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Standard heterosis in experimental single cross hybrids of maize

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Abstract
The estimation of standard heterosis over two popular checks, DHM 121 (local) Bio 9544 (national), revealed standard heterosis up to 28.99% for yield per plant over the better check DHM 121 (133.67 g) and twelve hybrids with more than 10% yield heterosis were identified. With respect to number of kernels per row, as many as 50 hybrids exhibited significant superior heterosis over the better check DHM 121.The evaluation of fresh single cross hybrids, as a whole, on the basis of performance and standard heterosis over the better check DHM 121 with respect to yield per plant and other yield contributing characters, six superior hybrids have been enlisted *viz*., N 128, N 137, N 122, N 130, N 104 and N 191. These crosses may be directly used as single cross hybrids after evaluation in multilocation trials or their homozygous inbred lines may be used in further breeding programmes.

Keywords: *Standard heterosis*, maize, single cross hybrids

1. Introduction

Maize (*Zea mays* L.), know as queen of cereals, globally occupies 1st rank in productivity among cereals, with 5.82 t/ha, followed by 4.66 t/ha of rice and 3.55 t/ha of wheat during 2019. Globally, maize is cultivated in 197.20 m ha area across 171 countries with a production of 1148.49 m t and a productivity of 5.82 t/ha, during 2019. The United States, China and Brazil accounted for about 62 per cent of global maize production (2019). In India, it is grown in an area of 9.03 m ha with a production of 27.72 m t with a productivity of 3.07 t/ha {2019-20, (FAOSTAT, 2020)} [4]. Globally, India has 5 percent of corn acreage but contributes only 2 per cent to the world's production. In India, though traditionally maize is mainly grown in kharif, area under rabi and spring seasons is increasing.

With the exploitation of heterosis as the method of producing hybrid maize given by Shull (1908) a new era was started. He outlined a plan using inbreeding to establish inbred lines and crossing these to produce uniformly productive hybrids. This documented phenomenon of heterosis was widely used by maize breeders for reporting varying levels of heterosis. Yield or other traits' improvement over the popular cultivated varieties and hybrids i.e. standard or useful or economic heterosis is the only heterosis of practical importance.

In India, maize hybrid varieties are planted in most of the area replacing the land races, synthetics and composites. Further, about 30% of the maize hybrids' area is under the single crosses. They are more uniform and higher yielders than the double and three way cross hybrids. With the advent of productive inbreds, seed production of single crosses has become more economical also. Production and evaluation of new hybrids is a continuous process.

The present study, therefore, was undertaken with 54 experimental single cross maize hybrids to estimate the standard heterosis for grain yield and its components for identifying the most promising single cross hybrids for commercial cultivation.

2. Materials and Methods

Fifty six experimental single cross hybrids, including two checks, DHM 121- zonal check and Bio 9544 - national check, obtained from Professor Jayashankar Telangana State Agricultural University (PJTSAU), Hyderabad were evaluated in a complete randomized block design with three replications during *Rabi*, 2019 at M.S Swaminathan School of Agriculture (MSSSoA), Centurion University and Technology and Management (CUTM), Paralakhemundi, Odisha. Thirteen traits of yield and its attributes *viz*., yield per plant, plant height, cob height, days to 50% tasseling, days to 50% silking, anthesis-silking interval, cob length, cob diameter, number of kernel rows per cob, number of kernels per row, shelling percentage and 1000 seed weight were studied.

Standard heterosis was estimated as per the formula of Virmani *et al*. (1982).

$$\text{Standard Heterosis (SH)} = \frac{\overline{F1} - \overline{SC}}{\overline{SC}} \times 100$$

Where

$\overline{F1}$ = Mean of hybrid

$\overline{SC}$ = Mean of Standard check

The significance of heterosis, was tested by Using 't' test as suggested by Snedecor and Cochran (1989) [21].

$$\text{Standard Heterosis } t = \frac{\overline{F1} - \overline{SC}}{\sqrt{2EMS/r}}$$

Where

$\overline{F1}$ = Mean of hybrid

$\overline{SC}$ = Mean of standard check

EMS = Error Mean sum of Squares

R = Number of replications

The Calculated 't' value was compared with table 't' value at error degrees of freedom.

3. Results and Discussions

The negative standard heterotic values for days to 50% tasseling, days to 50% silking and anthesis silk interval, cob height and also plant height {because of very tallness (> 210 cm) of the hybrids tested} which are desirable were considered in the present study. For other characters positive estimates were considered as desirable. The results of the standard heterosis expressed in per cent are presented in the Table.1

3.1 Plant Height

Standard heterosis of plant height over the better check DHM 121 varied from -11.62% (N 35) to 12.48% (N 183). Four hybrids *viz*., N 35 (-11.62%), N 70 (-11.42%), N 239 (-10.17%) and N 187 (-11.01%) have recorded significant negative heterosis over DHM 121. For this character, significant negative standard heterosis was also reported earlier by Kumar *et al*. (2019) [11], Hassan *et al*. (2019) [6], Onejeme, *et al*. (2020) [14] and Yadav and Gangwar (2021) [22].

