INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
12–059/2014/16–6–1041–1049
http://www.fspublishers.org

Full Length Article

Influence of *Fusarium moniliforme* Inoculation on Heterosis and Heterobeltiosis for Agronomic Traits in Maize (*Zea mays*)

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Abstract

In a 6×6 diallel cross, 30 hybrids were produced and tested for heterosis and heterobeltiosis for yield with or without *Fusarium moniliforme* inoculation for two growing seasons. The analysis of variance indicated highly significant ($P \leq 0.01$) influence of inoculation on all the studied traits during both experiments. Significant positive heterosis was observed for almost all studied yield traits in various hybrid combinations, whereas few traits showed significant negative heterosis and heterobeltiosis under both uninoculated and inoculated conditions. Hybrids between AKBAR × AGAITI-2002 and AGAITI-2002 × SADAF were the best performer for most of the traits with or without *F. moniliforme* inoculation.

Keywords: Inoculation; Heterosis; *Fusarium moniliforme*; Diallel cross

Introduction

Heterosis is important in maize breeding and is dependent on level of dominance and diversity in gene frequencies. The manifestation of heterosis depends on genetic divergence of two parental varieties (Wattoo *et al.,* 2014). Heterosis is the phenomenon wherein the performance of an F_1 derived by crossing two genetically different individuals is superior to that of the mean of the parents or the better parent. Maize has great potential for heterotic manifestation and its exploitation. This could be the reason that number of hybrid varieties in maize is much higher than any other varietal types i.e. open pollinated, double cross, synthetics or three way crosses.

Heterosis is directly proportional to the proportion of exotic germplasm (Gupta and Nagda, 2002) found good heterosis for early silking. The height of maize plant depends upon number of nodes and internodal length that also showed heterosis in different crops (Gupta and Nagda, 2002). Dickert and Tracy (2002) and Saleh *et al.* (2002) reported positive heterosis for plant of maize that was dependent upon the parents. Similarly, Cheres *et al.* (2002) reported heterosis for plant height in sunflower and maize. Heterosis for agronomic characters were observed when direct crosses developed through diallel mating scheme (Gupta and Nagada, 2000; Li-Jun *et al*., 2001; Shahwani *et al*., 2001). Rosa *et al*. (2000) recorded highest heterosis in yield after crossing Indian material with foreign material. It is evident that the heterogeneous material is the main cause of superior hybrids. Analysis of the variance with respect to parents and their crosses helps in selection of better parents to breed high yielding resistant cultivars.

The quality and quantity of the yield is affected due to diseases and pests (Suhaida and NurAinIzzati, 2013). The diseases are influenced by the environment (rainfall, humidity and temperature,) the pathogens, the host and their genetic differences. There are several diseases like seed rot, seedling disease, leaf blight, gall smut, rust, downy mildews and stalk rots that affect the growth of maize plants (Anonymous, 2009-2010). However, stalks rots are the most destructive diseases of maize throughout the world causing up to 18% losses in plant yield (Dey *et al*., 1992). Hot and humid weather favors the disease development. The stalk rot disease attacks pithy parts of the plant that ultimately reduce grain yield by producing small size kernels with losses as much as 20-50% under favorable conditions (Rehman *et al*., 1986). The stalk rot of maize is caused by several fungal and bacterial pathogens but *Fusarium* spp., particularly *F. moniliforme* are the most prominent among them (Pal *et al*., 2001). The present studies were undertaken to determine the effect of *F. moniliforme*on heterosis and heterobeltiosis for agronomic traits in maize.

Materials and Methods

The seeds of six approved and candidate genetic material *viz.*, 1) Ev 5098, 2) Ev 6098, 3) SWL 2002, 4) Ag 2002, 5) Sadaf, and 6) Akbar, obtained from the Maize and Millet Research Institute (MMRI), Yousefwala, Sahewal, Pakistan were used during the present studies. In Kharif (fall) 2009,

To cite this paper: Ahmad M.F., S. Shehzad, K. Hussain, S.H. Khan and M. Sajjad, 2014. Influence of *Fusarium moniliforme* inoculation on heterosis and heterobeltiosis for agronomic traits in maize (*Zea mays*). *Int. J. Agric. Biol.*, 16: 1041–1049

the seeds of hybrids and reciprocals were produced from parents by manual self and cross pollination techniques that were used for further experimentation.

F. moniliforme isolated from stalk rot affected plants was obtained from the MMRI. This isolate was found to be pathogenic to maize during initial screening. The field experiments were carried out during kahrif 2010 and 2011 in 5x3 m plots in a randomized complete block design with three replications keeping 75 cm row to row and 20 cm plant to plant distance. In each experiment, a set of treatments *viz*., Parents, Direct Crosses, Reciprocal Crosses were kept un-inoculated, whereas a comparable set was inoculated with the pathogen after 7-10 of the anthesis using toothpick inoculation method. Sterilized toothpicks were placed near the growing colony of the pathogen. The pathogen overgrew the toothpicks and colonized it. The fungal culture impregnated tooth picks, with changed color, were used for inoculating the maize plants at the initiation of silking stage. The toothpicks were inserted into the stalk, at second node from the base.

Plant morphological, disease and yield data for inoculated as well as un-inoculated plants were recorded at harvesting. Hetrosis and heterobeltiosis were calculated according to the following formulae:

(i) Mid-parent Heterosis (%) = (F_1- MP)/MP × 100
(ii) Best-parent Hetrosis (%) = (F_1- BP)/BP × 100.

Where, F_1 =Mean of F_1 hybrid for a specific trait; MP=Mean of the two parents in a cross for a specific trait; BP= Mean of the best parent in a cross for a specific trait

Significance of the mid-parent and best-parent heterosis was determined using t-test.

Results

The analysis of variance resulted in highly significant ($P \leq 0.01$) means squares for all the studied traits during first (2010) and second (2011) growing seasons under uninoculated and inoculated conditions (Table 1, 2). The extent of heterosis and heterobeltiosis for all crosses is given in Tables 3, 4, 5 and 6. The trait wise results and discussion is presented as under.

Kernel Rows per Cob

In first and second seasons, 18 and 15 F1 hybrids showed highly significant heterosis, ($P \leq 0.01$), respectively. 12 crosses exhibited significant heterosis ($P \leq 0.05$). During both seasons only two crosses (AKBAR × AGAITI-2002, AGAITI-2002 × AKBAR) showed significant heterobeltiosis ($P \leq 0.05$) (Table 3). The heterosis for kernel rows per cob ranged from +8.69% (EV-5098 × SAHIWAL-2002, SAHIWAL-2002 × EV-5098) to +25.00% (AGAITI-2002 × AKBAR, AKBAR × AGAITI-2002) (Table 3). However, the extent and magnitude of heterosis in season I was higher (+8.29 to +25.00%) as compared to that in season II. The cross SAHIWAL-2002 × EV-5098 was also least performer in uninoculated crop during season-I. The heterosis results in season-I under inoculation were different from those under uninoculated condition. When F_1 plant were inoculated with *F. moniliforme,* only 20 hybrids showed heterosis, in season and 30 hybrids showed in season II. The crosses AKBAR x EV-5098, SAHIWAL-2002 × EV-5098 and EV-5098 × SAHIWAL-2002 showed minimum heterosis (+10.52%), while SADAF × EV-6098 and AGAITI-2002 × SADAF showed maximum heterosis (+ 33.33%; Table 4). The cross SAHIWAL-2002 × EV-5098 also showed minimum heterosis under uninoculated condition.

Kernels Per Row

Under un-inoculated condition, 28 and all 30 F1s were significantly heterotic for kernels per row in season I and season II, respectively. The crosses SAHIWAL-2002 × EV-5098 and EV-5098 and SAHIWAL-2002 didn't show significant heterosis. Significant heterobeltiosis ($P \leq 0.05$) was expressed only in four crosses (EV-6098 × EV-5098, EV-5098 × EV-6098, EV-6098 × AKBAR, AKBAR × EV-6098; Table 3).The prevalence of heterosis ranged from +4.72% (SAHIWAL-2002 × EV-5098, EV-5098 × SAHIWAL-2002) to +14.17% (AKBAR x AGAITI-2002). The heterosis result for kernels per cob was mostly similar in season-I and season-II but heterobeltiosis result was quite different. The degree of increase in kernels per row ranged from +15.41% (EV-5098 × SAHIWAL-2002) to +29.87% (SADAF × EV-6098) over mid parent and +6.06% (EV-5098 × AGAITI-2002) to +33.98% (SADAF × AGAITI-2002) over better parent (Table 5).

