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Studies on heterosis in newly developed inbred lines of maize for yield and quantitative traits (*Zea mays* L.)

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Abstract
The present investigation entitled "Studies on heterosis in newly developed inbred lines of maize for yield and quantitative traits (*Zea mays* L.)" was conducted at Agricultural Research Station, Karimnagar to study heterosis in grain yield and yield contributing characters. The experimental material comprised of crossing of 10 parental lines in half diallele mating design and 45 single cross hybrids were generated in *Kharif,* 2021. The hybrids along with parents and six standard checks were evaluated in Randomized Block Design with two replications in *Rabi* 2021-22 for twelve agro-morphological traits. Standard heterotic effects over NK 6240 were obtained in 4 crosses for grain yield and crosses, KML 107 × KML 128 and KML 107 × KML 126 had exhibited highest heterotic effects, whereas for Cob Girth, two crosses (KML 110 × KML 126 and KML 107 × KML 126) were found to be highly heterotic. Finally, based on per se performance and standard heterosis KML 107 × KML 128 was a promising hybrid.

Keywords: Maize, heterosis, half diallele, yield, hybrid

Introduction
Maize (*Zea mays* L., 2n=20) is a notable cereal crop of the world, belonging to the tribe Maydeae, of the grass family, *Poaceae*. It is believed to be a domesticated variant of teosinte (*Zea mays* ssp. *parviglumis*). Maize possesses the highest yield potential among the cereals, so prominently known as queen of cereals. Maize emerged as the third most important crop after rice and wheat in India. Due to its wider adaptability, it can be cultivated in wider range of environmental conditions and is grown in more than 166 countries across the globe. Maize is an epitome of distinctive traits like allogamy, protandry, immense genetic variability and geographic diversity, which provide great opportunities for crop improvement. The present investigation was thus, conceptualized primarily to estimate the heterosis in single cross maize hybrids and identification of best cross combinations for yield and its contributing traits.

Materials and Methods
The experiment was carried out at Agriculture Research Station, Karimnagar. Agricultural Research Station, Karimnagar is located in Northern Telangana agro climatic zone of Telangana state. Geographically, it lies at 18.44º N latitude, 79.13º E longitude with an altitude of 275 meters above Mean Sea Level (MSL). The average rainfall of the Research Station is 907 mm. The soils are sandy loam type with pH of 7.3. Source of irrigation water is from Sri Ram Sagar Project (SRSP) and well. The experimental material used were 10 inbred lines developed by full-sibbing followed by two generations of selfing at ARS, Karimnagar. Heterosis was calculated using the genotype mean value for each character. Various methods were used to evaluate the amount of heterosis in relation to mid parental (MP), better parental (BP), and standard check (SC) values given by Turner (1953) [24]. Thus heterosis was calculated as the percentage increase or decrease of mean F1 performance as indicated below.

1. Heterosis over mid parent
Heterosis was expressed as percent increase or decrease observed in the F_1 over the mid-parent as per the following formula.

$$\text{Heterosis (\%)}\ \ (h_1) = \frac{\overline{F}_1 - \overline{BP}}{\overline{BP}} \text{x100}$$

Where,
$\overline{F_1}$= Mean of F_1
$\overline{MP}$ = Mean of parents

2. Heterosis over better parent

Heterobeltiosis was expressed as percent increase or decrease observed in F_1 over the better parent as per the formula of Liang *et al*. (1971) [9].

$$\text{Heterobeltiosis (\%) } (h_2) = \frac{\overline{F}_1 - \overline{BP}}{\overline{BP}} x100$$

Where,
$\overline{BP}$ = Mean of better parent (for the characters like days to 50% flowering, earliness is desirable so the early parents are taken as better parents).

3. Heterosis over standard checks

Standard heterosis was expressed as percent increase or decrease observed in F_1 over standard checks.

$$\text{Standard heterosis (\%) } (h_3) = \frac{\overline{F}_1 - \text{Mean of check}}{\text{Mean of check}} x100$$

4. Test of significance of heterosis

To test the significance for different types of heterosis needs computation of standard error (S.Em). For relative heterosis and heterobeltiosis, SEm were calculated based on error mean squares (EMS) from the ANOVA tables consisting parents and crosses, whereas, EMS from the RBD ANOVA (σ^2 e) table based on all treatments (parents, crosses and check) was used for standard heterosis.