3.2 Cob Height

Standard heterosis of cob height over the better check DHM 121 varied from -13.67% (N 239) to 28.02% (N 128). Only one hybrid, N 239 was significantly superior to the check DHM 121 with negative heterosis of -13.67%. The present results are comparable with the earlier findings of Kumar *et al*. (2019) [11] and Onejeme, *et al*. (2020) [14].

3.3 Days to 50 percent tasseling

Standard heterosis of days to 50 percent tasseling over the better check Bio 9544 varied from -10.93% (N 51) to 9.29% (N 148). Only two hybrids, N 51 (-10.93%) and N 236 (-4.92%) have shown significant negative heterosis over the check Bio 9544. Similar results of above nature were also reported by Kumar *et al*. (2019) [11], Darshan & Marker (2019) [16], Onejeme *et al*. (2020) [14] and Aswin *et al*. (2020) [2].

3.4 Days to 50 per cent silking

Range of standard heterosis for days to 50 percent silking over the better check Bio 9544 varied from -6.88% (N 51) to 12.17% (N 148). Only two hybrids, N 51 (-6.88%) and N 236 (-3.17%) have shown significant negative heterosis over the check Bio 9544. The present results are in agreement with the findings of other researchers like Nagada *et al*. (1995), Kumar *et al*. (2019) [11], Darshan and Marker (2019) [16] and Onejeme *et al*. (2020) [14].

3.5 Anthesis-silking interval (ASI)

Standard heterosis of ASI over the better check Bio 9544 ranged from -50.00% (N 70, N 98, N 180 & N 130) to 150.00% (N 308). As many as 32 hybrids have shown significant negative heterosis ranging from -70.00 to -40.00% over the check Bio 9544. For ASI, significant negative standard heterosis was also reported earlier by Onejeme *et al*. (2020) [14].

3.6 Cob length (cm)

Standard heterosis of cob diameter over the better check Bio 9544 varied from -14.19% (N 77) to 28.87% (N 128). As many as 15 hybrids *viz*., N 186, N 227, N 201, N 10, N 137, N 303, N 70, N 235, N 183, N 6, N 122, N 104, N 182, N 35 and N 128 have recorded significant positive heterosis ranging 10.64% to 28.87% over Bio 9544. The present results are in similar lines with the earlier findings of Singh *et al*. (2010), Jawahar Lal *et al*. (2012) [7], Vijayan and Kalamani (2014) [23], Arsode *et al*. (2017) [1], Hassan *et al*. (2019) [6], Darshan and Marker (2019) [16] and Aswin *et al*. (2020) [2].

3.7 Cob diameter

Standard heterosis of cob diameter over the better check DHM 121 varied from -10.26% (N 296) to 15.52% (N 308). Five hybrids *viz*., N 308 (15.52%), N 104 (12.25%), N 210 9.80%), N 183 (9.80%) and N 98 (9.64%) have recorded significant positive heterosis over DHM 121. Similar kinds of heterotic effects for cob diameter were reported earlier by Chattopadhyay and Dhiman (2005) [3], Singh *et al*. (2010), Arsode *et al*. (2017) [1], Darshan & Marker (2019) [16] and Keimeso *et al.* (2020) [9].

3.8 Number of kernel rows per cob

Standard heterosis of number of kernel rows per cob over the better check DHM 121 varied from -15.56% (N 239) to 9.68% (N 104). Only one hybrid, N 104 (9.68%) has recorded significant positive heterosis over the better check DHM 121. The present results are of similar nature reported earlier by Singh *et al*. (2010), Jawahar Lal *et al*. (2012) [7], Arsode *et al*. (2017) [1], Hassan *et al*. (2019) [6] and Darshan and Marker (2019) [16].

3.9 Number of kernels per row

Standard heterosis of number of kernels per row over the better check DHM 121 varied from -0.79% (N 227) to 55.00% (N 10). All the tested hybrids have shown positive standard heterosis over DHM 121 and as many as 50 hybrids were significantly superior. Darshan, and Marker (2019) [16] earlier reported the similar nature of standard heterosis in maize hybrids.

3.10 Shelling percentage (%)

Standard heterosis of shelling percentage over the better check DHM 121 varied from -9.76% (N 227) to 10.35% (N 10). As many as twelve hybrids *viz*., N 10 (10.35%), N 210 (10.00%), N 194 (9.23%), N 104 (8.73%), N 128 (8.59%), N70 (8.56%), N 122 (7.91%), N 185 (7.74%), N 208 (7.12%), N 130 (7.11%), N 137 (6.79%) and N 6 (6.77%) have recorded significant positive heterosis over DHM 121. Significant positive standard heterosis for shelling % revealed here was also reported earlier by Arsode *et al*. (2017) [1] and Yadav and Gangwar, (2021) [22].

3.12 1000 grain weight (g)

Standard heterosis of 1000 grain weight (g) over the better check DHM 121 varied from -15.30% (N 227) to 18.73% (N 149). Only two hybrids, N 149 (18.73%) and N 185 (11.35%) have recorded significantly superior grain weight over DHM 121. The above results are in similar lines with the earlier workers like Jawahar Lal *et al*. (2012) [7], Vijayan and Kalamani (2014) [23], Kumar *et al*. (2019) [11] and Darshan and Marker (2019) [16].

