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VARIABILITY, HERITABILITY, CHARACTER ASSOCIATION AND PATH ANALYSIS IN MAIZE (*Zea mays* L.)

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ABSTRACT

The study revealed highly significant differences for all the characters studied, indicating the presence of substantial genetic variability. The phenotypic and genotypic coefficient of variation (PCV and GCV) was high for days to 50% tasseling followed by kernel rows per ear and 100 grains weight, respectively. While the traits like grain yield per plant followed by grains per row, plant height, ear length and 100 grains weight are highly heritable. High heritability coupled with high genetic advance as percent of mean was observed for plant height followed by grain yield per plant and ear height. However, plant height showed positive and significant correlation with days to tasseling, days to silking, 100 grains weight, ear girth and grains per row at phenotypic level whereas direct effect on grain yield per plant was found to be highest for days to maturity followed by kernel rows per ear and grains per row indicating that these should be considered as selection criteria for increasing grain yield per plant in a breeding program. In path coefficient analysis significantly high positive and negative direct effects on grain yield are recorded also indirect effect of character was found on grain yield per plant which is highly beneficial for further breeding programmes.

To improve genetic diversity of local germplasm, it is important to know the extent of already existing genetic variability in the material. Genetic variability, which is a heritable difference among cultivars, is required in an appreciable level within a population to facilitate and sustain an effective long term plant breeding programmes. Thus analysis of genetic component of variability is essential for improvement of a trait (Sharma, 2014).

The existence of variability is also essential for resistance to biotic and abiotic factors as well as for wide adaptability in the genotypes. Selection is effective when there is genetic variability among the individuals in a population. Hence, insight into the magnitude of genetic variability present in a population is of paramount importance to a plant breeder for starting a judicious breeding programme. Knowledge of heritability and genetic advance of the character indicate the scope for the improvement through selection. Heritability estimates along with genetic advance are normally more helpful in predicting the gain under selection then heritability estimates alone (Johnson *et al.,* 1955).

Genetic variability is pre-requite and important tool of any breeding programme. It provides not only the basis of selection but also some valuable information regarding selection of diverse parent for use in hybridization programme. The heritability is most important among the parameters as this will provide information whether the trait is genetically inherited or influenced by environment and how this can be improved. Burton (1953) had suggested that the genetic components of variation together with heritability estimates would give the best picture of amount of genetic advance to be expected from the selection.

Genetic diversity in any crop is a valuable natural resource and plays a key role in its improvement. However, to improve genetic diversity of maize genotypes, it is important to know the extent of already existing genetic variability in the available material. The path coefficient analysis helps in making the selection more effective by partitioning the total correlation into direct and indirectly. The path analysis has been used by plant breeders in agriculture to assist in identifying traits that are useful as selection criteria to improve crop yield. By genotypic and phenotypic coefficient of correlation the association between traits may be measured according to the types of study materials (Rahman *et al.,* 2015).

The efficiency of the selection can be broadened for certain trait using estimates of genetic and non-genetic parameters, which are fundamental in the plant breeding, since they allow identifying the nature of the gene action involved in the control of the quantitative traits. The correlation estimated by the specific coefficient is important in the plant breeding because it quantifies the degree of the genetic and non-genetic association between two of more traits, allowing the indirect selection (Silva, 2016).

Estimates of heritability were extensively used by plant breeders in selection of promising genotypes and in prediction of percent heritability of desirable traits (Sharma *et al.,* 2014). Therefore, the present study was conducted to analyze the variance, genetic variability, heritability, genetic gain among different genotypes of maize with the following objectives.

