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Heritability and trait association studies in maize F_1 hybrids

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Abstract

Maize is the important staple food in many part of the world. Genetic variation in the breeding material and performance of hybrids are important to determine breeding strategies and heterosis. The experiment was conducted to evaluate eighty-one maize hybrids using alpha lattice design with three replications in experimental spot of National Agricultural Research Centre Islamabad, Pakistan. The data were collected for plant height, ear height, flag leaf area, ear leaf area, days to 50% tasseling, days to 50% silking, days to 50% anthesis, anthesis silking interval, chlorophyll content, ear length, number of cobs row^{-1}, fresh ear weight, kernels rows ear^{-1}, kernels row^{-1}, 100-kernel weight, grain moisture, ear diameter, cob diameter and grain yield. Statistically significant differences were observed among the genotypes. Plant height (38.5), ear height (32.6), days to 50% tasseling (48.4), 100-kernels weight (42.3), ear length (49.5), ear diameter (40.0) and cob diameter (28.5) revealed moderate heritability. High genetic advance was observed for all the traits except chlorophyll content. Grain yield showed positive correlation with plant height (0.35), ear height (0.29), days to silking (0.10), anthesis silking interval (0.07), fresh ear weight (0.51), 100-kernel weight (0.04), ear length (0.24), kernel rows ear^{-1} (0.10), kernels row^{-1}(0.19), ear diameter (0.07) and cob diameter (0.09). Variability among genotypes for the characters indicated the worth of selection for these characters in the genetic material used for upcoming improvement. The present research discloses that better yield response could be achieved through direct selection scheme in maize hybrids.

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Introduction

Maize (*Zea mays* L.) is a tropical cereal belongs to gramineae family. Maize is most widely cultivated crop due to its wider adaptability (Aminu *et al.*, 2014). Paramount position of maize is because of its broad and abundant consumptions.

It is consumed like human foodstuffs, farm animals feed, for manufacturing alcoholic food and drink, construct material, as a fuel for energy and approximating medicinal and ornate plant (Bekric and Radosavljevic, 2008). Maize grain comprises of 9.7396 % grain protein, 4.85% grain oil, 9.4392% grain crude fibre, 71.966% grain starch, 11.77% embryo while fodder contains 22.988% acid detergent fibre, 51.696% neutral detergent fibre, 28.797% fodder cellulose, 40.178% fodder dry matter, 26.845% fodder crude fibre, 10.353% fodder crude protein and 9.095% fodder moisture (Ali *et al.*, 2014).

Hybrids are used in most part of the world to amplify entire production. Abera *et al.* (2016) reported up to 250% high parent heterosis in maize hybrids. Most of the hybrids used by growers are double crossed. Hybrids are more resistant to different stresses that are biotic and abiotic like drought, salinity etc than open pollinated genotypes.

In recent times, growers have also been using single cross hybrids for the reason that superior yielding hybrids have been developed. Yield enhancement of 25 to 50% has been credited to the use of maize hybrids (Aycicek and Yildirim, 2006; Malik *et al.*, 2011).

It is investigated from most of the maize research that genetic variability is a heritable variation among genotypes, is mandatory in a considerable level within a populace to assist and keep going a valuable long term breeding programs. (Tabanao and Bernardo, 2005). Significant genetic variability is key in vital agronomic character specially earliness to satisfactorily rationalize the commencement of assortment programs (Salami *et al.*, 2007; Turi *et al.*, 2007). The hybrids with superior SCA showed that dominance effect of gene is more active than additive action in inheritance of maize characters.

Genetic variability is a prophetic feature that allows maize breeders to identify crosses with a higher probability of success. Particularly, the evaluation of variability can identify those crosses that will optimize heterosis while avoiding undesirable features (Oliboni *et al.*, 2012). Knowledge of genetic variability in the breeding material, and correlation between the genetic distance and hybrid performance are vital for determining breeding strategies, classifying the parental material, or defining heterosis (Legesse *et al.*, 2009).

