

Correlation analysis for morpho-physiological traits of maize (*Zea mays* L.)

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Abstract: The present study was conducted in the glasshouse of Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan during crop growing season 2011. It was concluded that higher heritability was recorded for all traits while higher genetic advance was recorded for fresh root-to-shoot weight ratio (49.07%), dry root weight (62.86%), dry shoot weight (47.75%), total dry weight (51.19%), dry root-to-shoot weight ratio (58.66%), chlorophyll contents (193.59%), photosynthetic rate (138.40%), sub-stomata CO₂ concentration (145.28%), water use efficiency (181.28%), transpiration rate (96.29%) and stomata conductance (75.98%). It was found that significant genotypic and phenotypic correlations were shown by fresh root length, fresh shoot length, fresh root weight, fresh shoot weight, total fresh weight, dry root weight, dry shoot weight, total dry weight, photosynthetic rate, chlorophyll contents, leaf temperature and water use efficiency. Higher heritability, genetic advance and significant correlation indicated that selection on basis of these morpho-physiological traits may be helpful to improve maize grain yield.

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Key words: *Zea mays*, heritability, genetic advance, genotypic, phenotypic, correlation

1. Introduction

Zea mays L. is the most important cereal food crop of world with supplementary importance for countries akin to Pakistan where swiftly increasing population has already outstripped the existing food provisions. Maize is the third vital cereal in Pakistan after wheat and rice. Maize contributes 5.67 % of the worth of agriculture outputs. It was grown on 1083 thousands hectares with annual production of 4271 thousands tons (Anonymous, 2011-12). Maize is used as food for human while feed for livestock and also used as industrial raw material to produce diverse types of by-products. It has highest 9.9% crude protein at early and at full bloom stages that decreases to 7% at milk stage (grain formation starting stage) and to 6% at maturity. Maize contains 72% starch, 10% protein, 4.80% oil, 9.50% fiber, 3.0% sugar, 1.70% ash, 82% endosperm, 12% embryo, 5% bran testa and 1% tip cap (Chaudhary, (1983) and Bureau of Chemistry, U.S., (2010)). The production of Pakistan is low as compared to other maize growing countries due to non-availability of resources and potential germplasm. Grain yield is related with various morphological, physiological and agronomic traits of maize. By improving these traits production of maize genotypes may be increased. Genotypic correlation provides an opportunity to a plant breeder to select genotypes on the basis of strong correlation among grain yielding contributing traits as reported by Mehdi and Ahsan

(2000a); Grzesiak *et al.* (2007); Ali *et al.* (2011a, b) and Ali *et al.* (2012). The present study was conducted to evaluate maize accessions for morpho-physiological seedling traits.

2. Material and methods

The current study was conducted out in the glasshouse of the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad to assess the maize genotypes for seedling traits for the period of the crop season in February 2011. The experimental material was comprising of 80 accessions including ten check varieties namely: F-121, F-130, F-140, F-143, F-113, F-111, F-105, F-148, F-146, B-303, F-128, B-306, B-303, B-313, F-117, B-316, EV-324, EV-335, EV-310, F-114, F-136, F-122, F-134, F-147, F-135, VB-06, EV-334, EV-330, EV-329, EV-338, B-314, B-305, B-321, B-326, B-308, F-118, B-304, EV-343, F-150, F-142, F-151, POP/209, BF-337, BF-248, BF-212, BF-236, EV-342, EV-323, BF-238, B-15, EV-347, F-96, B-312, EV-344, E-352, E-341, E-351, E-322, E-346, F-98, B-96, EV-340, E-349, B-121, E-336, B-11, Sh-213, Sh-139, SWL-2002, Pak-Afgooe, Islamabad W, EV-7004Q, EV-1097, Raka-Poshi, VB-51, Gold Islamabad, Sawan-3, BS-2 and POP/2007). The seeds of all accessions were sown in iron trays filled with sand following a randomized complete block design (RCBD) with three replications at the depth of 2.5 cm and twenty seedlings of each accession were established in each replication. The data of 5

plants was recorded for physiological traits including chlorophyll contents measured with the help of Chlorophyll Meter and leaf temperature, stomata conductance, transpiration rate, photosynthetic rate, sub-stomata CO₂ concentration, water use efficiency help of IRGA (Infrared Gas Analyzer), fresh root length, fresh shoot length, root-to-shoot length ratio, fresh root weight, fresh shoot weight, total fresh weight, fresh root-to-shoot weight ratio, dry root weight, dry shoot weight, total dry weight and dry root-to-shoot weight ratio by using meter rod (length) and electronic balance (weight). The data was statistically analyzed by using analysis of variance technique (Steel *et al.* 1997). The genotypic and phenotypic correlations were calculated by Kwon and Torrie (1964) technique. The genetic advance was calculated by using Falconer (1989) formula. Heritability was recorded by using Burton, (1951) technique.