Methods and Materials

The experiment was carried out during summer season 2016 at the Research Farm, Department of Agriculture, Mata Gujri College, Sri Fatehgarh Sahib, Punjab. This place is situated at 73”55'E longitude and 29”30'N latitude at an altitude of 271 meter above sea level in the North Gangetic zone. The experimental material under the study, comprised of 21 diverse genotype of maize were raised in randomized block design with three replications. Data were recorded for ten traits namely days to 50% tasseling, days to 50% silking, days to 75% maturity, plant height (cm), ear length (cm), ear girth (cm), kernel rows per cob, grains per row, 100-grain weight (g) and grain yield per plant (g). All the recommended package of practices were applied to raise a good and healthy crop. The technique of path coefficient analysis developed by Wright (1921) and demonstrated by Dewey and Lu (1959) facilitates the partitioning of correlation coefficients into direct and indirect contribution of various characters on yield. The analysis of variance was carried out for all the eleven traits. “F” test calculated that highly significant differences among genotypes for all the traits under investigation indicating ample genetic differences among genotypes.

Result and Discussion

Genetic variability (Phenotypic and Genotypic Coefficient of Variation)

Estimates of different genetic parameters are presented in Table 1. It is evident from the result showed that the phenotypic variance is greater than genotypic variance. Among the yield attributes maximum PCV and GCV was depicted by days to

50% tasseling (12.44 and 8.94) followed by kernel rows per ear (11.1 and 8.81) and 100 grain weight (23.58and 21.88) respectively. The lowest value for PCV and GCV was shown by grain yield per plant (36.45 and 36.23). A perusal of Table 1 indicated that PCV was higher than respective GCVs for all the traits denoting environmental factors influencing their expression to some degree or other. Wide difference between PCV and GCV for days to 50% tasseling, days to 50% silking, 100 grains weight, ear length, ear girth and kernel rows per ear whereas narrow differences between PCV and GCV for days to 75% maturity, grains per row, ear height, grain yield per plant and plant height suggested their relative give up to environmental alteration. Anshuman *et al.* (2013) also reported moderate value for PCV and GCV to grain yield per plant indicated the existence of genetic variability. Mahmood *et al.,* (2004), Abirami et al. (2005) and Singh *et al.* (2017) reported high to moderate GCV and PCV value grain yield and other traits results which indicate influence of environment on genotypes.

Heritability (broad sense) and Genetic Advance

All the traits except harvest index were found to be highly heritable on the basis of broad sense heritability estimates. Highest being for Grain yield per plant (99), followed by grains per row (95), plant height (95), ear length (94), 100 grains weight (94), days to 75% maturity (88), days to 50% silking (79), ear girth (79), kernel per row (63), days to 50% tasseling (52). The high estimate for heritability indicates that most of the variation is caused by genotype and very small due to environment, therefore, a simple selection procedure would be helpful in improvement of these traits. Moderate heritability was observed for days to 50% tasseling (52) which indicated that harvest content is moderately influenced by environmental agencies than genotypic differences.

Estimate of genetic advance was highest for plant height (54.97), followed by grain yield per plant (46.91), days to 75% maturity (14.85), days to 50% silking (11.10), 100 grains weight (10.53), grains per row (10.01), tasseling (8.41), ear length (4.60), ear girth (2.61) and that for kernel rows per ear (1.84) was lowest.

In contrast to their high heritability's grain yield per plant (46.91), plant height (54.97) and days to 75% maturity (14.85) exhibited high magnitude of genetic advance also. Similarly, most of the traits with high heritability and low genetic advance, ear girth (2.61), ear length (4.60), kernel rows per ear (1.84) portrayed a high heritability value but a very low genetic gain.

Genetic advance as per cent of mean was highest for grain yield per plant (74.18) followed by 100 grains weight (43.67) and grains per row (43.31) among yield contributing traits (Table-3). The lowest value for genetic advance as percent of mean was revealed by days to 50% tasseling (13.24) among all the traits under investigation which limits the scope of improvement in this trait through simple selection. Maruthi and Rani (2015) also reported high heritability estimates for plant height, silking date, days to maturity, ear length, 100 grains weight and number of rows per ear, which support the present findings. High heritability estimates were also reported by Aman (2016), Singh *et al.* (2017) and by several other workers in different studies which are supportive to the current findings.