The significance of heterosis *viz*., relative heterosis, heterobeltiosis and standard heterosis was then tested by comparing the calculated 't'- value with the tabulated student's 't'-value for appropriate error degrees of freedom at 5 percent and 1 percent level of significance (0.05 and 0.01 level of probability), respectively. t'_{cal} for

$$\text{Heterosis and heterobeltiosis} = \frac{\overline{F}_1 - \text{Mean of mid parents or better parent}}{\text{SEM}}$$

Where

$$\text{S.Em} = \sqrt{2\text{EMS}/\text{r}}$$

EMS = Error mean of squares
r = Number of replications

$$t'_{cal} \text{ for Standard heterosis} = \frac{\overline{F}_1 - \text{Mean of check}}{\text{SEM } \overline{\text{SC}}}$$

Where,

$$\text{S.Em } \overline{\text{SC}} = \sqrt{2\sigma e^2/\text{r}}$$

5. Least significance difference (Critical difference) for heterosis

The significance of the difference between two estimates of heterosis were tested by computing the least significant difference (LSD) by multiplying the SEm with the appropriate students 't' value of respective error degrees of freedom at desired level of probability.

CD = SEmx't' table value at error degrees of freedom.

Results and Discussion

Results obtained for studies pertaining to heterosis with respect to midparent heterosis (MPH), better parent heterosis (BPH) and standard heterosis (SH). Heterobeltiosis and standard heterosis of crosses were estimated over superior parent and widely adapted standard check NK-6240, respectively in 45 hybrids for 12 morpho-physiological characters. The character wise performance of hybrids are presented in Table 1.

1. Days to 50 percent tasseling

Out of 45 crosses, 45 and 20 crosses had negative and significant heterobeltiosis and standard heterosis, respectively. Heterobeltiosis varied from 4.27 (KML 110 × KML 132) to 37.86 percent (KML 132 × KML 135), while standard heterosis was from -6.87 (KML 110 × KML 132) to 8.40 percent (KML 132 × KML 135).Similar results were reported by Pole *et al*. (2018) [12], Abdulazeez *et al*. (2021) [1] indicating the possibility of deriving early hybrids.

2. Days to 50 percent silking

Among 45 crosses, 45 and 19 crosses had negative and significant heterobeltiosis and standard heterosis, respectively. Heterobeltiosis ranged between 4.07 (KML 110 × KML 132) to 36.11 percent (KML 132 × KML 136) and the standard heterosis was in the range of -7.25 (KML 110 × KML 132) to 7.25 percent (KML 132 × KML 135).The results were in agreement with that of Abdulazeez *et al*. (2021) [1].

3. Days to maturity

Among 45 crosses, 44 and 11 crosses had negative and significant heterobeltiosis and standard heterosis, respectively. Range of heterobeltiosis was from 1.85 (KML 110 × KML 132) to 19.60 (KML 132 × KML 136) percent while, standard heterosis ranged from -3.51 (KML 110 × KML 132) to 4.39 percent (KML 107 × KML 135, KML 132 × KML 135 and KML 132 × KML 136). Negative and significant heterobeltiosis and heterosis for earliness were reported by Rajitha *et al*. (2014) [14], whereas standard heterosis of similar nature was reported by Adu *et al*. (2013) [2].

4. Plant height (cm)

Among the crosses obtained, 45 out of 45 crosses had positive and significant heterobeltiosis effects for plant height. Whereas, 20 crosses had positive and significant standard heterotic effect. Heterobeltiosis varied from 21.59 (KML 132 × KML 120) to 126.53 percent (KML 126 × KML 140). Whereas, standard heterosis was -18.22 (KML 132 × KML 140) to 21.73 percent (KML 107 × KML 135).For this trait, positive and significant heterobeltiosis and heterosis for plant height were reported by Rajitha *et al*. (2014) [14], whereas positive and significant standard heterosis was reported by Motamedi *et al*. (2014) [11], Rajesh *et al*. (2014) [13] Ruswandi *et al*. (2015) [17], Shah *et al*. (2016) [18] and Kumar *et al*. (2018) [8].

5. Ear height (cm): Among the crosses obtained, 45 out of 45 crosses had positive and significant heterobeltiosis effects for plant height. Whereas, 19 crosses had positive and significant standard heterotic effect. Heterobeltiosis was in the range of 28.13 (KML 111 × KML 132) to 170.59 percent (KML 126 × KML 136) and standard heterosis was -19.30 (KML 132 × KML 140) to 25.00 percent (KML 107 × KML 126). Similar findings were reported by Shushay. (2014) [19], Pole *et al.* (2018) [12], Kumar *et al.* (2018) [10] and Abdulazeez *et al.* (2021) [1].

6. Ear length (cm)

Among the crosses obtained, 25 out of 45 crosses had positive and significant heterobeltiosis effects for plant height. Whereas, only 4 crosses had positive and significant standard heterotic effect. Heterobeltiosis was in the range of -15.37 (KML 111 × KML 126) to 31.80 percent (KML 111 × KML 128) and standard heterosis was -16.62 (KML 132 × KML 140) to 13.77 percent (KML 126 × KML 128).These findings exhibited parallelism with earlier results of Rajesh *et al.* (2014) [13], Rajitha *et al.* (2014) [14], Kumar *et al.* (2018) [10] and Abdulazeez *et al.* (2021) [1] for ear length.

