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Heterosis for nutritional quality and yield in conventional and non-conventional hybrids of maize (*Zea mays* L.)

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Abstract

A set of 12 lines were crossed with three testers *viz.*, CD(W) pool, CIMMYT-66 x X_2W-4001, a single cross hybrid and SLT-11, an inbred line and developed 16 conventional and 20 non-conventional hybrids of maize (*Zea mays* L.). These 36 hybrids alongwith 15 parents and 4 checks were evaluated in four environments in randomized block design with three replications. The heterosis over mid parent (MP), better parent (BP) and standard check (SC) was observed for seed oil content, starch content and grain yield per plant. The highest positive significant heterosis at all the three levels was exhibited by the non-conventional hybrid L10 x T_1 - VC for oil content and grain yield per plant. This hybrid also revealed highest *per se* performance for oil content (7.02%) and grain yield per plant (76.25 g/pl). Another non-conventional hybrid L_4 x T_1 - DTC exhibited maximum positive significant heterosis at all the three levels with highest *per se* performance (67.02%) for starch content.

Key words : *Zea mays* L., nutritional quality, heterosis, oil, starch

Introduction

Maize (*Zea mays* L.), an allogamous crop is an important cereal which is used as food for human consumption as well as feed for animal and poultry and as an important source of edible oil and starch. In India during 2006-07, it occupied on area of 7.89 million hectare with production of 15.09 million tones and productivity of 1912kg/ha (Fifteenth Annual Progress Report 2006-07, AICMIP). Exploitation of heterosis is considered to be one of the outstanding achievement of plant breeding. In India however, very less emphasis was given for exploitation of heterosis particularly for quality traits like high oil and starch content in maize grains. Available high oil genotypes/strains in USA have about 18-20 per cent oil on whole kernel basis [1] Most of the oil is present in the germ of seed [2]. Germ of ordinary corn contains about 30 per cent oil where as the germs of high oil strains contains as much as 50 per cent oil. There is a positive correlation between oil content in germ and size of germ. Strains having high oil content have a larger germ and reduced endosperm size.

Corn oil is considered suitable for human nutrition as it possess a very high proportion (about 80 per cent) of unsaturated fatty acids *viz.*, oleic acid and linoleic acid. However, limited breeding work has been done for exploiting the potentiality of maize as a source of edible oil. Therefore, an effort has been made to exploit the heterosis for quality traits through development and identification of conventional and non-conventional hybrids of maize.

Materials and methods

The experimental material comprising of twelve genotypes (Table 1) were crossed with three testers *viz.*, CD(W) pool (T_1), CIMMYT-66 x X_2W-4001 (T_2), a single cross and SLT-11 (T_3) an inbred line as per line x tester mating design to develop 36 hybrids (16 conventional and 20 non-conventional hybrids). The conventional hybrids are solely based on inbred lines, while non-conventional hybrids have at least one parent that is not an inbred line. These 36 hybrids along with 15 parents and 4 checks *viz.*, Arun, Kiran, Mahi Kanchan and D-107 were grown in randomized block design with three replications in a single row plot of 5 meter length with 60 x 25 cm crop geometry in four environments. The details of the environments is given in Table 2. The data were recorded on quality traits *viz.*, oil content and starch content and grain yield on ten randomly selected competitive plants (Table 3). The total oil content of dry seeds was determined by Soxhlet Method [3] and starch content was estimated by Anthrone reagent method [4]. Pooled magnitude of heterosis over mid-parent (MP),