The heterosis results were almost similar to those in season-I and II under un-inoculated and season-I under inoculated conditions. When F_1 plant were inoculated with *F. moniliforme*, only two hybrids (EV-6098 × EV-5098, AKBAR × EV-6098) didn't show heterosis and all other showed heterosis ($P \leq 0.01$). Out of the 30 F_1 hybrids, 27 showed significant heterobeltiosis (Table 5).The cross EV-6098 × EV-5098showed minimum increase (+10.52%) and AGAITI-2002 × AKBAR showed maximum heterosis (+ 74.57%) over mid parent. The extent and magnitude was almost close to that under inoculated condition (+18.46 to +77.61%). The minimum and maximum increase over better parent was +1.51% (EV-6098 × EV-5098) and +68.85% (AGAITI-2002 × AKBAR), respectively (Table 5).

Kernels Per Cob

All F_1 hybrids showed significant and positive heterosis and heterobeltiosis ($P \leq 0.01$). The degree of increase over mid parent ranged from +13.83% (SAHIWAL-2002 × EV-5098) to +41.70% (AKBAR × SADAF, AGAITI-2002 × SAHIWAL-2002) and increase over better parent ranged

Table 1: Analysis of variance for hetrosis and hetrobeltiosis for the year 2010 and 2011

S. No	Traits	Mean Squares of Genotypes			
		Replications	Uninoculated	Replications	Inoculated
2010 sowing					
1	Kernel rows per Ear	0.92 NS	4.51**	4.70 NS	4.35*
2	Kernels/Row	1.23 NS	18.02**	14.69 NS	85.83**
3	Kernels/Ear	3077 NS	25669.69**	10741 NS	28507.09
4	1000-grain weight	31.20 NS	1855.22**	26.51 NS	472.81**
5	Grain Yield/Plant	68.90 NS	546.34**	62.69 NS	676.34**
6	Days to 50% Silking	1.84 NS	13.60**	3.23 NS	22.00926**
7	Days to 50% Tasseling	1.19 NS	13.78**	3.69 NS	25.79**
8	Cob Height	7.86 NS	93.457*	5.80 NS	1188.50**
9	Cob Diameter	0.01 NS	0.39**	0.09 NS	1.16**
10	Cob Length	0.06 NS	8.72**	0.44 NS	6.93**
2011 Sowing					
1	Kernel rows per Ear	0.75NS	2.03*	0.11 NS	10.39**
2	Kernels/Row	3.02 NS	58.97**	19.18 NS	63.19**
3	Kernels/Ear	5334 NS	32309.32**	5896 NS	26460.61**
4	1000-grain weight	42.80 NS	1553.99**	59.37 NS	373.90**
5	Grain Yield/Plant	34.92 NS	726.98**	56.01 NS	612.19**
6	Days to 50% Silking	1.23 NS	16.95**	3.06 NS	24.142**
7	Days to 50% Tasseling	1.36 NS	20.36**	0.84 NS	27.050 **
8	Cob Height	11.35 NS	93.96 **	0.90 NS	656.73 **
9	Cob Diameter	0.16 NS	0.57 **	0.03 NS	0.56**
10	Cob Length	4.26 NS	7.39**	0.76 NS	6.38**

from +0.70% (EV-5098 x AGAITI-2002) to +25.42% (AGAITI-2002 × AKBAR). The heterosis and heterobeltiosis results are similar to those in season-I as all F1 hybrids exhibited significant heterosis and heterobeltiosis at $P\leq 0.01$. The degree of increase in kernels per cob ranged from +23.63% (EV-5098 x SAHIWAL-2002) to +50.29% (AKBAR × AGAITI-2002) over mid parent and +11.37% (EV-5098 × AGAITI-2002) to +39.90% (AGAITI-2002 × SADAF) over better parent (Table 5). Similar to the result under uninoculated growth condition, all hybrids except one (EV-6098 × AKBAR) showed significant heterosis and heterobeltiosis for kernels per cob (Table 4). The degree of increase over mid parent ranged from +26.69% (EV-6098 × AKBAR) to +142.12% (AGAITI-2002 × AKBAR4) and increase over better parent ranged from +19.45% (EV-6098 × AKBAR) to +112.40% (AGAITI-2002 × AKBAR).

The inoculation of *F. moniliforme* didn't affected the heterosis results for kernels per cob because all crosses showed significant heterosis and heterobeltiosis as was the case under uninoculated condition. The cross EV-6098x EV-5098 showed minimum increase (+36.40%) and AGAITI-2002 × AKBAR showed maximum heterosis (+ 179.53%) over mid parent. The minimum and maximum increase over better parent were +30.40% (EV-6098 × EV-5098) and +151.53% (AGAITI-2002 × AKBAR), respectively (Table 5).

1000-Grain Weight

All the F_1 hybrids showed highly significant heterosis ($P\leq0.01$), while 21 showed heterobeltiosis (three at $P\leq 0.05$ and 18 at $P\leq 0.01$) in season-I (Table 3). The heterosis for 1000-grain weight ranged from +4.38% (EV-5098 × EV-6098) to +26.87% (SADAF × AGAITI-2002), whereas, heterobeltiosis ranged from +0.26% (SAHIWAL-2002 × EV-5098) to +23.88% (SADAF × AGAITI-2002) (Table 3). There was no seasonal change on heterosis results for 1000-grain weight since all hybrids showed significant heterosis at $P\leq 0.01$ as was the case in season-I. Except only two hybrids (AGAITI-2002 × EV-6098, EV-5098 × SADAF) all other showed significant heterobeltiosis at $P\leq 0.01$. The heterosis for 1000-grain weight ranged from +7.62% (EV-5098 × SADAF) to +24.48% (SADAF × AGAITI-2002), and heterobeltiosis ranged from +0.77% (AGAITI-2002 × EV-6098) to +20.53% (EV-6098 × AGAITI-2002; Table 5). The heterosis results were similar to those under un-inoculated condition and all the 30 hybrids showed significant heterosis at $P\leq0.01$ and 28 hybrids also showed significant heterobeltiosis (Table 4). The crosses SAHIWAL-2002 × EV-5098, EV-5098 × SAHIWAL-2002 showed minimum heterosis (+7.36%), while SADAF × AKBAR and AKBAR × SADAF showed maximum heterosis (+ 15.66%; Table 4). All thirty crosses showed highly significant heterosis and heterobeltiosis ($P\leq 0.01$) in season-II under inoculation (Table 5). The heterosis for 1000-grain weight ranged from +6.23% (SAHIWAL-2002 × EV-6098) to +12.44% (SADAF × AKBAR) and heterobeltiosis ranged from +4.12% (AGAITI-2002 × EV-6098) to +10.62% (EV-5098 × EV-6098). The extent and magnitude of heterosis in season I and II under inoculated condition was almost similar.