7. Ear diameter (cm)

Heterobeltiosis for ear diameter was found significant in 20 out of 45 crosses and standard heterosis was found to be in 30 out of 45 crosses. Heterobeltiosis was in the range of -5.57 (KML 126 × KML 132) to 28.21 percent (KML 111 × KML 132) and standard heterosis was -20.80 (KML 132 × KML 136) to 3.01 percent (KML 110 × KML 126).Similar results of average, better parent and economic heterosis were obtained by Chakraborty *et al.* (2012) [4] and Kumar *et al.* (2016) [9] for ear diameter.

8. Number of kernel rows per ear

13 and 6crosses were found significant for heterobeltiosis and standard heterosis respectively. Heterobeltiosis was in the range of -15.15 (KML 111 × KML 126) to 42.22 percent (KML 128 × KML 120) and standard heterosis was -11.11 (KML 111 × KML 126) to 31.75 percent (KML 126 × KML 128). Aminu *et al.* (2014) [3] also reported similar findings.

9. Number of kernels per row: Heterobeltiosis for number of kernels per row was found significant in 15 out of 45 crosses and standard heterosis was found to be in 13 out of 45 crosses. Heterobeltiosis was in the range of -27.78 (KML 128 × KML 135) to 29.17 percent (KML 135 × KML 120) and standard heterosis was -21.21 (KML 128 × KML 135) to 15.15 percent (KML 126 × KML 132). Kumar *et al.* (2014) [13], Ruswandi *et al.* (2015) [17] and Chandana *et al.* (2018) mentioned similar findings for number of kernels per row.

10. Test weight (g): 37 and 25crosses were found significant for heterobeltiosis and standard heterosis respectively. Heterobeltiosis was in the range of 0.3 (KML 132 × KML 140) to 59.54 percent (KML 136 × KML 140) and standard heterosis was -40.14 (KML 132 × KML 140) to 6.5 cent (KML 110 × KML 126).Similar findings were reported by Rajesh *et al.* (2014) [13] for test weight.

11. Grain Yield

Among the crosses obtained, 30 out of 45 crosses had positive and significant heterobeltiosis effects for plant height. Whereas, 23 crosses had positive and significant standard heterotic effect. Heterobeltiosis was in the range of -7.8 (KML 126 × KML 132) to 141.89 percent (KML 111 × KML 135) and standard heterosis was -58.30 (KML 132 × KML 140) to 23.24 percent (KML 107 × KML 128). Rajesh *et al.* (2014) [13], Kumar *et al.* (2016) [9], mentioned similar results for grain yield.

12. Shelling percentage: Heterobeltiosis for shelling percentage was found significant in 23 out of 45 crosses and standard heterosis was found to be in 28 out of 45 crosses. Heterobeltiosis was in the range of -11.61 (KML 111 × KML 110) to 3.87 percent (KML 132 × KML 140) and standard heterosis was -4.41 (KML 111 × KML 110) to 14.66 percent (KML 107 × KML 128).The above findings on shelling percentage were supported by earlier reports of Rajesh *et al.* (2014) [13], Kumar *et al.* (2016) [9].

Table 1: Estimates of heterosis over mid parent, better parent and standard check *i.e.*, NK-6240 for yield and yield attributing traits in the maize hybrids.

