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HERITABILITY ESTIMATES FOR MATURITY AND MORPHOLOGICAL TRAITS BASED ON TESTCROSS PROGENY PERFORMANCE OF MAIZE

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ABSTRACT

The research entitled “Heritability estimates for maturity and morphological traits based on testcross progeny performance of maize S_1 lines” was carried out with a view to identify and evaluate the best performing S_1 lines based on testcross progeny performance and to determine their potential as parents in production of a superior hybrid/variety adapted to the agro-climatic conditions of NWFP. The experiment was conducted in the spring and summer of 2007-08 at Research Farm of NWFP Agricultural University, Peshawar (AUP) and Cereal Crop Research Institute (CCRI), Nowshera. During the spring crop season (March-June) 42 S_1 lines derived from maize variety testcrosses of maize variety “Sarhad White” were crossed to a single cross tester WD 2 x 8 were produced in isolation. After discarding nine testcrosses for no or low seed set, 33 testcrosses along with three checks were evaluated using randomized complete block design with three replications at Research farm of AUP and at CCRI during summer crop season (July-October). Heritability estimates for all the traits were calculated. The statistically analysis revealed that testcrosses differed significantly for all the characters studied except days to 50% anthesis, days to 50% silking, and ASI. The Genotype x Location interaction was also significant for all the traits except for ear length. Mean values for days to 50% tasseling, anthesis and silking, anthesis-silking interval (ASI), plant and ear height were 55.3, 58.2, 59.9, 1.69, 157.7 and 72.1, respectively. While analyzing the data we got some very interesting results. The TC-10 which was the highest yielding had the maximum value for ear height and had second highest value for plant height. The check WD3 x 6 had the lowest value for plant height and second lowest mean value for ear height.

Keywords: maize, testcross, anthesis, silking, ASI.

INTRODUCTION

Maize (*Zea mays* L.) belongs to the family Poaceae, is an important cereal crop throughout the world. In world, maize is the third most important cereal crop along with an important source of carbohydrates. These crops also serve as sources of income to small and large scale farmers in developing countries (Ahmed and Yusuf, 2007). Maize is used as forage and in the manufacture of livestock feed, food stuffs, sweeteners, beverage and industrial alcohol, and oil (Moyin-Jesu, 2010).

For improving maturity and morphological traits in high yielding varieties of maize, several methods of selection such as mass selection, modified ear to row selection and various methods of recurrent selection have been used by maize breeders (Horner *et al*., 1969). Realized progress with any breeding scheme, however, depends largely upon the ability of the breeder to identify superior genotypes (Ali *et al*., 2011a) and the accuracy with which the experiments are conducted (Genter, 1973). The S_1 progeny selection and half-Sib family selection with an unrelated tester are of particular interest to breeders in this regard (Tanner and Smith, 1987 and Beavis *et al*., 1994). Early generation testing of partial inbred lines was for the first time proposed by Jenkins (1935). He reported data on topcrosses of a number of inbred lines from the ‘Lancaster’ and ‘Iodent’ varieties made after S_1 through S_8. Based on his results he concluded that, “The inbred lines acquired their individuality as parents very early in the inbreeding process and remained relatively stable thereafter”, justifying early evaluation and early discarding of unpromising lines.

Genter (1973) reported that evaluation of early generation inbred lines in testcrosses has been the primary method used by maize breeders. Pfarr and Lamkey (1992) reported that now the widely used method of determining the value of germplasm have involved testcrosses to inbred lines, populations and various hybrids, as well as the performance per se of the germplasm. These methods will allow us to select inbred lines which will generally transmit desirable traits, without actually measuring general combining ability. Obaidi *et al*., (1998) and Mihaljevic *et al*., (2005) discerned that the testcross performance of experimental lines is the prime selection criterion in hybrid breeding of maize.

Identification of superior genotypes in a mixed or base population is one of the major objectives of plant breeders (Khan, 2004). Therefore S_1 lines were developed in Sarhad White, an improved population, and testcrossed to a common tester. This experiment was carried out to evaluate these testcrosses and identify superior S_1 lines and determine their potential as parents in the production of a superior hybrid/variety adapted to agro-climatic conditions of NWFP.

