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Comparative performance of top cross and population cross hybrids in white Maize using a common tester

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Abstract

Improved maize populations and cross hybrids can be beneficial alternatives for commercial single-cross hybrids and good elite sources for diverse inbred lines. A set of 22 genotypes comprised 10 population crosses, 10 top crosses, and two check cultivars were evaluated at Cereal Crop Research Institute, Pirsabak-Nowshera, in a randomized complete block design with three replicates in 2014. This research's major aims were to determine the magnitude of heterosis and the degree of character association between yield and its attributes to select superior genotypes from the breeding material. Data were recorded on maturity, and yield associated traits, where significant genetic variability was observed among the genotypes for all the studied traits except days to silking. Mean values for the studied traits ranged from 44 to 52 days for tasseling, 48 to 54 days for anthesis, 49 to 54 days for silking, -1.33 to 2.33 for the anthesis-silking interval, 2.53 to 8.47 kg for fresh ear weight, 12 to 16 rows for kernel rows cob^{-1}, 27.15 to 37.49 g for 100-kernel weight and 2830 to 7649 kg ha^{-1} for grain yield. Days to silking, anthesis silking interval, and kernel rows cob^{-1} showed low broad sense heritability (12.08%, 24.84%, 27.59%), days to tasseling, days to anthesis revealed moderate heritability (40.53%, 36.62%), while fresh ear, 100-kernel weight, and grain yield exhibited high broad-sense heritability (94.89%, 82.33%, 90%). Negative and significant heterotic values were observed for maturity traits, while heterotic values were positive and significant for yield-associated traits. Correlation analysis revealed that characters like fresh ear weight (r = 0.93) and 100-kernel weight (r = 0.50) manifested a strong positive and significant association with grain yield. Based on mean performance and grain yield, promising hybrids were 3008F$_3$ x 2007-WC and 3008F$_3$ x 2010. The current study revealed significant genetic variability among the tested hybrids; hence, it can be used in future breeding programs to produce early maturing and high-yielding maize hybrids.

Keywords: Days to tasseling, genetic variability, heterosis, population cross, top cross

Key words: HBV, HCV, ICT, PCR, Risk factors, Mansehra.

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1. INTRODUCTION

Maize (*Zea mays* L.) belongs to a small, highly specialized tribe. Maize is an important world cereal crop cultivated in irrigated and rain-fed areas and ranks third after wheat and rice [1]. Maize's major industrial uses are food, feed, pharmaceuticals, millers, distilling, and fermentation industries. About two-thirds of

Maize's total world production is used for livestock feed or commercial starch and oil production. It has excellent nutritional value as it contains about 66.7% starch, 10% protein, 4.8% oil, 8.5% fiber, 3% sugar, and 7% ash [2].

In Pakistan, Maize was grown on 1.330 million hectares, and total production was 6.1 million tonnes with an average grain yield of 5.0 million tons ha^{-1} [3]. The average maize yield in Pakistan is very low due to various constraints. Among these, the lack of high-yielding hybrids is a major problem [4]. The reliance on imported hybrid maize seed has increased annually because competitive hybrid crops are not available across the country and underdeveloped seed industries [4]. It seems more practical to develop varieties adapted to more than one environment and can be successfully grown over a range of environments. Hybrid maize seed marketing flourishes every year, but minimal commercial hybrids are suitable for cultivation because of their current diverse agro-environment. Top advances in modern agriculture have begun over 250 years to discover heterosis in plant crosses [5]. Heterosis (hybrid vigor) increases progeny size, increases growth, fertility, and yield compared to parents.

Low grain and fodder yield with sustained maturity is a major challenge for northern Pakistan breeders. Because of farmers' low land-keeping capacities, who can meet only their food requirements, they struggle to fulfill their livestock feed. Farmers have either to sell their livestock at a low market rate or buy costly feed for their animals, to meet the fodder requirements in cold winter. By designing a hybrid maize breeding program, high grain and fodder yields with early maturing characters can be obtained from such lowlands.

Approximately 65% of Maize is grown on irrigated land in Pakistan, while the rest is grown under rain-fed conditions. Maize is highly drought-sensitive, and therefore frequent irrigation is required for good vegetative and reproductive growth [6]. Drought affects many physiological processes and thus greatly decreases yield. Maize's production is also greatly affected by various diseases and insects, which often occur during later crop periods. The change in climate patterns is a recent constraint on increased crop production. To tackle this issue, farmers need to change the current farming and farming practices [7]. This climate change is also becoming a major threat to maize production. Early maturing varieties and hybrids are necessary to meet these newly evolving constraints. The development of early maturing varieties and hybrids will substantially prevent yield losses by the escape of terminal droughts and by diseases and insect attacks. Early maturing hybrids and varieties also promote two or more crops per year and adjust easily according to the existing crop pattern. Keeping in mind the importance of early maturing varieties and hybrids, the current experiment was conducted with the objective to (a) study the comparative performance of the top and population cross hybrids for yield, and yield-related traits (b) evaluate different maize hybrids for maturity and yield traits (c) select an early maturing and high yielding hybrid (s) from a group of hybrids (d) ascertain correlation coefficient among various morphological and grain yield traits.

2. MATERIALS AND METHODS

A set of 22 white Maize genotypes (Table 1) comprised ten top crosses, ten population crosses along with two check cultivars (local and commercial) were evaluated in summer-2014 at Cereal Crop Research Institute (CCRI), Pirsabak, Nowshera-Pakistan in a randomized complete block (RCB) design with three replications. Data were recorded on maturity and yield-associated traits.

Table 1. List of the experimental material.