Crosses	DT			DS			DM			PH		
	Mid	Better	Check	Mid	Better	Check	Mid	Better	Check	Mid	Better	Check
KML 111 x KML 110	21.62**	15.38**	3.05	20.51**	14.63**	2.17	10.79**	6.94**	1.32	59.86**	42.15**	7.94*
KML 111 x KML 107	27.18**	24.76**	0.00	26.27**	23.42**	-0.72	14.79**	13.93**	0.44	72.89**	45.23**	10.28**
KML 111 x KML 126	31.13**	29.91**	6.11**	28.89**	27.19**	5.07**	16.05**	15.20**	3.07*	72.36**	38.15**	4.91
KML 111 x KML 128	32.38**	32.38**	6.11**	30.63**	30.63**	5.07**	16.92**	16.92**	3.07*	48.81**	35.08**	2.57
KML 111 x KML 132	21.57**	18.10**	-5.34**	21.30**	18.02**	-5.07**	12.56**	11.44**	-1.75	48.07**	29.85**	-1.40
KML 111 x KML 135	33.65**	32.38**	6.11**	30.91**	29.73**	4.35**	16.71**	16.42**	2.63	62.37**	47.38**	11.92**
KML 111 x KML 136	28.85**	27.62**	2.29	27.85**	26.13**	1.45	15.00**	14.43**	0.88	76.36**	49.23**	13.32**
KML 111 x KML 120	30.19**	28.97**	5.34**	28.57**	27.43**	4.35**	14.99**	13.59**	2.63	38.75**	36.62**	3.74
KML 111 x KML 140	36.08**	25.71**	0.76	33.98**	24.32**	0.00	19.17**	14.43**	0.88	88.33**	39.08**	5.61
KML 110 x KML 107	21.10**	12.82**	0.76	20.52**	12.20**	0.00	10.14**	5.56**	0.00	93.67**	81.42**	7.24*
KML 110 x KML 126	19.64**	14.53**	2.29	18.14**	13.82**	1.45	9.52**	6.48**	0.88	91.98**	70.36**	0.70
KML 110 x KML 128	21.62**	15.38**	3.05	20.51**	14.63**	2.17	10.79**	6.94**	1.32	69.50**	65.66**	2.57
KML 110 x KML 132	12.96**	4.27*	-6.87**	12.28**	4.07*	-7.25**	6.54**	1.85	-3.51*	67.87**	65.22**	-2.34
KML 110 x KML 135	20.91**	13.68**	1.53	19.83**	13.01**	0.72	12.02**	7.87**	2.19	84.17**	80.00**	11.45**
KML 110 x KML 136	22.73**	15.38**	3.05	22.08**	14.63**	2.17	11.33**	6.94**	1.32	94.56**	83.79**	8.64*
KML 110 x KML 120	18.75**	13.68**	1.53	17.80**	13.01**	0.72	8.53**	6.02**	0.44	59.51**	43.81**	5.84
KML 110 x KML 140	29.13**	13.68**	1.53	27.52**	13.01**	0.72	15.71**	7.41**	1.75	101.47**	62.45**	-3.97
KML 107 x KML 126	29.81**	26.17**	3.05	28.18**	23.68**	2.17	15.42**	13.73**	1.75	127.34**	114.48**	10.75**
KML 107 x KML 128	28.16**	25.71**	0.76	27.19**	24.32**	0.00	16.29**	15.42**	1.75	76.54**	61.89**	0.23

KML 107 x KML 132	34.00**	32.67**	2.29	32.70**	32.08**	1.45	16.46**	16.16**	0.88	81.97**	73.06**	-0.93
KML 107 x KML 135	38.24**	36.89**	7.63**	36.74**	34.86**	6.52**	19.60**	19.00**	4.39**	114.40**	96.60**	21.73**
KML 107 x KML 136	34.31**	33.01**	4.58**	33.64**	32.41**	3.62*	17.88**	17.59**	2.63	109.42**	107.56**	9.11**

*Significantat5%value **Significantat1% value

Crosses	DT			DS			DM			PH		
	Mid	Better	Check	Mid	Better	Check	Mid	Better	Check	Mid	Better	Check
KML 107 x KML 120	31.73**	28.04**	4.58**	30.59**	26.55**	3.62*	16.34**	14.08**	3.07*	81.34**	54.29**	13.55**
KML 107 x KML 140	35.79**	27.72**	-1.53	35.32**	28.30**	-1.45	18.02**	14.14**	-0.88	139.36**	103.62**	5.14
KML 126 x KML 128	24.53**	23.36**	0.76	23.56**	21.93**	0.72	13.09**	12.25**	0.44	104.34**	77.74**	10.05**
KML 126 x KML 132	30.10**	25.23**	2.29	29.68**	24.56**	2.90	15.71**	13.73**	1.75	87.76**	68.98**	-3.27
KML 126 x KML 135	31.43**	28.97**	5.34**	29.15**	26.32**	4.35**	15.84**	14.71**	2.63	107.38**	80.38**	11.68**
KML 126 x KML 136	27.62**	25.23**	2.29	27.03**	23.68**	2.17	16.63**	15.20**	3.07*	135.63**	120.44**	15.89**
KML 126 x KML 120	25.23**	25.23**	2.29	24.23**	23.68**	2.17	12.68**	12.14**	1.32	89.43**	53.65**	13.08**
KML 126 x KML 140	26.53**	15.89**	-5.34**	24.40**	14.04**	-5.80**	15.68**	10.29**	-1.32	152.99**	126.53**	3.74
KML 128 x KML 132	29.41**	25.71**	0.76	29.63**	26.13**	1.45	15.58**	14.43**	0.88	57.25**	51.32**	-6.31
KML 128 x KML 135	31.73**	30.48**	4.58**	30.00**	28.83**	3.62*	16.21**	15.92**	2.19	66.79**	66.79**	3.27
KML 128 x KML 136	29.81**	28.57**	3.05	28.77**	27.03**	2.17	16.50**	15.92**	2.19	79.18**	65.66**	2.57
KML 128 x KML 120	28.30**	27.10**	3.82*	27.68**	26.55**	3.62*	14.99**	13.59**	2.63	38.28**	27.30**	-6.31
KML 128 x KML 1110	37.11**	26.67**	1.53	36.89**	27.03**	2.17	19.69**	14.93**	1.32	84.29**	46.04**	-9.58**
KML 132 x KML 135	40.59**	37.86**	8.40**	38.32**	35.78**	7.25**	19.90**	19.00**	4.39**	63.92**	57.74**	-2.34
KML 132 x KML 136	39.60**	36.89**	7.63**	38.03**	36.11**	6.52**	20.20**	19.60**	4.39**	74.47**	67.35**	-4.21
KML 132 x KML 120	33.01**	28.04**	4.58**	31.19**	26.55**	3.62*	15.63**	13.11**	2.19	36.79**	21.59**	-10.51**
KML 132 x KML 1110	44.68**	37.37**	3.82*	40.00**	33.33**	1.45	20.42**	16.75**	0.88	75.00**	42.86**	-18.22**
KML 135 x KML 136	35.92**	35.92**	6.87**	34.56**	33.94**	5.80**	18.30**	18.00**	3.51*	95.10**	80.38**	11.68**
KML 135 x KML 120	34.29**	31.78**	7.63**	32.43**	30.09**	6.52**	16.75**	15.05**	3.95**	56.90**	44.44**	6.31
KML 135 x KML 140	37.50**	28.16**	0.76	36.27**	27.52**	0.72	18.96**	14.50**	0.44	93.33**	53.21**	-5.14
KML 136 x KML 120	33.33**	30.84**	6.87**	32.13**	29.20**	5.80**	16.54**	14.56**	3.51*	55.56**	33.33**	-1.87
KML 136 x KML 140	37.50**	28.16**	0.76	36.95**	28.70**	0.72	19.27**	15.08**	0.44	140.53**	103.11**	6.78*
KML 120 x KML 140	36.73**	25.23**	2.29	34.62**	23.89**	1.45	17.65**	11.65**	0.88	74.89**	30.48**	-3.97