2.1. Statistical Analysis Formulae:

Phenotypic and genotypic coefficients of variation were calculated according to the formula given below:-

GCV = Genotypic coefficient of variation (%),

PCV = Phenotypic coefficient of variation

(%), \bar{X} = Grandmean of the trait, σ_p^2 = phenotypic

variance, σ_g^2 = genotypic variance

$$GCV = \frac{\sqrt{\sigma_g^2}}{\bar{X}} \times 100$$

$$PCV = \frac{\sqrt{\sigma_p^2}}{\bar{X}} \times 100$$

Broad sense heritability for each recorded trait was calculated as a ratio of the genotypic variances to phenotypic variances. Phenotypic (r_p) and genotypic (r_g) correlation coefficient was calculated as outlined by Kwon and Torrie (1964).

$$r_p = \frac{M_{ij}}{\sqrt{(M_{ii})(M_{jj})}}$$

$$r_g = \frac{Cov_{gij}}{\sqrt{(Var_{gi})(Var_{gj})}}$$

Where

r_p = the estimate of phenotypic correlation coefficient

M_{ij} = the mean product of genotypes for the *i*th and *j*th traits, M_{ii} and M_{jj} = Variety mean squares for *i*th and *j*th traits, respectively.

r_g = Genotypic correlation coefficient

CoV $_{gij}$ = Genotypic covariance of *i*th and *j*th traits

Var $_{gi}$ = Genotypic variance of *i*th traits

Var $_{gj}$ = Genotypic variance of *j*th traits

Standard error of genotypic correlation coefficients (SE of r_g) were calculated according to Reeve (1955). Genotypic correlation coefficient was considered significant if their absolute value exceeded twice their standard error.

$$S.E. \text{ of } r_g = \frac{1 - r_g^2}{\sqrt{2}} \sqrt{\frac{\sqrt{h_i^2} \sqrt{h_j^2}}{h_i^2 \cdot h_j^2}}$$

Where,

r_g^2 = The genotypic correlation coefficient between the traits *i* and *j*.

h_i^2 = The heritability of *i*th trait.

h_j^2 = The heritability of *j*th trait.

The estimates of heritability and genotypic correlation coefficient were considered significant if their absolute value exceeded twice of their standard error. Phenotypic correlation coefficients were tested using t-test (Steel and Torrie, 1997) as given below.

$$t = \frac{r}{\sqrt{(1 - r^2) / n - 2}}$$

Where, r = the phenotypic correlation coefficient, $n-2$ = correlation error degree of freedom

Genetic advance (GA) was calculated by the following formula.

$GA = \sigma_p \times h^2 \times i$

Where, σ_p = the phenotypic standard deviation, h^2 = Estimate of broad sense heritability, i = constant value (1.755) that reflects selection intensity (10%)

3. Results and discussions

It was persuaded from table 1 that heritability was found between the ranges of 82.35% to 100%. Higher heritability was reported for photosynthetic rate (100%) followed by chlorophyll contents (99.99%) while lower for dry root/shoot weight ratio (88.73%) followed by stomata conductance (82.35%). Higher genetic advance was found for chlorophyll contents (193.59%) followed by water use efficiency (181.28%) and sub-stomata CO₂ concentration (145.28%) while lower for fresh shoot length (28.95%) followed by total fresh weight (30.59%) and fresh shoot weight (36.10). Higher values of heritability and genetic advance indicated that selection of higher yielding maize genotypes may be useful on the basis of these traits. Higher genetic advance also indicated the additive effects were very higher and on the basis of genetic advance selection can be made to improve genetic potential of maize genotypes. Similar results were reported by Mehdi and Ahsan (2000b); Afarinesh *et al.* (2005); Ali *et al.* (2011a); Ali *et al.* (2011b); Fang *et al.* (2011); Ali *et al.* (2012) and Ahsan *et al.* (2013).