3.13 Grain yield per plant (g)

Standard heterosis of grain yield per plant over the better check DHM 121 varied from -25.99% (N 148) to 28.99% (N 128). As many as thirteen hybrids *viz*., N 128 (28.99%), N 137 (20.21%), N 201 (18.67%), N 122 (16.31%), N 182 (14.41%), N 130 (13.74%), N 303 (13.12%), N 104 (12.92%), N 183 (12.86%), N 237 (11.91%), N 6 (11.07%), N 191 (10.22%) and N 10 (9.24%) have recorded significant positive yield heterosis over DHM 121. Significant positive standard heterosis for grain yield per plant found in the present research was also reported earlier by several workers like Nagada *et al*. (1995), Kaushik *et al*. (2004) [8], Gowhar *et al.* (2007) [5], Saidaiah *et al*. (2008) [18], Singh *et al*. (2010), Patil *et al*. (2012) [15], Jawahar Lal *et al*. (2012) [7], Khan *et al.* (2014) [10], Roshni Vijayan and Kalamani (2014) [23], Rumana Khan *et al.* (2014) [10], Vijayan and Kalamani (2014) [23], Reddy *et al.* (2015) [16], Ruswandi *et al*. (2015) [17], Zeleke (2015) [24], Mesenbet *et al*. (2016) [12], Sharma *et al*. (2016) [19], Arsode *et al*. (2017) [1], Kumar *et al*. (2019) [11], Hassan *et al*. (2019) [6], Darshan and Marker (2019) [16] and Aswin *et al*. (2020) [2]**.** Standard heterosis up to 28.99% over the better check DHM 121 was observed for yield per plant in the hybrids evaluated. As many as twelve hybrids with higher than 10% yield *viz*., N 128 (28.99%), N 137 (20.21%), N 201 (18.67%), N 122 (16.31%), N 182 (14.41%), N 130 (13.74%), N 303 (13.12%), N 104 (12.92%), N 183 (12.86%), N 237 (11.91%), N 6 (11.07%) and N 191 (10.22%) were identified. Mean values for yield per plant also revealed a wide range of variability i.e. from 147.33 g (N 191) to 172.41 g (N128), compared to the checks DHM 121 (33.67 g) and Bio 9544 (130.13 g). Hence, these significantly superior hybrids may be further tested in advanced yield and as well as stability trails.

For any hybrid to be released commercially, along with yield, other traits like cob length, cob diameter, number of kernel rows per cob, number of kernels per row, shelling %, test weight, height and duration are also very important. Increased cob diameter and cob length can accommodate more number of rows per cob and kernels per row per, respectively. As many as fifteen hybrids *viz*., N 186, N 227, N 201, N 10, N 137, N 303, N 70, N 235, N 183, N 6, N 122, N 104, N 182, N 35 and N 128 with superior standard heterosis ranging from 10.64 to 28.87%) for cob length over the better check Bio 9544 (16.17 cm) were identified. Four hybrids, N 308 (15.52%), N 104 (12.25%), N 183 (9.80%) and N 98 (9.64%) have ten or more than 10% standard heterosis with respect to cob diameter over the better check DHM 121 (4.08 cm).

With respect to number of kernel rows per cob, N 104 hybrid exhibited significant superiority over both the checks DHM 121 and Bio 9544 with 9.68% and 13.33% heterosis, respectively. Whereas, N 128, N 183 and N 311 hybrids were superior over the other check Bio 9544. With respect to number of kernels per row, as many as 50 hybrids, including highest yielders, N 191 (50.26%), N 104 (42.37%), N 303 (39.47%), N 122 (36.32%), N 128 (28.16%), N 137 (35.79%), N 183 (33.95%), N 130 (34.47%), N 201 (31.32%), N 182 (23.68%) and N 237 (21.05%) exhibited significant superior heterosis over the better check DHM 121.

Shelling percent and 1000 kernel weight are the other two important traits which contribute directly towards the yield. With respect to shelling percent, as many as twelve hybrids *viz*., N 10 (10.35%), N 210 (10.00%), N 194 (9.23%), N 104 (8.73%), N 128 (8.59%), N70 (8.56%), N 122 (7.91%), N 185 (7.74%), N 208 (7.12%), N 130 (7.11%), N 137 (6.79%) and N 6 (6.77%) have recorded significant positive heterosis over DHM 121. Among them, N 104, N 128, N 122, N 130, N 137 and N 6 were also identified as top yielders. Though, only two hybrids, N 149 (18.73%) and N 185 (13.44%) have recorded significantly superior grain weight over the better check DHM 121, majority of the identified twelve high yielders have medium 1000 kernel weight of above 250 g and high shelling % of above 80.

All the hybrids in the present study were very tall (> 210 cm) and of late duration, except N 51 (with < 56 days to tasseling) and N 236 (with < 59 days to silking), including the checks, may be because of soil and climatic conditions. All the tested hybrids, in spite of their tall nature, have low cob height or placement (< 50% height in proportion to plant height), which is desirable for non-lodging. All the twelve identified superior yielding hybrids have low ASI period of less than 3 days, which is desirable for synchronization and higher seed set.