Phenotypic Correlation/ Character Association

The genotypic and phenotypic correlation coefficients estimated between yield and quality traits and inter-correlation among the different yield components and quality traits are furnished in and only significant correlations are discussed here. In general, the magnitude of genotypic correlation coefficient was higher than the corresponding phenotypic coefficient indicating thereby a strong inherent association between various traits under study (Table- 2).

Days to 50% tasseling showed significantly positive correlation with days to 50% silking (0.835), days to 75% maturity (0.767) and kernel rows per ear (-0.446) showed significantly negative correlation. Days to 50% silking significantly positive correlated with days to 75% maturity (0.815) and days to 50% tasseling (0.767) while kernel rows per ear (-0.393) is significantly negative correlated. Days to 75% maturity was significantly and positively correlated with days to 50% silking (0.815), whereas significant negative correlation was observed with kernel rows per ear (-0.281).

Plant height showed positive correlation with the 100 grains weight (0.546), ear length (0.629), ear girth (0.438) and grains per row (0.463) and negative correlation not found. 100 grains weight showed positive correlation with plant height (0.546), ear length (0.548), ear girth (0.554) and grains per row (0.450), whereas negative significant correlation was not observed. Ear length showed positive significant correlation with plant height (0.629), 100 grains weight (0.548), ear girth (587), grain yield per plant (0.427) and kernel rows per plant (0.775).

Ear girth showed positive significant correlation with plant height (0.438), 100 grains weight (0.554), ear length (0.587), kernel rows per ear (0.334) and grains per row (0.669). Kernel rows per ear showed significant positive correlation with grains per row (0.199), ear girth (0.334) and grain yield per plant (0.023) and shows negative significant correlation with days to 50% tasseling (-0.446), days to 50% silking (-0.393) and days to 75% maturity (-0.281). Similarly grains per rows showed positive significant correlation with plant height (0.463), 100 grains weight (0.450), ear length (0.775), ear girth (0.669), kernel rows per ear (0.199) and grain yield per plant (0.372).

Path-Coefficient Analysis

The simple correlation alone, however, is not a true reflection of the nature of association of the different traits with each other when other characters are held constant. Due to mutual relationship among different characters, which may be positive or negative, these associations become more complex and do not lead to any meaningful interpretations. The path coefficient analysis is a powerful method in analyzing the scheme of causal relationship in the development of various traits. The correlations are partitioned into direct and indirect effects to know the precise direct and indirect cause of associations. The concept of path coefficient analysis was originally developed by Wright in 1921, but its first use in plant breeding was demonstrated by Dewey and Lu in 1959.

Path-coefficient analysis is simply

standardized partial regression coefficient, which splits the correlation coefficients into the measures of direct and indirect effects of a set of independent variables on the dependent variables. If the correlation between yield and a character is due to the direct effect of the character it reflects a true relationship between them and selection can be practiced for such a character in order to improve the yield. But if the correlation is mainly due to indirect effect of the character through another component trait, the breeder has to select for the latter trait through which the indirect effect is exerted.

In the present investigation, the phenotypic correlations of grain yield per plant by means of selected yield traits were partitioned into their corresponding direct and indirect effects through path coefficient analysis.

The phenotypic path-coefficient analysis for the selected component traits are presented in Table 3. Analysis revealed that magnitude of direct effect on grain yield per plant was found to be highest for days to 50% silking (0.395) followed by grains per row (0.342), days to 75% maturity (0.339) followed by kernel rows per ear (0.262), ear length (0.227), plant height (178), days to 50% tasseling (-0.123). Ear girth (-0.293) and 100 grains weight (-0.0003) showed negative direct effects while other traits were observed to be had positive direct effects.

Days to 50% tasseling exhibited indirect negative effect via days to 50% silking (-0.103), days to 75 % maturity (-0.095), plant height (-0.001), and showed indirect positive effect via 100-grain weight (0.007), ear length (0.008), ear girth (0.003), kernels rows per ear (0.055) and grains per row.