It was suggested from tables 2 and 2a that positive and significant genotypic and phenotypic correlation of fresh root length was found with fresh shoot length, fresh root/shoot length ratio, fresh and dry root and

shoot weight, total fresh and dry weight and photosynthetic rate. Significant correlations with fresh and dry root and shoot weight indicated that selection on the basis of fresh root length for drought condition may be helpful to improve maize grain yield (Afarinesh *et al.* (2005); Ali *et al.* (2011a); Ali *et al.* (2011b); Fang *et al.* (2011) and Ali *et al.* (2012)). Fresh shoot length showed positive and significant genotypic and phenotypic correlation with fresh shoot length, fresh and dry shoot weight, dry root weight, total dry weight and leaf temperature while fresh root/shoot length ratio was positively and significantly correlated with fresh root length, sub-stomata CO₂ concentration and water use efficiency at genotypic and phenotypic levels. Similar results were obtained by Ali *et al.* (2011a); Ali *et al.* (2011b); Fang *et al.* (2011) and Ali *et al.* (2012). Fresh root weight was positively and significantly correlated with fresh root length, total fresh and dry weight, photosynthetic rate, fresh root/shoot weight ratio, chlorophyll contents, sub-stomata CO₂ concentration and water use efficiency at genotypic and phenotypic levels while dry root weight was correlated with fresh root and shoot length, fresh root and shoot weight, dry shoot weight, total fresh and dry weight, photosynthetic rate, dry root/shoot weight ratio and chlorophyll contents (Afarinesh *et al.* (2005); Fang *et al.* (2011) and Ali *et al.* (2012)). Fresh shoot weight was positively and significantly correlated with fresh root and shoot length, total fresh and dry weight, dry root and shoot weight, photosynthetic rate and sub-stomata CO₂ concentration while dry shoot weight was correlated with fresh root length, fresh shoot length, root-to-shoot length ratio, fresh root weight, fresh shoot weight, total fresh weight, fresh root-to-shoot weight ratio, dry root weight, dry shoot weight, total dry weight and dry root-to-shoot weight ratio, stomata conductance, transpiration rate, photosynthetic rate and water use efficiency. Significant correlations suggested that photosynthetic rate was higher that leads towards the accumulation of organic compounds in the plant body and helped to improve grain and fodder yield of maize. Similar results were obtained by Afarinesh *et al.* (2005); Grzesiak *et al.* (2007); Ali *et al.* (2011a); Ali *et al.* (2011b); Fang *et al.* (2011); Ali *et al.* (2012) and Ali *et al.* (2014).

Fresh root-to-shoot weight ratio was positively and significantly correlated with fresh root weight, dry root-to-shoot weight ratio, photosynthetic rate and water use efficiency while was positive and significant correlation of dry root-to-shoot weight ratio was found with fresh root-to-shoot weight ratio, dry root weight, total dry weight, leaf temperature, chlorophyll contents and water use efficiency at genotypic and phenotypic level. Significant positive genotypic and phenotypic correlation of total fresh weight was found with fresh root length, fresh and dry root and shoot weight, total

dry weight, sub-stomata CO₂ concentration and chlorophyll contents while total dry weight was positively and significantly correlated with fresh root length, leaf temperature, photosynthetic rate, dry root-to-shoot weight ratio, fresh and dry root and shoot weight, total dry weight, sub-stomata CO₂ concentration and chlorophyll contents. Similar results were obtained by Mehdi and Ahsan (2000b); Ali *et al.* (2011a); Ali *et al.* (2011b); Fang *et al.* (2011); Ali *et al.* (2012) and Ali *et al.* (2014). Photosynthetic rate was positively and significantly correlated with fresh root length, fresh root-to-shoot weight ratio fresh and dry root and shoot weight, total dry weight, stomata conductance, transpiration rate, water use efficiency and chlorophyll contents while leaf temperature was positively and significantly correlated with transpiration rate, fresh shoot length, dry shoot weight, total dry weight, dry root-to-shoot weight ratio and sub-stomata CO₂ concentration at genotypic and phenotypic level. Similar results were obtained by Mehdi and Ahsan (2000b); Ali *et al.* (2011a); Ali *et al.* (2011b); Fang *et al.* (2011) and Ali *et al.* (2013). Positive and significant genotypic and phenotypic correlation of chlorophyll contents was found with fresh and dry root weight, total fresh and dry weight, dry root-to-shoot weight ratio and photosynthetic rate while photosynthetic rate, leaf temperature and water use efficiency showed a significant positive genotypic and phenotypic correlation with stomata conductance and transpiration rate. Sub-stomata CO₂ concentration showed a significant positive genotypic and phenotypic correlation with fresh root-to-shoot length ratio, fresh root and shoot weight, total fresh and dry weight and photosynthetic rate while water use efficiency showed a significant positive genotypic and phenotypic correlation with fresh root-to-shoot length ratio, fresh root weight, stomata conductance, transpiration rate, sub-stomata CO₂ concentration, total fresh and dry weight, fresh and dry root-to-shoot weight ratio and photosynthetic rate. Similar results were obtained by Mehdi and Ahsan (2000b); Ali *et al.* (2011a); Ali *et al.* (2011b); Fang *et al.* (2011); Ali *et al.* (2012); Ali *et al.* (2013) and Ali *et al.* (2014).

