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REGULAR ARTICLE

HETEROTIC EXPRESSION IN INBREDS DERIVED FROM FOUR DIFFERENT BASE POPULATIONS IN MAIZE (ZEA MAYS L.)

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ABSTRACT

The concepts of combining ability and heterosis are the fundamental tools for enhancing productivity of different crops. The main objective is to study the usefulness of inbreds derived from four different base populations namely advanced generations of single cross hybrids, three way cross hybrids, hybrid mixtures and composites by analyzing the combining ability of inbreds and crosses derived and the heterosis obtained for important characters. One hundred and forty four maize inbreds derived from four different base populations namely advanced generations of single cross hybrids, three way cross hybrids, hybrid mixtures and composites were studied for their heterotic expression. The results indicated that composite and hybrid mixture base populations shall be of great use in deriving genetically divergent inbreds and single cross hybrids with significant standard heterosis suitable for commercial exploitation.

Keywords: Maize, Heterosis, Inbreds

INTRODUCTION

Maize is an extensively investigated crop for combining ability and heterosis breeding. After realizing the advantages of single cross hybrids in maize improvement, the thrust at present has been on this direction. With this reorientation towards breeding of single cross hybrids, it has become imperative now to use diverse source populations for deriving inbreds not only divergent but also heterotic and productive. It is well recognized that the crosses between genetically diverse parents show greater heterosis compared to crosses between closely related parents. The superiority of inbreds directly depend on the presence of desirable genes and gene complexes in the base population [1]. Populations of narrow genetic base have been considered as preferential germplasms in breeding programs compared to open pollinated varieties, since the latter are little improved. Besides single cross hybrids, elite line synthetics/composites, F_2 populations, backcross populations, pools and experimental varieties are also used as source materials [2]. Arshad *et al.* [3] suggested that, for successful breeding program, successful selection of superior genotypes is essential. Usually the breeders select genetically narrow-base types for developing recombination lines from F_2 of commercial single cross hybrids for maize [4]. Though widely followed by maize breeders, the study about the genetic divergence and usefulness of inbreds derived from such narrow-base populations are very limited.

In the development of a desirable hybrid, it is necessary to identify the potential inbred lines which have high combining ability for the characters under consideration in hybrid combinations [5]. The main objective of the present investigation is to assess the combining ability of inbreds and crosses derived and the heterosis obtained for important characters of inbreds derived from four different base populations namely advanced generations of single cross hybrids, three way cross hybrids, hybrid mixtures and composites.

MATERIALS AND METHODS

The material for the study comprised of 144 inbreds originated from different base populations of unknown pedigree *viz.* advanced generations of single cross hybrids, three way cross hybrids, hybrid mixtures and composites. The number of inbreds representing different base populations and their accession number is given in table 1. The experiment was laid in a 12 x 12 simple lattice design with two replications at the RandD Farm, Foliage Crop Solutions Private Limited, Attur, TamilNadu, India. The data were recorded on 19 characters viz., days to 50%

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tasseling, days to 50% silking, anthesis-silking interval, plant height (cm), ear height (cm), number of leaves, leaf length (cm), leaf width (cm), tassel length (cm), number of tassel branches, ear length (cm), ear circumference (cm), number of kernel rows, number of kernels/row, number of kernels/ear, days to maturity, hundred seed weight (g), shelling percentage and grain yield/plant (g). The statistical analysis was carried out using mean values of five plants over two replications for each character.

Based on *per se* performance of 144 inbreds, fifteen lines and four testers were chosen for the studying heterosis. The details of selected inbreds are presented in table 2. The experiment was conducted at the RandD farm, Foliage Crop Solutions Private Limited, Attur, Tamilnadu, India. Fifteen lines, four testers and the sixty hybrids derived by crossing the chosen lines and testers were raised in a randomized block design with three replications. The hybrids were randomized in a separate block and the parents in the adjacent block of the same layout as suggested by Arunachalam [6]. Three commercial hybrids namely 900M Gold, CP 818 and NK 6240 were included as standard checks for comparison and were randomized with the hybrids. Observations were recorded on 10 characters *viz.* days to 50% tasseling, days to 50% silking, days to maturity, ear length (cm), ear circumference (cm), number of kernel rows, number of kernels/row, number of kernels/ear, hundred seed weight(g) and grain yield (tonnes/ha). Line x tester analysis was done using the method suggested by Kempthorne (1957) and heterosis for individual characters was computed by the formulae suggested by Turner (1953) and Hayes *et al.* [7]. Statistical analysis for heterosis was carried out by WINDOSTAT software developed by Indostat services, Hyderabad, India. The mean values of observations on 10 consecutive plants were used for data analysis.

