Heterosis and Combining Ability Analysis in Medium Maturing Yellow Seeded Maize (*Zea mays* L.) Hybrids

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BHAGCHAND OLA

Thesis

Master of Science in Agriculture

(Plant Breeding and Genetics)

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DEPARTMENT OF PLANT BREEDING AND GENETICS

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Dated: / /2017

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Heterosis and Combining Ability Analysis in Medium Maturing Yellow Seeded Maize (*Zea mays* L.) Hybrids

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ABSTRACT

The present investigation consisted of 36 hybrids along with 15 parents and 4 checks *viz.*, Pratap Hybrid Maize-3, Vivek Hybrid-43, Pratap Makka -9 and HM-11, the total of 55 entries were evaluated during *Kharif-2016* in randomized block design with three replications. The data was recorded on fifteen traits to study the magnitude of relative heterosis, heterobeltiosis, economic heterosis, general and specific combining ability effects.

The analysis of variance indicated that mean squares due to genotypes, parents, crosses and parents v/s crosses were significant for all characters except for days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent brown husk, number of leaves per plant, cob girth and number of grain rows per cob due to genotypes, days to 75 per cent brown husk and number of leaves per plant due to parents, anthesis-silking interval, days to 75 per cent brown husk, number of leaves per plant, cob girth, number of grain rows per cob and 100-grain weight due to parents v/s crosses and anthesis-silking interval, days to 75 per cent brown husk and number of leaves per plant due to crosses. The significant mean squares or different traits, indicated the existence of appreciable amount of genetic variability under research experimental materials.

The inbred line L_2 exhibited maximum mean values for grain yield per plant, number or grain rows per cob, harvest index and minimum mean values for days to 50 per cent tassseling and days to 50 per cent silking. Whereas tester T_3 showed maximum mean values for grain yield per plant, harvest index, oil content and protein content and minimum mean values for days to 50 per cent tasseling and days to 50 per cent silking. Hybrid L_{12} xT_3 showed maximum mean values for grain yield per plant and harvest index.

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Out of 6 hybrids three hybrids *viz*, L_{12} x T_3, L_{11} x T_2 and L_9 x T_3 were showed significant positive economic heterosis for grain yield per plant over the best check Vivek Hybrid-43. There hybrids also depicted significant positive economic heterosis for harvest index. Number of hybrids depicting significant positive relative heterosis ranged from 1 (number of grain rows per cob) to 23 (grain yield per plant). The significant and positive heterobeltiosis in desirable direction ranged from 2 (number of leaves per plant) to 17 (grain yield per plant and harvest index). The maximum significant positive better parent heterosis for grain yield per plant was showed by hybrid L_2 x T_1 followed by hybrids L_7 x T_1, L_9 x T_1, L_{11} x T_2 and L_7 x $T_{1.}$

The ratio of σ^2_{sca} / σ^2_{gca} was greater than over for all the traits except anthesis-silking interval, number of leaves per plant, harvest index, grain yield per plant, oil content protein content and starch content. This indicated that the preponderance of non-additive gave effects in the expression of these traits.

The inbred line L_{10} was found good general combiners for grain yield per plant, cob girth, number of grain rows per cob, harvest index oil content and starch content, whereas the testers T_3 was good general combines for yield and majority of traits *viz*., grain yield per plant, harvest index, oil content, protein content and starch content. The general combing ability due to additive and additive x additive gene effects. Which are the fixable component of genetic variation.

Twelve hybrids showed significant positive sca effects for grain yield per plant. The maximum significant positive sca effects for grain yield per plant was depicted by hybrid L_{12} x T_3, followed by hybrids L_1 x T_2, L_{11} x T_2, L_7 x T_1 and L_4 x T_2. Hybrid L_{12} x T_3 showed highest significant positive sca effects along with highest *per se* performance and economic heterosis for grain yield per plant. This was cross between average x good gca effects parents for grain yield per plant