Hybridization between inbred lines from different heterotic groups results in higher heterosis than hybridization within the same heterotic group. In addition, the nature of gene action affects expression of both quantitative and qualitative traits of economic importance (Abera *et al.*, 2016). Heritability estimates measure the value of selection for a particular trait in a variety of progenies (Al-Tabbal and Al-Fraihat, 2012). Larger estimates of genotypic variances are useful provided that high heritability estimates can be obtained with genotypes with either small or large genetic progress. High heritability is coupled with additive gene effect whereas low heritability is due to dominance and epistasis.

The coefficient of variation illustrates the degree of variability presented by the different characters but it excludes the heritable portion. On the other hand, correlation helps to measure the level of relationship between the traits (Nagabhushan *et al.*, 2011). Therefore, the objectives of this study were (i) to study the genetic parameters which govern the inheritance of maize yield and other agronomic traits and (ii) to determine the heritability, heterosis and correlation in 81 maize hybrids.

Materials and methods

Plant material

The experiment was conducted in the Crop Sciences Institute, National Agricultural Research Centre Islamabad, Pakistan during Kharif season 2015. The experimental materials comprised of 81 hybrids including two checks namely: 89 × Q4, 107 × Q4, 36 × 26, 108 × Q4, 112 × Q4, 119 × Q4, 121 × Q4, 148 × Q4, 233 × Q4, 213 × Q4, 224 × Q4, 244 × Q4, 174 × Q4, 274 × Q4, 277 × Q4, 288 × Q4, 25 × 27, 30 × 24, 35 × 155, 36 × 26, 18 × 22, 107 × 168, 247 × 253, 382 × 381, 382 × 384, 431 × 368, 2 × 12, 5 × 6, 5 × 7, 8 × 15, 9 × 4, 10 × 5, 13 × 10, 13 × 16, 14 × 12, 15 × 13, 15 × 17, 17 × 9, 17 × 16, 17 × 22, 18 × 22, 24 × 18, 26 × 30, 26 × 31, 26 × 114, 50 × 94, 57 × 59, 64 × 66, 66 × 84, 80 × 77, 83 × 84, 87 × 86, 90 × 91, 92 × 94, 102 × 103, 103 × 99, 109 × 111, 139 × 5, 147 × 140, 149 × 146, 153 × 131, 167 × 165, 184 × 186, 201 × 232, 249 × 253, 340 × 336, 380 × 382, 394 × 347, 397 × 325, 401 × 417, 22 × 11, 18 × 22, 407 × 613, 410 × G1, C1 (China-1), C2 (China-2), HSM 16, Check-1, Check-2, NARC 2704 Reciprocal and NARC 2704 Regular.

Experimental design

The experiment was conducted following alpha lattice design with three replications. Each trial unit was one row plot comprising row length of five meters; row to row distance was 0.75 m and plant-to-plant distance was 0.20 m. To confirm reliable emergence of seeds, two seeds hill^{-1} were sown using hand dibbler and after the emergence, one seedling hill^{-1} was retained two weeks after appearance. Recommended culture practices required for marketable crop growing of maize hybrids were carried out all over the season. The data were recorded for plant height, ear height, flag leaf area, ear leaf area, days to 50% tasseling, days to 50% silking, days to 50% anthesis, anthesis silking interval, chlorophyll content, ear length, number of cobs row^{-1}, fresh ear weight, kernels rows ear^{-1}, kernels row^{-1}, 100-kernel weight, grain moisture, ear diameter, cob diameter and grain yield.

Statistical analysis

Analysis of variance (ANOVA) was done on the sample for the entire characters mentioned using MStat-C statistical program. The mean of five selected plants from each replication for all traits were compared by LSD at 5 % level of significance following the method of Steel *et al.* (1997). Association among a number of characters studied was calculated following Kwon and Torrie (1964). Estimates of variance components were computed from the ANOVA by using the following formula (Fehr, 1987):

Genotypic variance $(Vg) = (GMS - EMS) / r$

Environmental variance $(VE) = EMS$

Phenotypic variance $(VP) = Vg + VE$

Genetic Advance $(GA) = i \times \sqrt{VP} \times h2$

Where, i = Efficacy of selection which is 1.76 at 10 % selection intensity.