RESULTS

The results of heterosis (%) of 60 hybrids are presented in table 3. Except the cross "FI-113 x FI-109", all the remaining 59 crosses exhibited significant heterosis over mid parent in the preferred negative direction for days to 50 % tasseling. As many as 13 hybrids showed significant heterosis over the best commercial check NK 6240. Of these, "FI-139 x FI-143" was the only hybrid which recorded significant negative heterosis with a magnitude of-6.0% while the remaining 12 hybrids had significant positive heterosis for days to 50% tasseling. The magnitude of standard heterosis for days to 50% tasseling ranged from-6.0 to 9.3%. Fifty nine crosses over mid parent and 58 crosses over better parent exhibited significant negative heterosis for days to 50 % silking. A range of-5.1% to 8.3% standard heterosis was observed over the best commercial check NK 6240. Out of 60 crosses, 14 recorded significant standard heterosis for days to 50% silking, of which in 13 crosses it was in positive direction and in one in the negative direction. The hybrid "FI-139 x FI-143" which recorded significant negative heterosis for days to 50% tasseling was the only hybrid to record significant heterosis in the preferred negative direction.

Among the 60 crosses, 35 crosses exhibited significant negative heterosis over mid parent while six cross combinations showed significant positive heterosis for days to maturity. Of 42 hybrids which had significant heterosis over better parent, 40 were in the negative direction. The heterosis observed over the best commercial check NK 6240 ranged from-4.4 to 14.9. As many as 37 hybrids exhibited significant heterosis over the best check in which six were in the desired negative direction. The cross "FI-139 x FI-142" was the best combination recording negative significant standard heterosis of-4.4% followed by "FI-139 x FI-143" (-4.0%) and "FI-5 x FI-143" (-4.0%). Seventeen hybrids exhibited significantly positive heterosis over the mid parent while 10 hybrids (nine in positive and one in negative direction) showed significant heterosis over the better parent for the character number of kernel rows. The check 900M gold was found to be the best check with highest number of kernel rows. Out of 14 hybrids which had significant heterosis over 900M gold, four hybrids showed heterosis in the positive direction. This included 3 hybrids involving the tester FI-143, *viz.* "FI-54 x FI-143" (27.5%), "FI-5 x FI-143" (17.3%), "FI-101 x FI-143" (13.5%) and another hybrid "FI-127 x FI-142" (13.5%) involving the tester FI-142. The range of standard heterosis observed for number of kernel rows was from-19.4 and 27.5%. Except the cross "FI-139 x FI-142", all the 59 crosses showed significant positive heterosis over mid parent for number of kernels per row. Out of 60 crosses, 55 exhibited significant positive heterosis over the better parent. A heterosis range of-28.3 to 8.3% was recorded over the best check CP 818. However, 17 hybrids exhibited significant negative heterosis over CP 818 and none of the hybrids registered significant positive heterosis.

As many as 42 hybrids exhibited significant heterosis over mid parent for hundred seed weight and it was in the desired positive direction in 41 hybrids and in the negative direction in one hybrid. While 19 hybrids showed significant positive heterosis, it was significantly negative over better parent in 10 hybrids. Out of 35 hybrids showing significant heterosis over the best check CP818, only in three hybrids it was in the positive direction. The hybrids which showed significantly positive standard heterosis were "FI-139 x FI-109" (20.4%), "FI-104 x FI-142" (11.9%) and "FI-104 x FI-109" (10.2%). Among the 60 hybrids under study, 58 showed significant positive heterosis for grain yield over mid parent. Over the better parent, 58 hybrids exhibited significant heterosis out of which 57 were in positive direction and in one it was in negative direction. A range of-63.4 to 14.6% standard heterosis was observed over the best check CP 818. In all, 51 hybrids had significantly negative heterosis over CP 818. In the order of merit, three hybrids *viz.* "FI-24 x FI-142" (14.6%), "FI-54 x FI-109" (14.0%) and "FI-54 x FI-142" (10.8%) exhibited significant positive heterosis for grain yield over the best check CP 818.

Table 1: Details of 144 maize inbreds used for diversity analysis

S. No.	Source population	No. of inbreds	Inbred numbers
1	Advanced generation of Single cross hybrids	7	FI-1, FI-2, FI-3, FI-4, FI-5, FI-6, FI-7
		4	FI-29, FI-30, FI-31, FI-32
		20	FI-33, FI-34, FI-35, FI-36, FI-37, FI-38, FI-39, FI-40, FI-41, FI-42, FI-43, FI-44, FI-45,