S.No.	Population crosses	S.No.	Top crosses
1	$3008F_3$ x 2006	11	$3008F_3$ x EV_3-157-517395
2	$3008F_3$ x 2007-RC	12	$3008F_3$ x EV_3-120-222-517395-RC
3	$3008F_3$ x 2007-WC	13	$3008F_3$ x EV_3-120-222-517395-WC
4	$3008F_3$ x 2008	14	$3008F_3$ x EV_3-120-22214
5	$3008F_3$ x 2009-RC	15	$3008F_3$ x EV_3 -120-2321
6	$3008F_3$ x 2009-WC	16	$3008F_3$ x EV_3-120-232413
7	$3008F_3$ x 2010	17	$3008F_3$ x SW-4-9-1
8	$3008F_3$ x 2011-RC	18	$3008F_3$ x SW-66211-D
9	$3008F_3$ x 2011-WC	19	$3008F_3$ x SW-66211-T
10	$3008F_3$ x $PSEV_3$-2ES	20	$3008F_3$ x SW-6-6-3-6
Checks	30K08 (Pioneer Hybrid)-commercial		
	Jalal (Open pollinated variety)-local		

2.1 Statistical Analysis

2.1.1 Analysis of variance: The data were subjected to analysis of variance technique proposed for RCB design using Statistix 8.1 computer software [8].

2.1.2 Heritability (broad sense): Broad-sense heritability was estimated by the formula followed by [9].

The heritability was categorized as low, $h2(b.s) = Vg/Vp$ moderate, and high, as indicated [10].

0-30% = Low, 31-60% = Moderate, 61% and above = High

2.1.3 Estimation of heterosis: Standard heterosis was estimated in relation to commercial check (30K08) as a percentage increase or decrease of F_1s over check [11].

$$\text{Standard Heterosis (SH)} = \frac{F_1 - SC}{SC} \times 100$$

F_1 = mean values of F_1 hybrids, SC = mean values of the check (commercial check).

The difference in the magnitude of heterosis was tested following the procedure given by [12].

2.1.4 Critical difference (CD)

Standard heterosis = (2 Me/2r) ½ × t

Where r = no. of replications, Me = Error mean sum of the square from analysis of variance table

t = Table value of 't-test' at error degrees of freedom corresponding to 5% or 1% significance level.

2.1.5 Correlation (r): The following relationship determined a simple correlation of grain yield with other yielding traits, according to [13].

$$r = \frac{\sum xy}{\sqrt{(\sum x2)(\sum y2)}}$$

3. RESULTS AND DISCUSSIONS

3.1 Maturity Traits: Earliness is a desirable character as it is useful in multiple cropping and increases water land-use efficiency. Maturity is an important characteristic of a particular genotype, which directly or indirectly influences economic yield. Many components represent maturity: days to 50% tasseling, days to 50% silking, days to maturity, etc. In Maize, it was normally recorded that female inflorescence, i.e., ear formation is extremely sensitive to variations in the environment and plant density. The male inflorescence is less affected by these situations, namely, tassel formation [14]. Therefore, synchronization between male and female flowering is a very important phenomenon that directly affects grain yield.

3.1.1. Days to 50% tasseling: Days to tasseling determine the earliness or lateness of a hybrid. Days to 50% tasseling revealed significant genetic variability among the studied genotypes, and coefficient of variation (CV) was 2.78%, while moderate broad sense heritability (40.53%) was recorded for days to tasseling (Table 2). Among the studied genotypes, days to tasseling ranged from 44 to 52 days. Minimum number of days to 50% tasseling (44 days) were taken by hybrids (3008F_3 x EV_3-120-222-517395-WC, 3008F_3 x EV_3-120-22214) while check cultivar (30K08) matured very late and took 52 days to 50% tasseling (Fig.1). The maize crop's maturity period is determined by days to 50% tasseling and is significant in maize breeding. In hybrid maize production, negative heterosis is preferred for days to 50% tasseling. Significant and negative heterosis was recorded for all the hybrids except 3008F_3 x 2009-RC (Table 3). Standard heterosis regarding days to 50% tasseling over the check (30K08) ranged from -3.85 to -15.38%. Hybrids (3008F3 x EV3-120-222-517395-WC, 3008F3 x EV3-120-22214) took minimum days to tasseling and showed -15.38% heterosis, while hybrid (3008F_3 x 2009-RC) revealed -3.85% standard heterosis. Earlier researchers [2,15] also reported significant genetic variability for days to tasseling in half-sib families. Similarly, significant genetic variability was reported for the said trait [16,17]. Our results are in line with [18] while studying different maize cultivars under the Peshawar valley's agro-climatic conditions. Our results matched the outcomes of [19] while studying heterotic effects for yield and protein content in white quality protein maize. Negative heterotic patterns for the studied trait were also observed by [20,21], who worked with various maize breeding materials. Similar results suggesting negative heterotic patterns for days to 50% tasseling are also reported by [22–28]. In the heterosis assessment, [29] found that heterosis over the best check or the local variety was the best criterion for the hybrid evaluation. Majority of the hybrids were found to be earlier than the checks for days to 50% tasseling and thus could be used as germplasm source in developing varieties with early maturity. This variability can be attributed to their differential genetic makeup.

Table 2. Mean squares and broad-sense heritability for maturity and yield traits.

Traits	Reps (df= 02)	genotypes (df = 21)	Error (df= 42)	CV (%)	h2(b.s) (%)
Days to tasseling	2.28	5.45**	1.79	2.78	40.53
Days to anthesis	0.24	6.04**	2.21	2.98	36.62
Days to silking	2.01	4.18^{NS}	2.96	3.37	12.08
Anthesis silking interval	0.86	2.37*	1.19	2.57	24.84
Fresh ear weight	0.01	6.24**	0.11	6.28	94.89
Hundred kernel weight	14.53	15.28**	1.02	3.17	82.33
Kernel rows cob^{-1}	1.36	2.25*	1.05	7.2	27.59
Grain yield	999070	5182441**	185116	8.65	90.00

*, ** = Significant at the 1% and 5% level of probability, respectively.

