row (0.772) and 100 seed weight (0.438). Cob girth showed highly significant and positive correlation with number of kernel rows per cob (0.444), number of kernels per row (0.373) and (0.356).

Path coefficient analysis

Association of character determined by correlation co-efficient may not provide an exact picture of the relative importance of direct and indirect influence of each of yield components of yield. Path coefficient analysis furnished a method of partitioning the correlation coefficient into direct and indirect effect and provides the information on actual contribution of a trait on the yield (Dewey and Lu, 1959). In the present study, direct and indirect effects of nine characters on grain yield were estimated and presented in Table 3. From the table, days to 50 percent flowering (0.142) exhibited the largest direct effect on grain yield per plant at phenotypic level (Venugopal *et al*., 2003) [13] followed by cob height (0.131) (Raghu *et al*., 2011) [11]. Similar findings reported by Venugopal *et al*. (2003) [13] and vijay kumar *et al* (2015) [14]. Contrary to these findings days to 50 percent silk (-0.143), cob girth (-0.207), number of kernel rows per ear (-0.066), number of kernels per row (-0.138) and 100-seed weight (-0.033) showed negative direct effect on grain yield per plant and indicate that selection for high grain yield can be done by indirect selection through yield components (Pavan *et al*., 2011 and Juliet *et al*., 2013) [9, 5]. Batool *et al.* (2012) [1] and Begum *et al*. (2016) [2] also found that ear length had high positive direct effect on grain yield, which support the present result.

Conclusion

According to the results, in order to bring an effective improvement of grain yield, more attention should be given for traits such as cob height, cob girth and number of kernels per row which showed positive and significant phenotypic correlation coefficients with a considerable direct and indirect effect on grain yield. Path coefficient analysis revealed that days to 50 percent flowering exhibited the largest direct effect on grain yield per plant at phenotypic level followed by cob height indicating the effectiveness of direct selection. However, further evaluation of these and other hybrids at more locations and over years is advisable to confirm the promising results observed in present study. In general, it may be concluded that the information from this study could be valuable for researchers who intend to develop high yielding varieties of maize.

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