	a. Chola b. Ashoka c. SCH 55		FI-46, FI-47, FI-48, FI-49, FI-50, FI-51,FI-52
2	Advanced generation of	4	FI-25, FI-26, FI-27, FI-28
	Three way cross hybrids a. C555 b. TWH 001	17	FI-8, FI-9, FI-10, FI-11, FI-12, FI-13, FI-14, FI-15, FI-16, FI-17, FI-18, FI-19, FI-20, FI-21, FI-22, FI-23, FI-24
3	Hybrid mixtures	62	FI-53, FI-54, FI-55, FI-56, FI-57, FI-58, FI-59, FI-60, FI-61, FI-62, FI-63, FI-64, FI-65, FI-66, FI-67, FI-68, FI-69, FI-70, FI-71, FI-72, FI-73, FI-74, FI-75, FI-76, FI-77, FI-78, FI-79, FI-80, FI-81, FI-82, FI-83, FI-84, FI-85, FI-86, FI-87, FI-88, FI-89, FI-90, FI-91, FI-92, FI-93, FI-94, FI-95, FI-96, FI-97, FI-98, FI-99, FI-100, FI-101, FI-102, FI-103, FI-104, FI-105, FI-106, FI-107, FI-108, FI-109, FI-110, FI-111, FI-112, FI-113, FI-114
4	Composite-CMP001	30	FI-115, FI-116, FI-117, FI-118, FI-119, FI-120, FI-121, FI-122, FI-123, FI-124, FI-125, FI-126, FI-127, FI-128, FI-129, FI-130, FI-131, FI-132, FI-133, FI-134, FI-135, FI-136, FI-137, FI-138, FI-139, FI-140, FI-141, FI-142, FI-143, FI-144

Table 2: Details of fifteen lines and four testers chosen for study

S. No.	Inbred no	Base population	Days to 50% tasseling	Days to 50% silking	Days to maturity	No. of kernel rows	No. of kernels/row	No. of kernels/ear	Hundred seed wt. (g)	Grain yield/plant (g)
		Lines								
1	FI-5	Single cross hybrid	59	61	106	13.2	26.2	344.0	33.0	107.8
2	FI-7	Single cross hybrid	58	59	97	13.0	25.2	327.4	29.7	92.9
3	FI-24	Three way cross hybrid	60	60	102	13.4	21.7	292.3	31.1	89.9
4	FI-49	Single cross hybrid	63	65	104	13.8	27.3	376.8	28.9	102.1
5	FI-54	Hybrid mixture	61	63	97	16.7	25.2	419.8	28.2	101.9
6	FI-59	Hybrid mixture	63	64	102	14.0	26.0	365.3	26.9	93.8
7	FI-101	Hybrid mixture	58	60	96	14.2	20.9	297.0	31.5	86.4
8	FI-104	Hybrid mixture	56	58	101	13.0	27.7	359.6	29.6	113.4
9	FI-113	Hybrid mixture	66	68	128	12.4	24.9	308.2	36.6	94.9
10	FI-114	Hybrid mixture	64	67	118	14.6	23.1	337.4	32.1	90.9
11	FI-127	Composite	58	61	96	11.0	22.5	247.2	33.0	80.2
12	FI-130	Composite	59	60	102	14.4	21.2	305.3	31.8	78.9
13	FI-139	Composite	59	60	95	11.0	21.3	234.5	40.5	88.1
14	FI-141	Composite	61	63	107	13.0	23.7	307.1	31.1	99.8
15	FI-144	Composite	62	65	105	15.2	19.6	297.2	26.8	85.5
		Testers								
1	FI-109	Hybrid mixture	59	61	106	13.0	24.9	323.5	36.8	112.3
2	FI-140	Composite	59	61	97	14.2	23.7	337.7	24.1	74.7
3	FI-142	Composite	59	61	94	13.4	19.7	264.0	35.2	88.5
4	FI-143	Composite	57	59	102	16.2	27.7	452.9	21.1	87.5

Table 3: Heterosis (%) of 60 hybrids over mid parent, better parent and the best commercial check