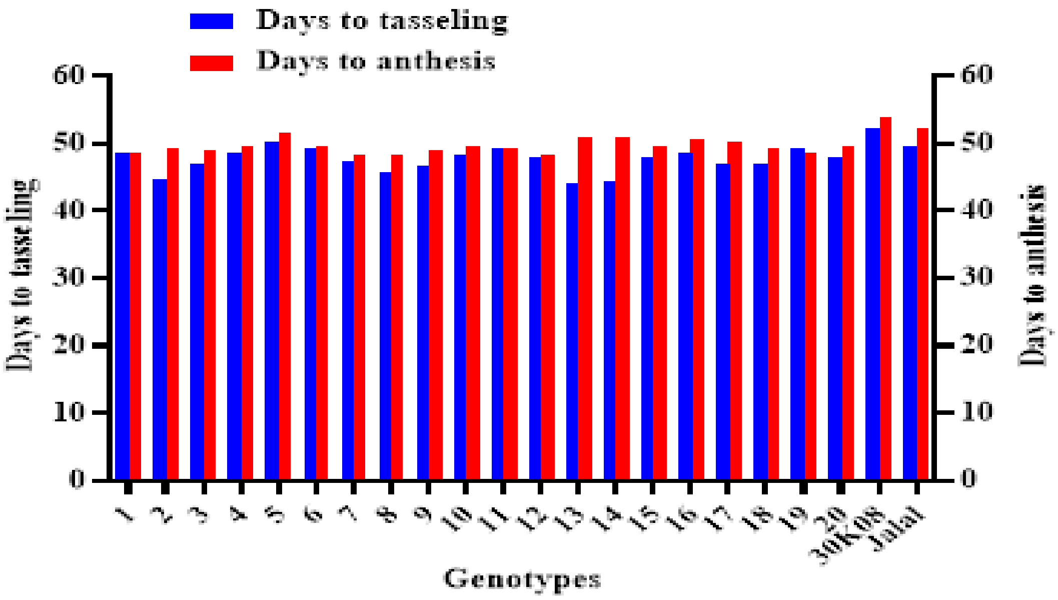

Fig 1. Mean performance of the evaluated genotypes.

3.1.2. Days to 50% anthesis: Days to 50% anthesis are important in maize crops, determining the maturity period. Pollen grains remain viable compared to silks for a shorter period and will desiccate and lose their viability if pollination does not occur within 1-2 days of anthesis. Pollen shedding at the right time and its perfect synchronization with silking ensures a high filling of the kernel and ultimately a higher yield. Statistical analysis exhibited genetic variability for days to 50% anthesis among the studied hybrids (Table 2). Moderate heritability (36.62%) was recorded with a coefficient of variation of 2.98%. Days to 50% anthesis ranged from 48 to 54 days. Minimum days to anthesis (48 days) were observed for hybrids, 3008F_3 x 2010, 3008F_3 x 2011-RC, and 3008F_3 x EV_3-120-222-517395-RC, while maximum (54 days) was observed for check cultivar 30K08 (Fig.1). Negative heterosis is favored in maize hybrids for anthesis. Standard heterosis values for days to anthesis ranged from -11.11% (3008F3 x 2010, 3008F3 x 2011-RC, 3008F3 x EV3-120-222-517395-RC) to -3.70% (3008F3 x 2009-RC). Negatively significant heterosis was reported for all the hybrids except 3008F_3 x 2009-RC (Table 3). Other researchers also reported significant genetic variability for days to anthesis [30–32]. Similar negative heterosis for days to anthesis has been reported earlier in Maize [5,33]. Variability is more important for the tolerance and adaptation of genotypes to biotic and abiotic factors [34]. Variability plays a major role in crop breeding. An insight into the extent of variability in crop species is extremely important, as it is the basis for the selection.

Table 3. Heterosis estimates for maturity traits of 20 maize hybrids.

Hybrids	Days to tasseling	Days to anthesis	Days to silking
3008F3 x 2006	-5.77^{*}	-9.26^{**}	-5.56^{NS}
3008F3 x 2007-RC	-13.46^{**}	-9.26^{**}	-5.56^{NS}
3008F3 x 2007-WC	-9.62^{**}	-9.26^{**}	-7.41^{*}
3008F3 x 2008	-5.77^{*}	-7.41^{**}	-5.56^{NS}
3008F3 x 2009-RC	-3.85^{NS}	-3.70^{NS}	-1.85^{NS}
3008F3 x 2009-WC	-5.77^{*}	-7.41^{**}	-3.70^{NS}
3008F3 x 2010	-9.62^{**}	-11.11^{**}	-7.41^{**}
3008F3 x 2011-RC	-11.54^{**}	-11.11^{**}	-9.26^{**}
3008F3 x 2011-WC	-9.62^{**}	-9.26^{**}	-7.41^{*}

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3008F3 x PSEV3-2ES	-7.69**	-7.41**	-5.56 NS
3008F3 x EV3-157-517395	-5.77*	-9.26**	-5.56 NS
3008F3 x EV3-120-222-517395-RC	-7.69**	-11.11**	-7.41*
3008F3 x EV3-120-222-517395-WC	-15.38**	-5.56*	-7.41*
3008F3 x EV3-120-22214	-15.38**	-5.56*	-3.70 NS
3008F3 x EV3 -120-2321	-7.69**	-7.41**	-3.70 NS
3008F3 x EV3-120-232413	-5.77*	-5.56*	-3.70 NS
3008F3 x SW-4-9-1	-9.62**	-7.41*	-3.70 NS
3008F3 x SW-66211-D	-9.62**	-9.26**	-5.56 NS
3008F3 x SW-66211-T	-5.77*	-9.26**	-7.41*
3008F3 x SW-6-6-3-6	-7.69**	-7.41**	-5.56 NS
***CD 0.01**, 0.05*	***6.25**, 4.68*	***6.95**, 5.20*	***8.04**, 6.01*

*, ** = Significant at the 1% and 5% critical difference (CD), respectively.