Table 1. Pedigree and sources of the genotypes used in the present study

Code	Pedigree	Source of Seed Material	Seed Colour	Seed Type
L_1	SLT-28 x X_1W-1076	AICMIP, RCA, Udaipur (Raj.)*	White	Flint
L_2	CIMMYT-56 x SLT-28	CIMMYT&AICMIP, RCA, Udaipur (Raj.)	White	Flint
L_3	QIB-19 x SLT-16	CIMMYT&AICMIP, RCA, Udaipur (Raj.)	White	Flint
L_4	SLT-16 x CIMMYT-56	CIMMYT&AICMIP, RCA, Udaipur (Raj.)	White	Flint
L_5	X_2W-3997-2-1-7	AICMIP, RCA, Udaipur (Raj.)	White	Flint
L_6	CD(W)-49-1-1-4-1	AICMIP, RCA, Udaipur (Raj.)	White	Flint
L_7	Pop-49-1-1-2	AICMIP, RCA, Udaipur (Raj .)	White	Flint
L_8	SS_3-35-3-1-2-2-1	AICMIP, RCA, Udaipur (Raj.)	White	Flint
L_9	EC-3087	AICMIP, RC A, Udaipur(Raj .)	White	Flint
L_{10}	EC-3095	AICMIP, RCA, Udaipur (Raj.)	White	Flint
L_{11}	EC-2091	AICMIP, RCA, Udaipur (Raj.)	White	Flint
L_{12}	EC-2092	AICMIP, RCA, Udaipur (Raj.)	White	Flint
T_1	CD(W) Pool	CIMMYT&AICMIP, RCA, Udaipur (Raj.)	White	Flint
T_2	CIMMYT-66 x X_2W-4001	CIMMYT&AICMIP, RCA, Udaipur (Raj.)	White	Flint
T_3	SLT-11	CIMMYT&AICMIP, RCA, Udaipur (Raj.)	White	Flint

*AICMIP, RCA: All India Co-ordinated Maize Improvement,Rajasthan College of Agriculture, Udaipur (Raj.)

Table 2. Details of the experimental environments

Environment	Soil type	Fertility level
E_1 Clay loam high fertility	Clay loam	120 : 60 : 00 NPK/ha
E_2 Clay loam low fertility	Clay loam	60 : 40 : 00 NPK/ha
E_3 Sandy loam high fertility	Sandy loam	120 : 60 : 00 NPK/ha
E_4 Sandy loam low fertility	Sandy loam	60 : 40 : 00 NPK/ha

better- parent (BP) or hetrobeltiosis and standard-check (SC) were calculated as per standard procedure [5].

Results and discussion

Oil content

Mid-parent heterosis and heterobeltiosis are important parameters as they provide information about the presence of dominance and over dominance type of gene action in the expression of various traits. The results on heterosis for oil content indicated existence of the positive significant MP heterosis in 10 non-conventional and 8 conventional hybrids on pool basis with range varying from 0.85 (L_5 x T2-DTC) to 53.13% (L_{10} x T_1VC) (Table 4). It revealed that the genes with positive effect were dominant. The highest positive significant MP heterosis was expressed by a varietal cross hybrid L_{10} x T_1. The estimates of positive and significant better parent heterosis were observed in 5 non-conventional and 6 conventional hybrids on pool basis with range of estimates varied from 0.55 (L_7 x T_1-TC) to 51.62% (L_{10} x T_1-VC). The positive significant heterosis over better parent for oil content was also reported by earlier workers [6-8]. The presence of better parent heterosis indicated that over dominance played an important role in the expression of oil content. The positive significant estimates of standard heterosis were expressed by 5 non-conventional and 6 conventional hybrids against the best check 'D-107' on pooled basis. Its values ranged from 2.57 (L_2 x T_1-DTC) to 54.96% (L_{10} x T_1-VC). The highest positive significant heterosis of all three types were exhibited by the hybrid L_{10} x T_1-VC followed by L_1 x T_3-TWC, L_7 x T_3-SC and L_5 x P_3-SC (Table 3). The positive significant standard heterosis for oil content were also reported by earlier workers [9-15].

