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Article

Genetic variability, correlation and path analysis of exotic and local hybrid maize (*Zea mays* L.) genotypes

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Abstract: The genetic parameters, characters association and path coefficient analysis between yield and yield components of 32 exotic and local hybrid maize genotypes were studied at Plant Breeding division, Regional Agricultural Research Station (RARS), Bangladesh Agricultural Research Institute (BARI), Rahmatpur, Barisahl during rabi 2015 to 2016, following Alpha Lattice Design with three replications. All the characters showed significant differences among the genotypes except cob length indicating their wide genetic variation. The highest genotypic co-efficient of variation (11.48) observed in yield and lowest (1.72) was found in days to maturity. All of the characters exhibited moderate to high heritability in broad sense (h^2b) coupled with a wide range of genetic advance and genetic advance in percentage of mean. Heritability ranged from 19.21 to 86.79 for cob length and thousand seed weight, respectively. Yield had a significant positive correlation with cob length, cob diameter, number of seeds per cob and number of rows per cob. Days to tasseling and number of seeds per cob make highest positive contribution toward yield. While, days to silking and ear height had highest negative direct effect on yield. The results indicated that ear height, number of rows per cob, thousand seeds weight and number of seeds per cob could be considered as selection criteria in maize breeding program.

Keywords: maize; correlation co-efficient; path analysis

1. Introduction

Maize is the third most important cereal crop after rice and wheat contributing to agricultural economy of Bangladesh in various ways. Maize is gaining importance in recent years as a promising crop aimed in boosting agricultural growth in Bangladesh. The area and production of maize in 2017-18 was 4.4 lac hectares and 3.3 million tons, respectively (USDA, 2018). In Bangladesh maize is extensively used as poultry feed. The total maize cultivated area in Bangladesh was 3.96 million hectare, production was 27.59 million metric tons and national average yield was 6.97 ton per hectare in 2015-16 (DAE, 2017). The acreage and production of maize in the country is increasing but not encouraging enough compared to the world perspective, and the demand of the crop in the country is increasing at a higher rate. To meet the ever increasing demand of increasing population of Bangladesh maize breeders need to pay special attention to investigate the genetic diversity of maize that could develop genotypes with higher yield and better quality. The availability of adequate genetic diversity is crucial for gaining significant genetic progress in applied breeding programs. Yield of maize like rest crops is the final product attributed by a complex chain of interrelating effects of different characters (Singh *et al*., 2005). Therefore, Determination of correlation and path coefficients between yield and yield traits is important for the selection of favorable plant types for effective maize breeding programs. Correlation coefficients in general show associations among independent characteristics and the degree of linear relation between these characteristics. It is not sufficient to describe their relationship when the causal association among characteristics is needed (Toker and Cagirgan, 2004). Genetic correlation analysis is a handy technique which elaborates the degree of association among important quantitative traits. The studies on correlation are quite old and extensive but, unfortunately, there is hardly any rule set on how much a character contributes towards the expression of other charater(s) in a plant population.

Path analysis is used to determine the amount of direct and indirect effect of the casual component on the effect component. Keeping this in view, the present study was therefore, designed to genetic basis of grain yield components and to develop a suitable selection criterion for future maize breeding program.

Keeping in view many other factors, the genetic base of the material under study and the effects of environment are very important while studying genetic correlation among various quantitative characters in crop species. Such studies could lead plant breeders in the selection of traits contributing towards the character(s) of concern, and ultimately their improvement through hybridization. Accordingly, the present study was carried out with the objective of generating information on variability, and relationship among yield and yield contributing traits to find important traits for selection process.

2. Materials and Methods

2.1. The genotypes, study area and experimental design

The experiment material for the present investigation comprised of nine local hybrids (IM 8013, IM 8119, BMS02, BMA01, BMA02, BMA03, BHM 6, BHM 7, BHM 9) and 23 exotic (9120, Titan, 987, 942, Elite, Super Gold, PAC 339, PAC 999 Super, PAC 293, 984, NK 40, Sunshine, PS-999, 25K60, Kaveri 50, CP 838, CP808, Pioneer 30V92, Pioneer 30V07, Pioneer 3396, VA Shaktiman, HP-701, BMS01) hybrid maize genotypes were studied following Alpha Lattice Design with three replications at Plant Breeding division, Regional Agricultural Research Station (RARS), Bangladesh Agricultural Research Institute (BARI), Rahmatpur, Barisahl during rabi 2015 to 2016. The unit plot size was 4.0 × 0.6 m long. The spacing was adopted 60 cm between rows and 20 cm between hills. Two border rows were used at each end of the replication to minimize the border effect.