*Significantat5%value **Significantat1% value

Crosses	EH			TW			SP			CL		
	Mid	Better	Check	Mid	Better	Check	Mid	Better	Check	Mid	Better	Check
KML 111 x KML 110	86.42**	54.38**	8.33	31.35**	24.22**	-14.98**	-10.36**	-11.61**	-4.41*	2.19	-2.39	-15.06**
KML 111 x KML 107	86.52**	64.38**	15.35*	46.49**	45.44**	-9.98	-3.57*	-4.03*	4.80**	21.95**	20.97**	-2.60
KML 111 x KML 126	71.76**	40.63**	-1.32	34.61**	27.67**	-13.15*	4.36**	0.30	8.48**	-2.94	-15.37**	-9.87
KML 111 x KML 128	84.91**	53.13**	7.46	41.16**	33.87**	-18.33**	-2.13	-3.43*	7.30**	35.13**	31.80**	4.42
KML 111 x KML 132	67.35**	28.13**	-10.09	39.24**	37.72**	-15.98**	-3.60*	-7.17**	0.39	13.68*	5.00	-1.82
KML 111 x KML 135	100.77**	63.13**	14.47*	58.68**	58.14**	-2.86	-7.35**	-7.66**	-0.13	31.65**	26.67**	8.57
KML 111 x KML 136	89.80**	51.25**	6.14	69.50**	58.98**	-3.01	-1.22	-1.52	6.51**	23.05**	15.14*	4.68
KML 111 x KML 120	56.43**	36.88**	-3.95	52.71**	39.64**	2.79	-8.76**	-9.73**	-2.37	30.53**	21.97**	-3.38
KML 111 x KML 140	111.06**	55.00**	8.77	46.56**	38.42**	-15.55**	-7.08**	**	-1.58	11.25	6.27	-7.53
KML 110 x KML 107	132.60**	116.39**	15.79**	23.74**	17.82*	-19.36**	-4.79**	-6.56**	2.04	24.65**	20.00**	4.42
KML 110 x KML 126	148.31**	144.76**	12.72*	56.07**	55.59**	6.5	-6.16**	-8.57**	-3.88*	1.21	-8.05	-2.08
KML 110 x KML 128	148.57**	148.57**	14.47*	21.90**	9.66	-24.94**	1.55	-1.18	9.80**	28.64**	20.00**	4.42
KML 110 x KML 132	144.21**	120.95**	1.75	8.01	1.09	-30.80**	4.87**	2.37	7.63**	0.43	-3.06	-9.35
KML 110 x KML 135	145.85**	140.00**	10.53	54.38**	46.47**	0.25	-5.42**	-6.43**	0.53	22.41**	21.49**	5.71
KML 110 x KML 136	163.00**	150.48**	15.35*	44.14**	28.33**	-12.16*	-0.31	-1.41	5.98**	21.46**	18.86**	8.05
KML 110 x KML 120	116.89**	103.33**	7.02	31.90**	27.28**	-6.31	-2.59	-2.92	2.76	27.33**	14.03*	-0.78
KML 110 x KML 140	148.89**	113.33**	-1.75	17.15*	4.99	-28.14**	-1.51	-2.19	2.83	12.54*	12.54	-2.08
KML 107 x KML 126	154.46**	133.61**	25.00**	40.90**	34.55**	-8.47	1.95	-2.47	6.51**	18.06**	3.66	10.39
KML 107 x KML 128	120.26**	104.92**	9.65	46.51**	37.99**	-14.58**	4.09**	3.20*	14.66**	22.00**	18.06*	-4.94
KML 107 x KML 132	147.34**	109.84**	12.28*	16.92*	14.82	-28.92**	-1.32	-5.42**	3.29	21.79**	13.33*	5.97
KML 107 x KML 135	154.05**	131.15**	23.68**	69.09**	68.44**	4.26	-8.22**	-8.97**	-0.59	20.00**	16.36*	-0.26