Grain Yield Per Plant

All the F_1 hybrids showed highly significant heterosis ($P\leq0.01$) in season I and II. Highly significant heterobeltiosis ($P \leq 0.01$) was expressed by all the crosses except two viz., AGAITI-2002 × EV-5098 and

Table 2: Hetrotic and hetrobeltiotic effects on various parameters in 6×6 F1 diallel cross of *Zea mays* L. in F_1 generation for the year 2010 under un-inoculated condition

Hybrids	Kernel rows/ ear		Kernels/rows		Kernels/ear		1000-grain weight		Grain yield per plant		Days to 50%silking		Days to 50% tasseling		Cob height		Cob Diameter		Cob Length	
	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %
P2xP1	14.89**	12.50^{NS}	10.86**	8.51*	27.50**	-3.11**	-3.93^{NS}	-4.29**	-5.64^{NS}	5.65**	4.41^{NS}	33.69**	32.74^{NS}	18.54**	17.57^{NS}	22.07**	4.66**	1.52*	34.15**	33.19**
P3xP1	11.62*	0.00^{NS}	12.94**	2.12^{NS}	24.60**	-0.30^{NS}	-7.30^{NS}	-1.52^{NS}	-9.03^{NS}	13.05**	4.41^{NS}	7.27**	3.50^{NS}	23.35**	2.70^{NS}	2.12**	13.95**	0.53^{NS}	5.74*	1.84^{NS}
P4xP1	18.18**	8.33^{NS}	8.33**	1.41^{NS}	27.30**	-2.27*	-3.37^{NS}	-3.70**	-4.51^{NS}	7.16**	1.17^{NS}	4.92*	1.50^{NS}	21.25**	11.79^{NS}	9.75**	11.67**	0.62^{NS}	8.78**	5.32**
P5xP1	15.55**	8.33^{NS}	7.29**	4.25^{NS}	23.44**	-3.57**	-8.98^{NS}	-3.60**	-9.60^{NS}	5.06*	0.58^{NS}	23.01**	19.46^{NS}	23.50**	15.28^{NS}	12.94**	10.28**	0.35^{NS}	12.72**	9.83**
P6xP1	8.69*	4.16^{NS}	4.72^{NS}	2.12^{NS}	13.83**	-5.08**	-5.61^{NS}	-6.01**	-7.34^{NS}	5.26**	2.94^{NS}	3.38^{NS}	0.91^{NS}	16.48**	13.75^{NS}	6.47**	8.79**	0.26^{NS}	11.92**	9.63**
P1xP2	14.89**	12.50^{NS}	10.86**	8.51*	27.50**	-3.11**	-3.92^{NS}	-4.29**	-5.64^{NS}	5.65**	4.41^{NS}	33.69**	32.74^{NS}	18.54**	17.57^{NS}	22.07**	4.38**	1.25^{NS}	34.15**	33.19**
P3xP2	14.28**	4.34^{NS}	10.84**	2.22^{NS}	25.95**	-1.21^{NS}	-7.42^{NS}	-1.24^{NS}	-7.55^{NS}	10.64**	3.31^{NS}	9.46**	6.35^{NS}	14.51**	-4.01^{NS}	6.97**	18.27**	7.23**	11.03**	7.69**
P4xP2	16.27**	8.69^{NS}	11.62**	6.66^{NS}	29.79**	-2.00^{NS}	-2.28^{NS}	-2.89*	-3.44^{NS}	9.46**	4.51^{NS}	4.04^{NS}	1.35^{NS}	20.19**	11.65^{NS}	16.27**	19.52**	10.76**	8.74**	6.02**
P5xP2	18.18**	13.04^{NS}	9.70**	8.88*	29.57**	-0.90^{NS}	-5.71^{NS}	-0.91^{NS}	-5.81^{NS}	8.24**	4.81^{NS}	7.01**	4.66^{NS}	21.41**	14.20^{NS}	23.54**	15.25**	7.90**	12.50**	10.39**
P6xP2	11.11*	8.69^{NS}	7.06**	6.66^{NS}	19.16**	-3.70**	-3.97^{NS}	-4.06**	-4.06^{NS}	8.98**	7.83^{NS}	2.84^{NS}	1.10^{NS}	14.81**	13.03^{NS}	16.27**	7.23**	1.80*	13.59**	12.05**
P1xP3	11.62*	0.00^{NS}	11.37**	0.70^{NS}	22.87**	-0.30^{NS}	-7.30^{NS}	-1.52^{NS}	-9.03^{NS}	13.05**	4.41^{NS}	7.27**	3.50^{NS}	23.35**	2.70^{NS}	0.70**	14.25**	0.98^{NS}	5.74*	1.84^{NS}
P2xP3	14.28**	4.34^{NS}	10.84**	2.22^{NS}	25.95**	-1.21^{NS}	-7.42^{NS}	-1.24^{NS}	-7.55^{NS}	10.64**	3.31^{NS}	9.46**	6.35^{NS}	19.83**	0.44^{NS}	6.97**	18.27**	7.23****	11.03**	7.69**
P4xP3	12.82*	10.00^{NS}	11.39**	7.31^{NS}	29.79**	3.36**	-2.87^{NS}	1.85^{NS}	-5.17^{NS}	7.11**	4.63^{NS}	5.19*	4.91^{NS}	23.84**	10.73^{NS}	18.23**	26.87**	23.88**	8.47**	7.87**