Days to 50% silking showed indirect positive effect on days to 50% tasseling (0.330), days to 75% maturity (0.322), plant height (0.033), 100 grains weight (0.027), ear girth (0.022) and exhibited indirect negative effect on ear length (-0.041), kernel rows per ear (-0.155) and grains per row (-0.060). Days to 75% maturity exhibited positive indirect effect on days to 50% silking (0.277), days to 50% tasseling (0.260), plant height (0.069), 100-grain weight (0.065), ear length (0.013), ear girth (0.013) and showed negative indirect effect on kernel rows per ear (-0.095) and grains per row (-0.046). Plant height exhibited indirect positive effect on ear length (112), 100 grains weight (0.097), grains per row (0.082) and ear girth (0.078), days to 75% maturity (0.036), days to 50% silking (0.015), days to 50% maturity (0.001)and showed indirect negative effect on kernel rows per ear (-0.026).

100-grain weight showed indirect negative effect on plant height (-0.0001), ear length (-0.0001), ear girth (-0.0001) and grains per row (-0.0001). Ear length exhibited indirect positive effect on grains per row (0.176), plant height (0.142), ear girth (0.133), 100-grain weight (0.124), kernels rows per ear (0.012), days to 75% maturity (0.009) and showed indirect negative effect on days to 50% tasseling (-0.016) and days to 50% silking (-0.023).

Ear girth exhibited indirect positive effect on days to 50% tasseling (0.009) and exhibits negative effect on 100 grains weight (-0.162), ear length (-0.172), grains per row (-0.196), days to 50% silking (-0.016), days to 75% maturity (-0.011), plant height (-0.012), kernels rows per ear (-0.098) whereas, kernel rows per ear showed indirect positive effect on ear girth (0.087), grains per row (0.052), 100-grain weight (0.038), ear length (0.014) and exhibited indirect negative effect on days to 50% tasseling (-0.117), days to 50% silking (-0.103), days to 75% maturity (-0.073), plant height (-0.038). Grains per row showed indirect positive effect on ear length (0.265), ear girth (0.229), plant height (0.158), 100-grain weight (0.154), kernels rows per ear (0.068) and showed indirect negative effect days to 50% tasseling (-0.060), days to 50% silking (-0.052) and days to 75% maturity (-0.046). Similar results in maize have earlier been reported by Khayatnezhad (2010), Jalili (2015), Begum *et al.,* (2016) and Singh *et al.,* (2017).

Conclusion

The amount of variability present was of wide range for all the characters studied hence attention needs to be given for these traits during selection for improvement of grain yield. Significant association between yield contributing traits can improve yield. Therefore, recurrent selection programme aimed in this direction may yield fruitful results. Path analysis revealed that for days to maturity followed by kernel rows per ear, grains per row had highest positive effect on grain yield at phenotypic levels. Hence, importance has to be given for these characters in future breeding programme to improve yield in maize.

Table-1. Estimates of genetic parameters for various traits of 21 Maize genotypes

Parameters / Characters	Mean ± S.E.	Range		σ^2_p	σ^2_g	PCV (%)	GCV (%)	h^2_{bs} (%)	GA (%)	GA as % of Mean
		Min	Max							
Days to 50% tasseling	63.56±3.17	56.19	76.57	62.61	32.34	12.44	8.94	52	8.41	13.24
Days to 50% silking	65.70±1.81	58.15	77.27	46.73	36.86	10.40	9.24	79	11.10	16.90
Days to 75% maturity	104.16±1.51	90.36	115.52	65.03	58.13	7.74	7.32	88	14.85	14.25
Plant height (cm)	140.58±3.78	99.65	190.96	796.12	753.03	20.07	19.51	95	54.97	39.10
Grain yield per plant (g)	63.24±1.46	38.52	127.19	531.45	525.02	36.45	36.23	99	46.91	74.18
100 grains weight(g)	24.12±0.77	19.07	37.08	29.67	27.85	23.58	21.88	94	10.53	43.67
Ear length(cm)	13.19±0.34	10.04	18.96	5.67	5.32	18.05	17.48	94	4.60	34.89
Ear girth (cm)	12.61±0.41	9.51	15.67	2.55	2.03	12.68	11.29	79	2.61	20.72
Kernel rows per ear	12.80±0.49	10.75	15.20	2.02	1.27	11.11	8.81	63	1.84	14.41
Grains per row	23.11±0.69	14.78	36.53	26.45	24.99	22.25	21.63	95	10.01	43.31

