Estimation of Heterosis for morphological and agronomic traits in maize at Hazara Region KP, Pakistan

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Abstracts: A study was undertaken to estimate the Heterosis effects in maize at Agricultural Research Station Baffa, Mansehra during 2014 and 2015 to identify combinations expressing high hybrid vigor. The 31 F_1 were planted along with their 7 parents during Kharif 2015. The Maximum positive heterosis was shown by Azam x Shaheen (35.1%) for stem girth, Jalal x Kissan (35.7%) for leaf area, Jalal x Kissan (40.0%) for number of cobs plant^{-1}, EV-2 x Shaheen (18.0%) for number of cobs plot^{-1}, EV-2 x Jalal (28.6%) for fresh cobs weight, Sadaf x Shaheen (19.2%) for cob length, Pahari x Sadaf and EV-2 x Shaheen (4.4%) for cob girth, Pahari x Kissan (4.8%) for number of grain rows, Pahari x Sadaf (10.8%) for number of grains row^{-1}, EV-2 x Jalal (33.9%) for plant weight, Azam x Kissan (20.0%) for dry cobs weight, Kissan x Azam (21.7%) for shelling percentage, Sadaf x Jalal (75.5%) for grains weight after shelling and cross of Sadaf x Jalal (4.8%) for dry 100 grains weight. While cross of Kissan x Jalal and Jalal x Kissan showed maximum negative heterosis (-11.6%) for days to germination, Kissan x Jalal and Jalal x Kissan (-11.6%) for days to 50% tasseling, Jalal x Azam (-5.1%) for days to 50% silking, Kissan x EV-2 (-17.9%) for plant height, Sadaf x Shaheen (-15.1%) for internode length, Azam x Sadaf (-4.9%) for ear height, Azam x Kissan (-11.4%) for fresh cobs moisture percentage and cross of EV-2 x Jalal (-13.7%) for dry cobs moisture percentage.

Key Words: Heterosis, Cross, Days, Length, Hight, Weight.

1. INTRODUCTION

Maize is the third most important cereal crop of Pakistan after wheat and rice, belonging to the family Poaceae and tribe Maydeae. Maize being a C4 plant and fertilizer responsive crop has very high yielding ability coupled with very high amount of cross pollination. Hence, offers tremendous scope for the plant breeders for genetic improvement. Maize has been recognized as an industrial crop because of the diversified products that can be developed like starch, syrup, glucose, gluten and oil. Nearly 49% of the maize produce is being utilized as a raw material in

poultry feed industry. Maize has hundreds of uses. The kernel contains about 77% starch. Corn starch (maize flour) is a major ingredient in home cooking and in many industrialized food products. Oil content of maize grain is about 4.5 percent, which has a high nutritional quality i.e., it is being considered as the highest Poly Unsaturated Fatty Acid (PUFA), linoleic acid (61.99%). Maize contains 9% protein. Protein present in maize is called as zein. It has a variety of industrial and food uses. There is a strong possibility to develop hybrids having higher yielding ability and nutritionally superior and industrially important with respect to high starch, protein and oil content. Yield in maize crop has increased dramatically over the years as the crop breeders are successful in harnessing the heterosis or hybrid vigor in maize than in any other crop species. Heterosis has been observed for most of the agronomically important qualitative traits, though yield is the most widely discussed trait. With the identification of heterosis by Shull (1908) and East (1936) it has been very well utilized in maize improvement program and for the identifying the suitable parents based on combining ability is the pre-requisite. Unay *et al*., (2004) defined heterosis as the superiority of F1 over the parental mean, and observed that generally high heterosis values are desirable for grain yield in maize. Dehghanpour *et al*., (1996) estimated 152% mid parent heterosis for grain yield. In KP (Pakistan), majority of research work on maize crop has been carried out on agronomic and physiological aspects of maize breeding material. Heterosis, or hybrid vigor, has been the subject of intense research and speculation for well over a century; however, the basic mechanisms that cause or contribute to heterosis remain unclear (Coors and Pandey, 1999). Despite this lack of understanding, breeders have quite successfully manipulated heterosis to increase the vigor of many domesticated species (Springer and Stupar, 2007). Heterosis has been used in the breeding and production of many crop and animal species (Melchinger and Gumber, 1988; Janick, 1998). In maize, it is estimated that the use of hybrids and heterosis increases yields by 15% per annum (Duvick, 1999). Maize breeders have been looking for the possibility of predicting heterosis between inbred lines of maize based on the morphological, pedigree, physiological, biochemical and molecular marker data during the past decades (Smith and Smith, 1989; Smith *et al*., 1990 and Ramesh *et al*., 1995).