The success of heterosis breeding depends on the amount of genetic diversity present in the material. To develop commercial hybrids, their *per se* performance and the extent of standard heterosis are essentially considered. In the present study, on the basis of *per se* performance and standard heterosis over the better check, six superior hybrids are enlisted *viz*., N 128, N 137, N 122, N 130, N 104 and N 191. Among the 54 hybrids evaluated, these six hybrids had significant *per se* performance and standard heterosis for grain yield and its contributing characters (Table 3 and Figure 1). These hybrids are of considerable practical importance as they proved to be superior over popular commercial zonal (DHM 121) and national checks (Bio 9544). These crosses may be directly used as single cross hybrids after evaluation in multilocation trials or their homozygous inbred lines may be used in further breeding programmes.

Table 1: Standard heterosis for grain yield and yield contributing characters studied over two standard checks DHM 121 (zonal check) and Bio 9544 (national check).

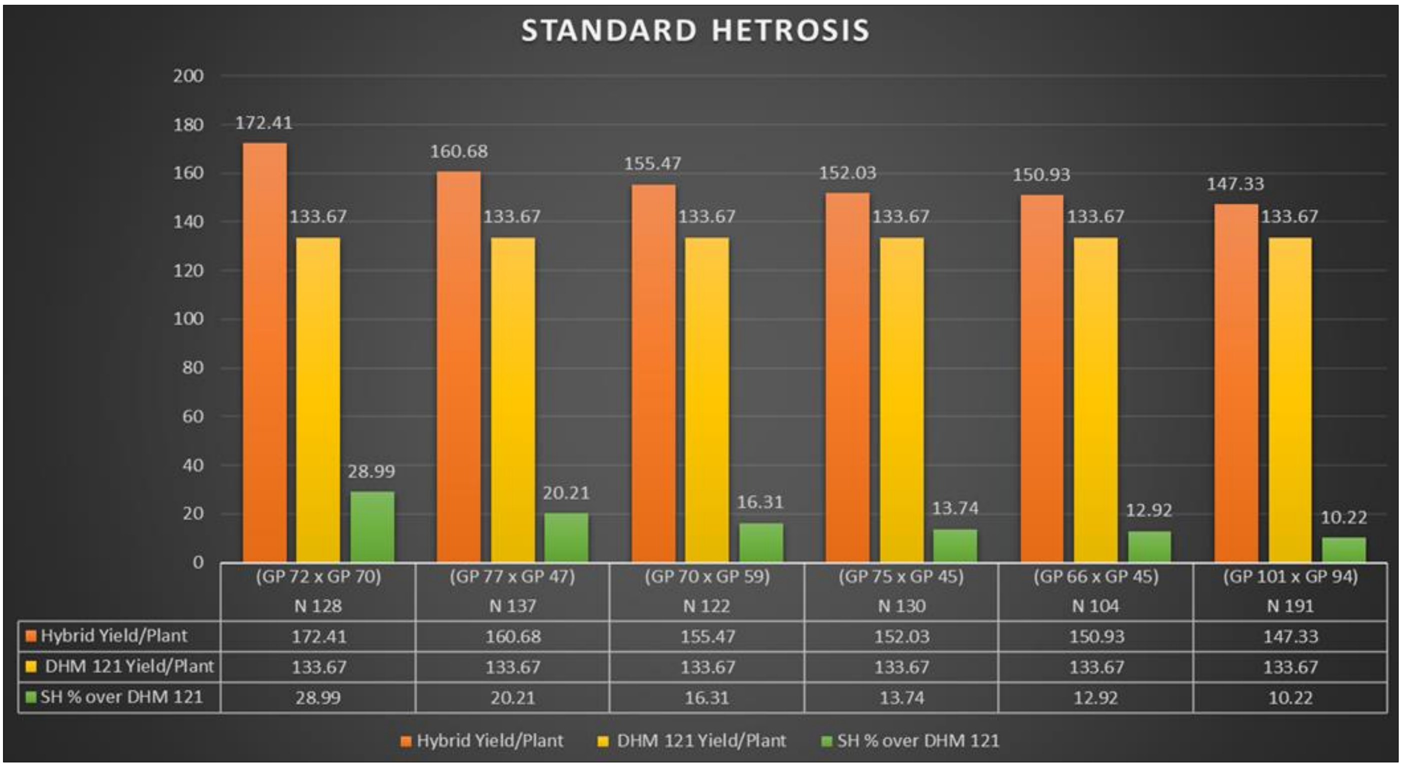
S. No.	Hybrids	Plant height (cm)		Cob height (cm)		Days to 50% tasseling		Days to 50% silking		Anthesis-silking interval (ASI)		Cob Length (cm)	
		DHM 121 (Zonal Check)	BIO 9544 (National Check)	DHM 121 (Zonal Check)	BIO 9544 (National Check)	DHM 121 (Zonal Check)	BIO 9544 (National Check)	DHM 121 (Zonal Check)	BIO 9544 (National Check)	DHM 121 (Zonal Check)	BIO 9544 (National Check)	DHM 121 (Zonal Check)	BIO 9544 (National Check)
1	N 194	9.09	5.21	4.39	-3.03	-7.07*	0.55	-8.17*	1.06	-30.00	16.67	-5.37	-5.61
2	N 193	3.71	0.02	10.24	2.40	-5.56*	2.19*	-5.29*	4.23*	0.00	66.67*	3.68	3.42
3	N 208	2.12	-1.51	12.66*	4.65	-7.07*	0.55	-8.65*	0.53	-40.00*	0.00	-8.19	-8.41
4	N 149	5.23	1.49	0.96	-6.22	-6.57*	1.09	-8.65*	0.53	-50.00*	-16.67	9.43*	9.16
5	N 278	4.94	1.21	6.02	-1.52	-2.53*	5.46*	-3.37*	6.35*	-20.00	33.33	5.38	5.12
6	N 7	7.95	4.11	9.90	2.09	-8.08*	-0.55	-9.62*	-0.53	-40.00*	0.00	-2.56	-2.80
7	N 104	5.22	1.48	8.38	0.68	-4.55*	3.28*	-6.25*	3.17*	-40.00*	0.00	22.30*	22.00*