P5xP3	25.00**	19.07*	14.17**	6.05^{NS}	29.57**	-1.60^{NS}	-3.16^{NS}	-1.63^{NS}	-3.22^{NS}	12.18**	8.03^{NS}	4.59^{NS}	3.90^{NS}	28.40**	13.47^{NS}	25.42**	15.70**	11.79**	10.60**	9.28**
P6xP3	12.19*	4.54^{NS}	12.90**	4.47^{NS}	19.16**	-1.51^{NS}	-7.95^{NS}	-0.62^{NS}	-6.97^{NS}	12.88**	6.46^{NS}	5.10*	3.85^{NS}	19.67**	1.60^{NS}	9.57**	16.81**	11.35**	7.60**	5.76**
P1xP4	18.18**	8.33^{NS}	8.33**	1.41^{NS}	22.87**	-2.27*	-3.37^{NS}	-3.70**	-4.51^{NS}	7.16**	1.17^{NS}	4.92*	1.50^{NS}	21.25**	11.79^{NS}	9.75**	11.97**	0.89^{NS}	8.78**	5.32**
P2xP4	16.27**	8.69^{NS}	11.62**	6.66^{NS}	25.95**	-2.00^{NS}	-2.28^{NS}	-2.89*	-3.44^{NS}	9.46**	4.51^{NS}	4.04^{NS}	1.35^{NS}	20.19**	11.65^{NS}	16.27**	12.23**	4.00**	8.74**	6.02**
P3xP4	12.82*	10.00^{NS}	11.39**	7.31^{NS}	25.61**	3.36**	-2.87^{NS}	1.85^{NS}	-5.17^{NS}	7.11**	4.63^{NS}	5.19*	4.91^{NS}	23.84**	10.73^{NS}	18.23**	14.51**	11.83**	11.55**	10.94**
P5xP4	17.07**	14.28^{NS}	10.15**	6.01^{NS}	41.70**	1.80^{NS}	-2.87^{NS}	0.30^{NS}	-5.17^{NS}	12.56**	10.93**	9.03**	8.59^{NS}	31.20**	29.47^{NS}	20.51**	15.34**	14.08**	9.56**	8.85**
P6xP4	9.52*	4.54^{NS}	8.17**	3.73^{NS}	26.36**	-1.14^{NS}	-1.70^{NS}	-1.73^{NS}	-2.29^{NS}	14.19**	10.15*	3.93^{NS}	2.98^{NS}	24.39**	17.27^{NS}	8.55**	12.94**	10.19**	9.83**	8.54**
P1xP5	15.55**	8.33^{NS}	7.29**	4.25^{NS}	27.30**	-3.57**	-8.98^{NS}	-3.61**	-9.60^{NS}	5.06*	0.58^{NS}	23.01**	19.46^{NS}	23.50**	15.28^{NS}	12.94**	11.26**	1.25^{NS}	12.72**	9.83**
P2xP5	18.18**	13.04^{NS}	9.70**	8.88*	29.79**	-0.90^{NS}	-5.71^{NS}	-0.91^{NS}	-5.81^{NS}	8.24**	4.81^{NS}	7.01**	4.66^{NS}	21.41**	14.20^{NS}	23.54**	13.93**	6.66**	12.50**	10.39**
P3xP5	25.00**	19.04*	14.17**	6.01^{NS}	25.61**	-1.60^{NS}	-3.16^{NS}	-1.63^{NS}	-3.22^{NS}	12.18**	8.03^{NS}	4.59^{NS}	3.90^{NS}	28.40**	13.47^{NS}	25.42**	18.98**	14.95**	10.60**	9.28**
P4xP5	17.07**	14.28^{NS}	10.15**	6.01^{NS}	28.69**	1.80^{NS}	-2.87^{NS}	0.30^{NS}	-5.17^{NS}	12.56**	10.93**	9.03**	8.59^{NS}	31.20**	29.47^{NS}	20.51**	18.43**	17.13**	9.56**	8.85**
P6xp5	16.27**	13.63^{NS}	6.36*	5.97^{NS}	18.51**	-3.59**	-8.52^{NS}	-3.36**	-8.13^{NS}	12.57**	10.15*	5.55*	5.00^{NS}	23.21**	17.64^{NS}	20.57**	13.24**	11.67**	5.90**	5.34**
P1xP6	8.69*	4.16^{NS}	4.72^{NS}	2.12^{NS}	23.44**	-5.08**	-5.61^{NS}	-6.01**	-7.34^{NS}	5.26**	2.94^{NS}	3.38^{NS}	0.91^{NS}	16.48**	13.75^{NS}	6.47**	14.03**	5.10**	11.92**	9.63**
P2xP6	11.11*	8.69^{NS}	7.06**	6.66^{NS}	29.57**	-3.70**	-3.97^{NS}	-4.06**	-4.06^{NS}	9.98**	7.83^{NS}	2.84^{NS}	1.10^{NS}	14.81**	13.03^{NS}	16.27**	7.53**	2.00*	13.59**	12.05**
P3xP6	12.19*	4.54^{NS}	11.29**	2.98^{NS}	41.70**	-1.51^{NS}	-7.95^{NS}	-0.62^{NS}	-6.97^{NS}	12.88**	6.46^{NS}	5.10*	3.85^{NS}	18.18**	0.34^{NS}	7.94**	15.47**	10.08**	7.60**	5.76**
P4xP6	9.52*	4.54^{NS}	8.17**	3.73^{NS}	28.69**	-1.14^{NS}	-1.70^{NS}	-1.73^{NS}	-2.29^{NS}	14.19**	10.15*	3.93^{NS}	2.98^{NS}	24.39**	17.27^{NS}	8.55**	12.40**	9.66**	9.83**	7.54**
P5xP6	16.27**	13.63^{NS}	6.36*	5.97^{NS}	23.46**	-3.59**	-8.52^{NS}	-3.36**	-8.13^{NS}	12.57**	10.15*	5.55*	5.00^{NS}	23.21**	17.64^{NS}	20.57**	14.42**	12.84**	5.90*	5.34**