Genetic advance was categorized as low (0 – 0.10), moderate (0.10 – 0.20) and high (> 0.20) as suggested by Johnson *et al.* (1955) as follows.

The mean values of studied traits were used for genetic analyses to calculate phenotypic coefficient of variation (PCV%) and genotypic coefficient of variation (GCV%), according to Singh and Chaudhary (1985).

Broad sense heritability was estimated following Hanson *et al.* (1956).

Broad sense heritability $(hbs2) = (Vg / Vp)$

Heritability percentage categorized as low (0 – 30%), moderate (30% – 60%), high (> 60%) and estimates of heritability and degree of dominance in corn following Robinson *et al.* (1949).

Results and discussion

Analysis of variance

Analysis of variance revealed significant differences for all the traits studied except chlorophyll content and grain yield (Table 1).

These results indicated that sufficient genetic variability is present in the studied germplasm for these traits which can be exploited in future breeding program.

The coefficients of variation (CV) were low for all the traits showing high level of uniformity for these inbred lines. Genotypic, environmental and phenotypic variances as well as their coefficients of variation, genotypic coefficient of variation (GCV%) and phenotypic coefficient of variation (PCV%), broad sense heritability and genetic advance are presented in Table 2. Phenotypic coefficient of variation were higher than the genotypic coefficient of variation.

Maximum GCV% and PCV% were recorded for anthesis silking interval. Ear leaf area and chlorophyll content showed least GCV%.

Table 1. Mean squares of 19 morpho-physiological and yield parameters of 81 maize hybrids.

Traits	Replications	Treatments	Block	Error	CV(%)
Plant height (cm)	30107.53	315.56**	174.99	109.54	5.85
Ear height (cm)	14107.46	68.26**	35.92	27.84	7.14
Flag leaf area cm^2	5149.26	15.47**	13.24	11.78	10.32
Ear leaf area cm^2	102870.02	182.29**	235.30	139.76	1.92
Days to 50% Tasseling	4272.79	12.04**	43.70	3.16	3.53
Days to 50% Silking	3667.33	5.11**	15.16	3.19	3.43
Days to 50% Anthesis	3463.36	6.47*	15.12	4.31	4.13
Anthesis Silking interval (ASI)	5.33	4.49*	5.11	2.90	93.09
Chlorophyll content	6949.85	9.07NS	11.73	8.61	7.22
Fresh ear weight at harvest (kg)	5.73	0.16**	0.11	0.08	10.26
Number of cobs row^{-1}	98.05	6.06**	3.39	3.81	12.59
100 kernel weight (kg)	1371.84	5.19**	4.30	1.62	5.03
Grain moisture content (%)	711.12	2.98**	6.53	1.41	7.58
Ear length	968.96	3.77**	1.83	0.96	4.33
Number of kernel rows ear^{-1}	400.20	1.99**	2.57	1.12	7.39
Number of kernel row^{-1}	5485.49	28.53**	7.58	13.04	10.30
Ear diameter	49.15	0.17**	0.42	0.06	5.75
Cob diameter	38.42	0.12**	0.13	0.05	8.15
Grain Yield (kg ha^{-1})	5598413.45	1590772NS	2667275.77	1765100.40	16.64

NS = Non-significant * = Significant at 5% level of significance.