Heterosis could also be estimated from generation means and variances. Estimation of heterosis is helpful in checking the performance of parents in hybrid combinations. According to Springer and Stupor (2007) heterosis refers to the phenomenon in which the hybrid F1 offspring exhibit phenotypic characteristics that are superior to the mean of the two parents (mid-parent heterosis), or the better of the two parents (better parent heterosis). Heterosis works as a basic

tool for improved production of crops in the form of F1 hybrids. Hybrid maize production has been successfully used by the grower in each area. The presence of sufficient hybrid vigor is an important prerequisite for successful production of hybrid varieties. A large number of researchers have found heterosis for grain yield and yield components in F1 maize populations (Hallauer and Miranda, 1988).

Figure 1. Map of Agriculture Research Station Baffa, Mansehra Pakistan

2. MATERIALS AND METHODS

The research work was carried out during 2013-2014 in the open experimental field at Agricultural Research Station (ARS) Baffa, Mansehra in collaboration with the Department of Genetics, Hazara University, Mansehra, Khyber Pakhtunkhwa Pakistan. The experimental material comprised of 7 inbred lines per parents. These inbreeds were developed by manual self-pollination procedures for 6 generation from amongst high yielding open pollinated varieties having distinct genetic make-up. The 7 inbred lines were Azam, Kissan, Pahari, EV-2, Jalal, Sadaf and Shaheen. These inbred were crossed during Kharif, 2013 in a crossing block. Harvesting and shelling was done manually. Hybrid seeds from each cross were harvested and bagged separately in envelops. The following 31 crosses were made using diallel mating design:

Table No-1. List of the crosses made during Kharif 2013

S.No	Crosses	S.No	Crosses	S.No	Crosses
1	Azam x Kissan	12	Kissan x Shaheen	22	Jalal x Shaheen
2	Azam x Pahari	13	Pahari x EV-2	23	Sadaf x Shaheen
3	Azam x EV-2	14	Pahari x Jalal	24	Pahari x Azam
4	Azam x Jalal	15	Pahari x Sadaf	25	Pahari x Kissan
5	Azam x Sadaf	16	Pahari x Shaheen	26	EV-2 x Azam
6	Azam x Shaheen	17	EV-2 x Jalal	27	EV-2 x Kissan
7	Kissan x Azam	18	EV-2 x Sadaf	28	EV-2 x Pahari
8	Kissan x Pahari	19	EV-2 x Shaheen	29	Jalal x Azam
9	Kissan x EV-2	20	Jalal x EV-2	30	Jalal x Kissan
10	Kissan x Jalal	21	Jalal x Sadaf	31	Jalal x Pahari
11	Kissan x Sadaf				

The experimental material comprised of 7 inbred lines and their 31 crosses were evaluated during Kharif 2014. The trial was laid out on 28th July, 2014. Sowing was done by dibbling two seeds per hill to ensure uniform stand which was later thinned to one plant per hill. These 38 entries were planted in the field in triplicate, using randomized complete block (RCB) design for evaluation at Agricultural Research Station (ARS) Baffa, Mansehra. The experimental plot size comprised of two rows per plot, each 5m long with row to row and plant to plant distances of 75cm and 25cm respectively. Manual power was used from plating to shelling. Recommended doses of fertilizers were applied at the rate of 90: 58: 38 (NPK) Kgha^{-1}. Whole of P_2O_5 in the form of Triple Super Phosphate (TSP) and potash as Sulphate of Potash and half Nitrogen in the form of urea were applied just before planting during land preparation, while remaining half N was applied as side dressing in the form of urea, about 3 weeks after emergence. Weeds were controlled by pre-emergence application of Prim extra Gold @ 600 ml acre^{-1}. Hand weeding and earthing-up operations were practiced for weed control in later stages, i.e. 4 weeks after emergence. Rainfall was high at Baffa, Mansehra during Kharif 2014 and no irrigation was needed. Harvesting and shelling was done manually.