*significant at α 0.05; **significant at α 0.01; ^{NS} Non significant

EV-5098 x AGAITI-2002 (Table 3). The degree of increase over mid parent ranged from +5.74% (AGAITI-2002 × EV-5098, EV-5098 × AGAITI-2002) to +34.15% (EV-6098 × EV-5098, EV-5098 × EV-6098) and increase over better parent ranged from +1.84% (EV-5098 × AGAITI-2002, AGAITI-2002 × EV-5098) to +33.19% (EV-6098 × EV-5098, EV-5098 × EV-6098). Similar to the result under un-inoculated growth condition, all the hybrids excluding three i.e., AGAITI-2002 × EV-5098, SADAF × EV-5098 and EV-5098 × AGAITI-2002 showed significant highly significant heterosis and heterobeltiosis (Table 4). The

Table 3: Hetrotic and hetrobeltiotic effects on various parameters in 6×6 F1 diallel cross of *Zea mays* L. in F_1 generation for the year 2010 under inoculated condition

Hybrids	Kernel rows/ear		Kernels/rows		Kernels/ear		1000-grain weight		Grain yield per plant		Days to 50%silking		Days to 50% tasseling		Cob height		Cob Diameter		Cob Length	
	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %
P2xP1	23.07**	20.00**	29.72**	21.52**	60.37**	46.67**	8.54**	6.36**	36.56**	34.44**	-6.40**	-7.18 NS	-9.29**	-10.55 NS	5.30*	4.24 NS	37.93**	36.50 NS	19.22**	15.45 NS
P3xP1	16.66 NS	5.00 NS	77.61**	50.63**	102.68**	57.49**	9.00**	1.42 NS	10.62**	1.77 NS	-3.85**	-10.49 NS	-6.90**	-13.88*	12.10**	4.24 NS	19.25**	7.33 NS	13.28*	1.30 NS
P4xP1	18.91*	10.00 NS	22.85*	8.86 NS	45.93*	20.83**	10.69**	3.50**	9.46**	1.55 NS	-5.58**	-6.62 NS	-8.68**	-9.44 NS	7.56**	1.10 NS	14.90**	5.33 NS	19.30**	9.94 NS
P5xP1	10.52 NS	5.00 NS	44.05**	30.37**	57.54**	36.62**	8.86**	3.63**	16.31**	9.77**	-7.01**	-12.15*	-8.87**	-14.44*	5.19*	0.52 NS	29.73**	23.25 NS	20.19**	13.27 NS
P6xP1	10.52 NS	5.00 NS	47.58**	35.44**	61.39**	40.41**	7.36**	3.11**	17.85**	12.22**	-8.33**	-8.83 NS	-10.98**	-12.22 NS	4.61*	2.81 NS	6.52 NS	4.75 NS	16.34**	11.81 NS
P1xP2	23.07**	20.00**	29.72**	21.51**	60.37**	46.67**	8.54**	6.36**	37.68**	35.55**	-6.40**	-7.18 NS	-8.73**	-10.00 NS	5.41*	4.36 NS	36.75**	35.33 NS	19.78**	15.99 NS
P3xP2	20.00*	10.52 NS	30.64**	17.37*	55.55**	29.74**	9.98**	4.33**	15.47**	7.79**	-4.79**	-10.67 NS	-6.70**	-12.57 NS	9.59**	2.87 NS	22.15**	10.97 NS	13.10 NS	4.16 NS
P4xP2	33.33**	26.31**	18.46 NS	11.59 NS	55.81**	39.58**	11.85**	6.63**	13.27**	6.65**	-5.35**	-5.61 NS	-7.95**	-8.47 NS	9.64**	4.04 NS	14.48*	5.95 NS	21.44**	15.38 NS
P5xP2	18.91*	15.78**	23.30*	18.84**	43.68*	35.46**	14.00**	10.69**	17.84**	12.84**	-4.42**	-8.98 NS	-6.20**	-10.85 NS	8.12**	4.33 NS	13.88*	9.27 NS	21.29**	17.93 NS
P6xP2	24.32**	21.05**	46.66**	43.47**	82.10**	72.31**	7.87**	5.68**	19.33**	15.36**	-7.00**	-7.26 NS	-9.14**	-9.14 NS	8.04**	7.25 NS	6.38	5.70 NS	17.61**	16.76 NS
P1xP3	16.66 NS	5.00 NS	37.31**	16.45**	56.04**	21.25**	9.00**	1.42 NS	10.86**	2.00 NS	-3.85**	-10.49 NS	-6.30**	-13.33*	12.23**	4.36 NS	17.96**	6.16 NS	13.88*	1.84 NS
P2xP3	25.71**	15.78**	62.90**	46.34**	104.39**	70.48**	9.98**	4.33**	17.93**	10.09**	-4.79**	-10.67 NS	-6.09**	-12.00 NS	9.72**	2.99 NS	20.84**	9.78 NS	8.92 NS	0.31 NS
P4xP3	27.27**	23.52**	46.55**	39.34**	87.14**	72.54**	12.07**	11.49**	19.00**	17.92**	-0.30 NS	-6.21 NS	-3.63*	-10.16 NS	7.02**	5.80 NS	24.79**	22.30 NS	13.37 NS	9.70 NS
P5xP3	23.52**	16.66**	68.06**	56.25**	106.77**	81.39**	13.17**	10.48**	20.97**	17.79**	-5.36**	-6.83 NS	-7.39**	-8.86 NS	11.58**	8.43*	19.70**	13.05 NS	16.14**	9.83 NS
P6xP3	23.52**	16.66**	45.45**	33.33**	80.05**	57.43**	11.37**	7.75**	18.47**	14.25**	-5.07**	-11.17 NS	-6.09**	-12.00 NS	11.39**	5.28 NS	16.32**	6.29 NS	8.51	0.65 NS
P1xP4	18.91*	10.00 NS	64.28**	45.56**	92.66**	59.58**	10.69**	3.50**	11.61**	3.55**	-5.58**	-6.62 NS	-8.12**	-8.88 NS	7.68**	1.21 NS	13.63*	4.16 NS	19.88**	10.48 NS
P2xP4	16.66 NS	10.52 NS	24.61*	17.39*	44.06*	29.09**	11.85**	6.63**	12.54**	5.96**	-5.37**	-5.6 NS NS	-7.38**	-7.90 NS	9.76**	4.16 NS	13.19*	4.76 NS	22.05**	15.96 NS
P3xP4	33.33**	29.41**	51.72**	44.26**	101.25**	85.54**	12.07**	11.49**	18.21**	17.14**	-0.30 NS	-6.2 NS NS	-3.03*	-9.60 NS	7.15**	5.93 NS	23.36**	20.90 NS	14.03*	10.34 NS
P5xP4	25.71**	22.22**	40.80**	37.50**	75.71**	66.408**	15.66**	13.50**	15.56**	13.53**	-1.77 NS	-6.21 NS	-5.07**	-10.16 NS	13.21**	11.25**	22.50**	17.96 NS	27.74**	24.74 NS
P6xP4	31.42**	27.77**	81.10**	74.24**	142.66**	128.97**	13.56**	10.43**	21.46**	18.18**	-4.49**	-5.02 NS	-6.81**	-7.34 NS	13.90**	8.84*	13.24*	5.43 NS	24.54**	19.21 NS
P1xP5	21.05**	15.00**	51.04**	36.70**	81.40**	57.30**	8.86**	3.63**	12.13**	5.77**	-7.01**	-12.15*	-8.28**	-13.88*	5.31*	0.64 NS	28.50**	22.08 NS	20.77**	13.81 NS
P2xP5	13.51 NS	10.52 NS	12.78 NS	8.69 NS	26.69 NS	19.45**	14.00**	10.69**	16.88**	11.92**	-4.42**	-8.98 NS	-5.70**	-10.28 NS	8.24**	4.45 NS	12.63*	8.08 NS	21.89**	18.51 NS
P3xP5	29.41**	22.22**	86.55**	73.43**	142.12**	112.40**	13.17**	10.48**	21.23**	18.04**	-5.36**	-6.83 NS	-6.75**	-8.22 NS	11.71**	8.55*	18.33**	11.75 NS	16.79**	10.44 NS
P4xP5	25.71**	22.22**	52.00**	48.43**	91.81**	81.65**	15.66**	13.50**	20.15**	18.04**	-1.77 NS	-6.21 NS	-4.47**	-9.60 NS	13.38**	11.38**	21.15**	16.66 NS	28.36**	25.35 NS
P6xp5	16.66 NS	16.66**	53.84**	51.51**	81.72**	81.02**	13.45**	12.41**	15.63**	14.49**	-7.05**	-11.73*	-8.70**	-13.14*	11.99**	8.84*	11.25*	7.41 NS	22.04**	19.57 NS
P1xP6	10.52 NS	5.00 NS	51.72**	39.24**	67.93**	46.11**	7.36**	3.11**	15.51**	10.00**	-8.33**	-8.83 NS	-10.42**	-11.66 NS	4.73*	2.93 NS	5.33 NS	3.58 NS	16.90**	12.35 NS
P2xP6	13.5 1 NS	10.52 NS	52.59**	49.27**	75.33**	65.90**	7.87**	5.68**	17.67**	13.76**	-7.00**	-7.26 NS	-8.57**	-8.57 NS	8.16**	7.37 NS	5.18	4.51 NS	8.25 NS	17.33 NS
P3xP6	29.41**	22.22**	65.28**	51.51**	115.83**	88.71**	11.37**	7.75	17.70**	13.51**	-5.07**	-11.17*	-5.48**	-11.42 NS	11.52**	5.40 NS	15.00**	5.08 NS	9.14 NS	1.23 NS
P4xP6	31.42**	27.77**	41.73**	36.36**	88.04**	77.43**	13.56**	10.43	20.70**	17.44**	-4.49**	-5.02 NS	-6.25**	-6.77 NS	14.03**	8.96*	11.94*	4.22 NS	25.15**	19.79 NS
P5xP6	16.66 NS	16.66**	44.61**	42.42**	69.36**	68.71**	13.45**	12.41	14.64**	13.51**	-7.05**	-11.73*	-8.10**	-12.57 NS	12.11**	8.96*	10.00 NS	6.20 NS	22.64**	20.15 NS