2.2. Data collection and statistical analysis

Five randomly selected plants of each plot were separately harvested for recording yield attributes and other data. The inner two lines were harvested for recording grain yield. The studied characters were Days to tasseling (DT), Days to silking (DS), Days to maturity (DM), Plant height (PH), Ear height (EH), Cob length (CL), Number of rows per cob (NRPC), Number of seeds per cob (NSPC), Thousand grain weight (TGW), Cob Diameter (CD), Yield (Y). Analysis of variance was done for all the characters under study using the mean values (Singh and Chaudhury, 1985). Genotypic and phenotypic variances were estimated according to the formula given by Johnson *et al.* (1995). Heritability in broad sense (h2b) was estimated according to the formula suggested by Johnson *et al.* (1955) and Hanson (1961). Genotypic and phenotypic co-efficient of variations were estimated according to Burton (1952) and Singh and Choudhury (1985). Genetic advance was calculated following formula given by Johnson *et al.* (1955) and Allard (1975). Genetic advance in percent of mean was calculated by the formula of Comstock *et al*. (1952). The phenotypic correlations were estimated by the formula suggested by Miller *et al.* (1958). Correlation coefficient were further partitioned into components of direct and indirect effects by path coefficient analysis originally developed by Wright (1921) and later described by Dewey and Lu (1959).

3. Results and Discussion

Analysis of variance (ANOVA) was done to split the total variability into traceable components (Table 1). ANOVA indicate that there was a substantial amount of variability in all of the character but cob length (Table 2). Genotypic and phenotypic co-efficient of variation was low for almost all of the characters studied in the present study. The phenotypic co-efficient of variation (PCV) were higher than their corresponding genotypic co-efficient of variation (GCV) for all the characters studied indicating that they all interacted with the environment to some intent. Phenotypic co-efficient of variation ranged from 2.27 to 13.25 for days to maturity and yield respectively. While the highest genotypic coefficient of variation (11.48) observed in yield and lowest (1.72) was found in days to maturity (Table 3). All of the characters exhibited moderate to high heritability in broad sense (h^2b) coupled with a wide range of genetic advance and genetic advance in percentage of mean. Heritability ranged from 19.21 to 86.79 for cob length and thousand seed weight respectively.

Number of seeds per cob and yield showed genetic advance and genetic advance in percentage of mean, which indicated the possibility of additive genes effect for the expression of this character. Therefore, selection would be effective for producing varieties with reduced plant from the genotypes under study. On the other hand, ear height, number of rows per cob and thousand seeds weight showed moderate genetic advance and genetic advance in percentage of mean indicating high degree of genetic variability for this character. Therefore, there is a good scope of isolating good genotypes based on this trait. Days to maturity, cob length, days to tasseling, days to sinking, cob diameter and plant height low genetic advance and genetic advance in percentage of mean indicating the actions of both additive and non-additive genes in the expression of this trait i.e. the scope of improvement of this character by direct selection would be also limited.

Several researches (El- Hefnawy and El- Zeir, 1991; Nawar *et al*., 1991; Mohamed, 1993) studied the genetic variance and heritability in corn, concerning narrow sense heritability, it was found to be high for ear height, ear diameter, 100- kernel weight and grain yield (Robinson *et al*., 1949; EL- Agamy *et al*., 1992; Mourad *et al*., 1992; Robinson *et al*., 1949) found that additive genetic variance had more important role in the expression for plant and ear height. Amer and Mosa (2004) reported that heritability estimates in narrow sense were 44% for silking date, 39% for plant height, 44% for ear height, 27% for ear length, 31% for ear diameter, 29% for number of rows per ear, 23% for number of kernels per row and 36% for grain yield. Yassien (1993) found that the narrow sense heritability estimates were 65% for plant height, 51% for ear length, 63 % for ear diameter, 44 % for number of rows per ear, 66% for number of kernels per row, 42% for 100-kernel weight and 27% for grain yield. Table 4 and Table 5 represent the genotypic and phenotypic correlation coefficient. Days to tasseling found to display significant positive relationships with day to silking and ear height. It also showed significant negative relationship with cob diameter, number of rows per cob, yield and number of seeds per cob.