S. No.	Hybrids	Days to 50% tasseling			Days to 50% silking			Days to maturity			Number of kernel rows		
		Mid Parent	Better Parent	NK 6240	Better Parent	CP 818	NK 6240	Mid Parent	Better Parent	NK 6240	Mid Parent	Better Parent	900M Gold
1	FI-5 x FI-109	-8.5**	-8.5**	0.0	-4.7*	-5.3*	3.9	-2.4	-5.2**	5.1**	13.8*	6.5	-6.8
2	FI-5 x FI-140	-8.4**	-10.0**	2.0	-10.0**	-11.8**	0.6	-10.3**	-11.8**	-2.2	15.4**	13.0*	-1.1
3	FI-5 x FI-142	-9.5**	-12.1**	2.0	-12.5**	-14.9**	-1.3	-10.9**	-12.8**	-3.3*	6.5	4.2	-4.6
4	FI-5 X FI-143	-9.8**	-9.8**	-1.3	-7.0**	-7.0**	1.9	-10.0**	-13.4**	-4.0*	21.3**	10.8*	17.3**
5	FI-7 x FI-109	-10.5**	-12.3**	0.0	-6.7**	-8.5**	3.2	1.4	0.3	6.9**	3.7	-5.1	-12.7*
6	FI-7 x FI-140	-11.4**	-11.7**	0.7	-10.7**	-11.2**	1.3	-5.1**	-5.4**	1.5	6.7	2.0	-6.1
7	FI-7 x FI-142	-12.5**	-13.2**	0.7	-13.2**	-14.4**	-0.6	-7.0**	-7.1**	-1.1	-4.9	-5.1	-12.7*
8	FI-7 x FI-143	-11.6**	-13.5**	-1.3	-9.5**	-10.8**	0.6	-6.8**	-8.5**	-2.5	5.3	-1.6	4.2
9	FI-24 x FI-109	-8.3**	-10.9**	3.3	-5.2**	-7.8**	5.8*	-1.0	-4.8**	7.6**	5.8	-2.3	-11.8*
10	FI-24 x FI-140	-11.1**	-12.1**	2.0	-9.2**	-9.5**	3.9	-4.0**	-6.4**	5.8**	10.9	7.0	-3.4
11	FI-24 x FI-142	-12.1**	-12.1**	2.0	-12.8**	-13.3**	0.6	-7.1**	-9.9**	1.8	-0.2	-0.9	-9.3
12	FI-24 x FI-143	-10.7**	-13.2**	0.7	-9.7**	-11.7**	1.3	-9.2**	-13.5**	-2.2	-0.8	-8.1	-2.6
13	FI-49 x FI-109	-5.3**	-9.0**	8.0**	-4.3*	-7.7**	7.7**	3.2*	1.3	9.8**	12.2*	3.3	-6.1
14	FI-49 x FI-140	-8.6**	-10.7**	6.0**	-7.8**	-8.8**	6.4**	-9.6**	-10.0**	-2.5	2.3	-1.6	-10.6
15	FI-49 x FI-142	-10.2**	-11.2**	5.3*	-10.7**	-11.0**	3.9	-0.7	-1.7	6.5**	3.6	3.2	-5.5
16	FI-49 x FI-143	-6.4**	-10.1**	6.7**	-6.0**	-8.8**	6.4**	-1.0	-3.7*	4.4**	7.6	0.0	5.9
17	FI-54 x FI-109	-5.7**	-6.6**	4.0	-5.5**	-6.9**	3.9	1.6	1.4	6.2**	26.2**	19.9**	1.7
18	FI-54 x FI-140	-7.4**	-8.2**	4.0	-6.8**	-7.9**	5.1*	-5.3**	-6.4**	0.4	21.0**	20.4	2.1
19	FI-54 x FI-142	-8.5**	-10.3**	4.0	-9.3**	-11.1**	3.2	-8.6**	-9.2**	-3.6*	14.4*	10.1	0.8