The non-conventional varietal cross hybrid L_{10} x T_1-VC which exhibited highest positive significant mid parent, better parent and standard heterosis for oil content and grain yield per plant along with highest mean

Table 3. Superior hybrids identified on the basis of mid-parent, better parent and standard check heterosis for oil content with relationship between starch content and grain yield per plant in maize

Hybrids/Parent/Checks	Code	Heterosis (%)			*Per se*		
		Oil content	Starch content	Grain yield/plant	Oil content (%)	Starch content (%)	Grain yield/plant (g)
Mid-parent heterosis (MP)							
EC-3095 x CD(W) pool-VC	L_{10} x T_1	53.13**	-8.84**	50.62**	7.02	55.72	76.25
SLT-28 x X_1W-1076 x SLT-11 TWC	L_1 x T_3	43.74**	-6.76**	36.45**	6.56	56.58	68.00
Pop-49-1-1-2 x SLT-11 SC	L_7 x T_3	37.11**	-7.67**	16.40**	5.65	56.60	57.67
X_2W-3997-2-1-7 x SLT-11-SC	L_5 x T_3	23.03**	-6.78**	20.83**	5.48	56.77	58.50
Better parent heterosis (BP)							
EC-3095 x CD(W) pool-VC	L_{10} x T_1	51.62**	x	50.49**	7.02	55.72	76.25
SLT-28 x X_1 W-1076 x SLT-11-TWC	L_1 x T_3	41.80**	x	22.89**	6.56	56.58	68.00
Pop-49-1-1-2 x SLT-11-SC	L_7 x T_3	25.56*	x	5.33**	5.65	56.60	57.67
X_2W-3997-2-1-7 x SLT-11-SC	L_5 x T_3	21.67**	x	11.43**	5.48	56.77	58.50
Standard check heterosis (SC)							
EC-3095 x CD(W) pool - VC	L_{10} x T_1	54.96**	x	32.03**	7.02	55.72	76.25
SLT-28 x X_1W-1076 x SLT-11-TWC	L_1 x T_3	44.67**	x	17.75**	6.56	56.58	68.00
Pop-49-1-1 -2 x SLT-11-SC	L_7 x T_3	24.63**	x	-	5.65	56.60	57.67
X_2W-3997-2-1-7 x SLT-11-SC	L_5 x T_3	20.77**	x	1.30	5.48	56.77	58.50
SLT-28 xY_1W-1076	L_1		x		4.62	61.44	55.33
CIMMYT-56 x SLT-28	L_2		x		3.87	63.59	55.00
QIB-19 x SLT-16	L_3		x		3.93	65.21	49.33
SLT-16 x CIMMYT-56	L_4	x	x	x	4.07	63.84	57.58
X_2W-3997-2-1-7	L_5	x	x	x	4.40	61.87	52.50
CD(W)-49-1-1-4-1	L_6	x	x	x	3.81	65.76	58.17
Pop-49-1-1-2	L_7	x	x	x	3.74	62.67	54.75
SS_3.35-3-1-2-2-1	L_8	x	x	x	3.39	64.40	48.08
EC-3087	L_9	x	x	x	3.93	64.87	50.50
EC-3095	L_{10}	x	x	x	4.63	61.62	50.58
EC-2091	L_{11}	x	x	x	4.41	62.50	51.42
EC-2092	L_{12}	x	x	x	4.53	61.82	50.92
CD(W) Pool	T_1	x	x	x	4.54	60.62	50.67
CIMMYT-66 x X_2W-4001	T_2	x	x	x	4.43	61.51	48.08
SLT-11	T_3	x	x	x	4.50	59.92	44.33
Arun	C_1	x	x	x	4.52	59.22	57.75
Kiran	C_2	x	x	x	4.50	62.47	51.50
Mahi Kanchan	C_3	x	x	x	3.86	64.70	48.25
D-107	C_4	x	x	x	4.53	62.45	43.25

*Significant at 1%; Where, VC = Varietal Cross, TWC = Three ways cross, SC = Single cross, DTC = Double top cross L = female line, T = Tester (male line) and C = Check; x = indicate no heterosis or no value

Table 4. Superior hybrids identified on the basis of mid-parent, relationship with oil content and grain yield per plant in maize better parent and standard check heterosis for starch content with