Conclusion

It was concluded from above study that significant genotypic and phenotypic correlations were shown by fresh root length, fresh shoot length, fresh root weight, fresh shoot weight, total fresh weight, dry root weight, dry shoot weight, total dry weight, photosynthetic rate, chlorophyll contents, leaf temperature and water use efficiency. Higher heritability, genetic advance and significant correlation indicated that selection on basis of these morphophysiological traits may be helpful to improve maize grain yield.

Table 1: heritability and genetic advance for various morpho-physiological traits of maize

Traits	Heritability (h^2_{bs} %)	Genetic advance %
Fresh root length	99.88	41.01
Fresh shoot length	99.19	28.95
Fresh Root-to-shoot length ratio	99.49	41.67
Fresh root weight	96.00	37.26
Fresh shoot weight	96.67	36.10
Total fresh weight	98.63	30.59
Fresh root-to-shoot weight ratio	98.51	49.07
Dry root weight	97.07	62.86
Dry shoot weight	92.31	47.75
Total dry weight	97.47	51.19
Dry root-to-shoot weight ratio	88.73	58.66
Chlorophyll contents	99.99	193.59
Photosynthetic rate	100.00	138.40
Stomata conductance	82.35	57.98
Transpiration rate	99.30	96.29
Sub-stomata CO ₂ concentration	99.97	145.28
Water use efficiency	99.70	181.28
Leaf temperature	99.63	9.88

Table 2: Genotypic correlations of various morphological and physiological traits of maize seedlings

Traits	FSL	RSLR	FRW	FSW	TFW	FRSW R	DRW	DSW	TDW	DRSW R	A	LT	Chl. C	gs	E	Ci	WUE	
FRL	0.3967*	0.7156*	0.2894*	0.4006*	0.4269*	-0.0723	0.2779*	0.2643*	0.3133*	0.0841	0.0586*	-0.0758	-	0.0132	0.1412	0.0786	-	0.0231
FSL	-	0.3288*	0.0079	0.3984*	0.2616	-0.3369	0.2244*	0.3876*	0.3074*	-0.0998	0.0597	0.110*	-	0.0741	0.1567	-	0.1442	-0.1120
RSLR	-	-	0.2877	0.0893	0.2251	0.2013	0.1199	-	0.0875	0.1977	-0.0087	0.0299	0.0641	0.0292	0.1399	0.0529*	0.1927*	-
FRW	-	-	-	0.3263	0.7926*	0.4927*	0.3856*	0.1059	0.3486*	0.3106	0.1082*	0.0121	0.1787*	-	0.0812	0.0289	0.0986*	0.1231*
FSW	-	-	-	-	0.8350*	-	0.2956*	0.6189*	0.4404*	-0.2394	0.1146*	-0.0702	0.1326	0.0266	-	-0.039	0.0576*	-0.0023
TFW	-	-	-	-	-	-0.6099*	-	0.4609*	0.4870*	0.0264	0.0109	-0.0382	0.1896*	0.0644	-	-0.042	0.0946*	0.1344*
FRSW R	-	-	-	-	-	-	0.0083	0.4661*	0.1432	0.4414*	0.1526*	0.0799	-	0.0248	0.0783	0.0344	0.0090	0.3122*
DRW	-	-	-	-	-	-	-	0.4312*	0.9573*	0.6405*	0.0983*	-0.0371	0.2233*	-	0.0624	0.0094	-0.1002	
DSW	-	-	-	-	-	-	-	-	0.6735*	0.3948*	0.0775	0.2295*	0.1344	0.0781	0.0733	0.0414*	-0.1023	
TDW	-	-	-	-	-	-	-	-	-	0.3984*	0.1063*	0.1029*	0.1933*	0.1357	0.0745	0.0200*	0.4123*	
DRSW R	-	-	-	-	-	-	-	-	-	-	-0.0103	0.1452*	0.1432	0.0286	0.0099	0.0352	0.1102*	
A	-	-	-	-	-	-	-	-	-	-	-	0.0273	0.2904*	0.2348	0.2761*	0.1776	0.2102*	
LT	-	-	-	-	-	-	-	-	-	-	-	-	0.0258	0.1395	0.2837*	0.1364*	0.0754	
Chl. C	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1270	0.1085	0.2107	0.1022	
Gs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1391	0.2653	0.3211*	
E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0692	0.2612*	
Ci	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3912*	