8	N 61	4.94	1.21	0.90	-6.27	-7.07*	0.55	-7.21*	2.12	-10.00	50.00	-1.03	-1.28
9	N 303	3.57	-0.12	4.61	-2.82	-4.55*	3.28*	-6.25*	3.17*	-40.00*	0.00	13.31*	13.03*
10	N 128	11.45*	7.48	28.02*	18.92*	-5.56*	2.19*	-7.69*	1.59	-50.00*	-16.67	29.19*	28.87*
11	N 71	7.30	3.49	7.20	-0.42	-4.04*	3.83*	-5.29*	4.23*	-30.00	16.67	6.86	6.60
12	N 182	-1.25	-4.77	7.32	-0.31	-5.56*	2.19*	-8.65*	0.53	-70.00*	-50.00	25.26*	24.95*
13	N 66	5.98	2.21	11.54*	3.61	-8.08*	-0.55	-10.58*	-1.59	-60.00*	-33.33	7.52	7.26
14	N 185	5.18	1.44	-6.92	-13.54*	-4.55*	3.28*	-5.77*	3.70*	-30.00	16.67	1.86	1.61
15	N 210	-3.37	-6.81	-5.97	-12.65*	-4.04*	3.83*	-6.73*	2.65*	-60.00*	-33.33	3.47	3.22
16	N 187	-11.01*	-14.18*	-10.07	-16.47*	-4.55*	3.28*	-7.21*	2.12	-60.00*	-33.33	-4.26	-4.50
17	N 296	-4.00	-7.42	6.30	-1.25	-1.01	7.10*	-2.88*	6.88*	-40.00*	0.00	-11.09*	-11.31*
18	N 70	-11.42*	-14.57*	-9.85	-16.26*	-6.57*	1.09	-9.62*	-0.53	-70.00*	-50.00	14.51*	14.23*
19	N 98	6.00	2.23	10.75	2.88	-3.03*	4.92*	-6.25*	3.17*	-70.00*	-50.00	8.76	8.49
20	N 6	6.22	2.44	6.58	-0.99	-5.56*	2.19*	-8.17*	1.06	-60.00*	-33.33	19.43*	19.13*
21	N 277	0.00	-3.56	16.88*	8.57	-5.05*	2.73*	-6.25*	3.17*	-30.00	16.67	-2.32	-2.56
22	N 122	4.77	1.05	9.45	1.67	-5.05*	2.73*	-7.21*	2.12	-50.00*	-16.67	19.97*	19.67*
23	N 235	-7.50	-10.79*	-4.61	-11.40*	-1.52	6.56*	-3.37*	6.35*	-40.00*	0.00	15.63*	15.34*
24	N 191	-0.10	-3.65	-3.55	-10.40	-8.08*	-0.55	-8.65*	0.53	-20.00	33.33	7.85	7.59
25	N 199	-3.81	-7.23	-3.71	-10.56	-6.57*	1.09	-6.73*	2.65*	-10.00	50.00	-5.79	-6.02
26	N 180	-2.96	-6.42	-7.03	-13.64*	-6.57*	1.09	-9.62*	-0.53	-70.00*	-50.00	-1.24	-1.48
27	N 239	-10.17*	-13.37*	-13.67*	-19.81*	-8.08*	-0.55	-10.10*	-1.06	-50.00*	-16.67	6.20	5.94
28	N 5	1.52	-2.09	13.00*	4.97	-5.56*	2.19*	-8.17*	1.06	-60.00*	-33.33	-0.17	-0.41
29	N 186	3.49	-0.19	7.48	-0.16	-7.07*	0.55	-9.62*	-0.53	-60.00*	-33.33	10.91*	10.64*
30	N 10	4.84	1.12	-0.06	-7.16	-8.59*	-1.09	-8.65*	0.53	-10.00	50.00	11.89*	11.61*
31	N 91	10.97*	7.02	11.82*	3.87	-4.55*	3.28*	-5.77*	3.70*	-30.00	16.67	1.07	0.82
32	N 77	-6.87	-10.18*	3.43	-3.92	-5.05*	2.73*	-7.69*	1.59	-60.00	-33.33	-13.97*	-14.19