Statistical Analysis

The data recorded on the aforementioned parameters were assessed by analysis of variance (ANOVA) in a completely randomized design with three replications. Mean reviews were

conducted using least significant difference test (LSD) at alpha level of 0.05. The full statistical work was done by using the computer program i.e., MS Excel, Statistics-9 and Statistics-7.

3. RESULTS AND DISCUSSION

The analysis of variance for all entries, were highly significant. This shows the occurrence of variability among genotypes which is prerequisite for any crop improvement program. The results and observations documented during the course of this current research are presented below.

1. Days to Germination

Maximum heterosis for days to emergence was recorded in the crosses of Kissan x Azam and Pahari x Kissan (17.9%) followed by Azam x Pahari (15.8%) and EV-2 x Shaheen (15.0%). Similarly lowest value of heterosis was observed in the cross combinations Kissan x Jalal and Jalal x Kissan (11.6%). Out of 31 cross combinations negative heterosis was recorded in 13 crosses and are considered better for early emergence. The cross combination showing significantly positive values of heterosis are not desirable one as observed in the table no-7.

2. Days to Tasseling

Maximum heterosis was observed in the cross combination Kissan x EV-2 (20.0%) followed by Kissan x Azam and Pahari x Kissan (17.9%). Similarly maximum negative heterosis was observed in the cross combinations Jalal x Kissan and Kissan x Jalal (-11.6%) followed by Azam x EV-2 (-7.7%) and Jalal x Sadaf (-7.0%). Out of 31 cross combinations, negative heterosis was recorded in 13 crosses and are considered better for early 50% tasseling. The cross combination showing significantly positive values of heterosis are not desirable one as depicted in the table no-7.

3. Days to Silking

Maximum heterosis for days to silking was recorded in the crosses of Pahari x Sadaf (4.5%) followed by EV-2 x Sadaf (4.2%) and Jalal x Sadaf (3.1%). Similarly lowest value of heterosis was observed in the cross combinations Jalal x Azam (-5.1%) and EV-2 x Pahari (-4.4%). Out of 31 cross combinations negative heterosis was recorded in 20 crosses and are considered better for early 50% silking. The cross combination showing significantly positive values of heterosis are not desirable one as depicted in the table no-7.

4. Plant Hight

Maximum heterosis was observed in the cross combination EV-2 x Pahari (41.4%) followed by Pahari x EV-2 (38.0%) and EV-2 x Kissan (34.3%). Similarly maximum negative heterosis was observed in the cross combinations Kissan x EV-2 (-17.9%) followed by Kissan x

Shaheen (-11.8%). Out of 31 cross combinations negative heterosis was recorded in 6 crosses and are considered better for more plant height. The cross combination showing significantly positive values of heterosis are not desirable one as given in the table no-7.

5. Stem Girth

Maximum heterosis for stem girth was recorded in the crosses of Azam x Shaheen (35.1%) followed by EV-2 x Azam (29.7%) and Sadaf x Shaheen (26.2%). Similarly lowest value of heterosis was observed in the cross combinations Kissan x Pahari, and Pahari x Sadaf (-22.2%). Out of 31 cross combinations negative heterosis was recorded in 11 crosses and are considered better for more stem girth. The cross combination showing significantly positive values of heterosis are not desirable one as expressed in the table no-8.

6. Leaf Area

Maximum heterosis was observed in the cross combination Jalal x Kissan (35.7) followed by EV-2 x Kissan (25.2%). Similarly maximum negative heterosis was observed in the cross combinations Jalal x Pahari (-67.7%) followed by Jalal x Sadaf (-46.4%). Out of 31 cross combinations negative heterosis was recorded in 22 crosses and are considered better for more leaf area. The cross combination showing significantly positive values of heterosis are not desirable one as indicated in the table no-8.

7. Internode Length

Maximum heterosis for internode length was recorded in the crosses of Azam x Kissan (26.6%) followed by Kissan x Azam (14.9%). Similarly lowest value of heterosis was observed in the cross combinations Sadaf x Shaheen (-15.1%) and EV-2 x Sadaf (-14.3%). Out of 31 cross combinations negative heterosis was recorded in 17 crosses and are considered better for more internode length. The cross combination showing significantly positive values of heterosis are not desirable one as revealed in the table no-8.