20	FI-54 x FI-143	-7.6**	-8.4**	2.0	-6.1**	-6.9**	3.9	-6.3**	-7.3**	-2.9	33.7**	20.4	27.5**
21	FI-59 x FI-109	-8.7**	-10.5**	2.0	-5.0**	-5.8**	3.9	4.2**	4.2**	8.7**	6.6	-1.9	-11.0
22	FI-59 x FI-140	-9.1**	-9.4**	3.3	-9.1**	-10.7**	1.9	-0.7	-2.0	5.1**	3.4	-0.5	-9.7
23	FI-59 x FI-142	-9.6**	-10.3**	4.0	-9.4**	-11.6**	2.6	-2.9*	-3.8*	2.2	-1.9	-2.3	-10.6
24	FI-59 x FI-143	-6.9**	-8.8**	4.0	-3.8*	-4.1	5.8*	-6.1**	-6.9**	-2.9	3.0	-4.4	1.3
25	FI-101 x FI-109	-11.0**	-13.3**	0.0	-7.3**	-8.1**	1.3	-0.2	-0.4	4.4**	9.0	-0.9	-7.6
26	FI-101 x FI-140	-12.0**	-12.7**	0.7	-10.3**	-11.8**	0.6	-0.2	-1.4	5.8**	10.0	4.5	-2.5
27	FI-101 x FI-142	-13.0**	-13.2**	0.7	-13.3**	-15.5**	-1.9	-3.8**	-4.4**	1.5	-0.5	-1.4	-8.0
28	FI-101 x FI-143	-12.2**	-14.5**	-1.3	-10.2**	-10.5**	-1.3	-0.4	-1.4	3.3*	14.0**	7.2	13.5*
29	FI-104 x FI-109	-8.6**	-11.0**	2.7	-5.7**	-8.8**	5.8*	4.8**	2.3	12.0**	-0.4	-5.7	-19.4**
30	FI-104 x FI-140	-11.4**	-12.1**	1.3	-9.8**	-10.5**	3.9	-5.0**	-6.0**	2.9	2.6	1.7	-13.1*
31	FI-104 x FI-142	-9.5**	-9.8**	4.7*	-11.1**	-11.1**	3.2	-5.9**	-7.3**	1.5	-1.3	-4.6	-12.7*
32	FI-104 x FI-143	-11.0**	-13.3**	0.0	-9.1**	-11.6**	2.6	-5.3**	-8.3**	0.4	8.9	-1.6	4.2
33	FI-113 x FI-109	-2.7**	-4.7*	8.7**	-2.0	-4.0	8.3**	7.2**	5.4**	13.8**	6.8	-2.3	-10.1
34	FI-113 x FI-140	-7.9**	-8.2**	4.7*	-7.9**	-8.4**	4.5	-3.4**	-3.7*	4.0*	2.6	-1.8	-9.7
35	FI-113 x FI-142	-9.0**	-9.8**	4.7*	-9.2**	-10.5**	3.9	0.5	-0.3	7.6**	-0.9	-1.2	-9.1
36	FI-113 x FI-143	-6.9**	-8.8**	4.0	-6.6**	-8.0**	3.9	3.3*	0.7	8.7**	8.6	1.4	7.4
37	FI-114 x FI-109	-8.1**	-12.2**	5.3*	-6.4**	-11.2**	7.1**	-1.9	-11.5**	14.9**	11.8	8.4	-11.8*
38	FI-114 x FI-140	-8.0**	-10.6**	7.3**	-8.7**	-11.2**	7.1**	-10.7**	-18.4**	5.8**	22.0**	20.1**	0.8
39	FI-114 x FI-142	-10.7**	-12.2**	5.3*	-12.2**	-13.8**	3.9	-10.3**	-18.4**	5.8**	11.3	5.1	-3.8
40	FI-114 x FI-143	-9.9**	-13.9**	3.3	-7.5**	-11.7**	6.4**	-6.4**	-16.2**	8.7**	13.6*	0.4	6.3
41	FI-127 x FI-109	-8.3**	-8.5**	0.0	-6.1**	-8.0**	3.9	3.9**	2.4	10.1**	15.3*	14.1	-11.0
42	FI-127 x FI-140	-8.1**	-10.0**	2.0	-9.0**	-9.6**	3.2	-8.9**	-9.1**	-2.2	18.2**	14.1*	-4.2
43	FI-127 x FI-142	-11.6**	-14.4**	-0.7	-12.6**	-13.8**	0.0	-8.8**	-9.4**	-2.5	33.8**	24.0**	13.5*
44	FI-127 x FI-143	-8.9**	-9.2**	-0.7	-7.8**	-9.1**	2.6	-8.3**	-10.4**	-3.6*	2.3	-11.2*	-5.9
45	FI-130 x FI-109	-8.4**	-9.5**	1.3	-5.3**	-5.9**	3.2	1.2	-0.3	7.3**	12.2*	0.4	-3.0
46	FI-130 x FI-140	-11.8**	-12.4**	-0.7	-10.0**	-11.8**	0.6	-3.2*	-3.4*	4.0*	6.5	-0.4	-3.8
47	FI-130 x FI-142	-10.5**	-12.1**	2.0	-10.2**	-12.7**	1.3	-2.0	-2.7	4.7**	-4.5	-7.0	-10.1
48	FI-130 x FI-143	-10.2**	-11.3**	-0.7	-8.2**	-8.2**	0.6	-2.8*	-5.1*	2.2	8.3	3.6	9.7
49	FI-139 x FI-109	-11.0**	-12.9**	-0.7	-10.5**	-12.0**	-1.3	0.7	0.7	5.1**	3.9	-1.2	-6.2**
50	FI-139 x FI-140	-12.6**	-12.9**	-0.7	-12.2**	-12.9**	-0.6	-8.2**	-9.5**	-2.9	4.5	4.0	-11.8*
51	FI-139 x FI-142	-4.9**	-5.8**	9.3**	-7.3**	-8.8**	5.8*	-9.1**	-9.9**	-4.4**	-2.9	-6.5	-14.4*
52	FI-139 x FI-143	-15.8**	-17.5**	-6.0*	-14.5**	-15.4**	-5.1*	-7.2**	-8.0**	-4.0*	5.3	-5.2	0.4
53	FI-141 x FI-109	-8.2**	-11.4**	4.0	-4.7*	-5.8**	4.5	1.4	0.0	7.3**	12.1*	4.8	-8.0
54	FI-141 x FI-140	-10.4**	-11.9**	3.3	-9.4**	-10.7**	1.9	-2.0	-2.0	5.1**	16.5**	13.9*	0.0
55	FI-141 x FI-142	-11.4**	-11.9**	3.3	-10.2**	-12.2**	1.9	-5.9**	-6.4**	0.4	0.2	-1.8	-10.1
56	FI-141 x FI-143	-10.0**	-13.1**	2.0	-5.8**	-6.4**	3.9	-1.2	-3.4*	3.6*	0.2	-8.4	-3.0
57	FI-144 x FI-109	-8.3**	-10.9**	3.3	-5.4**	-8.8**	6.4**	-1.0	-2.4	4.7**	10.6	0.0	-5.5
58	FI-144 x FI-140	-11.1**	-12.1**	2.0	-11.1**	-12.1**	2.6	-5.4**	-5.4**	1.5	8.7	2.7	-3.0
59	FI-144 x FI-142	-10.9**	-10.9**	3.3	-10.7**	-11.0**	3.9	-3.9**	-4.4**	2.5	5.2	3.6	-2.1
60	FI-144 x FI-143	-10.7**	-13.2**	0.7	-9.4**	-12.1**	2.6	-3.6**	-5.7**	1.1	-1.5	-6.8	-1.3

Table 3: (contd.)