Days to to silking was found highly significant positive relationships with days to ear height and days to tasseling. Cob diameter, number of rows per cob and thousand grain weight showed significant negative correlation with days to silking. D**a**ys to maturity was found highly significant positive relationships with number of rows per cob and number of seeds per cob. Days to maturity showed significant negative correlation with ear height. Plant height showed significant positive relationship with ear height. Days to maturity were found significant negative correlation with ear height. Ear height showed significant positive relationships with days to tasseling, days to silking and plant height.

Cob length showed significant positive relationships with number of rows per cob, number of seeds per cob and yield. Cob Diameter were found significant negative relationships with days to tasseling and days to sidling. This trait showed significant positive relationships with number of rows per cob, number of seeds per cob and yield. Number of rows per cob was found highly significant positive relationships with days to maturity, cob length, cob diameter, number of seeds per cob and yield. This trait also showed significant negative relationship with days to tasseling and days to silking. Number of seeds per cob was found highly significant positive relationships with days to maturity, cob length, cob diameter, number of rows per cob and yield. This trait also showed significant negative relationship with days to tasseling. Thousand grain weight did not show any significant positive relationships with other characters. Thousand grain weight was found significant negative correlation with days to silking. Fruit weight was found highly significant positive relationships with fruit cob length, cob diameter, number of rows per cob and number of seeds per cob and significant negative relationship with days to tasseling.

Many investigators determined the associations among different characters in corn. Moursi *et al*. (1975) mentioned that number of kernels per row, ear diameter and 100-kernel weight had consistent positive and significant correlations with grain yield. Katta (1976) found positive and significant correlation between grain yield and each of plant height, number of rows per ear, number of kernel per row and 100- kernel weight and emphasized the role of these traits in selection of high grain yield in corn. Also, (AL- Ahmad, 2004; Aydin *et al*., 2007; Najeeb *et al*., 2009) indicated that the correlation values were positive and significant between grain yield and each of ear diameter, ear length and number of kernels per row. El-Shouny *et al*. (2005) and Tollenaar *et al*. (2004) identified different traits like ear length, ear diameter, kernels per row, ears per plant, 100-seed weight and rows per ear as potential selection criteria in breeding programs aiming at higher yield. Grain yield is positively genetically correlated with days to silking and tasselling (Altenbas and Algan, 1993; Ahmad, 1997; Rather *et al*., 1999). Some other published results are contrary to this (Umakanth *et al*., 2000). Plant and ear heights are strongly associated with grain yield (Martin and Russell, 1984; Burak and Magoja, 1991; Singh and Dash, 2000; Umakanth *et al*., 2000), but Rather *et al*. (1999) reported the association of plant height with grain yield as non-significant. Similarly, strong genetic correlation exists between grain yield and leaf area (Khakim *et al*., 1998; Lee *et al*., 2001). Number of ears per plant and ear weight are also strongly associated with grain yield (Martin and Russell, 1984; Khakim *et al*., 1998). Ear height, ear length and ear diameter have also positive genetic correlation with grain yield (Burak and Magoja, 1991; Malvarr *et al*., 1994; Khatun *et al*., 1999; Singha and Prodhan, 2000) but negatively with kernel weight (Martin and Russell, 1984). Number of kernels row^{-1} and kernel rows ear^{-1} also have positive genetic correlation with grain yield (Shalygina, 1990; Altenbas and Algan, 1993; Gyandra and Singh, 1993; Khakim *et al*., 1998; Khatun *et al*., 1999). The analysis of path coefficient has been made to identify the important yield attributes by estimating the direct effects of the contributing characters to yield and separating the direct from the indirect effects through other related characters by partitioning the correlation coefficient and finding out the relative importance of different characters as selection criteria. Table 6 represent the path analysis. Days to silking, ear height, number of rows per cob, days to maturity, thousand seeds weight and plant height had direct negative effect on yield. While days to tasseling, number of seeds per cob, cob diameter and cob length contribute direct positive effect on yield. Days to tasseling and number of seeds per cob make highest positive contribution towards yield. While, days to silking and ear height had highest negative direct effect on yield. Thus, these character should be kept in consideration during crop improvement program. As yield is a complex trait and other trait contribute on yield positively or negatively, so, selection based on these character will be effective. In this study residual effect was 0.67504, which was pretty high. The high residual effect indicates that there was other yield contributing characters, which was not considered in this study or a large extent of environmental effect. Efforts made to determine the relative contributions of yield related characters to grain yield variation, revealed that the most sources of variation in plant yield were the direct effects of number of kernels per row (Sary *et al*., 1990; Mohamed and Sedhom, 1993) and both number of kernels per row and ear diameter (Yasien, 2000). On the other hand, the direct effect of ear diameter, ear length and number of kernels per row had the highest effect on yield variation (Al-Ahmad, 2004; Sadek *et al*., 2006). Amin *et al*. (2003) also indicated that number of kernels per row and 100-kernel weight were the highest contributors to variation in grain yield directly or indirectly.