MATERIALS AND METHODS

The procedure, material and methods used in the research entitled "Evaluation of maize S_1 lines for maturity and morphological traits based on testcross progeny performance" are as follows.

Breeding material

Breeding materials used in this experiment comprised of 42 S_1 lines developed from maize variety 'Sarhad White'. Sarhad White is a composite of [Vikram (B11 x B37)] x Akbar. It is a white, semi dent variety having medium tall stature, semi dense tassel with profuse branching.

The tester that used was a single cross tester (WD 2 x 8), developed at Cereal Crop Research Institute (CCRI), Nowshera. The checks that used were WD 3 x 6, WD 2 x 8 and the open pollinated (WD 2 x 8) F_2.

Procedure and field experiment

During spring crop season (March-June) 2007, 42 S_1 lines, derived from maize variety Sarhad White were crossed to a single cross tester in isolation at research farm of NWFP Agricultural University Peshawar (AUP). During the flowering time regular visits were made to detassel the plants well before the pollen shedding to avoid any kind of contamination. The detasseled S_1 lines were allowed to be pollinated naturally by the tester. As initially sowing was delayed due to a prolonged rain spell, so at the time of pollination temperature was very high. To eliminate the risk of low or no kernel setting, manual pollinations were also carried out to save resources. The top of the ear shoot was cut 2-3 cm to allow uniform silk emergence for effective pollination and the next morning pollen from tester plants were collected in bulk to pollinate the respective lines (Ali *et al*., 2011a). At physiological maturity (black layer formation at hilum of maize kernel) plants were hand harvested. Testcrosses that had no or very low seed setting were discarded. During Kharif (summer) of 2007, testcrosses along with three checks were evaluated in replicated trial using randomized complete block design with three replications at research farm of AUP and CCRI, Nowshera. Row length was kept at 5 m with plant to plant spacing of 0.25 m and row to row spacing of 0.75 m. In both seasons and locations standard cultural practices were carried out. Fertilizer was applied in the form of diammonium phosphate (DAP) and urea at the rate of 125 and 250 kg ha^{-1}, respectively. Entire DAP was applied at the time of sowing while half of urea was applied before sowing and rest was applied when plants were at knee height stage. The crop was irrigated weekly. Data were recorded on the following parameters.

Days to 50% tasseling

Data regarding days to 50% tasseling were recorded by regular visits to the field and days were counted from sowing to the day when 50% of the plants produced tassels in a plot.

Days to 50% silking

Silking data were recorded as the number of days from sowing until 50% of the plants in each plot showed silks.

Days to 50% anthesis

The number of days required from planting till 50% of plants was shedding pollen in a plot. The days were counted from date of sowing.

Anthesis silking interval (ASI)

ASI was calculated by the following formula:
ASI = Days to 50% silking - Days to 50% Anthesis

Ear height (cm)

Ear height was measured in cm from ground level to node bearing the upper most ear. Five randomly selected plants were averaged for each plot.

Plant height (cm)

Plant height was recorded as the distance in cm from base of the plant to the base of the flag leaf and was averaged for five randomly selected plants from each plot.

Statistical analysis

An analysis of variance according to randomized complete block design model was computed to derive mean squares for testcrosses and their interaction with location using computer package 'MstatC'. LSD was applied at both 1% and 5% level of significance. Heritability (h^2) was calculated from the mean squares obtained from ANOVA.

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Table-1. Analysis of variance format for the testcrosses.

Analysis of variation	Degree of freedom	Mean square	Error mean square
Location	(L-1)		
Error	L(r-1)		
Genotypes	(g-1)	M3	$\sigma^2_E + r\,\sigma^2 gl + rl\,\sigma^2 g$
G x L	(L-1)(g-1)	M2	$\sigma^2_E + r\,\sigma^2 gl$
Error	L(r-1)(g-1)	M1	σ^2_E

Variance components and heritability estimates were computed as under.
$\sigma^2_E = M1$
$\sigma^2 gl = M2\text{-}M1/r$
$\sigma^2 g = M3\text{-}M2/rl$
$h^2_{BS} = \sigma^2 g / \sigma^2 g + \sigma^2_E + \sigma^2 gl$ (Fehr, 1987)
σ^2_E = Environmental variance
σ^2_G = Genotypic variance
h^2_{BS} = Broad sense heritability

RESULT AND DISCUSSIONS

Days to 50% tasseling

Global production of all cereals is not sufficient to feed the total population (Ali and Yan, 2012). For this purpose increasing the productivity of maize must be considered for food security because maximum part of the food in the coming year will come from maize. Maturity is an important character in plants and days to tasseling along with days to 50% anthesis and days to 50% silking determines the maturity duration of plants. Earlier tasseling will lead to earlier pollen shedding and silking, which will eventually affect the overall maturity duration of maize plants.