S. No.	Hybrids	Number of kernels/row			Number of kernels/ear			100 seed weight			Grain yield		
		Mid Parent	Better Parent	CP 818	Mid Parent	Better Parent	900M Gold	Mid Parent	Better Parent	CP 818	Mid Parent	Better Parent	CP 818
1	FI-5 x FI-109	24.5**	22.9**	-9.3	41.7**	34.2*	-14.6	8.3	0.7	-3.5	92.2**	87.1**	-13.5**
2	FI-5 x FI-140	32.5**	22.3**	-12.1*	52.4**	37.9**	-12.2	-5.4	-7.2	-20.5**	99.0**	55.6**	-28.0**
3	FI-5 x FI-142	29.7**	23.4**	-11.3	38.0**	34.2*	-14.5	25.2**	22.8**	1.2	87.2**	86.1**	-13.9**
4	FI-5 X FI-143	34.8**	29.0**	-7.3	63.9**	56.3**	9.8	15.3*	-13.2*	-28.5**	65.9**	58.1**	-26.9**
5	FI-7 x FI-109	33.4**	29.6**	1.5	37.8**	22.7	-10.6	18.9**	7.8	3.3	94.7**	90.8**	-12.9**
6	FI-7 x FI-140	35.0**	19.9**	-6.1	43.1**	22.2	-10.9	12.4*	7.2	-8.1	126.3**	77.8**	-18.8**
7	FI-7 x FI-142	36.3**	24.6**	-2.4	29.4*	18.0	-14.0	37.1**	35.9**	7.7	102.7**	102.5**	-7.4
8	FI-7 x FI-143	35.2**	24.2**	-2.7	43.2**	40.6**	2.5	17.6**	-9.7	-29.7**	64.0**	57.2**	-28.2**
9	FI-24 x FI-109	65.3**	46.7**	8.3	76.8**	69.3**	-3.6	-4.7	-9.8*	-13.6**	110.6**	92.8**	-15.6**
10	FI-24 x FI-140	61.5**	56.6**	-4.7	79.7**	78.8**	-6.8	-1.9	-2.0	-16.0**	158.0**	121.4**	-19.4**
11	FI-24 x FI-142	68.8**	58.7**	3.1	68.5**	57.2**	-5.5	22.5**	18.1**	0.9	179.1**	150.6**	14.6**
12	FI-24 x FI-143	65.5**	54.8**	1.6	63.1**	42.1**	-0.2	3.7	-22.9**	-34.1**	53.1**	43.0**	-40.1**
13	FI-49 x FI-109	32.5**	30.8**	-3.5	48.9**	38.8**	-8.6	-5.4	-7.8	-11.6*	80.3**	78.2**	-20.1**
14	FI-49 x FI-140	20.3**	11.1	-20.1**	23.4	10.1	-27.5**	-12.9**	-15.3**	-23.1**	48.4**	17.3	-47.4**
15	FI-49 x FI-142	35.2**	28.7**	-7.5	40.2**	34.1*	-11.6	19.0**	11.4*	1.2	88.3**	86.5**	-14.7**
16	FI-49 x FI-143	24.0**	18.6*	-14.7*	34.5**	30.3*	-8.5	1.6	-25.9**	-32.7**	60.8**	55.5**	-30.2**
17	FI-54 x FI-109	32.8**	31.5**	-2.9	67.7**	60.7**	-0.2	0.3	-2.8	-6.8	156.5**	152.8**	14.0**
18	FI-54 x FI-140	36.8**	25.9**	-8.9	65.8**	51.8**	-5.7	-6.8	-9.0	-18.2**	166.4**	110.2**	-5.2
19	FI-54 x FI-142	42.1**	34.8**	-2.4	62.7**	60.1**	-0.6	17.0	10.1*	-1.1	144.0**	142.2**	10.8*
20	FI-54 x FI-143	51.3**	44.3**	4.5	103.5**	91.7**	34.7**	-2.4	-28.6**	-35.8**	70.8**	64.7**	-25.7**
21	FI-59 x FI-109	25.6**	22.8**	-9.4	34.1**	26.1	-18.6*	-7.7	-15.5**	-19.0**	30.9**	21.0*	-37.6**
22	FI-59 x FI-140	44.8**	34.9**	-4.9	49.4**	34.4*	-13.2	-2.6	-6.0	-19.4**	114.1**	61.2**	-16.9**
23	FI-59 x FI-142	54.9**	48.7**	4.9	52.0**	46.7**	-5.2	27.3**	27.0**	1.2	85.8**	75.3**	-9.6*
24	FI-59 x FI-143	42.7**	37.7**	-2.9	47.2**	41.3**	-0.7	29.6**	-1.3	-21.4**	36.5**	23.8**	-36.2**