8. Number of Cobs Plant^{-1}

Maximum heterosis was observed in the cross combination Jalal x Kissan (40.0%) followed by EV-2 x Azam (33.3%). Similarly maximum negative heterosis was observed in the cross combinations Pahari x Azam and Pahari x Kissan (-33.3%) followed by Pahari x Sadaf (-23.1%). Out of 31 cross combinations negative heterosis was recorded in 11 crosses and are

considered better for greater number of cobs plant^{-1}. The cross combination showing significantly positive values of heterosis are not desirable one as observed in the table no-8.

9. Number of Cobs Plot^{-1}

Maximum heterosis for number of cobs plot^{-1} was recorded in the crosses of EV-2 x Shaheen (18.0%) followed by Pahari x Jalal (12.1%). Similarly lowest value of heterosis was observed in the cross combinations EV-2 x Azam (-28.2%) and Kissan x Pahari (-26.5%). Out of 31 cross combinations negative heterosis was recorded in 23 crosses and are considered better for greater number of cobs plot^{-1}. The cross combination showing significantly positive values of heterosis are not desirable one as given in the table no-9.

10. Ear Length

Maximum heterosis was observed in the cross combination Pahari x Kissan (91.8%) followed by Pahari x EV-2 (91.5%). Similarly maximum negative heterosis was observed in the cross combination Azam x Sadaf (-4.9%) followed by Sadaf x Jalal (-4.4%). Out of 31 cross combinations negative heterosis was recorded in 2 crosses and are considered better for high ear length. The cross combination showing significantly positive values of heterosis are not desirable one as indicated in the table no-9.

11. Fresh Cob Weight

Maximum heterosis for fresh cob weight was recorded in the crosses of EV-2 x Jalal (28.6%) followed by Azam x Pahari (24.8%). Similarly lowest value of heterosis was observed in the cross combinations Azam x Sadaf (-35.1%) and Kissan x EV-2 (-30.8%). Out of 31 cross combinations negative heterosis was recorded in 16 crosses and are considered better for more fresh cobs weight. The cross combination showing significantly positive values of heterosis are not desirable one as depicted in the table no-9.

12. Cob Length

Maximum heterosis was observed in the cross combination Sadaf x Shaheen (19.2%) followed by EV-2 x Jalal (17.6%). Similarly maximum negative heterosis was observed in the cross combinations Kissan x Jalal (-5.3%) followed by Pahari x Jalal (-2.8%). Out of 31 cross combinations negative heterosis was recorded in 3 crosses and are considered better for more length of cob. The cross combination showing significantly positive values of heterosis are not desirable one as observed in the table no-9.

13. Cob Girth

Maximum heterosis for cob girth was recorded in the crosses of Pahari x Sadaf and EV-2 x Shaheen (4.4%) followed by Jalal x Kissan (4.2%). Similarly lowest value of heterosis was observed in the cross combinations Jalal x Azam (-7.4%) and Sadaf x Jalal (-7.0%). Out of 31 cross combinations negative heterosis was recorded in 19 crosses and are considered better for high cob girth. The cross combination showing significantly positive values of heterosis are not desirable one as indicated in the table no-10.

14. Number of Grain Rows Cob^{-1}

Maximum positive heterosis was observed in the cross combination Kissan x Pahari (4.0%) followed by Kissan x Shaheen (3.6%). Similarly maximum negative heterosis was observed in the cross combinations Azam x Pahari (-10.3%) followed by EV-2 x Azam (-7.2%). Out of 31 cross combinations negative heterosis was recorded in 15 crosses and are considered better for more number of grain row cob^{-1}. The cross combination showing significantly positive values of heterosis are not desirable one as depicted in the table no-10.

15. Number of Grains Row^{-1}

Maximum heterosis for number of grains row^{-1} was recorded in the crosses of Pahari x Sadaf (10.8%) followed by Kissan x Jalal (5.6%). Similarly lowest value of heterosis was observed in the cross combinations Azam x Jalal (-9.0%) and Jalal x Shaheen (-8.4%). Out of 31 cross combinations negative heterosis was recorded in 15 crosses and are considered better for more number of grain row^{-1}. The cross combination showing significantly positive values of heterosis are not desirable one as revealed in the table no-10.