33	N 148	4.87	1.14	13.56*	5.49	1.01	9.29*	1.92	12.17*	20.00	100.00*	-3.39	-3.63
34	N 202	1.61	-2.00	12.72*	4.70	-2.02*	6.01*	-4.81*	4.76*	-60.00*	-33.33	0.62	0.37
35	N 35	-11.62*	-14.76*	-7.26	-13.85*	-5.05*	2.73*	-6.73*	2.65*	-40.00*	0.00	28.77*	28.45*
36	N 227	8.48	4.63	-7.26	-13.85*	-3.54*	4.37*	-4.33*	5.29*	-20.00	33.33	11.26*	10.98*
37	N 183	12.48*	8.48	5.40	-2.09	-0.51	7.65*	0.00	10.05*	10.00	83.33*	19.08*	18.79*
38	N 51	3.59	-0.09	-4.67	-11.45*	-17.68*	-10.93*	-15.38*	-6.88*	30.00	116.67*	-3.35	-3.59
39	N 236	-1.93	-5.42	-1.18	-8.21	-12.12*	-4.92*	-12.02*	-3.17*	-10.00	50.00	-8.80	-9.02
40	N 53	-8.44	-11.69*	-10.13	-16.52*	-5.56*	2.19*	-7.69*	1.59	-50.00*	-16.67	-1.65	-1.90
41	N 137	5.47	1.72	4.22	-3.19	-4.55*	3.28*	-6.25*	3.17*	-40.00*	0.00	12.36*	12.09*
42	N 201	-0.87	-4.39	-6.87	-13.49*	-5.05*	2.73*	-6.73*	2.65*	-40.00*	0.00	11.57*	11.30*
43	N 293	-7.91	-11.18*	-2.93	-9.83	-7.07*	0.55	-8.17*	1.06	-30.00	16.67	-1.32	-1.57
44	N 37	8.63	4.77	3.77	-3.61	-8.08*	-0.55	-9.13*	0.00	-30.00	16.67	4.36	4.10
45	N 99	5.74	1.98	-2.31	-9.25	-7.07*	0.55	-9.13*	0.00	-50.00*	-16.67	1.98	1.73
46	N 130	8.70	4.83	-2.14	-9.10	-6.06*	1.64	-9.13*	0.00	-70.00*	-50.00	7.65	7.38
47	N 181	4.92	1.19	3.83	-3.55	-6.57*	1.09	-8.65*	0.53	-50.00*	-16.67	-6.55	-6.78
48	N 237	0.84	-2.74	-1.58	-8.57	-8.08*	-0.55	-7.21*	2.12	10.00	83.33*	-0.48	-0.72
49	N 67	-4.65	-8.04	-0.51	-7.58	-7.07*	0.55	-8.65*	0.53	-40.00*	0.00	-12.17*	-12.39*
50	N 233	4.00	0.30	10.02	2.20	-5.56*	2.19*	-6.73*	2.65*	-30.00	16.67	-0.41	-0.66
51	N 308	4.94	1.21	2.25	-5.02	-6.57*	1.09	-3.85*	5.82*	50.00*	150.00*	2.85	2.60
52	N 309	10.03*	6.11	-4.00	-10.82*	-3.54*	4.37*	-6.25*	3.17*	-60.00*	-33.33	-2.03	-2.27
53	N 310	-1.69	-5.18	1.52	-5.70	-5.05*	2.73*	-6.73*	2.65*	-40.00*	0.00	-2.60	-2.85
54	N 311	8.12	4.28	10.07	2.25	-5.05*	2.73*	-6.73*	2.65*	-40.00*	0.00	1.17	0.92
	MIN	-11.62	-14.76	-13.67	-19.81	-17.68	-10.93	-15.38	-6.88	-70.00	-50.00	-13.97	-14.19
	MAX	12.48	8.48	28.02	18.92	1.01	9.29	1.92	12.17	50.00	150.00	29.19	28.87
	S.Ed.	12.87	12.87	6.85	6.85	0.61	0.61	0.79	0.79	0.55	0.55	0.76	0.76
C.D. (5%)		25.51	25.51	13.58	13.58	1.20	1.20	1.57	1.57	1.09	1.09	1.51	1.51