*Significantat5%value **Significantat1% value

Crosses	EH			TW			SP			CL		
	Mid	Better	Check	Mid	Better	Check	Mid	Better	Check	Mid	Better	Check
KML 107 x KML 136	132.26**	106.56**	10.53	68.57**	57.04**	-2.79	-0.79	-1.57	7.50**	28.48**	21.14**	10.13
KML 107 x KML 120	112.40**	110.66**	12.72*	41.35**	30.10**	-4.23	-3.03*	-4.52**	4.27*	37.04**	27.10**	2.34
KML 107 x KML 140	149.75**	101.64**	7.89	40.81**	32.09**	-18.24**	0.86	-1.69	7.36**	17.21**	12.84*	-1.82
KML 126 x KML 128	150.24**	146.67**	13.60*	38.14**	24.61**	-15.23**	-0.16	-5.27**	5.26**	25.14**	6.83	13.77*
KML 126 x KML 132	147.06**	126.47**	1.32	20.39**	13.00	-23.12**	0.99	0.79	0.92	3.38	-2.93	3.38
KML 126 x KML 135	156.44**	153.92**	13.60*	52.20**	44.81**	-1.48	1.56	-2.08	5.19**	17.30**	5.85	12.73*
KML 126 x KML 136	180.20**	170.59**	21.05**	39.23**	24.29**	-15.45**	0.00	-3.61*	3.62*	7.89	0.00	6.49
KML 126 x KML 120	136.04**	118.33**	14.91*	30.22**	25.28**	-7.78	-1.44	-4.29*	1.31	22.37**	0.73	7.27

KML 126 x KML 140	188.14**	150.00**	11.84*	46.00**	31.19**	-10.75*	-2.26	-4.12*	-0.59	12.21*	1.95	8.57
KML 128 x KML 132	127.37**	105.71**	-5.26	22.37**	17.27	-30.02**	7.00**	1.72	13.02**	24.62**	12.50*	5.19
KML 128 x KML 135	135.12**	129.52**	5.70	55.50**	46.98**	-9.71	0.72	-0.95	10.06**	23.55**	16.06*	-0.52
KML 128 x KML 136	132.00**	120.95**	1.75	44.32**	42.65**	-21.97**	2.26	0.59	11.77**	25.63**	14.86*	4.42
KML 128 x KML 120	92.00**	80.00**	-5.26	17.41*	2.33	-24.67**	4.97**	2.49	13.87**	33.69**	27.93**	-3.64
KML 128 x KML 140	132.22**	99.05**	-8.33	23.97**	23.43*	-32.48**	2.42	-1.01	9.99**	29.28**	20.60**	4.94
KML 132 x KML 135	151.89**	133.00**	2.19	37.43**	35.48**	-16.78**	-3.58*	-6.85**	0.07	20.00**	15.00*	7.53
KML 132 x KML 136	138.89**	126.32**	-5.70	38.20**	30.97**	-21.84**	4.81**	1.22	8.81**	7.89	6.39	-0.52
KML 132 x KML 120	92.20**	64.17**	-13.60*	36.28**	23.38**	-9.18	5.65**	2.80	8.81**	25.44**	8.89	1.82
KML 132 x KML 140	130.00**	116.47**	-19.30**	5.09	0.30	-40.14**	5.68**	3.87*	7.69**	-7.63	-10.83	-16.62**
KML 135 x KML 136	173.85**	167.00**	17.11**	70.08**	59.01**	-2.32	-4.68**	-4.71**	2.43	11.76*	8.57	-1.30
KML 135 x KML 120	108.18**	90.83**	0.44	48.46**	36.17**	0.24	-2.47	-3.18	4.01*	26.72**	14.24*	-2.08
KML 135 x KML 140	156.00**	124.00**	-1.75	61.18**	51.74**	-6.79	-2.15	-3.86*	3.29	13.38*	12.54	-2.08
KML 136 x KML 120	98.14**	77.50**	-6.58	57.66**	36.05**	0.15	-4.90**	-5.63**	1.45	20.00**	5.43	-4.16
KML 136 x KML 140	188.24**	157.89**	7.46	60.72**	59.54**	-13.48*	-0.12	-1.90	5.46**	14.45**	12.00	1.82
KML 120 x KML 140	105.13**	66.67**	-12.28*	55.88**	35.36**	-0.36	0.16	-0.87	4.93**	36.00**	21.79**	5.97