16. Plant Weight

Maximum heterosis for plant weight plot^{-1}was recorded in the crosses of EV-2 x Jalal (33.9) followed by Pahari x EV-2 (12.1%). Similarly lowest value of heterosis was observed in the cross combinations EV-2 x Pahari (-32.8%) and Kissan x EV-2 (-24.5%). Out of 31 cross combinations negative heterosis was recorded in 22 crosses and are considered better for more plant weight. The cross combination showing significantly positive values of heterosis are not desirable one as expressed in the table no-10.

17. Fresh cob Moisture Percentage

Maximum heterosis for fresh cob moisture percentage was recorded in the crosses of Jalal x Shaheen (2.5%) followed by EV-2 x Shaheen and EV-2 x Pahari (1.7%). Similarly lowest value of heterosis was observed in the cross combinations Azam x Kissan (-11.4%) and Kissan x Azam (-10.5%). Out of 31 cross combinations negative heterosis was recorded in 25 crosses and

are considered better for more fresh cobs moisture percentage. The cross combination showing significantly positive values of heterosis are not desirable one as indicated in the table no-11.

18. Dry cob Moisture Percentage

Maximum heterosis for dry cob moisture percentage was recorded in the crosses of Kissan x Sadaf (11.6%) followed by Kissan x EV-2 (4.1%). Similarly lowest value of heterosis was observed in the cross combinations EV-2 x Jalal (-13.7%) and EV-2 x Azam (-13.1%). Out of 31 cross combinations negative heterosis was recorded in 21 crosses and are considered better for more dry cobs moisture percentage. The cross combination showing significantly positive values of heterosis are not desirable one as expressed in the table no-11.

19. Dry Cob Weight

Maximum heterosis for dry cob moisture percentage was recorded in the crosses of Azam x Kissan (20.0%) followed by Kissan x Jalal (13.5%). Similarly lowest value of heterosis was observed in the cross combinations Azam x EV-2, Kissan x EV-2, EV-2 x Sadaf, EV-2 x Shaheen, EV-2 x Azam, EV-2 x Kissan and EV-2 x Pahari (-9.9%) followed by Pahari x Kissan (-7.0%). Out of 31 cross combinations negative heterosis was recorded in 13 crosses and are considered better for more dry cobs weight. The cross combination showing significantly positive values of heterosis are not desirable one as shown in the table no-11.

20. Shelling Percentage

Maximum heterosis for shelling percentage was recorded in the crosses of Kissan x Azam (21.7%) followed by Azam x Kissan (19.6%). Similarly lowest value of heterosis was observed in the cross combinations Azam x Shaheen (-21.9%) followed by Pahari x Jalal (-21.3%). Out of 31 cross combinations negative heterosis was recorded in 7 crosses and are considered better for more shelling %age. The cross combination showing significantly positive values of heterosis are not desirable one as revealed in the table n-11.

21. Grain Weight after Shelling

Maximum heterosis for grain weight after shelling was recorded in the crosses of EV-2 x Shaheen (15.0%) followed by Pahari x Sadaf (11.8%). Similarly lowest value of heterosis was observed in the cross combinations Azam x Shaheen (-19.4%) followed by Azam x Kissan, Kissan x Azam, Kissan x Jalal, Pahari x Shaheen and Jalal x Kissan (-9.9%). Out of 31 cross combinations negative heterosis was recorded in 8 crosses and are considered better for more grains

weight after shelling. The cross combination showing significantly positive values of heterosis are not desirable one as given in the table no-12.

22. Dry 100 Grains Weight

Maximum heterosis for dry 100 grains weight was recorded in the crosses of Jalal x Sadaf (5.7%) followed by Sadaf x Jalal (4.8%). Similarly lowest value of heterosis was observed in the cross combinations was Pahari x Azam (-2.6%) followed by Azam x Sadaf (-2.3%). Out of 31 cross combinations negative heterosis was recorded in 12 crosses and are considered better for more dry 100 grains weight. The cross combination showing significantly positive values of heterosis are not desirable one as indicated in the table no-12.

Table No-1. Heterosis of days to germination and days to 50% tasseling, days to 50% silking, plant height, stem girth, leaf area and Internode Length.