Hybrids/Parent/Checks	Code	Heterosis (%)			*Per se*		
		Starch content	Oil content	Grain yield/ plant	Starch content (%)	Oil content (%)	Grain yield/ plant(g)
Mid-parent heterosis (MP)							
(SLT-16 x CIMMYT-56) x CD(W) pool-DTC	L_4 x T_1	7.69**	–31.66**	15.78**	67.02	2.94	62.67
EC-3095 x SLT-11-TC	L_{10} x T_3	6.38**	–15.15**	32.75**	64.65	3.88	63.00
EC-3087 x SLT-11-TC	L_9 x T_3	5.99**	–29.64**	21.44**	66.13	2.97	57.58
EC-2092 x (CIMMYT-66 x X_2W-4001)-DTC	L_{12} x T_2	5.21**	–26.70**	34.68**	64.88	3.28	66.67
Better parent heterosis (BP)							
(SLT-16 x CIMMYT-56) x CD(W) pool-DTC	L_4 x T_1	4.97**	x	8.83**	x	x	x
EC-2092 x (CIMMYT-66 x X_2W-4001)-DTC	L_{12} x T_2	4.95**	x	30.93**	x	x	x
EC-3095 x SLT-11-TC	L_{10} x T_3	4.92**	x	24.55**	x	x	x
(SLT-28 x X_1W-1076) x (CIMMYT-66 X_2W-4001)-DC	L_1 xT_2	2.94**	x	2.56	63.22	4.24	56.75
Standard check heterosis (SC)							
(SLT-16 x CIMMYT-56) x CD(W) pool-DTC	L_4 x T_1	3.58**	x	8.51**	x	x	x
EC-3087 x SLT-11-TC	L_9 x T_3	2.22**	x	x	x	x	x
CD(W) 49-1-1-4-1 x CD(W) pool-TC	L_6 x T_1	1.47**	x	9.09**	65.65	3.10	63.00
EC-2092 x (CIMMYT-66 x X_2W-4001)-DTC	L_{12} x T_2	0.27	x	15.44	x	x	x

**Significant at 1%; x-indicate no heterosis or no value

Table 5. Superior hybrids identified on the basis of mid-parent, better parent and standard check heterosis for grain yield per plant with relationship between oil and starch content in maize

Hybrids/Parent/Checks	Code	Heterosis (%)			*Per se*		
		Grain yield/ plant	Oil content	Starch content	Grain yield/ plant(g)	Oil content (%)	Starch content (%)
Mid-parent heterosis (MP)							
EC-3095 x CD (W) Pool - VC	L_{10} x T_1	50.62**	53.13**	–8.84**	76.25	7.02	55.72
SS_3 - 35-3-1-2-2-1 x SLT-11-SC	L_8 x T_3	46.44**	–0.32	1.45**	67.67	3.93	63.07
X_2W - 3997-2-1-7 x CD (W) Pool-TC	L_5 x T_1	45.40**	–14.36**	1.48**	75.00	3.82	62.15
QIB-19 x SLT-16 x SLT-11-TWC	L_3 x T_3	45.37	0.00	–1.62**	68.08	4.22	61.55
Better parent heterosis (BP)							
EC-3095 x CD (W) Pool - VC	L_{10} x T_1	50.49**	51.62**	x	x	x	x
X_2W-3997-2-1-7 x CD (W) Pool-TC	L_5 x T_1	42.86**	x	0.46**	x	x	x
SS3-35-3-1-2-2-1 x SLT-11-SC	L_8 x T_3	40.73**	x	x	x	x	x
QTB-19 x SLT-16 x SLT-11-TWC	L_3 x T_3	38.01**	x	x	x	x	x
Standard check heterosis (SC)							
EC-3095 x CD (W) Pool - VC	L_{10} x T_1	32.03**	54.96**	-8.84**	x	x	x
X_2W -3997-2-1-7 x CD (W) Pool-TC	L_5 x T_1	29.87**	x	x	x	x	x
(SLT-16 x CIMMYT-56) x (CIMMYT-66 x X_2W-4001)-DC	L_4 xT_2	20.92**	x	x	69.83	4.23	62.28
SLT-28 x X_1W-1076 x CD (W) Pool-DTC	L_1 x T_1	20.35**	x	x	69.50	4.43	60.52

**Significant at 1%; x-indicate no heterosis or no value

Table 6. Range of heterosis over mid-parent (MP), better parent (BP) and standard check (SC) and number of significant positive hybrids (in parenthesis) for oil, starch content and grain yield per plant in maize