Table 1. Maximum, minimum, mean, standard deviation and variance for different characters of thirty-two maize genotypes.

Characters	**Days to tasseling**	**Days to silking**	**Days to maturity**	**Plant Height**	**Ear height**	**Cob length**	**Cob Diameter**	**Number of rows per cob**	**Number of seeds per cob**	**1000 grain weight**	**Yield**
Max	90.00	93.00	156.00	300.66	157.00	21.60	5.50	18.00	748.00	549.30	9.25
Min	79.00	82.00	142.00	232.66	89.33	15.00	4.40	12.00	458.00	352.60	5.01
Mean	82.36	85.56	149.02	271.78	126.88	18.27	5.02	15.23	600.01	418.22	6.92
Standard deviation	2.471	2.536	3.360	13.195	12.083	1.311	0.228	1.407	63.029	34.340	0.912
Variance	6.107	6.434	11.291	174.115	146.005	1.717	0.052	1.979	3972.698	1179.237	0.831

Table 2. Analysis of variance (mean squares) for different characters of 32 genotypes of maize.

Source of Variation	**Degree of freedom**	**Mean squares value of**									
		Days to tasseling	**Days to silking**	**Days to maturity**	**Plant Height**	**Ear height**	**Cob length**	**Cob diameter**	**Number of rows per cob**	**Number of seeds per cob**	**1000 grain weight**	**Yield**
Replication	2	0.948	0.094	11.167	85.31	87.069	0.376	0.002	0.015	685.073	366.998	0.727
Factor A	31	14.975**	16.655**	24.579	436.927**	339.364**	2.443^{ns}	0.115**	4.762**	11166.4*	3308.705**	2.109**
Error	62	1.937	1.631	4.833	48.382	53.582	1.426	0.023	0.682	545.976	159.724	0.211

Table 3. Heritability, genetic advance and genetic advance in percentage of mean in respect of yield and yield contributing characters of Maize.

Characters	σ^2_g	σ^2_e	σ^2_p	**PCV**	**GCV**	h^2_b **(%)**	**GA**	**% GA**
DT	4.35	1.94	6.28	3.04	2.53	69.17	3.57	4.34
DS	5.01	1.63	6.64	3.01	2.62	75.43	4.00	4.68
DM	6.58	4.83	11.42	2.27	1.72	57.66	4.01	2.69
PH	129.52	48.38	177.90	4.91	4.19	72.80	20.00	7.36
EH	95.26	53.58	148.84	9.62	7.69	64.00	16.08	12.68
CL	0.34	1.43	1.76	7.27	3.19	19.21	0.53	2.88
CD	0.03	0.02	0.05	4.62	3.47	56.66	0.27	5.39
NRPC	1.36	0.68	2.04	9.39	7.66	66.59	1.96	12.87
NSPC	3540.14	545.98	4086.12	10.65	9.92	86.64	114.09	19.01
TGW	1049.66	159.72	1209.38	8.32	7.75	86.79	62.18	14.87
YLD	0.63	0.21	0.84	13.25	11.48	74.99	1.42	20.48

σ^2_g = Genotypic variation, σ^2_e = Environmental variation, σ^2_p = Phenotypic variation,
GCV = Genotypic co-efficient of variance, PCV = Phenotypic co-efficient of variance, GA = Genetic advance, % GA = genetic advance in percentage of mean.
DT=days to tasseling, DS= days to silking, DM= days to maturity, PH= plant height, EH= Ear height, CL = Cob length, CD= Cob diameter, NRPC= Number of rows per cob, NSPC= Number of seeds per cob, TGW= thousand grain weight, YLD= Yield

Table 4. Genotypic correlations between eleven characters of 32 genotypes of maize.