3.1.3 Days to 50% silking: Days to 50% silking measure maturity in maize crops. Plant breeders consider days to 50% silking and other maturity traits to determine maturity duration in maize crops. Analysis of variance for days to silking revealed non-significant differences among the studied breeding material, and the coefficient of variation (CV) was a little bit higher (3.37%) than the other maturity traits, and low broad-sense heritability (12.08%) was observed (Table 2). Days to 50% silking ranged from 49 to 54 days. Hybrid ($3008F_3$ x 2011-RC) mature earlier (49 days) as compared to other hybrids, while check cultivar (30K08) took maximum days to 50% silking (Fig-2). Contrary to our results, other researchers reported significant genetic variability for days to 50% silking [17,35]. Negative heterosis for silking is necessary because it indicates early maturity. Standard heterosis values regarding days to 50% silking are given in Table 3. Heterosis values for days to silking ranged between -7.41 (3008F3 x 2007-WC, 3008F3 x 2010, 3008F3 x 2011-WC, 3008F3 x EV3-120-222-517395-RC, 3008F3 x EV3-120-222-517395-WC and 3008F3 x SW-66211-T) to -1.85% (3008F3 x 2009-RC). About 65% of hybrids showed negative and non-significant standard heterosis for days to 50% silking, while 35% of hybrids revealed significantly negative standard heterosis over the check. The results obtained in the present study are in accordance with the outcomes of [36], who studied heterosis for morphological traits in subtropical Maize. Varying degrees of negative heterotic effects for days to silking were also reported earlier [37].

3.1.4 Anthesis Silking Interval (ASI): Short anthesis silking interval (ASI) is an important component of drought tolerance in Maize [38]. Statistical analysis revealed significant genetic variability for anthesis silking interval among the genotypes (Table 2). Moderate heritability (24.84%) was manifested for ASI with a coefficient of variation of 2.57%. Mean values regarding anthesis-silking interval ranged between -1.33 to 2.33. Hybrid, $3008F_3$ x EV_3-120-222-517395-WC showed a minimum anthesis-silking interval of -1.33, followed by check cultivar Jalal (-0.67). Maximum anthesis-silking interval of 2.33 was manifested by $3008F_3$ x 2006 (Fig.2). Non-significant genetic differences were reported by [39] for anthesis silking interval in Maize. This contrast may be due to the experimental material and environment difference. Pollen grains are more susceptible to environmental stress, and under high temperatures and drought conditions, they will quickly lose their viability. Synchronization between pollen shedding and silking needs to be done for successful pollination as this results in a greater seed setting and, finally, a greater yield. If asynchrony prevails in days to pollen shedding and silking, it will lead to low seed setting and ultimately low grain yield. Our findings agree with the results of [16,40].

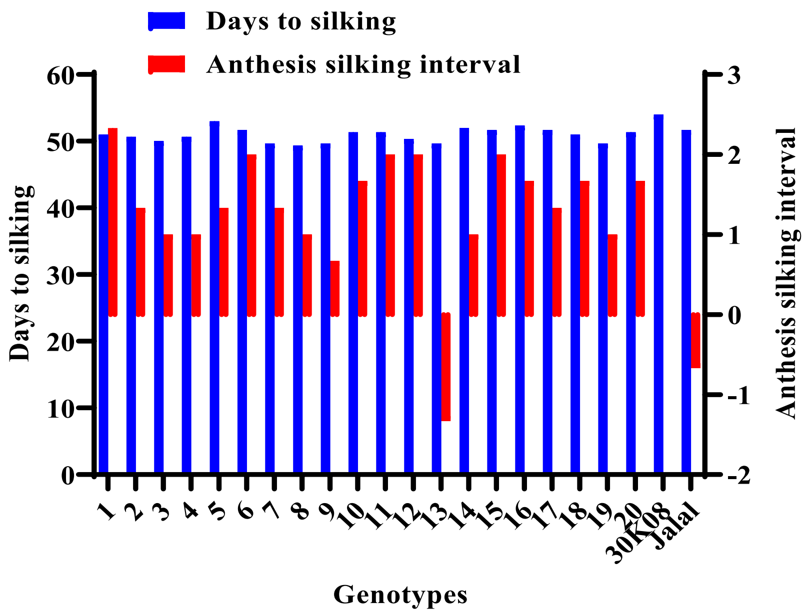

Fig. 2. Mean performance of the evaluated genotypes.

3.2 Yield associated traits:

3.2.1 Fresh ear weight (Kg plot^{-1}): Analysis of variance revealed a significant amount of genetic variability for the fresh weight (Table 2). The coefficient of variation was 6.28%, and broad-sense heritability was high (94.89%). Mean values regarding fresh ear weight ranged from 2.53 to 8.47 kg. Maximum fresh ear weight of 8.47 kg was observed for hybrid, 3008F_3 x 2010, followed by 3008F_3 x 2007-WC (7.70 kg), while minimum fresh ear weight (2.53 kg) was manifested by hybrid, 3008F_3 x EV_3-120-22214 (Fig.3). Our results agree with the previous findings [16,17]. Substantial differences among genotypes for the studied trait while studying genetic variation and correlation in Maize's different test crosses [17]. Heterosis values regarding fresh ear weight are given in Table 4. Heterosis values regarding fresh ear weight ranged between -25.59 (3008F_3 x EV_3-120-22214) to 149.12% (3008F_3 x 2010). Highly significant heterosis was observed for all the hybrids except 3008F_3 x EV_3-120-22214. The perusal of correlation for fresh ear weight revealed that the studied character showed significant positive association (r = 0.49, r = 0.93) with 100-kernel weight and grain yield, respectively (Fig-5). These results indicated that fresh ear weight significantly affects 100-kernel weight and ultimately increases grain yield. The studied character had non-significant relation with the remaining traits. Earlier researchers [16] investigated 48 elite maize hybrids and stated that fresh ear weight is significantly associated with 100-seed weight and grain yield.

Table 4. Heterosis estimates for yield and yield associated traits of 20 maize hybrids.