S.No	Crosses	Days to Germination	Days to 50% Tasseling	Days to Silking	Plant Height	Stem girth	Leaf Area	Internode Length
		Het*	Het*	Het*	Het*	Het*	Het*	Het*
1	Azam x Kissan	7.7	7.7	1.0	26.6	-9.3	-3.4	26.6
2	Azam x Pahari	15.8	15.8	0.3	-3.9	-18.8	4.1	-3.9
3	Azam x EV-2	-7.7	-7.7	-0.7	11.3	10.5	-11.2	11.3
4	Azam x Jalal	-4.8	-4.8	-2.4	-1.6	18.6	-14.4	-1.6
5	Azam x Sadaf	-2.6	-2.6	1.4	-11.1	5.1	-33.8	-11.1
6	Azam x Shaheen	12.8	12.8	-2.0	1.9	35.1	-39.7	1.9
7	Kissan x Azam	17.9	17.9	-3.8	14.9	5.3	-5.3	14.9
8	Kissan x Pahari	12.8	12.8	-1.4	14.3	-22.2	-5.8	14.3
9	Kissan x EV-2	20.0	20.0	-1.7	-4.8	2.8	-16.3	-4.8
10	Kissan x Jalal	-11.6	-11.6	0.7	-9.8	13.0	16.2	-9.8
11	Kissan x Sadaf	10.0	10.0	-1.8	-4.2	-8.5	1.2	-4.2
12	Kissan x Shaheen	5.0	5.0	0.3	-4.9	-2.9	6.5	-4.9
13	Pahari x EV-2	-2.6	-2.6	-1.0	-1.6	11.6	-36.0	-1.6
14	Pahari x Jalal	0.0^{ns}	0.0	-0.7	-0.7	3.2	19.1	-0.7
15	Pahari x Sadaf	-2.6	-2.6	4.5	-0.7	-22.2	-13.5	-0.7
16	Pahari x Shaheen	-2.6	-2.6	-1.7	13.7	-15.5	-12.5	13.7
17	EV-2 x Jalal	2.3	2.3	-3.1	-10.9	21.2	2.8	-10.9
18	EV-2 x Sadaf	-5.0	-5.0	4.2	-14.3	23.4	-15.2	-14.3
19	EV-2 x Shaheen	15.0	15.0	0.0	1.4	2.1	-29.0	1.4
20	Jalal x Sadaf	-7.0	-7.0	3.1	-5.1	3.8	-46.4	-5.1
21	Jalal x Shaheen	7.0	7.0	-1.7	-12.4	-1.8	11.7	-12.4
22	Sadaf x Shaheen	5.0	5.0	-2.1	-15.1	26.2	-28.6	-15.1
23	Pahari x Azam	5.3	5.3	-3.7	12.6	15.4	-20.7	12.6

24	Pahari x Kissan	17.9	17.9	-2.0	11.9	-16.8	-11.2	11.9
25	EV-2 x Azam	7.7	7.7	0.7	-10.6	29.7	-19.5	-10.6
26	EV-2 x Kissan	10.0	10.0	-3.1	6.1	14.9	25.2	6.1
27	EV-2 x Pahari	-2.6	-2.6	-4.4	2.6	24.8	-38.6	2.6
28	Jalal x Azam	-4.8	-4.8	-5.1	0.8	-4.9	-10.7	0.8
29	Jalal x Kissan	-11.6	-11.6	-1.4	6.2	3.6	35.7	6.2
30	Jalal x Pahari	4.8	4.8	-1.4	0.9	-19.5	-67.7	0.9
31	Sadaf x Jalal	-2.3	-2.3	1.0	-0.5	17.2	-13.1	-0.5

*=Heterosis

Table No-2. Heterosis of Number of Cobs/Plant, Number of cobs/plots, Ears Hight, Fresh cob weight, Cobs Length, Cob Girth, Number of grain rows /cob and Number of Grain/Row.