	Days to silking	**Days to maturity**	**Plant height**	**Ear height**	**Cob length**	**Cob diameter**	**No. of rows per cob**	**No. of seeds per cob**	**1000 grain weight**	**Yield**
Days to tasseling	0.989**	-0.006	0.132	0.461**	0.185	-0.567**	-0.509**	-0.306*	-0.261	-0.368**
Days to silking		0.022	0.082	0.318*	0.287	-0.511**	-0.436**	0.205	-0.304*	-0.228
Days to maturity			-0.081	-0.559**	0.077	0.276	0.328*	0.325*	0.136	0.143
Plant height				0.460**	0.136	0.089	0.255	0.123	-0.254	-0.205
Ear height					0.211	-0.187	0.164	-0.105	-0.230	-0.196
Cob length						0.260	0.544**	0.837**	-0.113	0.388**
Cob diameter							0.862**	0.809**	0.199	0.508**
No. of rows per cob								0.966**	-0.212	0.551**
No. of seeds per cob									-0.167	0.546**
1000 grain weight										0.060

**, * denotes significant at 1% level of significance, significant at 5% level of significance respectively.

Table 5. Phenotypic correlations between eleven characters of 32 genotypes of maize.

	Days to silking	Days to maturity	Plant height	Ear height	Cob length	Cob diameter	No. of rows per cob	No. of seeds per cob	1000 grain weight	Yield
Days to tasseling	0.927**	-0.008	0.056	0.268	0.033	-0.412**	-0.363**	-0.223	-0.182	-0.295
Days to silking		0.005	0.021	0.207	0.124	-0.395**	-0.310*	-0.144	-0.229	-0.200
Days to maturity			-0.026	-0.365**	-0.024	0.306*	0.257	0.258	0.127	0.192
Plant height				0.356**	0.060	0.029	0.108	0.120	-0.194	-0.106
Ear height					-0.043	-0.112	-0.109	-0.082	-0.201	-0.168
Cob length						0.118	0.202	0.438**	-0.040	0.090
Cob diameter							0.726**	0.635**	0.166	0.395
No. of rows per cob								0.826**	-0.161	0.416**
No. of seeds per cob									-0.150	0.451**
1000 grain weight										0.090**

**, * denotes significant at 1% level of significance, significant at 5% level of significance respectively.

Table 6. Partitioning of genotypic correlations into direct and indirect effects of the studied characters as influenced by thirty-two genotypes by path analysis.

	Days to tasseling	Days to silking	Days to maturity	Plant height	Ear height	Cob length	Cob diameter	No. of rows per cob	No. of seeds per cob	1000 seed weight	Yield
Days to tasseling	**1.947**	-1.876	0.002	-0.010	-0.305	0.020	-0.180	0.327	-0.329	0.035	-0.368
Days to silking	1.925	**-1.897**	-0.009	-0.006	-0.211	0.031	-0.162	0.280	-0.220	0.041	-0.228
Days to maturity	-0.012	-0.042	**-0.396**	0.006	0.370	0.008	0.088	-0.210	0.349	-0.018	0.143
Plant height	0.256	-0.155	0.032	**-0.079**	-0.304	0.015	0.028	-0.164	0.132	0.034	-0.205
Ear height	0.897	-0.604	0.222	-0.036	**-0.661**	0.023	-0.059	0.105	-0.113	0.031	-0.196
Cob length	0.360	-0.545	-0.031	-0.011	-0.140	**0.107**	0.082	-0.349	0.900	0.015	0.388
Cob diameter	-1.103	0.970	-0.110	-0.007	0.124	0.028	**0.317**	-0.554	0.869	-0.027	0.508
No. of rows per cob	-0.992	0.828	-0.130	-0.020	0.108	0.058	0.273	**-0.642**	1.038	0.028	0.551
No. of seeds per cob	-0.595	0.388	-0.129	-0.010	0.069	0.090	0.256	-0.620	**1.075**	0.022	0.546
1000 grain weight	-0.508	0.577	-0.054	0.020	0.152	-0.012	0.063	0.136	-0.179	**-0.134**	0.060

The bold figures indicate direct effect towards yield.
Residual effect= 0.67504

4. Conclusions

From the results, it could be concluded that high heritability values in broad sense were accompanied with either higher or moderate genetic advance upon selection particularly for ear height, number of rows per cob, thousand seeds weight, number of seeds per cob and yield. Such results indicated the effectiveness of selection processes in subsequent generations for these traits. For cob length where low heritability values in broad sense were associated with low genetic advance selection may be less effective.

Conflict of interest

None to declare.

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