Hybrids	FEW	HKW	KRPC	GY
3008F3 x 2006	112.65**	28.92**	0.00^{NS}	113.64**
3008F3 x 2007-RC	61.76**	17.19**	7.14**	113.29**
3008F3 x 2007-WC	126.47**	17.33**	0.00^{NS}	170.28**
3008F3 x 2008	37.35**	3.58*	-7.14^{NS}	46.75*
3008F3 x 2009-RC	49.12**	7.15**	14.29**	56.96**
3008F3 x 2009-WC	83.24**	1.00^{NS}	0.00^{NS}	91.52**
3008F3 x 2010	149.12****	14.27**	7.14**	153.71**
3008F3 x 2011-RC	52.06**	11.97**	-14.29^{NS}	76.61**
3008F3 x 2011-WC	40.59**	2.79^{NS}	-7.14^{NS}	61.06**

3008F3 x PSEV3-2ES	106.76**	17.47**	0.00NS	117.99**
3008F3 x EV3-157-517395	31.76**	16.20**	0.00NS	47.35*
3008F3 x EV3-120-222-517395-RC	62.94**	7.39**	7.14**	65.02**
3008F3 x EV3-120-222-517395-WC	91.47**	10.83**	0.00NS	140.60**
3008F3 x EV3-120-22214	-25.59NS	8.43**	0.00NS	18.16NS
3008F3 x EV3 -120-2321	37.35**	17.85**	7.14**	50.49**
3008F3 x EV3-120-232413	14.71**	5.47**	0.00NS	38.59*
3008F3 x SW-4-9-1	64.71**	9.56**	7.14**	95.41**
3008F3 x SW-66211-D	88.24**	7.02**	7.14**	109.86
3008F3 x SW-66211-T	24.71**	13.00**	7.14**	14.42NS
3008F3 x SW-6-6-3-6	37.35**	5.85**	7.14**	51.48**
***CD 0.01**, 0.05*	***1.55**, 1.16*	***4.72**, 3.53*	***4.79**, 3.58*	***50.44**, 37.73*

*, ** = Significant at the 1% and 5% critical difference (CD), respectively. FEW = Fresh ear weight, KRPC = Kernel rows cob^{-1}, HKW = 100-kernel weight, GY = Grain yield

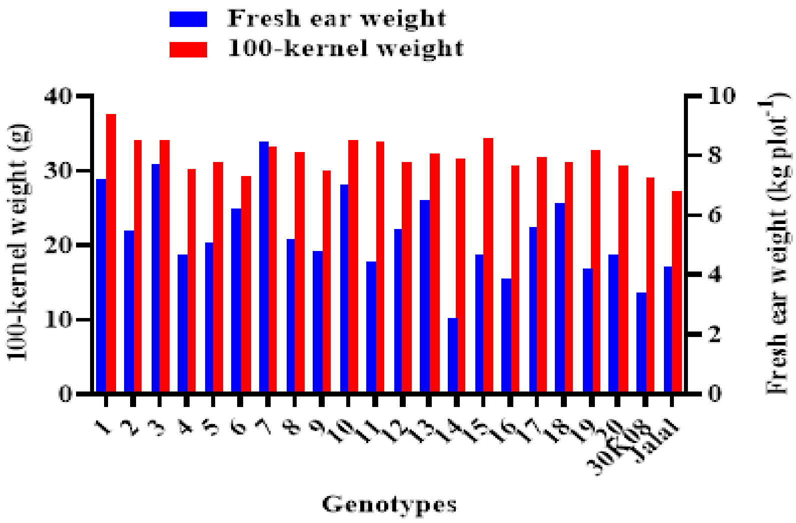

Fig.3. Mean performance of the evaluated genotypes.

3.2.2 100-kernel weight (g): The investigation of 100-kernel weight deserves much consideration because grain yield results from several yield components and is expressed through changes in its components. Statistical analysis manifested significant differences among genotypes for the 100-kernel weight (Table 2). Mean values for 100-seed weight ranged from 27.15 to 37.49 g. Maximum 100-seed weight of 37.49 g was manifested by 3008F_3 x 2006, closely followed by hybrid 3008F_3 x EV_3-120-2321 (34.27 g). Minimum 100-kernel weight of 27.15 g was calculated for check cultivar Jalal (Fig.3). The coefficient of variation was 3.17% (Table 2), and broad-sense heritability was in the high range (82.33%). Similar findings were reported by [17,35]. Considerable differences among genotypes for 100-seed weight were observed while studying genetic differences and correlation in Maize's different test crosses [17]. Correlation analysis regarding 100-kernel weight manifested that the association between 100-kernel weight and yield was positive and significant (r = 0.50) (Fig.5). These results indicated that 100-kernel weight could be used to improve yield in maize genotypes. Earlier researcher [17] conducted an experiment on genetic variation and correlation estimates in maize test crosses. They corroborated the outcome of a positive and significant relationship between 100-kernel weight and grain yield. However, [16]reported a non-significant association between 100-kernel weight and grain yield while studying correlation and path coefficient in elite maize hybrids.

Heterosis values regarding 100-kernel weight ranged from 1.00 to 28.92% (Table 4). All the hybrids exhibited significantly positive heterosis in a desirable direction except 3008F_3 x 2009-WC (1.00%), which exhibited non-significant heterosis. Among all hybrids, 3008F_3 x 2006 (28.92%), 3008F_3 x EV_3 -120-2321 (17.85%) and 3008F_3 x $PSEV_3$-2ES (17.47%) were top three desirable crosses. The results obtained in the present study oppose the outcomes of [41,42]. They reported positive patterns of heterosis for 100-seed weight while studying heterosis breeding for Maize's yield characters.