Highly significant variations were observed among testcrosses for days to tasseling which shows the unfixed and genetically variable nature of S_1 lines. Analysis of variance of maize S_1 lines indicated the presence of highly significant ($P<0.01$) genetic variation in Sarhad white and Azam populations for days to tasseling, silking and pollen shedding (Shah, 2006). The co-efficient of variation for days to tasseling was very low 2.24% (Table-2). The test crosses that took minimum days to tasseling i.e., TC-10, TC-51 and check WD3 x 6 also took minimum days to 50% silking and days to 50% anthesis and at the time of harvesting had low percent grain moisture too.

The heritability value calculated for days to tasseling was low (0.56) which indicates high environmental influence on this trait. Observing the mean days to tasseling of all testcrosses it becomes clear that 9% of testcrosses took less number of days to tasseling when compared with the mean of testcrosses. While 60.6% took equal to and 30.3% took greater number of days to tasseling, respectively, when compared with the mean of testcrosses.

Days to 50% anthesis

Data regarding days to 50% Anthesis was recorded as a measure of maturity. Pollen grains as compared to silks remain viable for a shorter period of time and are prone to desiccation and viability loss if pollination does not occur within 1-2 days of Anthesis. Pollen shed at the right time and its perfect synchronization with silking will ensure high kernel fill and ultimately higher yield.

The ANOVA for days to 50% Anthesis showed non-significant variations among testcrosses. Contrary to our results significant ($P<0.05$) variations for days to 50% Anthesis were recorded by Abel and Pollak (1991) in testcross evaluation of exotic maize accessions.

Highly significant differences were observed by Carlone and Russell (1989) for days to 50% Anthesis while evaluating testcrosses of maize synthetic 'BSSS' lines with two unrelated testers. The co-efficient of variation for days to anthesis was very low at 2.91%.

Low heritability value (0.54) was recorded for days to 50% Anthesis. Environmental influence on such traits with low heritability is quite high.

The mean days to 50% Anthesis shows that the 27.2% of the testcrosses took less days to 50% Anthesis than the mean of all the testcrosses. About 21.2% and 51.5% of the testcrosses took equal and greater number of days to 50% Anthesis, respectively, when compared with mean of testcrosses'.

Days to 50% silking

In multiple cropping systems and for regions with short growing seasons, early maturing varieties (hybrids) are needed. Days required to 50% silking along with other maturity traits are commonly used by plant breeders as basis of determining maturity of maize. Neguly *et al*., (1983) observed that yield was indirectly affected by days to 50% silking via ear height.

Non-significant variations were observed among testcrosses for days to 50% silking. Completely opposite results were reported by Genter and Alexander (1965) who observed significant differences among testcrosses for days to 50% silking. Highly significant differences were observed among testcrosses of maize synthetic ‘BSSS’ lines for days to 50% silking by Carlone and Russell (1989). The co-efficient of variation was very low at 3.13% (Tables 4-2). Heritability value (0.49) for days to 50% silking was quite low. High heritability (0.85) for the same trait in testcross of BSK (HI) C_8 was recorded by Mulamba *et al*., (1983).

Our results show that 9% of the testcrosses took less days for 50% silking than the mean days to 50% silking of all the testcrosses. While 69.6% and 21.2% of the testcrosses took equal to and greater number of days to 50% silking, respectively, when compared with mean of testcrosses.