** = Significant at 1% level of significance.

Heritability

Heritability estimates were moderate for plant height (38.54), ear height (32.63), days to 50% tasseling (48.44), 100-kernel weight (42.35), ear length (49.47) and ear diameter (40.0) while remaining traits showed low heritability estimates (Table 2). Genetic advance was high for plant height (9.05), ear height (3.69), flag leaf area (0.60), ear leaf area (2.01), days to 50% tasseling (2.11), days to 50% silking (0.58), days to 50% anthesis (0.57), anthesis silking interval (0.50), 100-kernel weight (1.25), moisture content (0.67), ear length (1.20), kernel rows ear^{-1} (0.43), kernel row^{-1} of ear (2.13), ear diameter (0.22) and grain yield $plant^{-1}$ (60.06) while remaining traits showed low to moderate genetic advance (Table 2).

Abdelmula and Sabiel (2007) reported moderate levels of heritability estimates for plant height while Ali *et al.* (2015) observed higher genetic advance for plant height. Bekele and Roa (2014) found that genetic advance for ear height was high and heritability estimates was moderate. Salami *et al.* (2007) reported low heritability for days to silking and anthesis. Tusuz and Balabanli (1997) found low heritability estimates for grain moisture content (0.03) during evaluation of maize hybrids. These results are in agreement with the findings of Tusuz and Balabanli (1997); Beyene (2005); Salami *et al.* (2007) reported low heritability estimates for grain yield.

Correlation

Correlation coefficients are presented in the Table 3. Plant height showed positive and significant correlation with ear height, ear leaf area, fresh ear weight, ear length, kernels row^{-1}, ear diameter and grain yield. Similar results were reported by Bekele and Roa (2014). Ear height have significantly and positively correlation with ear leaf area, days to tasseling, silking, anthesis, chlorophyll content, ear weight, ear length, kernels row^{-1}, cob diameter and grain yield. Golam *et al.* (2011) also observed positive correlation of ear height with grain yield. Flag leaf area is positively and significantly correlated with ear leaf area, days to flowering, chlorophyll content and kernels row^{-1}. It was also observed that there is negative correlation of flag leaf area with ASI and grain yield. Ear leaf area is positively and significantly correlated with days to flowering, chlorophyll content, ear length, kernels rows ear^{-1} and kernels row^{-1} while negatively and non-significantly correlated with grain yield.

Table 2. Genotypic variance, environmental variance, phenotypic variance, heritability (%) and genetic advance of all traits under study.

Traits	Vg	Ve	Vp	GCV%	PCV%	Hbs2 (%)	GA
PH	68.67	109.53	178.20	4.63	7.47	38.54	9.05
EH	13.48	27.83	41.31	4.97	8.70	32.63	3.69
FLA	1.23	11.78	13.00	3.33	10.83	9.46	0.60
ELA	14.18	139.76	153.94	0.61	2.01	9.21	2.01
DT	2.96	3.15	6.11	3.41	4.90	48.44	2.11
DS	0.64	3.19	3.83	1.53	3.75	16.71	0.58
DA	0.72	4.31	5.03	1.69	4.46	14.31	0.57
ASI	0.53	2.90	3.43	40.45	102.89	15.45	0.50
CC	0.15	8.61	8.76	0.95	7.29	1.71	0.09
FEW	0.03	0.08	0.11	6.19	11.85	27.27	0.16
#COBS	0.75	3.81	4.56	5.62	13.87	16.45	0.62
100KW	1.19	1.62	2.81	4.31	6.63	42.35	1.25
MC	0.53	1.40	1.93	4.67	8.91	27.46	0.67
EL	0.94	0.96	1.90	4.29	6.10	49.47	1.20
#KR/E	0.29	1.12	1.41	3.74	8.25	20.57	0.43
#K/R	5.16	13.04	18.20	6.70	12.58	28.36	2.13
ED	0.04	0.06	0.10	4.65	7.35	40.00	0.22
CD	0.02	0.05	0.07	4.88	9.12	28.50	0.13
GYPH	41890.73	1465100.40	1506991.13	2.56	15.38	2.78	60.06