3.2.3 Kernel rows cob^{-1}: The number of kernel rows cob^{-1} is also a genetically controlled character and plays an essential role in determining final yield. The more number of rows per cob results in higher grain yield. Analysis of variance manifested significant differences among genotypes for the number of kernels rows cob^{-1} (Table 2). The coefficient of variation was 7.20%, while low broad-sense heritability (27.59%) was observed for the trait under study. Mean values for kernel rows cob^{-1} ranged from 12 to 16. The highest number of kernel rows cob-1 (16) among genotypes were produced by hybrid 3008F_3 x 2009-RC. The lowest (12) kernel rows cob^{-1} were produced by hybrid, 3008F_3 x 2011-RC (Fig.4). Our findings agree with [17,35]. Heterosis values regarding number of kernel rows cob^{-1} ranged between -14.29 (3008F_3 x 2011-RC) to 14.29% (3008F_3 x 2009-RC) (Table 4). It is obvious from Table-4 that 45% of hybrids showed positively significant heterosis, while 55% of the hybrids manifested non-significant heterosis for the studied character. Nearly the same heterotic effects were also reported earlier by [43] while studying heterosis for grain yield and its component traits in 60 maize hybrids. Similarly, varying heterotic effects for this were also reported by [44] while studying heterosis for grain yield and its attributing components in Maize. Correlation analysis of the studied trait revealed a non-significant association with grain yield (Fig.5), which is in line with the results obtained earlier by [16] while studying correlation path coefficient in elite maize hybrids.

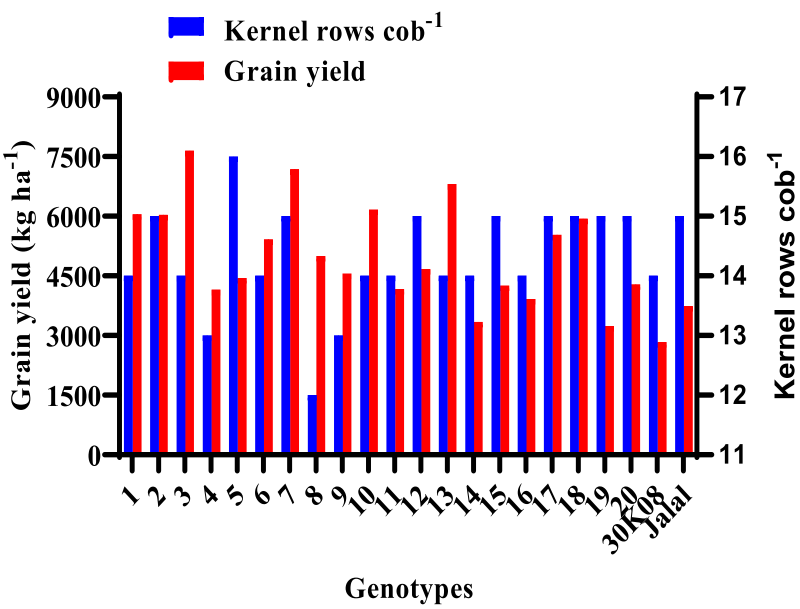

Fig.4. Mean performance of the evaluated genotypes

3.2.4 Grain yield (Kg ha^{-1}): Development of maize cultivars with high yield potential is one of the prime objectives of maize breeders. Mean square due to genotypes were highly significant for grain yield (Table 2). The variability observed for grain yield was high, ranging from 2830 kg ha^{-1} to 7649 kg ha^{-1}. Hybrid, 3008F$_3$ x 2007-WC showed superiority for grain yield (7649 kg ha^{-1}), closely followed by 3008F$_3$ x 2010 (7180 kg ha^{-1}). Minimum grain yield (2830 kg ha^{-1}) was manifested by check cultivar 30K08 (Fig.4). The coefficient of variation was 8.65%, and high broad-sense heritability (90%) was observed (Table 2). Our findings are in a similarity to the results of [17,35,45]. Exploiting hybrid vigor or heterosis is essential in highly out-crossed crops like Maize for better crop improvement. Heterosis values regarding grain yield ranged from 14.42 to 170.28% (Table 4). The critical difference test showed positive and significant heterosis for all the hybrids except 3008F$_3$ x SW-66211-T and 3008F$_3$ x EV$_3$-120-22214. However, best crosses in respect of higher heterotic values for grain yield were 3008F$_3$ x 2007-WC (170.28%), 3008F$_3$ x 2010 (153.71%) and 3008F$_3$ x EV$_3$-120-222-517395-WC (140.60%) while minimum heterosis (14.42%) was assessed for hybrid, 3008F$_3$ x SW-66211-T. Grain yield revealed a significant and positive correlation with fresh ear weight (r = 0.93) and 100-kernel weight (r = 0.50) (Fig.5). The results obtained in the present study follow earlier researcher [42], who studied heterosis for maturity, yield, and quality traits in Maize. Similarly, the results of [41,46] also conform to the findings of the present work.

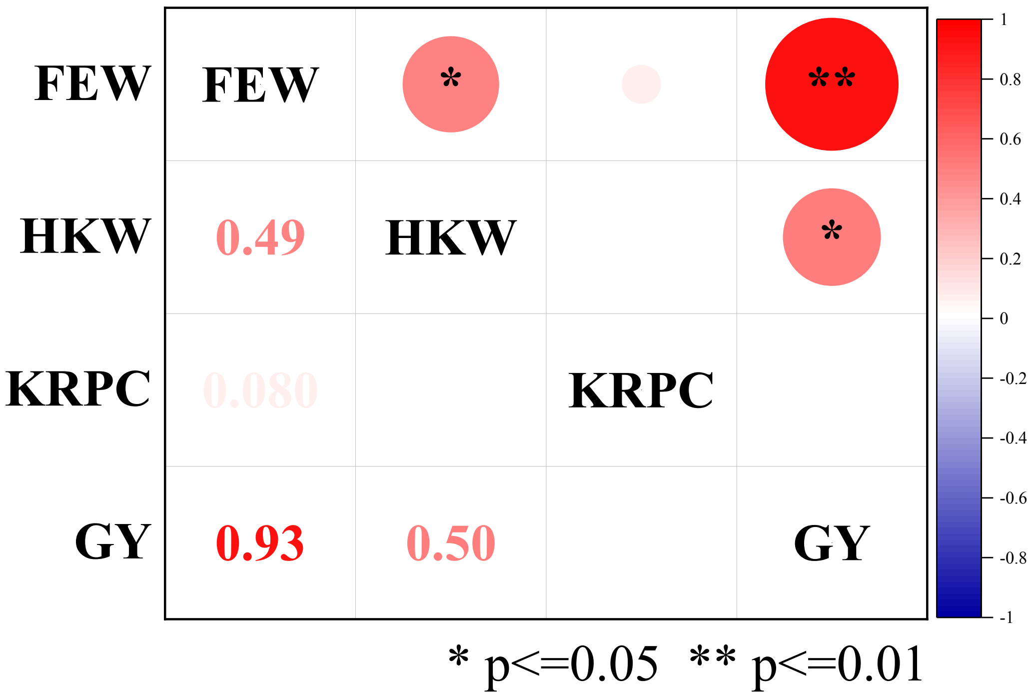

Fig.5. Correlation coefficients of various traits with grain yield.