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ch- nc**
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oreku vul/kku e 36 ldjk] 12 irdk rFkk pkj ekud ryudk irki ldj eDdk&3] food ldj&43] irki eDdk&9] ,p-,e-&11] dk lekfo"V fd;k x;k] rnkulkj dy 55 ifof"V;k 'kkfey dj o"k [kjhQ&2016 e ;knfPNd [k.M vfHkdYiuk }kjk rhu iujkofÙk;k e yxk;k x;kA ldj vkt] vfr ldj vkt] vkfFkd ldj vkt] lkekU; rFkk fof'k"V l;ktu {kerk ekudk d v/;;u gr iUng y{k.kk d vkdM fy, x; FkA

ilj.k d fo'y"k.kk l Kkr gvk fd lHkh o'kØek irdk] ldjk ,o ird cuke ldjk d fy, x.kk d fy, lkFkdrk flok; 50 ifr'kr uj etjh d fnu] 50 ifr'kr eknk etjh d fnu] 75 ifr'kr Hkj 'kYdk d fnu] ifr ik/kk ifRr;k dh l[;k] HkVV dh ifjf/k rFkk ifr HkVVk nku dh drkjk dh l[;k dk NkMdj o'kØek e lHkh y{k.kk d fy, lkFkdrk irdk d fy, vklr ox ek/; 75 ifr'kr Hkj 'kYdk d fnu rFkk ifRr;k dh l[;k ifr ik/kk dk NkMdj lHkh y{k.kk d fy, lkFkd FkkA

ird cuke ldjk d fy, vklr ox ek/; i"iu eknk etjh d vrjky d fy, 75 ifr'kr Hkj 'kYdk d fnu ifr ik/kk ifRr;k dh l[;k] HkVV dh ifjf/k] ifr HkVVk nku dh drkjk dh l[;k rFkk 100 nkuk dk otu dk NkMdj lHkh y{k.kk d fy, lkFkd FkkA

ldjk d fy, vklr ox ek/; i"iu eknk etjh d vrjky d fy,] 75 ifr'kr Hkj 'kYdk d fnu rFkk ifr ik/kk ifRr;k dh l[;k dk NkMdj lHkh y{k.kk d fy, lkFkd FkkA fofHkUu y{k.kk d fy, vklr ek/; lkFkd Fkk] tk fd oreku vul/kku dh ik;kfxd lkexh e lkFkd lkexh e fofHkUurkvk dh mifLFkfr n'kkrk gA

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* 'kk/k Nk=] ikni ituu ,o vkuof'kdh foHkkx] jktLFkku df"k egkfo|ky;] egkjk.kk irki df"k ,o ik|kfxdh fo'ofo|ky;] mn;ij ¼jkt-½

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lkekU; voykdu n'kkrk g fd o'kØe ,y$_2$ u nku dh mit ifr ik/kk] ifr HkVVk nkuk dh drkjk dh l[;k dVkb lpdkd d fy; vf/kdre rFkk 50 ifr'kr uj etjh d fnu ,o 50 ifr'kr eknk etjh d fnu d fy; U;ure ekud ryud n'kk;kA tcfd ijh{k.k Vh$_3$ u nku dh mit ifr ik/kk] dVkb lpdkd] ry dh ek=k] ikVhu dh ek=k d fy; vf/kdre ,o 50 ifr'kr uj etjh d fnu vkj 50 ifr'kr eknk etjh d fnu d fy; U;ure vkIr eku n'kk;kA ldj ,y$_{12}$ x Vh$_3$ u nku dh mit ifr ik/kk ,o dVkb lpdkd d fy; vf/kdre vkIr eku n'kk;kA