*significant at α 0.05; **significant at α 0.01; NS Non significant

degree of increase over mid parent ranged from +9.46% (SADAF × EV-5098) to +37.68% (EV-5098 × EV-6098) and increase over better parent ranged from +1.55% (SADAF × EV-5098) to +34.44% (EV-6098 × EV-5098). The inoculation of *F. moniliforme* didn't affect the heterosis results for grain yield since all the crosses showed significant heterosis at $P \leq 0.01$. All crosses except EV-5098 × AGAITI-2002 also showed significant heterobeltiosis. The cross SADAF × EV-5098 showed minimum increase (+ 9.54%) and EV-6098 × EV-5098 showed maximum heterosis (+39.95%) over mid parent. The minimum and maximum increase over better parent was + 4.96% (SADAF × EV-5098) and + 38.37% (EV-6098 × EV-5098), respectively (Table 5).

Table 4: Hetrotic and hetrobeltiotic effects on various parameters in 6×6 F1 diallel cross of *Zea mays* L. in F_1 generation for the year 2011 under uninoculated condition.

Hybrids	Kernel rows/ ear		Kernels/rows		Kernels/ear		1000-grain weight		Grain yield per plant		Days to 50%silking		Days to 50% tasseling		Cob height		Cob Diameter		Cob Length	
	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %
P2xP1	11.91**	11.34 NS	22.30**	20.45**	36.80**	33.98**	10.09**	8.94**	31.73**	28.76**	-10.42**	-12.15*	-16.27**	-16.76**	28.28**	13.37 NS	56.13**	47.48 NS	23.52**	22.25 NS
P3xP1	9.89*	3.09 NS	24.67**	9.09 NS	35.65**	12.35**	17.37**	7.32**	11.11**	-1.17 NS	-6.58**	-13.81*	-6.54**	-13.29*	72.32**	12.20 NS	36.14**	11.31 NS	27.85**	12.80 NS
P4xP1	11.82**	7.21 NS	25.10**	11.36*	39.07**	19.38**	14.58**	7.99**	10.94**	2.15 NS	-6.04**	-6.55 NS	-6.62**	-6.89 NS	46.55**	5.23 NS	21.67*	6.47 NS	22.02**	16.68 NS
P5xP1	10.05*	7.21 NS	25.40**	15.90**	37.48**	24.15**	8.22**	3.23**	13.16**	6.47**	0.58 NS	-5.52 NS	-1.51 NS	-6.35 NS	86.63**	44.76**	37.74**	22.20 NS	23.77**	21.21 NS
P6xP1	5.26 NS	3.09 NS	18.57**	13.63**	24.47**	16.94**	7.86**	3.71**	10.03**	6.26**	-11.17**	-12.15*	-4.98**	-6.35 NS	25.08**	5.81 NS	17.91*	8.89 NS	18.77**	17.46 NS
P1xP2	11.91**	11.34 NS	19.23**	17.42**	33.36**	30.61**	10.38**	9.22**	30.73**	27.78**	-10.42**	-12.15*	-14.53**	-15.02*	76.31**	55.81**	92.76**	82.09 NS	23.36**	27.03 NS
P3xP2	6.07 NS	00 NS	26.87**	12.50*	33.54**	12.50**	9.15**	0.77	18.73**	7.78**	-6.42**	-12.09*	-4.07**	-10.52 NS	131.52**	61.36**	70.63**	46.25 NS	15.54**	2.87 NS
P4xP2	8.10 NS	4.16 NS	29.87**	17.18**	39.59**	21.97**	19.85**	14.09**	12.85**	6.14**	-13.16**	-15.30**	-7.82**	-8.62 NS	131.88**	81.81**	44.94**	33.60 NS	22.23**	18.07 NS
P5xP2	10.63*	8.33 NS	27.50**	19.53**	40.58**	29.39**	15.38**	11.17**	15.29**	10.45**	2.70 NS	-1.72 NS	-.0.91 NS	-5.26 NS	103.57**	72.72**	38.36**	38.77 NS	20.42**	19.15 NS
P6xP2	5.82 NS	4.16 NS	20.48**	17.18**	27.37**	22.07**	8.05**	4.15**	13.48**	12.09**	-4.27**	-5.08 NS	-7.96**	-8.77 NS	91.23**	81.81**	23.34**	20.40 NS	17.88**	17.80 NS
P1xP3	12.08**	5.15 NS	21.21**	6.06	34.57**	11.47**	17.68**	7.61**	22.77**	9.19**	-4.79**	-12.15*	-14.01**	-20.23**	130.35**	50.00**	63.52**	33.69 NS	30.20**	14.87 NS
P2xP3	8.28 NS	2.08 NS	23.34**	9.37	32.67**	11.76**	20.52**	11.27**	17.60**	6.76**	-4.58**	-10.34 NS	-9.71**	-15.78*	208.69**	115.15**	80.15**	54.42 NS	19.58**	6.47 NS
P4xP3	5.74 NS	3.37 NS	36.67**	33.98**	44.53**	38.47**	24.48**	20.53**	21.01**	16.51**	-3.57**	-11.47*	-5.59**	-12.62*	296.85**	236.00**	46.72**	35.48 NS	20.02**	10.29 NS
P5xP3	12.99**	8.69 NS	33.64**	25.89**	50.29**	36.35**	13.42**	8.49**	21.65**	14.9**8	7.69**	5.66 NS	4.60**	1.92 NS	165.27**	107.60**	60.51**	46.09 NS	18.16**	6.20 NS
P6xP3	7.84 NS	3.22 NS	25.45**	14.04**	33.90**	16.96**	15.15**	9.27**	15.10**	5.67**	1.81 NS	-5.04 NS	0.63 NS	-5.35 NS	194.73**	111.76**	36.32**	19.28 NS	15.96**	3.30 NS
P1xP4	11.82**	7.21 NS	21.70**	8.33 NS	35.04**	15.91**	7.62**	1.42 NS	9.88**	1.17 NS	-8.79**	-9.28 NS	-8.93**	-9.19 NS	111.33**	51.74**	50.98**	32.12 NS	28.51**	22.89 NS
P2xP4	8.10 NS	4.16 NS	26.40**	14.06**	35.79**	18.65**	10.05**	4.76**	11.76**	5.12**	-4.20**	-6.55 NS	-6.08**	-6.89 NS	120.29**	72.72**	52.02**	40.13 NS	28.00**	23.64 NS
P3xP4	10.34*	7.86 NS	32.67**	30.09**	46.02**	39.90**	12.82**	9.24**	19.80**	15.34**	-5.35**	-13.11*	-6.83**	-13.79*	322.04**	257.33**	80.78**	66.93 NS	31.74**	21.06 NS
P5xP4	6.07 NS	4.34 NS	31.16**	25.89**	38.70**	31.01**	12.10**	10.69**	16.76**	14.54**	-5.26**	-11.47*	-5.45**	-10.34 NS	116.76**	96.37**	45.23**	42.96 NS	25.00**	21.99 NS
P6xP4	5.49 NS	3.22 NS	29.46**	19.83**	36.24**	23.67**	10.42**	8.14**	13.90**	8.40**	-1.6 NS	-3.27 NS	-3.50*	-5.17 NS	135.05**	91.59**	32.57**	25.00 NS	25.49**	21.29 NS
P1xP5	10.05*	7.21 NS	22.13**	12.87**	33.64**	20.69**	13.61**	8.37**	12.52**	5.47**	-1.17 NS	-7.18 NS	-1.51 NS	-6.35 NS	84.84**	41.86**	69.79**	50.63 NS	29.19**	26.52 NS
P2xP5	10.63*	8.33 NS	24.16**	16.40**	36.97**	26.07**	15.68**	11.46**	14.22**	9.42**	-2.70 NS	-6.89 NS	-1.52 NS	-5.84 NS	91.96**	62.87**	52.00**	42.17 NS	28.70**	27.34 NS
P3xP5	12.99**	8.69 NS	29.85**	22.32**	46.71**	33.10**	17.04**	11.94**	20.47**	13.87**	1.92 NS	0.00 NS	2.63 NS	0.00 NS	248.61**	172.82**	79.57**	63.43 NS	26.27**	13.49 NS
P4xP5	6.07 NS	4.34 NS	27.44**	22.32**	34.76**	27.29**	12.42**	11.00**	15.62**	13.42**	-7.01**	-13.11*	-3.63*	-8.62 NS	198.20**	170.65**	71.42**	68.75 NS	30.58**	27.39 NS
P6xp5	8.10 NS	7.52 NS	27.03**	22.31**	37.24**	31.55**	10.49**	9.58**	8.55**	5.25**	0.00 NS	-5.08 NS	0.00 NS	-3.57 NS	146.44**	118.48**	35.07**	29.28 NS	21.57**	20.37 NS
P1xP6	7.36 NS	5.15 NS	15.41**	10.60**	23.63**	16.15**	17.07**	12.55**	9.01**	5.28**	-9.49**	-10.49 NS	-15.54**	-16.76**	82.81**	54.65**	39.53**	28.85 NS	26.35**	24.96 NS
P2xP6	5.82 NS	4.16 NS	17.26**	14.06**	24.00**	18.84**	5.05**	2.04*	12.44**	11.06**	-2.56 NS	-3.38 NS	-6.19**	-7.07 NS	154.81**	141.66**	44.94**	41.49 NS	25.44**	25.36 NS
P3xP6	7.86 NS	3.22 NS	21.81**	10.74*	31.82**	15.15**	15.48**	9.58**	13.95**	4.62*	-9.09**	-15.28**	-12.65**	-17.85**	161.98**	88.23**	75.67**	53.71 NS	23.68**	10.18 NS
P4xP6	9.89*	7.52 NS	25.89**	16.52**	38.00**	25.27**	10.73**	8.45**	12.80**	7.35**	-11.66**	-13.11*	-10.52**	-12.06 NS	165.97**	116.80**	53.78**	45.00 NS	28.50**	24.20 NS
P5xP6	8.10 NS	7.52 NS	23.60**	19.00**	33.24**	27.72**	12.37**	11.44**	7.47**	4.20*	0.00 NS	-5.08 NS	-1.85 NS	-5.35 NS	107.58**	84.03**	58.20**	51.48 NS	27.58**	26.32 NS

*significant at α 0.05; **significant at α 0.01; NS Non significant

Days to 50% Silking

Fifteen and twenty-six F_1 hybrids showed significant negative heterosis in season I and II under un-inoculated condition (Table 3). The heterosis for days to 50% silking ranged from -0.30% (EV-5098 × AGAITI-2002, AGAITI-2002 × EV-5098) to -5.08% (SAHIWAL-2002 × EV-5098). The extent of heterobeltiosis was from -1.70 (SAHIWAL-2002 × SADAF) to -9.98 (AKBAR × EV-5098) (Table 3).

The crosses SAHIWAL-2002 × SADAF (-5.02) was also least and AKBAR × EV-5098, EV-5098 × AKBAR (-12.15) were highest performer over better parent, respectively (Table 5). The heterosis results in season-I under inoculation were similar to those under un-inoculated condition. The cross AKBAR × EV-5098 showed minimum heterosis (+0.58%), while SADAF × EV-6098 showed maximum heterosis (-13.16%; Table 4).