Table 2: Standard heterosis for grain yield and yield contributing characters studied over two standard checks DHM 121 (zonal check) and Bio 9544 (national check).

S. No.	Hybrids	Cob diameter (cm)		No. of kernel rows per cob		No. of kernels per row		Shelling %		1000 grain weight (g)		Yield per plant (g)	
		DHM 121 (Zonal Check)	BIO 9544 (National Check)	DHM 121 (Zonal Check)	BIO 9544 (National Check)	DHM 121 (Zonal Check)	BIO 9544 (National Check)	DHM 121 (Zonal Check)	BIO 9544 (National Check)	DHM 121 (Zonal Check)	BIO 9544 (National Check)	DHM 121 (Zonal Check)	BIO 9544 (National Check)
1	N 194	1.31	7.83	-1.38	1.90	37.89*	42.01*	9.23*	5.24	-8.71	-6.99	-7.48	-4.97
2	N 193	-2.48	3.80	-4.15	-0.95	34.21*	38.21*	-2.66	-6.21	-9.76	-8.06	-23.99*	-21.93*
3	N 208	2.61	9.22	-1.84	1.43	27.89*	31.71*	7.12*	3.21	-8.44	-6.72	-13.32*	-10.96*
4	N 149	5.39	12.17*	0.46	3.81	50.79*	55.28*	-3.27	-6.80*	18.73*	20.97*	5.89	8.76
5	N 278	6.62	13.48	0.07	3.40	45.53*	49.86*	-7.19*	-10.58*	-0.53	1.34	-6.94	-4.42
6	N 7	1.80	8.35	-2.30	0.95	23.68*	27.37*	-0.77	-4.39	-1.06	0.81	-8.43	-5.94
7	N 104	12.25*	19.48	9.68*	13.33*	42.37*	46.61*	8.73*	4.76	-3.43	-1.61	12.92*	15.98
8	N 61	-2.33	3.96	-2.30	0.95	6.05*	9.21*	-0.72	-4.35	-2.11	-0.27	-2.14	0.51
9	N 303	3.60	10.27*	-3.50	-0.29	39.47*	43.63*	-2.23	-5.80	8.97	11.02	13.12*	16.19*
10	N 128	-1.47	4.87	4.61	8.10*	28.16*	31.98*	8.59*	4.63	6.33	8.33	28.99*	32.49*
11	N 71	-1.96	4.35	-1.38	1.90	37.89*	42.01*	-2.99	-6.53*	-1.72	0.13	7.33	10.25*
12	N 182	-2.86	3.39	2.38	5.79	23.68*	27.37*	2.37	-1.37	6.86	8.87	14.41*	17.52*
13	N 66	-1.88	4.44	-3.16	0.07	27.11*	30.89*	-4.28	-7.78*	-7.39	-5.65	-5.14	-2.56
14	N 185	1.21	7.73	-6.22	-3.10	39.74*	43.90*	7.74*	3.81	11.35*	13.44*	3.94	6.76
15	N 210	9.80*	16.87*	-9.68*	-6.67	25.00*	28.73*	10.00*	5.98	2.51	4.44	-11.92*	-9.53*
16	N 187	2.45	9.04	-4.54	-1.36	23.95*	27.64*	-3.41	-6.94*	-8.97	-7.26	-20.80*	-18.65*
17	N 296	-10.26*	-4.48	-9.48*	-6.47	35.53*	39.57*	5.31	1.46	-3.56	-1.75	2.49	5.28
18	N 70	4.74	11.48*	0.92	4.29	2.11	5.15	8.56*	4.60	-3.83	-2.02	7.18	10.09*
19	N 98	9.64*	16.70*	-2.77	0.48	40.53*	44.72*	4.24	0.43	3.30	5.24	4.14	6.97
20	N 6	0.33	6.78	-6.91*	-3.81	2.11	5.15	6.77*	2.87	-7.92	-6.18	11.07*	14.09*
21	N 277	-4.29	1.87	-5.41	-2.26	40.53*	44.72*	1.11	-2.58	-15.30*	-13.71*	4.40	7.23
22	N 122	3.33	9.98	-1.30	1.99	36.32*	40.38*	7.91*	3.97	1.32	3.23	16.31*	19.47*
23	N 235	-3.50	2.71	-4.06	-0.86	37.11*	41.19*	3.85	0.06	5.67	7.66	0.70	3.43
24	N 191	1.86	8.41	-1.33	1.96	50.26*	54.74*	5.60	1.75	-6.73	-4.97	10.22*	13.22*
25	N 199	-0.27	6.15	-2.30	0.95	15.79*	19.24*	-4.46	-7.95*	-13.06*	-11.42	0.04	2.76
26	N 180	-4.01	2.16	-7.33*	-4.24	33.16*	37.13*	-0.98	-4.60	-10.42	-8.74	-23.31*	-21.22*
27	N 239	-1.80	4.52	-15.56*	-12.75*	24.47*	28.18*	1.49	-2.21	-6.20	-4.44	-15.07*	-12.77*
28	N 5	-7.35	-1.39	1.84	5.24	37.37*	41.46*	-2.82	-6.37	5.28	7.26	1.79	4.56
29	N 186	3.10	9.74	-5.53	-2.38	38.95*	43.09*	0.07	-3.59	-3.96	-2.15	2.08	4.85
30	N 10	-0.65	5.74	1.38	4.76	55.00*	59.62*	10.35*	6.32	0.26	2.15	9.24*	12.20*
31	N 91	2.45	9.04	-2.30	0.95	25.53*	29.27*	-1.67	-5.26	0.53	2.42	-14.82*	-12.51*