Vg =genotypic variance, Ve =environmental variance, Vp =phenotypic variance, hbs2 = broad sense heritability, GA =genetic advance, PH = plant height, EH = ear height, FLA = flag leaf area, ELA = ear leaf area, DT = days to tasseling, DS = days to silking, DA = days to anthesis, CC = chlorophyll content, FEW = fresh ear weight, #COBS number of cobs row^{-1}, 100 – KW = hundred kernel weight, MC = moisture content, EL = ear length, #KR/E = number of kernel rows ear^{-1}, #K/R = number of kernels row^{-1} of ear, ED = ear diameter, CD = cob diameter and GYPH = grain yield ha^{-1}

Days to mid tasseling was positively and significantly correlated with days to silking, anthesis, chlorophyll content, ear weight, hundred kernels weight, moisture content, kernels row^{-1}, cob diameter and showed negative correlation with grain yield. Days to mid silking was positively and significantly correlated with days to mid anthesis, chlorophyll content, ear length, kernels row^{-1} and ear diameter but non-significant correlation with grain yield. Golam *et al.* 2011 also found similar results of correlation for tasseling and silking with grain yield. Days to 50% anthesis was positively and significantly correlated with chlorophyll content, ear length, kernels row^{-1}, ear diameter but negative correlation with grain yield.

Abdelmula and Sabiel (2007) also observed negative and non-significant association of days to anthesis with grain yield.

ASI was positively correlated with field weight, kernels row^{-1} of ear, cob diameter, grain yield and negative correlation with most of the traits mentioned.

Table 3. Correlation among various characters of maize hybrids.

Variables	PH	EH	FLA	ELA	DT	DS	DA	*ASI*	*CC*
PH									
EH	0.629**								
FLA	0.099	0.171							
ELA	0.267**	0.454**	0.476**						
DT	0.066	0.229*	0.199*	0.094					
DS	0.122	0.392**	0.225*	0.217*	0.616**				
DA	0.085	0.260**	0.306**	0.321**	0.525**	0.747**			
CC	-0.032	0.232*	0.197*	0.320**	0.404**	0.343**	0.397**	-0.172	
FEW	0.570**	0.366**	0.090	-0.004	0.208*	0.136	0.053	0.092	-0.138
COBS	0.115	0.019	0.093	-0.013	0.252*	0.046	0.054	0.055	0.063
HKW	-0.101	0.070	0.191	0.269**	-0.228*	0.052	0.030	-0.023	0.140
MC	0.021	0.062	0.157	0.094	0.432**	0.142	0.145	-0.067	0.243
EL	0.234*	0.364**	0.181	0.402**	0.008	0.208*	0.224*	-0.146	0.208*
$\#KR/E-1$	0.123	0.190	0.149	0.236*	0.045	-0.002	0.127	-0.167	0.177
#K/R	0.302**	0.409**	0.235*	0.296**	0.285**	0.419**	0.311**	0.014	0.260**
ED	0.010	0.120	0.084	0.110	0.098	0.258**	0.211*	-0.049	0.197
CD	0.260**	0.254*	0.036	0.059	0.202*	0.185	0.117	0.118	0.075
GYPH	0.355**	0.299**	-0.034	-0.038	-0.068	0.104	-0.003	0.072	-0.232*

(Cont.) **Table 3.** Correlation among various characters of maize hybrids.

Variables	FEW	COBS	HKW	MC	EL	#KR/E	#K/R	ED	CD
COBS	0.401**								
HKW	-0.244*	-0.256**							
MC	0.312**	0.243*	-0.387**						
EL	-0.048	-0.320**	0.630**	-0.190					
#KR/E	-0.057	-0.194	0.060	0.115	0.035				
#K/R	0.201*	-0.025	0.295**	0.049	0.342**	0.269**			
ED	-0.010	-0.108	-0.072	0.352**	-0.074	0.297**	0.255*		
CD	0.130	-0.027	0.029	0.252*	0.068	0.315**	0.371**	0.493**	
GYPH	0.512**	-0.550**	0.044	-0.016	0.241*	0.102	0.196	0.070	0.091