σ^2_p phenotypic variance; σ^2_g genotypic variance; PCV Phenotypic coefficient of variance; GCV Genotypic coefficient of variance; h^2_{bs} heritability in broad sense; GA Genetic advance (at 5% selection intensity i.e. K = 2.06)

Table-2: Phenotypic contribution to phenotypic correlation for yield and yield traits among 21 genotypes of Maize.

Character	Days to 50% Tasseling	Days to 50 % Silking	Days to 75% Maturity	Plant Height (cm)	100-grain Weight (g)	Ear Length (cm)	Ear Girth (cm)	Kernel Rows/ Ear	Grains/ Row
Days to 50 % Tasseling	1.0000								
Days to 50 % Silking	0.8359	1.0000							
Days to 75 % Maturity	0.7670	0.8152	1.0000						
Plant Height (cm)	0.0084	0.0838	0.2037	1.0000					
100-grain Weight (g)	-0.0583	0.0699	0.1925	0.5463	1.0000				
Ear Length (cm)	-0.0721	-0.1053	0.0403	0.6292	0.5480	1.0000			
Ear Girth (cm)	-0.0312	0.0556	0.0388	0.4386	0.5549	0.5878	1.0000		
Kernel Rows/ Ear	-0.4469	-0.3935	-0.2812	-0.1453	0.1465	0.0543	0.3344	1.0000	
Grains/ Row	-0.1753	-0.1519	-0.1368	0.4630	0.4507	0.7751	0.6697	0.1993	1.0000
Grain Yield/ Plant (g)	**0.2839**	**0.3880**	**0.4804**	**0.4145**	**0.3521**	**0.4277**	**0.2745**	**0.0236**	**0.3722**

Table-3: Direct and indirect effect (phenotypic) of nine component characters on grain yield per plant in maize

Characters	Days to 50% tasseling	Days to 50% silking	Days to 75% maturity	Plant height (cm)	100-grain weight	Ear length (cm)	Ear girth (cm)	Kernel rows per Ear	Grains per row
Days to 50% tasseling	**-0.1239**	-0.1035	-0.0950	-0.0010	0.0072	0.0089	0.0039	0.0554	0.0217
Days to 50% silking	0.3303	**0.3952**	0.3222	0.0331	0.0276	-0.0416	0.0220	-0.1555	-0.0600
Days to 75% maturity	0.2607	0.2771	**0.3399**	0.0692	0.0654	0.0137	0.0132	-0.0956	-0.0465
Plant height (cm)	0.0015	0.0150	0.0364	**0.1788**	0.0977	0.1125	0.0784	-0.0260	0.0828
100-grain weight	0.0001	0.0001	0.0001	-0.0001	**-0.0003**	-0.0001	-0.0001	0.0001	-0.0001
Ear length (cm)	-0.0164	-0.0239	0.0092	0.1429	0.1245	**0.2271**	0.1335	0.0123	0.1760
Ear girth(cm)	0.0092	-0.0163	-0.0114	-0.1288	-0.1629	-0.1726	**-0.2937**	-0.0982	-0.1967
Kernel rows per Ear	-0.1175	-0.1035	-0.0739	-0.0382	0.0385	0.0143	0.0879	**0.2629**	0.0524
Grains per row	-0.0601	-0.0520	-0.0469	0.1586	0.1544	0.2656	0.2294	0.0683	**0.3426**
Grain yield per plant	**0.2839**	**0.3880**	**0.4804**	**0.4145**	**0.3521**	**0.4277**	**0.2745**	**0.0236**	**0.3722**
Partial R^2	-0.0352	0.1533	0.1633	0.0741	-0.0001	0.0971	-0.0806	0.0062	0.1275

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