FWT = Fresh ear weight, HKW = 100-kernel weight, KRPC = kernel rows cob^{-1}, GY = grain yield

4. CONCLUSIONS

A significant amount of genetic variations were observed among the hybrids for all the studied traits except days to tasseling, which indicates the presence of sufficient genetic variability and could be exploited through selection. All the hybrids revealed significant and negative heterosis for maturity traits and could be used in future maize breeding programs to develop early maturing varieties. Some of the hybrids took maximum days to tasseling, anthesis, and silking, which can be grouped as late maturing types and could be used in the breeding programs to develop high-yielding hybrids in areas that receive sufficient rainfall. Correlation analysis revealed that fresh ear weight and 100-kernel weight exhibited significant contribution towards grain yield, which envisages these traits in the improvement of final yield. Best crosses in respect of higher heterotic values for grain yield were 3008F_3 x 2007-WC, 3008F_3 x 2010, and 3008F_3 x EV_3-120-222-517395-WC, while based on mean performance, hybrids, 3008F3 x 2007-WC and 3008F_3 x 2010 were found most promising for grain yield and hence could be exploited for the development of improved maize hybrids in the upcoming maize breeding programs.

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CONFLICT OF INTEREST

All authors declare no conflict of interest regarding this article.

REFERENCES

1. Gerpacio RV, Pingali PL. Tropical and subtropical maize in Asia. CIMMYT. 2007.1-93.
2. Ahmad N, Rahman H, Mahmood F, Ahmad S, Ali R, Khan A. Evaluation of half-sib families derived from maize variety *Sarhad White* for grain yield and agronomic traits. Middle East. J. Med. Pl. Res. 2012;1(4): 80-85. https://doi.org/10.5829/idosi.mejmpr.2011.1.4.1118.
3. United State Department of Agriculture (USDA).https://www.indexmundi.com/agriculture/.
4. Sharma HP, Dhakal KH, Kharel R, Shrestha J. Estimation of heterosis in yield and yield attributing traits in single cross hybrids of maize. J Maize Res Dev. 2016;2(1):123-132. doi:10.3126/jmrd.v2i1.16223
5. Malik HN, Malik SI, Chughtai SR, Javed HI. Estimates of Heterosis among Temperate, Subtropical, and Tropical Maize Germplasm. Asian J Plant Sci. 2004;3(1):6-10. doi:10.3923/ajps.2004.6.10
6. Rashid K, Rasul G. Rainfall Variability and Maize Production over the Potohar Plateau of Pakistan J Meteorology. 2011;8(15).
7. Bhandari G. Assessment of Climate Change Impacts and Adaptation Measures in the Kapilbastu District of Nepal. Appl Ecol Environ Sci. 2013;1(5):75-83. doi:10.12691/aees-1-5-2
8. Stell RGD, Torrie JH, Dickey D. Principles and procedures of statistics: a biometrical approach. New York MacGraw-Hill. Published online 1980.
9. Singh RK, Chaudhary BD. Biometrical Methods in Quantitative Genetic Analysis. Kalyani.; 1977.
10. Robinson HF, Comstock RE, Harvey PH. Genotypic and phenotypic correlations in corn and their implications in selection. Agron. 1949;282-287
11. .Hayes HK. Present-Day Problems of Corn Breeding. Agron J. 1926;18(4):344-363. doi:10.2134/agronj1926.00021962001800040006x
12. Panse VG, Sukhatme PV. Statistical Methods for Agricultural Workers. Indian Council of Agricultural Research, New Delhi.; 1954.
13. Kwon SH, Torrie JH. Heritability of and Interrelationships Among Traits of Two Soybean Populations. Crop Sci. 1964;4(2):196-198.
14. Sher H, Iqbal M, Khan K, Yasir M, Rahman HU. Genetic analysis of maturity and flowering characteristics in maize (Zea mays L.). Asian Pac J Trop Biomed. 2012;2(8):621-626. doi:10.1016/S2221-1691(12)60108-7