Anthesis-silking interval (ASI)

Non-significant variations were observed for Anthesis-silking interval among the testcrosses. Highly significant variations among testcrosses for Anthesis-silking interval were observed by Carlone and Russell (1989) in testcrosses evaluation of maize synthetic ‘BSSS’ lines. The co-efficient of variation for anthesi-silking interval was 51.91% (Table-2). Heritability (0.52) for ASI was very low; such traits which exhibit low heritability are influenced by environment to a greater extent. The mean ASI of testcrosses shows that 45.4% of the testcrosses had lower ASI than the mean of all testcrosses’. On the other hand, about 21.2% testcrosses had ASI equal to that of testcrosses’ mean while 33.3% of testcrosses had ASI which was greater than the mean ASI of all the testcrosses’. Pollen grains as compared to silks are more sensitive to environmental stresses and under high temperature and drought conditions may quickly lose their viability. If there is pollen-silk asynchrony the silk may not be receptive to pollen and may not be effectively pollinated within few days of Anthesis. This will lead to low kernel setting and ultimately loss in grain yield.

Plant height (cm)

Plant height is an important agronomic character for selecting desirable genotype for breeding program (Ali *et al*., 2012). In our experiment the highest yielding testcross, TC-10 had plant height which was second highest among the testcrosses and checks while the lowest yield was observed in check WD 3 x 6 which had minimum plant height. It seems logical to deduce that with short stature the chances of lodging will decrease but it seems that there is a threshold level for decreasing the height; beyond that level further decrease will start affecting the yield negatively. Supporting our argument are the results of Lackney and Russell (1971) who observed that plant height was significantly correlated with yield in testcrosses of M14 x C130 at low, intermediate and high plant densities.

Data regarding plant height revealed highly significant differences among testcrosses. Significant variation among testcrosses of exotic maize accessions for plant height was also observed by Abel and Pollak (1991). Carlone and Russell (1989) recorded highly significant ($P<0.05$) variations among testcrosses of ‘BSSS’ lines with two unrelated testers. Co-efficient of variation was low at 5.93%. Heritability of plant height was moderately high (73). Mihaljevic *et al*., (2005) obtained high heritability values (0.90) for plant height. The greater the heritability of a particular trait, the lesser will be the environmental effect on its expression.

The mean plant height for all the testcrosses revealed that 45.4% of testcrosses showed inferior performance than the testcrosses’ mean. While 15.1% were at par with and 39.3% of the testcrosses were superior to the testcrosses’ mean. Plant height plays a vital role in plant lodging and affects grain yield. Breeders also give consideration to plant height in order to improve lodging resistance in breeding maize populations. Low plant height is desired, because such plants are more resistant to lodging.

Ear height (cm)

Highly significant variations were observed among testcrosses for ear height. Our results are in agreement with those of Abel and Pollak (1991). They evaluated testcrosses of exotic maize accessions with several testers and found highly significant variations among testcrosses for ear height. While Genter and Alexander (1965) results after testcross evaluation are in disagreement with our results. In their study testcrosses of Va31xHy with CBS were not significantly different for ear height. Co-efficent of variation for ear height was 8.25% (Table-2).

Ear height is a highly heritable character as it is controlled by relatively few genes. Due to its high heritability it can easily be improved by selection (Ali *et al*., 2011b; Alam, 1999). Heritability value for ear height in our experiment was moderately high (71).

Looking at the mean ear height of testcrosses’ 51.5% of the testcrosses had lower ear height than the mean of all the testcrosses’. About 6% had equal to and 42.4% had higher ear height than the mean of testcrosses’. Similar to the effect of plant height on lodging, ear height also has an effect on plant lodging and ultimately grain yield. High ear placement is undesirable because ear at a greater height from ground level exerts pressure on plant during grain filling and maturity and may cause lodging, thereby affecting grain yield. Therefore, cultivars with optimum ear height are required. Ideally, the ear should be centrally located on plant. TC-10, a high yielding testcross had the maximum ear height and check WD 3 x 6 the lowest yielding had ear height which was second lowest among testcrosses and checks. A logical explanation for that would be that even though reducing the ear height will indirectly increase yield through reduction in lodging, but it seems like that there should be a threshold level for it too. Reducing the ear height beyond that will affect the yield negatively. Lackney and Russell (1971) observed that ear height was significantly correlated with yield in testcrosses of M14xC130 at low, intermediate and high plant densities. Burgess and West (1993) reported that after 10 cycles of selection for low ear height, grain yield had declined 29% in Tennesse Late Low-Ear synthetic.