** = Significance at 5% level, * = Significance at 1% level

FRL = Fresh root length, FSL = Fresh shoot length, RSLR = Root-to-shoot length ratio, FRW = Fresh root weight, FSW = Fresh shoot weight, TFW = Total fresh weight (Fresh biomass per seedling), FRSWR = Fresh root-to-shoot weight ratio, DRW = Dry root weight, DSW = Dry shoot weight, TDW = Total dry weight (Dry biomass per seedling) DRSWR = Dry root-to-shoot weight ratio, A = Photosynthetic rate, LT = Leaf temperature, Chl. C = Chlorophyll contents, gs = Stomata conductance, E = Transpiration rate, Ci = Sub-stomata CO₂ concentration, WUE = Water use efficiency.

Table 2a: Phenotypic correlations of various morphological and physiological traits of maize seedlings

Traits	FSL	RSLR	FRW	FSW	TFW	FRSW R	DRW	DSW	TDW	DRSW R	A	LT	Chl. C	gs	E	Ci	WUE
FRL	0.3948 **	0.7148 **	0.2868 **	0.3994 **	0.4249 **	-0.0722	0.2727 **	0.2527 **	0.3080 **	0.0766	0.0586	-0.0755	-0.0132	0.1295	0.0778	-0.1558	-0.1021
FSL		- 0.3319 **	0.0078	0.3948 **	0.2590 **	- 0.3332 **	0.2215 **	0.3671 **	0.3026 **	-0.0912	0.0594	-0.1097	-0.0738	0.1381	-0.0881	-0.1437	-0.1102
RSLR			0.2851 **	0.0895	0.2242 **	0.1992 *	0.1161	-0.0341	0.0850	0.1814 *	- 0.0086	0.0300	0.0639	0.0308	0.1391	0.0527	0.0782
FRW				0.3237 **	0.7925 **	0.4967 **	0.3760 **	0.0992	0.3400 **	0.2896 **	0.1074 *	0.0117	0.1774 *	-0.0723	-0.0279	0.0977	0.2311 *
FSW					0.8335 **	- 0.6088 **	0.2904 **	0.5909 **	0.4338 **	- 0.2296 **	0.1141 *	-0.0688	0.1320	-0.0229	-0.0382	0.0574	0.0987
TFW						-0.1023	0.4067 **	0.4386 **	0.4781 **	0.0211	0.0108	-0.0375	0.1887 *	-0.0570	-0.0409	0.0941	0.0954
FRSW R							0.0071	- 0.4454 **	-0.1423	0.4182 **	0.1517 *	0.0784	-0.0245	-0.0722	0.0345	0.0088	0.3215 **
DRW								0.4041 **	0.9530 **	0.6228 **	0.0970	-0.0376	0.2206 **	-0.1335	0.0626	0.0097	0.0663
DSW									0.6620 **	- 0.428* **	0.0739	0.2206 **	0.0294	-0.0777	0.0651	0.0403	0.0781
TDW										0.3687 **	0.1049 *	-0.1028	0.1911 *	-0.1352	0.0728	0.0203	0.4211 **
DRSW R											0.0097	0.1359	0.1346	-0.0415	0.0133	-0.0333	-0.0654
A												0.0273	0.2904 **	0.2132 **	0.2750 **	0.2775 **	0.1123 *
LT													0.0256	0.1297	0.2828 **	0.1362	0.0971
Chl. C														-0.1160	-0.1081	0.2106 **	0.0621
Gs															0.1301	0.2405 **	0.2316 *
E																0.0689	0.2132 *
Ci																	0.3421 **

** = Significance at 5% level, * = Significance at 1% level

FRL = Fresh root length, FSL = Fresh shoot length, RSLR = Root-to-shoot length ratio, FRW = Fresh root weight, FSW = Fresh shoot weight, TFW = Total fresh weight (Fresh biomass per seedling), FRSWR = Fresh root-to-shoot weight ratio, DRW = Dry root weight, DSW = Dry shoot weight, TDW = Total dry weight (Dry biomass per seedling) DRSWR = Dry root-to-shoot weight ratio, A = Photosynthetic rate, LT = Leaf temperature, Chl. C = Chlorophyll contents, gs = Stomata conductance, E = Transpiration rate, Ci = Sub-stomata CO₂ concentration, WUE = Water use efficiency.

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