*Significantat5%value **Significantat1% value

Crosses	CG			KR			NKR			GY		
	Mid	Better	Check	Mid	Better	Check	Mid	Better	Check	Mid	Better	Check
KML 111 x KML 110	18.19**	7.05	-5.64	6.67	0.00	-3.03	-5.51	-13.04	-4.76	33.52*	4.53	-37.04**
KML 111 x KML 107	19.39**	14.28**	-10.61**	10.71	10.71	-6.06	0.80	-5.97	0.00	92.57**	47.22**	-5.18
KML 111 x KML 126	10.09**	-5.35	-5.91	3.13	-8.33	0.00	-9.68	-15.15*	-11.11	54.19**	13.00	-17.32
KML 111 x KML 128	24.68**	21.81**	-12.87**	-9.38	-19.44**	-12.12*	32.04**	17.24*	7.94	57.05**	21.53	-24.39**
KML 111 x KML 132	29.71**	28.21**	-8.30*	17.86**	17.86*	0.00	29.73**	24.14**	14.29	78.14**	60.48**	-31.80**
KML 111 x KML 135	28.09**	23.66**	-4.97	15.38*	7.14	-9.09	29.82**	27.59**	17.46*	145.31**	141.89**	-15.21
KML 111 x KML 136	18.71**	12.67**	-10.29**	-6.67	-12.50*	-15.15*	8.06	1.52	6.35	97.75**	78.15**	-24.29**
KML 111 x KML 120	22.30**	19.04**	-10.07**	15.38*	7.14	-9.09	27.45**	12.07	3.17	69.11**	50.98*	-34.51**
KML 111 x KML 140	14.20**	10.73*	-15.68**	3.57	3.57	-12.12*	10.53	8.62	0.00	64.59**	55.86*	-40.59**
KML 110 x KML 107	11.13**	4.88	-7.56*	10.00	3.13	0.00	-4.41	-5.80	3.17	18.20	14.37	-26.34**
KML 110 x KML 126	9.85**	3.62	3.01	5.88	0.00	9.09	-0.74	-2.90	6.35	28.37*	17.02	-14.37
KML 110 x KML 128	4.01	-7.74	-18.68**	-14.71**	-19.44**	-12.12*	7.02	-11.59	-3.17	39.99**	37.76*	-14.3
KML 110 x KML 132	8.45*	-2.79	-14.32**	6.67	0.00	-3.03	9.84	-2.90	6.35	38.32*	17.96	-28.95**
KML 110 x KML 135	19.70**	12.03**	-1.25	14.29*	0.00	-3.03	2.40	-7.25	1.59	71.99**	36.04*	-18.06*
KML 110 x KML 136	8.84*	3.57	-8.71*	-9.38	-9.38	-12.12*	12.59*	10.14	20.63**	77.20**	51.12**	-8.98
KML 110 x KML 120	15.23**	7.00	-5.69	7.14	-6.25	-9.09	18.58**	-2.90	6.35	66.45**	43.16**	-13.77
KML 110 x KML 140	11.02**	3.47	-8.80*	13.33*	6.25	3.03	12.00	1.45	11.11	59.93**	30.57*	-21.36*
KML 107 x KML 126	13.49**	1.39	0.79	12.50*	0.00	9.09	12.78*	11.94	19.05*	59.56**	50.00**	9.76
KML 107 x KML 128	16.95**	9.48*	-14.37**	-6.25	-16.67**	-9.09	8.93	-8.96	-3.17	94.66**	91.35**	23.24*
KML 107 x KML 132	21.46**	14.98**	-10.06**	25.00**	25.00**	6.06	15.00*	2.99	9.52	41.27**	17.24	-24.49**
KML 107 x KML 135	21.35**	20.29**	-5.91	15.38*	7.14	-9.09	8.94	0.00	6.35	83.78**	41.90**	-8.61
KML 107 x KML 136	9.98*	9.01*	-13.20**	0.00	-6.25	-9.09	0.75	0.00	6.35	40.71**	16.78	-24.79**
KML 107 x KML 120	19.40**	17.36**	-8.20*	15.38*	7.14	-9.09	18.92**	-1.49	4.76	70.20**	42.42**	-8.28
KML 107 x KML 140	22.17**	20.55**	-5.71	25.00**	25.00**	6.06	10.57	1.49	7.94	84.36**	46.73**	-5.49
KML 126 x KML 128	15.08**	-2.97	-3.54	-2.78	-2.78	6.06	49.55**	25.76**	31.75**	54.73**	43.14**	4.74