25	FI-101 x FI-109	27.8**	18.1*	-12.9*	40.3**	38.0*	-18.7*	14.3**	1.5	-2.7	109.2**	84.0**	-19.4**
26	FI-101 x FI-140	40.3**	38.4**	-13.5*	53.7**	44.2**	-15.1	15.0**	7.4	-7.9	189.8**	158.5**	-14.0**
27	FI-101 x FI-142	33.0**	30.5**	-15.2*	32.2*	30.9*	-21.3*	37.5**	33.2**	5.6	112.9**	83.9**	-15.9**
28	FI-101 x FI-143	23.4**	20.5*	-20.9**	40.5**	29.2*	-9.3	22.6**	-4.4	-28.9**	61.8**	45.1**	-39.2**
29	FI-104 x FI-109	31.6**	28.7**	-5.0	31.6*	27.4	-22.5*	29.6**	14.9**	10.2*	107.0**	99.8**	-12.5**
30	FI-104 x FI-140	38.3**	28.8**	-9.1	42.0**	31.2*	-20.2*	17.7**	9.8	-5.9	148.7**	103.9**	-16.9**
31	FI-104 x FI-142	34.9**	29.5**	-8.6	33.2**	32.4*	-19.5*	45.8**	41.2**	11.9**	112.7**	101.1**	-8.0
32	FI-104 x FI-143	40.6**	35.7**	-4.2	54.1**	43.8**	1.0	39.7**	9.1	-19.0**	78.0**	75.5**	-26.5**
33	FI-113 x FI-109	43.9**	31.8**	-2.7	54.8**	54.5**	-11.8	2.5	-10.5*	-14.2**	71.6**	67.3**	-22.9**
34	FI-113 x FI-140	54.7**	54.0**	-5.4	58.5**	50.9**	-13.9	13.4**	4.0	-10.8*	91.1**	49.6**	-31.0**
35	FI-113 x FI-142	46.4**	42.5**	-7.5	44.6**	41.0**	-15.2	34.1**	27.6**	1.1	64.3**	63.7**	-24.6**
36	FI-113 x FI-143	50.4**	45.6**	-4.4	62.7**	47.5**	3.6	38.7**	9.7	-21.5**	72.9**	65.1**	-23.9**
37	FI-114 x FI-109	40.8**	13.5	-16.2**	59.0**	31.3*	-25.3**	11.0*	1.8	-2.4	106.7**	105.8**	-9.9*
38	FI-114 x FI-140	64.8**	43.5**	-12.7*	100.9**	72.6**	-10.9	3.4	-0.1	-14.3**	119.1**	75.3**	-23.9**
39	FI-114 x FI-142	70.6**	44.6**	-6.1	87.7**	51.7**	-8.7	26.7**	26.1**	0.9	110.7	105.3	-6.1
40	FI-114 x FI-143	75.5**	48.1**	-2.8	94.3**	48.4**	4.3	27.9**	-2.8	-22.2**	106.6	103.0	-11.9**
41	FI-127 x FI-109	44.2**	36.3**	0.6	66.1**	58.6**	-9.7	15.3**	8.2	3.8	94.0**	88.9**	-12.7**
42	FI-127 x FI-140	50.4**	44.9**	-4.8	78.3**	78.0**	-7.8	2.2	1.3	-13.2**	140.5**	88.1**	-13.1**
43	FI-127 x FI-142	46.5**	45.6**	-4.3	97.6**	83.9**	10.6	22.1**	18.5**	-0.2	88.9**	88.0**	-13.1**
44	FI-127 x FI-143	40.3**	40.2**	-7.9	43.6**	24.8	-12.4	13.7*	-15.0**	-28.4**	36.3**	29.9**	-39.9**
45	FI-130 x FI-109	14.8*	11.4	-17.7**	29.1*	18.7	-19.4*	19.4**	3.0	-1.3	86.0**	80.9**	-20.8**
46	FI-130 x FI-140	32.4**	24.2**	-13.7*	40.5**	23.6	-16.1	16.3**	5.3	-9.7*	132.6**	89.6**	-21.5**
47	FI-130 x FI-142	17.0*	13.1	-21.3**	11.7	5.3	-28.5**	41.5**	32.8**	5.3	85.1**	76.3**	-19.4**
48	FI-130 x FI-143	42.2**	38.2**	-3.9	53.9**	51.3**	6.3	22.6**	-2.0	-31.9**	90.6**	89.5**	-20.6**
49	FI-139 x FI-109	32.9**	28.2**	-5.4	38.0**	35.7*	-20.0*	45.0**	25.6**	20.4**	109.6**	104.0**	-10.6*
50	FI-139 x FI-140	47.7**	39.3**	-4.4	54.2**	44.6**	-14.8	29.2**	17.5**	0.8	164.2**	115.1**	-10.8*
51	FI-139 x FI-142	7.4	4.5	-28.3**	5.5	4.4	-37.2**	17.4**	10.7	-12.3**	-16.1	-20.0*	-63.4**
52	FI-139 x FI-143	47.5**	44.3**	-1.0	55.4**	42.9**	0.4	47.8**	17.8**	-17.3**	110.1**	109.1**	-12.4**
53	FI-141 x FI-109	42.3**	38.6**	2.3	59.8**	53.4**	-5.0	0.2	-5.7	-9.6*	90.2**	68.0**	-4.0
54	FI-141 x FI-140	54.8**	44.7**	1.2	80.0**	65.0**	2.1	2.2	1.6	-12.9**	97.3**	43.7**	-17.9**
55	FI-141 x FI-142	50.8**	45.4**	1.7	51.3**	49.2**	-7.7	25.9**	21.9**	3.2	109.0**	88.2**	7.5
56	FI-141 x FI-143	24.5**	20.7*	-15.6**	25.9*	18.4	-16.8	2.7	-23.4**	-35.1**	0.4	-13.0	-50.3**
57	FI-144 x FI-109	31.3**	22.9**	-9.3	47.0**	41.5**	-13.0	24.9**	6.7	2.3	120.8**	93.9**	-15.1**
58	FI-144 x FI-140	39.5**	35.6**	-12.7*	51.5**	39.3**	-14.4	17.1**	4.9	-10.1*	179.5**	149.8**	-17.3**
59	FI-144 x FI-142	20.9**	20.4*	-21.8**	27.0*	25.6	-22.7*	41.8**	31.7**	4.4	119.7**	89.4**	-13.4**
60	FI-144 x FI-143	34.8**	33.5**	-12.4*	33.3**	25.0*	-12.2	40.4**	13.2*	-23.1**	85.4**	66.0**	-30.5**