S.No	Crosses	Number of Cobs/Plant Het*	Number of cobs /plot Het*	Ears Height Het*	Fresh cob weight Het*	Cobs Length Het*	Cob Girth Het*	Number of grain rows/cob Het*	Number of Grain /Row Het*
1	Azam x Kissan	0.0	-10.3	15.6	1.8	6.5	-3.2	1.6	-3.0
2	Azam x Pahari	0.0	3.4	63.3	24.8	1.4	-5.4	-10.3	3.1
3	Azam x EV-2	11.1	-21.6	15.4	5.1	9.3	1.1	0.0	-4.0
4	Azam x Jalal	0.0	-12.6	0.7	1.0	1.4	-0.5	1.2	-9.0
5	Azam x Sadaf	-9.1	-15.3	-4.9	-35.1	7.4	-5.0	-1.5	2.8
6	Azam x Shaheen	0.0	-12.8	12.6	-16.4	3.2	-1.4	-2.8	-4.4
7	Kissan x Azam	0.0	-7.7	32.5	-3.5	0.3	-1.6	-5.6	-0.5
8	Kissan x Pahari	16.7	-26.5	36.8	-0.9	3.1	-3.2	4.0	8.2
9	Kissan x EV-2	11.1	-17.4	19.1	-30.8	2.5	0.2	0.0	0.9
10	Kissan x Jalal	0.0	-19.5	12.1	-23.9	-5.3	-4.3	-0.4	5.6
11	Kissan x Sadaf	9.1	-2.5	25.2	4.9	12.4	-4.2	0.8	4.7
12	Kissan x Shaheen	0.0	9.9	23.8	5.1	0.0	1.8	3.6	-1.6
13	Pahari x EV-2	-9.1	8.9	91.5	0.0	2.2	1.0	0.0	-3.6
14	Pahari x Jalal	0.0	12.1	34.0	-27.8	-2.8	-3.0	0.4	-2.0
15	Pahari x Sadaf	-23.1	-5.8	34.3	-24.8	0.8	4.4	-2.4	10.8
16	Pahari x Shaheen	-16.7	-7.2	44.6	4.4	6.1	2.5	-2.0	3.3
17	EV-2 x Jalal	11.1	2.6	70.9	28.6	17.6	-4.9	-0.4	1.8
18	EV-2 x Sadaf	20.0	-7.6	61.3	-17.8	3.1	-6.8	0.0	3.3
19	EV-2 x Shaheen	11.1	18.0	44.3	-2.9	16.2	4.4	-2.0	-7.3
20	Jalal x Sadaf	9.1	-8.1	16.0	-6.2	3.1	-3.1	-6.8	-5.6
21	Jalal x Shaheen	-20.0	-4.3	22.4	0.9	12.9	1.6	0.0	-8.4
22	Sadaf x Shaheen	-9.1	-6.1	32.0	1.7	19.2	-3.6	0.4	2.4
23	Pahari x Azam	-33.3	-12.7	42.2	6.4	6.2	1.5	-2.4	-1.8
24	Pahari x Kissan	-33.3	-5.3	91.8	-11.1	2.4	2.4	4.8	-3.4
25	EV-2 x Azam	33.3	-28.2	45.0	-13.1	2.9	1.9	-7.2	0.4
26	EV-2 x Kissan	11.1	-5.5	70.0	-10.3	7.6	-0.3	-2.4	-8.0

27	EV-2 x Pahari	-9.1	0.4	72.5	-7.8	0.7	-1.7	-0.8	2.0
28	Jalal x Azam	0.0	4.8	19.3	12.4	9.8	-7.4	-0.4	4.1
29	Jalal x Kissan	40.0	-1.4	45.3	-11.5	4.6	4.2	1.2	4.1
30	Jalal x Pahari	-16.7	-15.7	55.4	11.1	-2.1	-4.9	0.4	0.5
31	Sadaf x Jalal	-9.1	-5.5	-4.4	0.9	15.3	-7.0	2.8	-6.2

*=Heterosis

Table No-3. Heterosis of Plant Weights/Plot, Fresh cobs moisture %age, Dry cobs moisture %age, Dry cobs weight/plot, Shelling %age, Grains weight after shelling and Dry 100 grains weight.