Table-2. Mean squares and co-efficient of variation for days to 50% tasseling, days to 50% Anthesis, days to 50% silking, anthesis silking interval, plant height and ear height of 33 testcrosses and 3 checks.

Plant traits	**Genotype**	**Replication**	**CV** (%)
Days to 50% tasseling	2.5*	17.8**	2.24
Days to 50% anthesis	4.3^{NS}	17.5**	2.91
Days to 50% silking	4.5^{NS}	14.5*	3.13
Anthesis silking interval	1.0^{NS}	0.2**	51.91
Plant height	542.0**	16154.7**	5.93
Ear height	174.1**	637.2**	8.25

*significant at 0.05 level of significance
**significant at 0.01 level of significance
NS non-significant

Table-3. Variance components and heritability values for days to 50% tasseling, days to 50% anthesis, days to 50% silking, anthesis silking interval (ASI), plant height and ear height of 33 testcrosses along with 3 checks.

Plant traits	σ^2_E	σ^2_P	σ^2_G	h^2_{BS}
Days to 50% tasseling	1.53	3.51	1.98	0.56
Days to 50% anthesis	2.87	6.24	3.37	0.54
Days to 50% silking	3.51	6.84	3.33	0.49
Anthesis silking interval	0.77	1.62	0.85	0.52
Plant height	86.0	520.2	102.3	0.73
Ear height	34.8	166.5	34.0	0.71

σ^2_P = Phenotypic variance
σ^2_E = Environmental variance
σ^2_G = Genotypic variance
h^2_{BS}= Broad sense heritability

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Table-4. Mean values for days to 50% tasseling, days to 50% anthesis, days to 50% silking, and anthesis silking interval of 33 testcrosses along with 3 checks.

S. No.	Testcr	Days to 50% tasseling	Days to 50% tasseling	Days to 50% tasseling	ASI	Plant height (cm)	Ear height (cm)
1	TC-1	55	57	59	2	143	62
2	TC-3	58	60	61	1	142	67
3	TC-4	55	57	60	2.7	151	72
4	TC-7	57	59	60	1	157	72
5	TC-8	55	59	60	0.7	151	71
6	TC-10	54	57	58	1.7	173	82
7	TC-13	55	58	60	2.3	170	79
8	TC-14	55	57	60	3	166	80
9	TC-17	56	59	60	1.7	167	75
10	TC-21	56	59	60	1	162	76
11	TC-22	57	59	61	2	159	75
12	TC-23	56	60	61	1	150	66
13	TC-24	55	58	59	1.3	147	68
14	TC-34	55	58	59	1.3	158	80
15	TC-37	55	59	60	1	164	70
16	TC-38	55	57	59	1.3	157	67
17	TC-42	54	57	59	1.7	159	71
18	TC-46	55	58	60	2	160	69
19	TC-48	55	58	59	1.3	169	79
20	TC-50	55	57	58	1	156	69
21	TC-51	54	56	58	1.3	149	69
22	TC-55	56	59	61	2	149	71
23	TC-57	56	59	62	3	155	64
24	TC-60	55	59	60	1.7	153	67
25	TC-64	55	58	60	2	163	74
26	TC-65	55	58	60	2	155	66
27	TC-67	55	59	60	1.3	159	76
28	TC-68	55	59	60	1	157	74
29	TC-70	55	57	59	2	179	81
30	TC-71	55	59	60	1.3	155	73
31	TC-72	55	59	60	1.7	158	70
32	TC-73	57	60	62	2.7	160	69
33	TC-74	56	59	61	2.7	152	76
34	(WD2x8)F_2	58	62	64	1.7	142	64
35	WD2x8	55	58	60	1.7	158	74
36	WD3x6	54	56	58	2	130	64
Means of Testcrosses’		55.3	58.2	59.9	1.69	157.7	72.1
$LSD_{(0.05)}$		2.01	NS	NS	NS	NS	6.74
$LSD_{(0.01)}$		2.68	NS	NS	NS	NS	8.90

CONCLUSIONS AND RECOMMENDATIONS

On the basis of our results we conclude that early generation testing for production of inbred line is very crucial, to avoid wastage of resources and time. At early stages we can select our desirable material for the production of superior inbred lines. It is recommended that plant height and ear height should take in consideration during production of inbred lines for superior hybrids.

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