*-significant at 5% level; **-significant at 1% level

DISCUSSION

Earliness for days to 50% tasseling, days to 50% silking and days to maturity are considered as desirable traits to ensure better hybrid performance under rainfed conditions. The hybrid "FI-139 x FI-143" recorded significantly negative heterosis over mid parent, better parent and the standard check for these characters. Both the inbreds involved in this cross were derived from composite base populations. Also another 5 hybrid combinations showed significant negative heterosis over mid parent, better parent and standard check. It was found that significant negative heterosis was observed in crosses which involve testers from composite base population confirming their suitability in developing early inbreds and hybrids. Bhavana *et al.* [8] observed significant negative heterosis for days to 50% tasseling and days to 50% silking. Xiaocong Zhang *et al.* [9] evaluated the parental populations and 21 crosses.

Four crosses *viz.* "FI-54 x FI-143" (27.5%), "FI-5 x FI-143" (17.3%), "FI-101 x FI-143" (13.5%) and "FI-127 x FI-142" (13.5%) recorded significant positive standard heterosis for number of kernel rows. These hybrids had parents derived from single cross hybrid, hybrid mixture and composite base population. Among these 2 hybrids, "FI-54 x FI-143" which is a cross between inbreds derived from hybrid mixture and composite base population registered significant positive standard heterosis also. Three hybrids which had both the parents as good general combiners *viz.* "FI-139 x FI-109", "FI-104 x FI-142" and "FI-104 x FI-109" exhibited significant positive heterosis over the standard check. All the inbreds involved in the crosses were derivatives of composite and hybrid mixture base population. Obtaining higher grain yield is the ultimate objective of any maize breeding program. Sixty hybrids over mid parent and 58 over better parent exhibited significant positive heterosis for grain yield which substantiates the importance and usefulness of heterosis breeding in maize yield improvement. Three hybrids *viz.* "FI-24 x FI-142", "FI-54 x FI-109" and "FI-54 xFI-142" recorded significant positive standard heterosis for grain yield.

It was noticed that among the five superior cross combinations which had significant heterosis for grain yield, "FI-24 x FI-142" was the only cross which involved inbreds derived from three-way cross hybrid and composite base population. Two cross combinations namely "FI-54 x FI-142" and "FI-113 x FI-142" were the crosses between inbred parents derived from hybrid mixtures and composite base population. The remaining two hybrids *viz.* "FI-54 x FI-109" and "FI-139 x FI-143" involved the cross between the inbreds derived from same base population namely hybrid mixture and composite respectively. Wende Abera *et al.* [10] reported almost similar results.

This clearly indicated that composites and hybrid mixtures could be important source populations for deriving inbred parents for utilization in single cross hybrid development. Further, superiority of crosses between inbreds derived from the same base population for grain yield indicated the possibilities of deriving heterotic inbred lines from the same base population to develop single cross hybrids for successful commercial exploitation.

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