* Significant at 5% and, ** Significant at 1% probability levels

PH = plant height, EH = ear height, FLA = flag leaf area, ELA = ear leaf area, DT = days to tasseling, DS = days to silking, DA = days to anthesis, CC = chlorophyll content, FEW = fresh ear weight, $\#COBS$ number of cobs row^{-1}, HKW = hundred kernel weight, MC = moisture content, EL = ear length, $\#KR/E$ = number of kernel rows ear^{-1}, $\#K/R$ = number of kernels row^{-1} of ear, ED = ear diameter, CD = cob diameter and $GYPH$ = grain yield ha^{-1}

Chlorophyll content was positively and significantly correlated with ear height, flag and ear leaf area, ear length, grains row^{-1} and negative correlation with plant height, ASI and grain yield. Ali *et al.* (2015) also observed that chlorophyll content is positively and significantly correlated with leaf area. Fresh ear weight was positively correlated with number of cobs, moisture content, kernels row^{-1}, cob diameter and grain yield.

The results are in line with the findings of Golam *et al.* (2011). 100-kernels weight was positively and significantly correlated with ear leaf area, ear length, and kernels row^{-1} while positive and non-significant with ear length and grain yield. It was observed that 100-grains weight negatively correlated with plant height, days to tasseling, ASI, moisture content, number of cobs row^{-1} and ear diameter. Grain moisture is positively correlated with kernel rows ear^{-1}, kernels per row, ear diameter, cob diameter and negative with ear length and grain yield under observation.

Ear length is positively and significantly correlated with yield, its component and most of the other traits mentioned but non-significantly with flag leaf area, days to tasseling, kernel rows ear^{-1} and cob diameter (Table 3). Kanagarasu *et al.* (2012) also observed that ear length is positively correlated plant height, ear height, leaf length and breath, grain rows per cob and grain yield. Kernel rows ear^{-1} is positively and significantly correlated with ear leaf area, kernel row^{-1}, ear diameter, cob diameter but non-significant with grain yield. Kernel row^{-1} of ear is positively and significantly correlated with all traits mentioned except ASI, moisture content and grain yield which showed non-significantly correlation (Table 3).

Ear diameter is positively correlated with all the traits discussed except anthesis silking interval, number of cobs, 100-grains weight and ear length whose correlation is of negative nature. Cob diameter is positively correlated with all the characters under study except number of cobs per row which shows negative correlation.

The findings are in agreement with the results of Kanagarasu *et al.* (2012) that cob diameter is positively correlated plant height, ear height, leaf length and breath, cob length, grain rows ear^{-1}, 100-grain weight and grain yield. Grain yield was positively and significantly correlated with plant height, ear height, chlorophyll content, filed weight, cobs row^{-1} and ear length but non-significant with remaining traits under study.

The results are in agreement with the findings of Golam *et al.* (2011) who also found positive and significant correlation of yield with plant height, ear height, field weight and no correlation with days to tasseling, days to silking and thousand grains weight. Similar results were also observed by Sadek *et al.* (2006), Singha and Prodhan (2000) that grain yield is positively associated with plant height.

Analysis of variance and genotypic, phenotypic coefficient of variation of 19 morphological and physiological traits in 81 maize hybrids revealed significant genetic variation in the studied traits. Prevalence of significant genetic variability implied that these maize hybrids had diverse genetic backgrounds and could be exploited by plant breeders to develop maize varieties adapted to the prevailing conditions. Heritability estimates empowers the plant breeder to choose the selection procedure to be followed in a particular situation (Li and Yang, 1985). However heritability estimates together with genetic advance considered to be more reliable in formulating selection procedure.

Conclusion

It was accomplished from current study that high genetic advance was found for grain yield per plant and its contributing traits ear length, fresh cob weight, 100-grains weight, kernel rows, kernels per row of ear and ear diameter. Moderate heritability estimates were observed for most of the traits. Positive and significant correlation was found for grain yield per plant with plant height, ear height, ear weight and length. That's why selection of higher grain yielding maize genotypes may be useful on the basis of these traits.

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