S.No	Crosses	Plant Weights/ Plot	Fresh cobs moisture %age	Dry cobs moisture %age	Dry cobs weight/plot	Shelling %age	Grains weight after shelling	Dry 100 grains weight
		Het*	Het*	Het*	Het*	Het*	Het*	Het*
1	Azam x Kissan	1.7	-11.4	2.0	20.0	19.6	-9.9	0.3
2	Azam x Pahari	9.5	-3.2	-6.6	1.4	7.9	10.4	-0.8
3	Azam x EV-2	6.7	-6.1	-10.7	-9.9	7.4	6.5	1.7
4	Azam x Jalal	6.6	-5.9	-6.7	2.7	10.4	11.5	3.6
5	Azam x Sadaf	-20.6	-4.6	2.7	-4.3	7.7	-2.9	-2.3
6	Azam x Shaheen	-5.3	-3.1	-12.5	7.2	-21.9	-19.4	-1.1
7	Kissan x Azam	-9.0	-10.5	-11.1	11.4	21.7	-9.9	-0.9
8	Kissan x Pahari	9.5	-4.8	0.5	1.4	5.7	11.7	0.6
9	Kissan x EV-2	-24.5	-3.3	4.1	-9.9	18.9	19.2	2.1
10	Kissan x Jalal	-12.8	-2.5	2.2	13.5	11.7	-9.7	4.2
11	Kissan x Sadaf	11.8	-2.9	11.6	4.3	4.3	-7.2	0.2
12	Kissan x Shaheen	-2.1	-3.7	-1.4	4.3	7.5	6.0	-0.6
13	Pahari x EV-2	12.1	-2.8	-4.7	10.7	-13.1	9.5	-0.1
14	Pahari x Jalal	-6.8	-0.1	-0.5	6.4	-21.3	5.6	2.6
15	Pahari x Sadaf	-6.1	-4.0	2.1	2.9	0.5	11.8	1.0
16	Pahari x Shaheen	-8.5	-1.2	-10.9	11.4	4.7	-9.7	-0.2
17	EV-2 x Jalal	33.9	0.8	-13.7	10.7	-14.1	10.2	-0.9
18	EV-2 x Sadaf	-7.9	0.7	-10.5	-9.9	12.6	9.1	0.1
19	EV-2 x Shaheen	-2.4	1.7	-1.3	-9.9	9.3	15.0	1.5
20	Jalal x Sadaf	-14.1	-4.1	2.1	-1.4	2.9	11.5	5.7
21	Jalal x Shaheen	-13.6	2.5	-1.2	-1.4	-0.5	11.0	3.4
22	Sadaf x Shaheen	-7.9	-2.8	-7.0	2.9	3.8	-0.8	0.8
23	Pahari x Azam	9.5	-1.0	-12.3	-1.4	13.1	10.9	-2.6
24	Pahari x Kissan	-7.7	-3.7	0.0	-7.0	2.2	9.6	-1.6
25	EV-2 x Azam	-5.0	-2.5	-13.1	-9.7	19.5	8.1	0.2
26	EV-2 x Kissan	-6.4	-4.5	-7.3	-9.7	18.9	17.5	-0.5
27	EV-2 x Pahari	-32.8	1.7	-2.6	-9.7	6.5	15.2	-0.2
28	Jalal x Azam	-18.0	-4.5	-7.9	-2.7	4.2	10.9	3.4

29	Jalal x Kissan	-1.5	-5.1	-4.8	5.4	10.5	-9.7	3.7
30	Jalal x Pahari	-6.8	0.0	-10.9	7.0	-19.8	5.7	3.2
31	Sadaf x Jalal	-9.4	-2.9	1.9	7.5	-15.1	75.5	4.8

*=Heterosis

CONCLUSION

None of a single cross was found better for all the traits. Maximum and positive heterosis was recorded in for stem girth in Azam x Shaheen (35.1), for leaf area in Jalal x Kissan (35.7), for number of cobs plant^{-1} in Jalal x Kissan (40.0),for number of cobs plot^{-1} in EV-2 x Shaheen (18.0), for fresh cobs weight in EV-2 x Jalal (28.6), for cob length in Sadaf x Shaheen (19.2), for cob girth in Pahari x Sadaf and EV-2 x Shaheen (4.4), for number of grain rows in Pahari x Kissan (4.8), for number of grains row^{-1} in Pahari x Sadaf (10.8), for plant weight in EV-2 x Jalal (33.9), for dry cobs weight in Azam x Kissan (20.0), for shelling percentage in Kissan x Azam (21.7), for grains weight after shelling in Sadaf x Jalal (75.5) and dry 100 grains weight in Sadaf x Jalal (4.8).Minimum negative heterosis for days to germination were observed in Kissan x Jalal and Jalal x Kissan (-11.6), for days to 50% tasseling in Kissan x Jalal and Jalal x Kissan (-11.6), for days to 50% silking in Jalal x Azam (-5.1), for plant height in Kissan x EV-2 (-17.9), for internode length in Sadaf x Shaheen (-15.1), for ear height in Azam x Sadaf (-4.9),), for fresh cobs moisture percentage in Azam x Kissan (-11.4), for dry cobs moisture percentage in EV-2 x Jalal (-13.7).

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