*Significantat5%value **Significantat1% value

Crosses	CG			KR			NKR			GY		
	Mid	Better	Check	Mid	Better	Check	Mid	Better	Check	Mid	Better	Check
KML 126 x KML 132	10.91**	-5.57	-6.13	18.75**	5.56	15.15*	15.97*	4.55	9.52	16.65	-7.80	-32.54**
KML 126 x KML 135	9.34**	-3.07	-3.64	6.67	-11.11*	-3.03	9.84	1.52	6.35	91.93**	41.93**	3.85
KML 126 x KML 136	5.92	-4.62	-5.18	5.88	0.00	9.09	4.55	4.55	9.52	65.33**	30.67*	-4.38
KML 126 x KML 120	9.06**	-4.03	-4.60	13.33*	-5.56	3.03	23.64**	3.03	7.94	44.63**	15.18	-15.72
KML 126 x KML 140	10.39**	-2.53	-3.10	12.50*	0.00	9.09	8.20	0.00	4.76	51.72**	15.38	-15.58
KML 128 x KML 132	15.78**	14.43**	-20.05**	-3.13	-13.89*	-6.06	48.98**	37.74**	15.87*	64.54**	38.47**	-13.85
KML 128 x KML 135	11.46**	5.22	-19.14**	-13.33*	-27.78**	-21.21**	42.57**	28.57**	14.29	80.95**	41.45**	-12.00
KML 128 x KML 136	10.88**	2.95	-18.03**	-14.71**	-19.44**	-12.12*	33.33**	12.12	17.46*	45.08**	22.09	-24.04**
KML 128 x KML 120	10.68*	5.32	-20.43**	-3.33	-19.44**	-12.12*	43.82**	42.22**	1.59	49.48**	26.85	-21.08*
KML 128 x KML 140	10.97**	5.2	-19.89**	-15.63**	-25.00**	-18.18**	40.59**	26.79**	12.7	18.96	-4.07	-40.32**
KML 132 x KML 135	19.86**	14.42**	-12.07**	15.38*	7.14	-9.09	32.11**	28.57**	14.29	125.10**	105.38**	-12.72
KML 132 x KML 136	5.96	-0.53	-20.80**	-3.33	-9.38	-12.12*	14.29*	3.03	7.94	47.27*	47.27*	-37.41**
KML 132 x KML 120	13.99**	9.71*	-17.12**	15.38*	7.14	-9.09	46.39**	33.96**	12.7	126.50**	124.21**	-2.75
KML 132 x KML 140	14.64**	9.92*	-16.30**	21.43**	21.43**	3.03	19.27**	16.07	3.17	3.45	-1.88	-58.30**
KML 135 x KML 136	10.67**	8.75*	-13.42**	14.29*	0.00	-3.03	14.75*	6.06	11.11	129.94**	109.80**	-10.84
KML 135 x KML 120	20.18**	19.16**	-8.43*	29.17**	29.17**	-6.06	36.00**	21.43*	7.94	142.19**	118.96**	-5.03
KML 135 x KML 140	15.03**	14.51**	-12.00**	11.54	3.57	-12.12*	21.43**	21.43*	7.94	94.73**	86.90**	-28.76**
KML 136 x KML 120	8.32*	5.55	-15.96**	7.14	-6.25	-9.09	18.18*	-1.52	3.17	55.11**	53.54*	-33.40**

KML 136 x KML 140	8.21*	5.85	-15.73**	3.33	-3.13	-6.06	1.64	-6.06	-1.59	96.44**	86.32**	-20.82*
KML 120 x KML 140	9.38*	8.95	-17.04**	7.69	0.00	-15.15*	28.00**	14.29	1.59	88.75**	77.31**	-23.09*

*Significantat5%value **Significantat1% value

Conclusion

Standard heterotic effects over NK 6240 were obtained in 4 crosses for grain yield and crosses, KML 107 × KML 128 and KML 107 × KML 126 had exhibited highest heterotic effects. Whereas for CG, two crosses (KML 110 × KML 126 and KML 107 × KML 126) were found to be highly heterotic. Finally, based on per se performance, combining abilities and standard heterosis KML 107 × KML 128 was a promising hybrid.

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