Characters	Range of Heterosis (%)			Best hybrid on the basis of highest heterosis		
	MP	BP	SC	MP	BP	SC
Oil content	–31.66-53.13(18)	0.55-51.62(11)	0.37-54.96(11)	L_{10}xT_1VC-MP	L_{10}xT_1-VC-NC	L_{10}xT_1-VC-MP
Starch content	–8.84-7.69(13)	0.39-4.97(8)	0.27-3.58(3)	L_{11}xT_1-DTC-NC	L_{11}xT_1-VC-NC	L_4xT_1-DTC-NC
Grain yield/plant	–2.76-50.62(34)	2.56-50.62(21)	0.14-32.03(23)	L_{10}xT_1-VC-NC	L_{10} x T_1-VC-NC	L_{10} x T_1-VC-NC

Where, NC = Non -conventional, C = Conventional, VC = Varietal cross and DTC = Double top cross

value for oil content and grain yield per plant (Table 3), was a cross between high x high *gca* effect of parent for oil content and average x high *gca* effect of parent for grain yield per plant.

Starch content

The positive significant mid-parent heterosis for starch content was exhibited by 8 non-conventional and 6 conventional hybrids on pool basis having the range varied from 0.71 (L_9 x T_2-DTC) to 7.69% (L_4 x T_1-DTC). The positive significant better parent heterosis was observed in 7 non-conventional and 1 conventional hybrids with range varying between 0.46 (L_5 x T_1-TC) to 4.97% (L_4 x T_1-DTC) on pooled basis. The estimates of significant standard heterosis in positive direction against the best check 'Mahi Kanchan' were found in 2 non-conventional and 1 conventional hybrids across the environments having the range varied from 1.47 (L_6 x T_1-TWC) to 3.58% (L_4 x T_1-DTC). The significant positive mid parent, better parent and standard heterosis for starch content were reported by [16].

A non-conventional double top cross hybrid (L_4 x T_1-DTC) exhibited maximum positive mid parent, better parent and standard heterosis for starch content (Table 4). This hybrid exhibited highest mean value for starch content and was a cross between high x high *gca* effect of parent for starch content.

Grain yield per plant

The heterosis for grain yield per plant indicated that the estimates of positive significant mid-parent heterosis were manifested by 19 non-conventional and 15 conventional hybrids on pool basis with the magnitude of estimates varying from 3.63 (L_2 x T_1-DTC) to 50.62% (L_{10} x T_1-VC). The significant positive better parent heterosis was exhibited by 18 non-conventional and 13 conventional hybrids on pooled basis, with magnitude of range varied from 3.44 (L_6 x T_3-SC) to 50.49% (L_{10} x T_1-VC).

The positive significant standard heterosis in positive direction was observed in 13 non-conventional and 10 conventional hybrids on pool basis over the best check 'Arun' with magnitude of heterosis varied from 4.18 (L_6 x T_3-SC) to 32.03% (L_{10} x T_1-VC). A varietal cross (L_{10} x T_1 exhibited highest magnitude of positive significant MP, BP and SC heterosis for grain yield per plant (Table 5). This hybrid also exhibited highest mean value for oil content and grain yield per plant. Standard heterosis for grain yield per plant was also reported by several maize workers in the past [17-19].

On pool basis the genotype L_{10} exhibited maximum mean value for oil content while the genotype L_6 exhibited highest mean value for starch content and grain yield per plant. Among the testers, T_1 exhibited highest mean value for oil content and grain yield per plant. Another tester T_2 showed maximum mean value for starch content. Standard heterosis for oil content on pool basis ranged from 0.55-54.96%. The magnitude of standard heterosis for grain yield per plant varied from 0.14-32.03% (Table 6). The hybrid L_{10} x T_1-VC non-conventional was found to exhibit high standard heterosis for grain yield along with high oil content. However, in case of starch content no hybrid could be found exhibiting high grain yield along with high starch content as most of the hybrids exhibited negative standard heterosis for starch content (Table 5).

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