Ng ldjk e l rhu ldjk u ,y$_{12}$ x Vh$_3$] ,y$_{11}$ x Vh$_2$ rFkk ,y$_9$ x Vh$_3$ e nku dh mit ifr ik/kk d fy; lokÙke ryud food ldj&43 dh ryuk e lkFkd /kukRed vkfFkd ldj vkt n'kk;kA rhu ldjk u dVkb lpdkd d fy; /kukRed vkfFkd ldjvkt d fy; lkFkd eku n'kk;kA lHkh ldjk e lkFkd /kukRed vkfFkd ldjvkt dk eku ifr HkVVk nkuk d drkjk dh l[;k dk ilj.k dk eku 1 rFkk nku dh mit ifr ik/kk dh eku 23 n'kk;k x;k rFkk lkekU; l;ktu {kerk ;kxkRed vkj ;kxkRed x ;kxkRed thu iHkko d dkj.k g tk fd vkuokf'kd ilj.k dk LFkk;h vo;o gA

l;ktu {kerk d fy; ilj.k d fo'y"k.k e n'kk;k fd fof"k"V l;ktu {kerk ,o lkekU; l;ktu dk vuikr lHkh y{k.kk d fy; ,d l vf/kd Fkk flok; i"iu eknk etjh d vrjky d fnu] ifr ik/kk ifÙk;k dh l[;k] dVkb lpdkd] nku dh mit ifr ik/kk] ry dh ek=k] ikVhu ,o LVkp dh ek=k d vykok lHkh y{k.kk d fy; lkFkd FkkA tk n'kkrk g fd bu y{k.kk d fy; vl;kth thu ilj.k vf/kd iHkkoh jgkA

ird o'kØe ,y 10 nku dh mit ifr ik/kk] HkVV dh ifjf/k] ifr ik/kk nkuk dh l[;k] dVkb lpdkd] ry dh ek=k ,o LVkp dh ek=k d fy; vPNk lkekU; l;ktd ik;k x;k tcfd ifj{kd Vh$_3$ nku dh mit ifr ik/kk] dVkb lpdkd] ry dh ek=k] ikVhu dh ek=k rFkk LVkp dh /kukRed vfr ldj vkt d fy, 2 ¼ifr ik/kk½ ifÙk;k dh l[;k rFkk 17 ¼ifr ik/kk nkuk dh l[;k ,o dVkb lpdkd½ d fy; bfPNr fn'kk eku n'kk;kA ldj ,y$_2$ x Vh$_1$ ifr ik/kk nkuk dh l[;k dk vf/kdre /kukRed vPN ird ldjvkt dk eku lkFkd n'kk;kA rnkulkj ldy ,y$_7$ x Vh$_1$] ,y$_9$ x Vh$_1$] nku dh mit ifr ik/kk d fy; ckjg ldjk u lkFkd /kukRed lkekU; vFkok ckjg ldjk u lkekU; lkFkd /kukRed eku n'kk;kA ldj ,y$_{12}$ x Vh$_3$] ,y$_1$ x Vh$_2$ rFkk ,y$_4$ x Vh$_2$ u lcl vf/kd lkekU; voykdu {kerk d fy; eku n'kk;kA ldj ,y$_{12}$ x Vh$_3$ u nku dh mit ifr ik/kk d fy; lokf/kd lkFkd /kukRed fof"k"V l;ktu {kerk d lkFk vPNk lkekU; voykdu vkj lkFkd /kukRed vkfFkd eku n'kk;kA ;g ldj ¼lekU; x vPNk½ lekU; l;ktu {kerk iHkko oky ifr ik/kk vUu mit oky irdk dk x.kt FkkA

1. INTRODUCTION

Maize (*Zea mays* L.) is an important multipurpose, cross pollinated crop belonging to family *Gramineae* and tribe Maydeae. It is the third most widely distributed crop of the world being grown in diverse seasons and ecologies with highest production and productivity among food cereals. It is used worldwide for feed, food and also serves as source of basic raw material for a number of industries *viz.,* oil, starch, protein, food, alcoholic beverages, sweeteners, cosmetics and bio-fuels etc.

Through the maize is being cultivated in almost all the part of the country from latitude 50°N to 40°S, from sea level to higher than 3000 m altitude and in areas receiving yearly rainfall of 250 to 500 mm (Downsell *et al*., 1996). Maize is a monoecious plant in that the reproductive organs are partitioned into separate pistillate (ear) and staminate (tassel) inflorescences. It is cross pollinated crop because of wind borne nature of the pollen grains and protoandry, but there may also be about 5 per cent self-pollination.