Days to 50% Tasselling

Fourteen and thirty F1 crosses were significantly heterotic in season I and II, respectively under un-inoculated condition. The degree of decrease in days to 50% tasselling ranged from -3.63% (EV-5098 × SAHIWAL-2002) to -10.98%

Table 5: Hetrotic and hetrobeltiotic effects on various parameters in 6×6 F1 diallel cross of *Zea mays* L. in F_1 generation for the year 2011 under inoculated condition

Hybrids	Kernel rows/ cob		Kernels/rows		Kernels/cob		1000-grain weight		Grain yield per plant		Days to 50%silking		Days to 50% tasseling		Cob height		Cob Diameter		Cob Length	
	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %	Het (M.P) %	Het (B.P) %
P2xP1	33.33**	29.41**	3.07 NS	1.51 NS	36.40*	30.40**	10.37**	10.22**	39.00**	38.37**	-12.35	-12.15*	-16.27**	28.28**	5.30*	4.24 NS	4.66**	1.52*	19.22**	33.19**
P3xP1	44.82**	23.52*	47.96**	37.87**	112.27**	70.66**	9.69**	5.17**	12.01**	5.19*	-8.65**	-13.81*	-6.54**	72.32**	12.10**	4.24 NS	13.95**	0.53 NS	13.28*	1.84 NS
P4xP1	46.66**	29.41**	40.80**	33.33**	104.43**	72.00**	11.06**	7.30**	9.54**	4.96*	-6.40**	-6.55 NS	-6.62**	46.55**	7.56**	1.10 NS	11.67**	0.62 NS	19.30**	5.32**
P5xP1	29.03**	17.64 NS	54.33**	48.48**	97.87**	74.13**	9.25**	7.43**	16.33**	13.31**	2.08 NS	-5.52 NS	-1.51 NS	86.63**	5.19*	0.52 NS	10.28**	0.35 NS	20.19**	9.83**
P6xP1	31.25**	23.52*	47.28**	43.93**	94.48**	78.66**	7.83**	6.90**	17.79**	15.80**	-6.51**	-12.15*	-4.98**	25.08**	4.61*	2.81 NS	8.79**	0.26 NS	16.34**	9.63**
P1xP2	39.39**	35.29**	44.61**	42.42**	101.39**	92.53**	10.77**	10.62**	37.86**	37.24**	-14.4**	-12.15*	-14.53**	76.31**	5.41*	4.36 NS	4.38**	1.25 NS	19.78**	33.19**
P3xP2	28.57**	12.50 NS	43.80**	35.93**	82.80**	52.33**	8.46**	4.12**	15.45**	8.88**	-6.30**	-12.09*	-4.07**	131.52**	9.59**	2.87 NS	18.27**	7.23**	13.10 NS	7.69**
P4xP2	31.03**	18.75 NS	44.71**	39.06**	85.95**	62.57**	9.97**	6.39**	11.95**	7.74**	-15**	-15.30**	-7.82**	131.88**	9.64**	4.04 NS	19.52**	10.76**	21.44**	6.02**
P5xP2	40.00**	31.25**	15.20 NS	12.50 NS	60.44**	47.07**	12.10**	10.38**	16.41**	13.89**	2.70*	-1.72 NS	-.0.91 NS	103.57**	8.12**	4.33 NS	15.25**	7.90**	21.29**	10.39**
P6xP2	54.83**	50.00**	32.28**	31.25**	103.65**	95.32**	6.23**	5.45**	17.87**	16.40**	-4.2*	-5.08 NS	-7.96**	91.23**	8.04**	7.25 NS	7.23**	1.80*	17.61**	12.05**
P1xP3	51.72**	29.41**	69.10**	57.57**	154.06**	104.26**	10.11**	5.57**	10.81**	4.06 NS	-6.86**	-12.15*	-14.01**	130.35**	12.23**	4.36 NS	14.25**	0.98 NS	13.88*	1.84 NS
P2xP3	42.85**	25.00*	57.02**	48.43**	121.05**	84.21**	8.87**	4.52**	16.42**	9.79**	-6.30**	-10.34 NS	-9.71**	208.69**	9.72**	2.99 NS	18.27**	7.23**	8.92 NS	7.69**
P4xP3	68.00**	61.53**	48.27**	45.76**	150.00**	136.32**	8.82**	7.97**	16.22**	13.79**	-5.35**	-11.47*	-5.59**	296.85**	7.02**	5.80 NS	26.87**	23.88**	13.37 NS	7.87**
P5xP3	69.23**	57.14**	35.59**	31.14**	129.24**	106.31**	9.93**	7.14**	18.17**	13.80**	3..84**	5.66 NS	4.60**	165.27**	11.58**	8.43*	15.70**	11.79**	16.14**	9.28**
P6xP3	40.74**	26.66*	66.66**	58.73**	130.62**	99.04**	8.31**	4.72**	15.78**	10.51**	3.63**	-5.04 NS	0.63 NS	194.73**	11.39**	5.28 NS	16.81**	11.35**	8.51	5.76**
P1xP4	46.66**	29.41**	56.80**	48.48**	127.25**	91.20**	11.47**	7.70**	10.48**	5.86**	-8.67**	-9.28 NS	-8.93**	111.33**	7.68**	1.21 NS	11.97**	0.89 NS	19.88**	5.32**
P2xP4	37.93**	25.00*	21.95*	17.18*	69.90**	48.53**	10.39**	6.79**	11.47**	7.28**	-7.67**	-6.55 NS	-6.08**	120.29**	9.76**	4.16 NS	12.23**	4.00**	22.05**	6.02**
P3xP4	52.00**	46.15**	56.89**	54.23**	139.25**	126.17**	9.26**	8.40**	11.94**	9.60**	-7.38**	-13.11*	-6.83**	322.04**	7.15**	5.93 NS	14.51**	11.83**	14.03*	10.94**
P5xP4	48.14**	42.85**	65.00**	62.29**	143.25**	130.83**	12.02**	10.02**	11.62**	9.76**	-5.96**	-11.47*	-5.45**	116.76**	13.21**	11.25**	15.34**	14.08**	27.74**	8.85**
P6xP4	57.14**	46.66**	49.18**	44.44**	135.08**	113.37**	10.12**	7.29**	17.26**	14.25**	-1.69 NS	-3.27 NS	-3.50*	135.05**	13.90**	8.84*	12.94**	10.19**	24.54**	8.54**
P1xP5	29.03**	17.64 NS	57.48**	51.51**	102.12**	77.86**	9.65**	7.83**	11.70**	8.80**	-1.49 NS	-7.18 NS	-1.51 NS	84.84**	5.31*	0.64 NS	11.26**	1.25 NS	20.77**	9.83**
P2xP5	40.00**	31.25**	15.20	12.50	58.21**	45.02**	12.50**	10.78**	15.25**	12.75**	0.90 NS	-6.89 NS	-1.52 NS	91.96**	8.24**	4.45 NS	13.93**	6.66**	21.89**	10.39**
P3xP5	61.53**	50.00**	74.57**	68.85**	179.53**	151.57**	10.35**	7.55**	18.41**	14.04**	0.00 NS	0.00 NS	2.63 NS	248.61**	11.71**	8.55*	18.98**	14.95**	16.79**	9.28**
P4xP5	55.55**	50.00**	51.66**	49.18**	134.75**	122.80**	12.44**	10.43**	14.04**	12.14**	0.00 NS	-13.11*	-3.63*	198.20**	13.38**	11.38**	18.43**	17.13**	28.36**	8.85**
P6xp5	58.62**	53.33**	43.54**	41.26**	128.04**	117.51**	10.08**	9.18**	11.79**	10.74**	-7.14**	-5.08 NS	0.00 NS	146.44**	11.99**	8.84*	13.24**	11.67**	22.04**	5.34**
P1xP6	18.75*	11.76 NS	34.88**	31.81**	59.94**	46.53**	8.23**	7.30**	13.20**	11.28**	-3.03*	-10.49 NS	-15.54**	82.81**	4.73*	2.93 NS	14.03**	5.10**	16.90**	9.63**
P2xP6	29.03**	25.00*	59.05**	57.81**	105.79**	97.36**	6.63**	5.85**	16.72**	15.26**	-9.91**	-3.38 NS	-6.19**	154.81**	8.16**	7.37 NS	7.53**	2.00*	8.25 NS	12.05**
P3xP6	55.55**	40.00**	60.00**	52.38**	148.33**	114.33**	8.73**	5.13**	14.56**	9.34**	-5.58**	-15.28**	-12.65**	161.98**	11.52**	5.40 NS	15.47**	10.08**	9.14 NS	5.76**
P4xP6	35.71**	26.66*	37.74**	33.33**	85.61**	68.44**	10.54**	7.70**	15.34**	12.38**	-10.9**	-13.11*	-10.52**	165.97**	14.03**	8.96*	12.40**	9.66**	25.15**	7.54**
P5xP6	44.82**	40.00**	40.32**	38.09**	103.67**	94.26**	10.49**	9.59**	10.61**	9.57**	-1.81 NS	-5.08 NS	-1.85 NS	107.58**	12.11**	8.96*	14.42**	12.84**	22.64**	5.34**

*significant at α 0.05; **significant at α 0.01; NS Non significant

(SAHIWAL-2002 × EV-5098) over mid parent, and -6.77% (SADAF × SAHIWAL-2002) to -13.88% (AGAITI-2002 × EV-5098, EV-5098 × AGAITI-2002) over better parent (Table 5).