32	N 77	-5.88	0.17	-3.23	0.00	10.79*	14.09*	4.42	0.60	6.07	8.06	-21.01*	-18.87*
33	N 148	-4.90	1.22	-5.99	-2.86	10.79*	14.09*	-3.88	-7.39*	2.64	4.57	-25.99*	-23.98*
34	N 202	-2.61	3.65	-7.83*	-4.76	27.89*	31.71*	2.29	-1.45	-10.55	-8.87	-6.58	-4.05
35	N 35	0.82	7.31	1.38	4.76	28.68*	32.52*	-4.63	-8.11*	-0.79	1.08	-4.14	-1.54
36	N 227	-5.59	0.48	-10.48*	-7.50*	0.79	3.79	-9.76*	-13.06*	2.37	4.30	-2.13	0.52
37	N 183	9.80*	16.87*	4.61	8.10*	33.95*	37.94*	3.05	-0.72	4.75	6.72	12.86*	15.92*
38	N 51	-3.35	2.87	-2.30	0.95	35.79*	39.84*	-1.04	-4.65	4.35	6.32	-18.45*	-16.24*
39	N 236	-5.31	0.78	-0.46	2.86	22.37*	26.02*	-2.15	-5.72	0.26	2.15	-13.22*	-10.86*
40	N 53	-6.94	-0.96	-5.53	-2.38	16.58*	20.05*	-4.78	-8.25*	-1.45	0.40	-19.80*	-17.62*
41	N 137	-5.47	0.61	-2.07	1.19	35.79*	39.84*	6.79*	2.89	5.15	7.12	20.21*	23.47*
42	N 201	-1.14	5.22	-0.39	2.93	31.32*	35.23*	3.64	-0.15	7.12	9.14	18.67*	21.90*
43	N 293	-6.94	-0.96	-5.48	-2.33	28.16*	31.98*	2.17	-1.56	-2.11	-0.27	-15.24*	-12.94*
44	N 37	-3.56	2.65	-5.02	-1.86	48.42*	52.85*	3.46	-0.32	-3.69	-1.88	1.81	4.57
45	N 99	-4.17	2.00	2.37	5.78	33.68*	37.67*	5.46	1.61	2.90	4.84	-3.52	-0.90
46	N 130	9.31	16.35*	0.99	4.36	34.47*	38.48*	7.11*	3.20	4.75	6.72	13.74*	16.82*
47	N 181	-3.35	2.87	-4.61	-1.43	4.21	7.32*	0.69	-2.99	6.07	8.06	-15.91*	-13.63*
48	N 237	6.13	12.96*	-2.23	1.03	21.05*	24.66*	6.55	2.66	8.18	10.22	11.91*	14.95*
49	N 67	-8.74	-2.87	-1.79	1.49	29.74*	33.60*	-2.94	-6.48	-0.79	1.08	-10.59*	-8.17
50	N 233	-0.98	5.39	-2.72	0.52	13.42*	16.80*	2.58	-1.17	0.13	2.02	-11.82*	-9.43*
51	N 308	15.52*	22.96*	0.92	4.29	12.89*	16.26*	0.27	-3.40	-14.64*	-13.04*	-3.04	-0.41
52	N 309	0.82	7.31	-6.91*	-3.81	33.68*	37.67*	0.80	-2.88	-0.13	1.75	1.25	4.00
53	N 310	9.48	16.52*	-1.38	1.90	16.32*	19.78**	-2.66	-6.21	4.75	6.72	-8.78	-6.30
54	N 311	1.63	8.17	4.15	7.62*	22.11*	25.75*	-1.04	-4.66	4.22	6.18	2.29	5.07
	MIN	-10.26	-4.48	-15.56	-12.75	0.79	3.79	-9.76	-13.06	-15.30	-13.71	-25.99	-23.98
	MAX	15.52	22.96	9.68	13.33	55.00	59.62	10.35	6.32	18.73	20.97	28.99	32.49
	S.Ed.	0.20	0.20	0.50	0.50	0.69	0.69	2.61	2.61	14.34	14.34	6.07	6.07
	C.D. (5%)	0.39	0.39	0.98	0.98	1.38	1.38	5.17	5.17	28.43	28.43	12.03	12.03

Table 3: Superior hybrids identified for grain yield based on standard heterosis over the better check DHM 121.

S. No.	Hybrid	Parentage	Standard heterosis of yield per plant over better check DHM 121
1	N 128	GP 72 x GP 70	28.99%
2	N 137	GP 77 x GP 47	20.21%
3	N 122	GP 70 x GP 59	16.31%
4	N 130	GP 75 x GP 45	13.74%
5	N 104	GP 66 x GP 45	12.92%
6	N 191	GP 101 x GP 94	10.22%



	(GP 72 x GP 70) N 128	(GP 77 x GP 47) N 137	(GP 70 x GP 59) N 122	(GP 75 x GP 45) N 130	(GP 66 x GP 45) N 104	(GP 101 x GP 94) N 191
Hybrid Yield/Plant	172.41	160.68	155.47	152.03	150.93	147.33
DHM 121 Yield/Plant	133.67	133.67	133.67	133.67	133.67	133.67
SH % over DHM 121	28.99	20.21	16.31	13.74	12.92	10.22

Fig 1: Superior single cross hybrids identified for yield per plant based on standard heterosis over the better check DHM 121

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