In India maize is traditionally cultivated in monsoon season both as irrigated and rainfed. It is also grown during winter and summer season in some parts of India where, temperatures are congenial and irrigation facilities are available. The *Rabi* maize is gaining popularity among farmers and multinationals because of higher yield potential and assured irrigation facilities. The success of *Rabi* maize is due to sunny days, long growing season, dry and cool temperatures which are more suitable to the crop and less for the pest.

The important maize cultivating states in area are Karnataka (11.79 lakh ha), M.P. (10.98 lakh ha), Maharashtra (10.07 lakh ha), Rajasthan (8.81 lakh ha), Bihar (7.01 lakh ha) and U.P. (6.79 lakh ha). At national level area, production and productivity of the crop is 8.69 m ha, 21.8 m tonnes and 2509 kg/ha respectively. While at Rajasthan level, it occupied 0.88 m ha area and 1.14 million tonnes production with productivity level of 1318 Kg/ha, (Annual Progress Report, AICRP on Maize, IIMR, and New Delhi-17). The productivity level of maize in India is very low then worlds productivity. Maize has high yield potential owing to its efficient carboxylation mechanism, suggesting tremendous scope to increase the yield potential through proper breeding strategy.

Incessant population growth is a big challenge for the nation demanding more food production. Therefor, now there is great need to develop high yielding hybrids with wider adoptability, which are primarily dependent on genotypically superior inbreed lines. Now-a-days superior inbreeds are being developed and most scientists are engaged with production of single cross hybrids. Because of more productive, uniform easly and cheap commercial hybrid seed production.

The estimation of heterosis, heterobeltiosis and economic heterosis of crosses provide information regarding yield potential of that particular genotype. Hybrids between diverse genotype may provide higher level of heterosis in comparison to genotype form similar origin.

In breeding of high yielding hybrids/varieties, the breeder often faces the problem of selecting the desirable parents. Information on combining ability provides guidelines to the plant breeder in selecting the elite parents and desirable cross combinations to be used in the formulation of systematic breeding programme and at the same time reveals the nature of gene action involved in the inheritance of various traits, combining ability analysis also provide the requisite information on the magnitude of gab and sac variances and effects, to formulate an efficient breeding methodology.

Considering the above facts, an attempt has been made through the study to evaluate some inbred lines from a diverse material which may be exploited to produce single cross hybrids for Rajasthan. The present investigation was undertaken by using Line x Tester mating design (Kempthrone, 1957) with the objectives:-

1. To estimate heterosis, mid parent heterosis, better parent for various quantitative and qualitative traits and economic heterosis.
2. To estimate general and specific combining ability and nature of gene actions.

2. REVIEW OF LITERATURE

The present investigation was undertaken to study the magnitude of **'Heterosis and Combining Ability Analysis in Medium Maturing Yellow Seeded Maize (*Zea mays* L.) Hybrids'.** The large amount of work has been on these aspect in maize, hence the relevant reference of the work are presented here under following needs available literature on these aspects in maize is presented here under following heads:

2.1 Heterosis, heterobeltiosis and economic heterosis

2.2 Combining ability and gene actions

2.1 Heterosis, Heterobeltiosis and Economic Heterosis:

Superiority of the hybrids over its parents is known as heterosis or hybrid vigour. The term hybrid vigour is used for the superiority of hybrids over parents only in positive direction. While term heterosis (Shull, 1908 and 1914) is measured in both positive and negative directions. The term "Heterobeltiosis" was given by Fonseca and Patterson (1968) to describe superiority of hybrids over the best parent. The term economic heterosis explains the superiority of hybrid over the best adopted commercial variety used as check.

Various theories have been proposed to explain and understand the phenomenon of heterosis. Among the various theories of genetic basis of heterosis dominance hypothesis was independently proposed by Davenport (1908), Bruce (1910), Keeble and Pellow (1910) and Jones (1917), whereas over dominance hypothesis was independently proposed by Shull (1908), East (1908), Stadler (1939), Hull (1945) and Gustafson (1946). Literatures reviewed on this aspect are furnished in Table: 2.1.