15. Mahmood F, Rahman HU, Ahmad N, Haq FU, Gul S, Hussain Q, Khalid A, Iqbal T, Rozi S. Yield performance with heritability measurements of half-sib families obtained from maize variety Azam. J Exp Sci. 2017;8:33-36. doi:10.25081/jes.2017.v8.3435
16. Kinfe H, Tsehaye Y. Studies of Heritability, Genetic Parameters, Correlation and Path Coefficient in Elite Maize Hybrids. Acad Res J Agric Sci Res. 2015;3(10):296-303. doi:10.14662/ARJASR2015.062
17. Khan KM, Ali S, Iqbal M, et al. Genetic variation and correlation studies in maize test crosses under the agro-climatic condition of Nowshera. Int J Biosci. 2015;25:383-391. doi:10.12692/ijb/7.6.57-64
18. Hidayat U, Khalil IH, Ghulam H, Iltaf U. Performance of local and exotic inbred lines of maize under agro-ecological conditions of Peshawar. Sarhad J Agric. 2006;22(3):409-414.
19. Ikramullah IH, Khalil MN. Heterotic effects for yield and protein content in white quality protein maize. Sarhad J Agric. 2011;27(3):403-409.
20. Saleh GB, Abdullah D, Anuar AR. Performance, heterosis, and heritability in selected tropical maize single, double, and three-way cross hybrids. J Agric Sci. 2002;138(1):21-28.
21. Flint-Garcia SA, Buckler ES, Tiffin P, Ersoz E, Springer NM. Heterosis is Prevalent for Multiple Traits in Diverse Maize Germplasm. PLoS One. 2009;4(10). doi:10.1371/journal.pone.0007433
22. Dickert TE, Tracy WF. Heterosis for flowering time and agronomic traits among early open-pollinated sweet corn cultivars. J Am Soc Hortic Sci. 2002;127(5):793-797. doi:10.21273/jashs.127.5.793
23. Gebre AB, Mohammed H, Abakemal D. Standard Heterosis of Hybrids Maize (Zea mays L.) for Grain Yield and Yield Related Traits at Kulumsa, Southeastern Ethiopia. Int J Res Stud Agric Sci. 2019;5(9):1-7. doi:10.20431/2454-6224.0509001
24. Lobato-Ortiz R, López-Reynoso JJ, Molina-Galán JD, Cervantes-Santana T. Mass and family selection on F2 of the intervarietal cross of maize Zacatecas 58 SM20 × Compuesto Universal SM12. Rev Chapingo Ser Ing Agropecu. 2000;3(1):27-31.
25. Mendoza M, Oyervides A, López A. Nuevos cultivares de maíz con potencial agronómico para el trópico húmedo. Agron Mesoam. 2006;11(1):83. doi:10.15517/am.v11i1.17355
26. Nagda SCG. Analysis of variety diallel cross for yield and its components in winter maize (*Zea mays* L.). Indian J Genet. 2000;60(3):301-303.
27. Singh SB, Gupta BB. Heterotic expression and combining ability analysis for yield and its components in maize (*Zea mays* L.) inbreds. Progress Agric. 2009;9(2):184-191.
28. Labroo MR, Studer AJ, Rutkoski JE. Heterosis and Hybrid Crop Breeding: A Multidisciplinary Review. Front Genet. 2021;12:1-19. doi:10.3389/fgene.2021.643761
29. Sumalini K, Rani TS. Heterosis and combining ability for polygenic traits in late maturity hybrids of maize (Zea mays L.). Madras Agric J. 2011;97(10-12):340-343.
30. Saleem M, Shahzad K, Javid M, Ahmed A. Genetic Analysis for Various Quantitative Traits in Maize (Zea mays L.) Inbred Lines. Int J Agric Biol. Published online 2002:379-382.
31. Sesay S, Ojo DK, Ariyo OJ, Meseka S. Genetic variability, heritability, and genetic advance studies in top-cross and three-way cross maize (*Zea mays* L.) hybrids. Maydica. 2016;61(2).
32. Muchie A, Fentie D. Performance Evaluation of Maize Hybrids (Zea mays L.) in Bahir Dar Zuria District, North-Western Ethiopia. Int Invent J Agric Soil Sci. 2016;4(3):37-43.
33. Kara ŞM. Evaluation of Yield and Yield Components in Inbred Maize Lines I. Heterosis and Line x Tester Analysis of Combining Ability. Turkish J Agric For. 2001;25:383-391.
34. Anshuman V, Dixit NN, Dipika SK, Sharma SM. Studies on heritability and genetic advance estimates in maize genotypes. Biosci Discov. 2013;14(2):1155-1157.
35. Wattoo FM, Saleem M, Ahsan M. Genetic Analysis for Yield Potential and Quality Traits in Maize (Zea mays L.). Am J Agric Environ Sci. 2009;6(6):723-729.
36. Iqbal M, Khan K, Rahman H, Khalil IH, Sher H, Bakht J. Heterosis for morphological traits in subtropical maize (Zea mays L.). Maydica. 2010;55(1):41-48.
37. Alam AKMM, Ahmed S, Begum M, Sultan MK. Heterosis and combining ability for grain yield and its contributing characters in maize. Bangladesh J Agric Res. 2008;33(3):375-379. doi:https://doi.org/10.3329/bjar.v33i3.1596
38. Santos ÁDO, Pinho RG Von, Souza FD. Grain yield, anthesis-silking interval, and drought tolerance indices of tropical maize hybrids. Crop Breed Appl Biotechnol. 2020;20(1):1-9.
39. Rahman H, Durreshawar, Ali S. Stability analysis of maize hybrids across the northwest of Pakistan. Pakistan J Bot. 2010;42(2):1083-1091.

40. Ngugi K, Collins JO, Muchira S. Combining, earliness, short anthesis to silking interval and yield based selection indices under intermittent water stress to select for drought-tolerant maize. Aust J Crop Sci. 2013;7(13):2014-2020.
41. Ünay A, Konak C, Başal H. Inheritance of grain yield in a half-diallel maize population. Turkish J Agric For. 2004;28(4):239-244.
42. Hiremath N, Shantakumar G, Adiger S, Gangashetty P. Heterosis Beeding for Maturity, Yield and Quality Characters in Maize (*Zea mays* L.). Mol Plant Breed. 2013;4.
43. Kumar GP, Prashanth Y, Reddy VN, Kumar SS, Rao PV. Heterosis for Grain yield and its Component traits in Maize (Zea mays L.). Inter. J. Pure and Appl. Biosci. 2012;2(1):106-111.
44. Ali A, Rahman HU, Shah L, Shah KA, Rehman S. Heterosis for grain yield and its attributing components in maize variety Azam using line × tester analysis method. Acad J Agric Res. 2014;2(11):225-230. http://dx.doi.org/10.15413/ajar.2014.0143
45. Rahman S, Mia MM, Quddus T, Hassan L, Haque MA. Assessing genetic diversity of Maize (*Zea mays* L.) genotypes for agronomic traits. Res Agric Livest Fish. 2015;2(1):53-61.
46. Devi TR, Prodhan HS. Combining ability and heterosis studies in high oil maize (*Zea mays* L.) genotypes. Indian J Genet. 2004;64(4):323-324.