A total of 22 and 24 hybrids showed significant heterosis under inoculated as compared to 14 under un-inoculated condition (Table 3, 4). Similar to the un-inoculated condition none of the hybrid showed significant heterobeltiosis (Table 4). The range of heterosis was from 0.00 (SAHIWAL-2002 × AKBAR) to -16.27% (EV-6098 × EV-5098). The significant negative heterosisunder un-inoculated and inoculated conditions showed that inoculation of *F. moniliforme* reduced numbers of days to 50% tasselling.

Cob Height

For cob height all F_1 hybrids showed highly significant heterosis ($P \leq 0.01$), while 4 showed heterobeltiosis (two at $P \leq 0.05$ and two at $P \leq 0.01$) (Table 3).The heterosis for cob height ranged from +5.05% (EV-5098 × AKBAR) to +13.05% (EV-5098 × AGAITI-2002) and heterobeltiosis ranged from +0.58% (AKBAR × EV-5098, EV-5098 × AKBAR) to +10.93% (SADAF × AKBAR, AKBAR × SADAF) (Table 3). Like the previous year, all the hybrids showed significant heterosis at $P \leq 0.01$. Eight hybrids showed significant heterobeltiosis. The heterosis for cob height ranged from +4.61% (SAHIWAL-2002 × EV-5098) to +14.03% (SADAF × SAHIWAL-2002) and heterobeltiosis ranged from +0.52% (AKBAR × EV-5098) to +11.38% (SADAF × AKBAR; Table 5). The heterosis results in season-I under inoculation were similar to those under un-inoculated condition as all the hybrids showed significant heterosis ($P \leq 0.01$). It was interesting to note that 26 hybrids showed significant heterobeltiosis as compared to 4 in un-inoculated condition (Table 4). The crosses SAHIWAL-2002 × EV-5098, EV-5098 × SAHIWAL-2002 showed minimum heterosis (+25.08%), while AGAITI-2002 × SADAF had maximum heterosis (+ 322.04%; Table 4).

Cob Diameter

A total of 20 and 27 F_1 hybrids showed heterosis in season I and II, respectively, and one of the hybrids exhibited significant heterobeltiosis for cob diameter. The degree of increase over mid parent ranged from +2.84% (EV-6098 × SAHIWAL-2002) to +33.69% (EV-6098 × EV-5098, EV-5098 × EV-6098). All hybrids showed significant heterosis but didn't show heterobeltiosis for cob diameter (Table 4). The degree of increase over mid parent ranged from +17.91% (SAHIWAL-2002 × EV-5098) to +92.76% (EV-5098 × EV-6098).

Cob Length

All the F_1 hybrids showed heterosis at $P \leq 0.01$ in both seasons under un-inoculated condition. However, significant heterobeltiosis was expressed by none of the crosses (Table 3, 4). The degree of increase over mid parent ranged from +14.51% (AGAITI-2002 × EV-6098) to +31.20% (SADAF x AKBAR). Similar to the result under un-inoculated growth condition all hybrids showed significant heterosis but did not also show heterobeltiosis for cob length (Table 4). The degree of increase over mid parent ranged from +15.96% (SAHIWAL-2002 × AGAITI-2002) to +31.74% (AGAITI-2002 × SADAF). The inoculation of *F. moniliforme* didn't affect the heterosis results for cob length because all crosses showed significant heterosis at $P \leq 0.01$ as was the case under normal condition. None of the crosses showed significant heterobeltiosis. The cross AGAITI-2002 × EV-6098 showed minimum increase (+11.12%) and AKBAR × EV-6098 showed maximum heterosis (+ 34.39%) over mid parent (Table 5).

Discussion

The significant mean square for a specific trait indicates the valuable genetic variability for that trait exists among genotypes and that variability can be exploited for breeding improved cultivars. The significant genetic variability for the studied traits have also been previously reported by many researchers using various sets of genotypes (Wattoo *et al*., 2009; Shalim-uddin *et al*., 2006; Ojo *et al*., 2007; Amanullah *et al*., 2011). All F_1 hybrids showing significant heterosis for kernels rows/cob were positive as also observed by Ahmad (1995) who found that all direct crosses were significantly heterotic for kernel rows per cob under un-inoculated condition. Results from un-inoculated and inoculated conditions clearly depicted that inoculation of *F. moniliforme* did not affect the trait of kernels rows per cob negatively; rather, it seemed to be positively correlated with the heterosis in this trait. The positive heterosis in kernels per plant provides the breeders an opportunity to increase number of kernels rows per rows in improved F1 hybrids.

The positive heterosis for kernels per row under un-inoculated condition was also reported by Park *et al.* (1985), Khristova (1990). Ahmad (1995) also found significant heterosis and heterobeltiosis for kernel rows per cob in different sets of F_1 hybrids. Furthermore, the findings of this research are also in agreement with El-Shouny *et al*. (1999), Chen and Xiang (2001), Shahwani *et al.* (2001), Suba *et al.* (2001), Saleh *et al.* (2002), Alvi (2004), Wattoo *et al.* (2009). However, Ahmad (1995) also found negative heterosis only in one hybrid.

These results under inoculated conditions for kernels per row are quite similar to the results under un-inoculated conditions reported by Khristova (1990). Ahmad (1995) also found significant heterosis and heterobeltiosis for kernel rows per cob in different sets of F_1 hybrids. Furthermore, the finding of this research is also in agreement with El-Shouny *et al*. (1999), Chen and Xiang (2001), Shahwani *et al.* (2001), Suba *et al.* (2001), Saleh *et al.* (2002) and Alvi (2004). However, Ahmad (1995) also found negative heterosis only in one hybrid. The crosses AGAITI-2002 x EV-5098 and AGAITI-2002 x AKBAR are useful for developing hybrids with increased kernels per row even under *F. moniliforme* infested soils. The positive and significant heterosis for kernels per cob under un-inoculated condition was also reported by Park *et al*. (1985), Ahmad (1995), El-Shouny *et al*. (1999), Suba *et al.* (2001), Saleh *et al.* (2002) and Alvi (2004).

The positive and significant heterosis for kernels per cob and 1000-graing weight, grain yield per plant under uninoculated condition was also reported by Park *et al*. (1985), Ahmad (1995), El-Shouny *et al*. (1999), Suba *et al.* (2001), Saleh *et al.* (2002) and Alvi (2004. Gupta and Nagda (2000), Saleh *et al.* (2002) and Dickert and Tracy (2002) have reported negative heterosis and heterobeltiosis in various hybrids. The extent and magnitude of heterosis and heterobeltiosis was higher under un-inoculated condition as compared to under inoculated condition, as was the case in other agronomic traits. The similar findings have been reported by Arias and Souza (1998), El-Shouny *et al*. (1999), Saleh *et al*. (2000), and Rafique *et al*. (2011).

The prevalence of significant heterobeltiosis for cob diameter though in one cross shows the preponderance of over dominance in that combination of genes. Similar outcome for cob length have also been reported by El-Shouny *et al*. (1989), Gupta and Ngda (2000), Saleh *et al*. (2002), Dickert and Tracy (2002), Alvi (2004) and Rafique *et al*. (2011). The higher magnitude of heterosis for all traits under un-inoculated condition than that of under inoculated condition indicated the negative influence of *F. moniliforme* infection.

In crux, significant positive heterosis for yield traits and negative heterosis for duration to cropp maturity traits indentified crosses with relatively higher yield and shorter crop maturity period. The inoculation decreased the magnitude of heterosis for all traits. Regarding better yield under un-inoculated and inoculated conditions, hybrids between AKBAR × AGAITI-2002 and AGAITI-2002 × SADAF were the best performer for most of the traits with or without *F. moniliforme* inoculation.

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(Received 27 December 2012; Accepted 13 February 2013)