Table 2.1: Review of literature for heterosis, heterobeltiosis and economic heterosis for fifteen characters in maize

S. No	Characters	Name of Author	Design of experiment	Remarks
1	**Days to 50 per cent tasseling**	Atanaw *et al.* (2006)	Line x Tester	Reported positive significant heterosis for yield and yield contributing traits , cob length, cob girth, grain rows per cob, 100-grain weight and grain yield were also estimated and negative heterosis for maturity traits days to 50 per cent tasseling and silking, plant height, cob height value estimated.
		Ravikant *et al.* (2006)	Diallel	Heterosis was observed for grain yield per plant, days to 50 per cent tasseling, shelling per centage and ear length whereas positive and significant heterosis for grain yield per plant, days to 50 per cent
		Amiruzzaman *et al.* (2013)	Diallel	Observations were recorded on days to 50 per cent tasseling and silking, plant height, cob height, cob length, cob diameter, grain rows per cob, 100-grain weight, grain yield and Protein Contents. The negative significant heterosis varied from -0.10 to -4.42 per cent for days to tasseling.
		Shah *et al.* (2015)	Line x Tester	desirable heterosis varied from -0.10 to -4.42 %, -0.03 to -4.20 per cent, -2.44 to -42.11 per cent and -1.33 to -21.87 % for days to tasseling, days to silking, plant height and ear height, respectively.
2	**Days to 50 per cent silking**	Singhal *et al.* (2006)	Line x Tester	2 crosses observations were recorded on days to 50 per cent tasselling and silking, plant height, cob height, cob length, cob diameter, grain rows per cob, 100-grain weight, grain yield and protein contents were also estimated. The crosses, L_8 x T_1, L_1 x T_3, L_8 x T_2, L_5 x T_2, L_5 x T_1, L_2 x T_1, L_{13} x T_3, L_3 x T_1 and L_8 x T_3 revealed significant positive heterosis for grain yield.
		Firoz *et al.* (2007)	Line x Tester	Heterosis was observed for characters *viz.*, days to 50 % tasseling, days to 50 % silking, plant height (cm), ear length , number of kernels per row, number of

S. No	Characters	Name of Author	Design of experiment	Remarks
				kernel rows per cob, 100-grain weight , grain yield per plant , fodder yield and grain yield. The negative heterosis is observed for days to 50 per cent tasseling and days to 50 per cent silking.
		Sundararajan and Kumar (2011)	Line x Tester	Eight characters *viz.*, plant height, days to 50 per cent tasseling, days to 50 per cent silking, cob length, cob girth, number of grains per cob, 100 grain weight and grain yield per plant. Significant and positive standard heterosis for grain yield per plant and significant and positive standard heterosis for cob length, cob girth, number of grains per cob, and 100 grain weight were found.
		Kage *et al*. (2013)	Line x Tester	All the experimental hybrids exhibited significant positive heterosis over mid parent heterosis and the hybrid $L_2 \times T_1$ had highest mid parent positive heterosis followed by $L_4 \times T_1$.
3	**Anthesis - silking interval (ASI)**	Dubey *et al.* (2009)	Line x Tester	The relative heterosis, heterobetiosis and economic heterosis was observed for seed oil content, starch content and grain yield per plant hybrids revealed highest *per se* performance for oil content (7.02 per cent) and grain yield per plant (76.25 g/p). 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.
		Elmyhum *et al.* (2013)	Diallel	Studied at maturity related traits days to 50 per cent tasseling, days to 50 per cent silking, anthesis silking interval. exhibited negative significant heterosis for anthesis-silking interval.
		Kumar *et al.* (2014)	Line x Tester	Showed desirable significant heterosis for grain yield per plant, number of kernels per row, number of kernel rows per ear and ear length.

S. No	Characters	Name of Author	Design of experiment	Remarks
4	**Days to 75 per cent brown husk**	Premlatha and Kalamani (2010)	Line x Tester	The heterosis for the characters *viz.*, plant height, cob height, days to 75 per cent brown husk and grain yield traits. The hybrid UMI 278, UMI 217 and UMI 334, UMI 217 had significant and superior *per se* performances for grain yield per plant and exploitation of yield heterosis.
		Singh *et al.* (2013)	Line x Tester	The heterosis for the characters *viz.*, plant height, cob height, days to 75 per cent brown husk and grain yield traits. Crosses L_9 x T_1 and L_9 x T_2 elucidated desirable and significant heterosis both over mid parent and better parent.
		Chahar *et al.* (2014)	Diallel	Estimate the significant and positive heterosis for the characters *viz.*, plant height, cob height, days to 75 per cent brown husk plant height and ear height. exhibited negative significant heterosis for day to 75 per cent brown husk.
5	**Plant height**	Sumalini and Rani (2010)	Line x Tester	Medium maturity inbred lines of maize. Exhibited heterosis for the characters *viz.*, plant height, ear height and grain yield traits.
		Silva *et al.* (2011)	Diallel	They concluded that estimated mid parent heterosis was found to be significant for traits *viz.*, grain yield (1061.58), plant height (0.1391), ear height (0.1153), days to silking (-7.0119) and popping expansion (-0.5098).
6	**Ear height**	Kumar and Bharathi (2011)	Line x Tester	Evaluated for nine characters *viz.* plant height, ear height, days to 50 per cent tasseling, days to 50 per cent silking, cob length, cob girth, number of grains per row, 100 grain weight and grain yield per plant for exploitation the mid parent heterosis.
		Singh *et al.* (2015)	Diallel	To evaluate heterosis for identify promising hybrids of maize for various characters like grain yield, days to 50 per cent flowering, days to maturity and plant height (cm) showed better parent heterosis.

S. No	Characters	Name of Author	Design of experiment	Remarks
7	**Number of leaves per plant**	Pavan *et al.* (2011)	Line x Tester	Heterosis was observed for twelve characters *viz.*, days to 50 per cent tasseling, days to 50 per cent silking, plant height, cob length, number of leaves per plant, 100-grain weight, grain yield per plant and. negative heterosis is observed for number of leaves per plant and cob girth.
		Anusheela *et al.* (2013)	Line x Tester	UQPM 13 x UQPM 14, UQPM 5 x UQPM 9, UQPM 15 x UQPM 10 and UQPM 12 x UQPM 10 were observed to be potential hybrids for exploitation of yield heterosis and utilizing them in pedigree breeding . Significant positive heterosis for number of laves per plant was depicted.
8	**Cob girth**	Singhal *et al.* (2006)	Line x Tester	Observations were recorded on days to 50 % tasselling and silking, plant height, ear height, cob length, cob girth, grain rows per cob and grain yield. exhibited positive significant heterosis for cob girth.
		Zare *et al.* (2010)	Diallel	Days from germination to physiological maturity, days from silking to physiological maturity, plant height, ear height, ear length, 100-grain weight, grain depth, number of rows ear, number of kernels row and grain yield were measured and recorded. Showed positive significant heterosis for cob girth.
		Sundararajan and Kumar (2011)	Line x Tester	The significant and positive standard heterosis for cob length, cob girth, number of grains per cob, and 100 grain weight was depicted.
		Kumar *et al.* (2014)	Line x Tester	It recorded maximum, significant and positive standard heterosis for grain yield per plant and significant and positive standard heterosis for cob length, cob girth, number of grains per cob, and 100 grain weight.
9	**Number of grain rows per**	Muraya *et al.*	Diallel	Eleven crosses expressed positive and significant relative heterosis for number of grain row per cob ranged from 0.41 to 48.44 per cent, for number of lines per cob

S. No	Characters	Name of Author	Design of experiment	Remarks
	cob	(2006)		ranged from 1.53 to 24.44 per cent and for plant height ranged from 3.87 to 27.57 per cent.
		Sumalini (2012)	Line x Tester	The crosses KML-57 x KML-226, and KML-286 x KML-29 are desirable with significant positive heterosis. KML-223 x KML-3 recorded significant negative heterosis for days to 75 per cent brown husk and number of grain rows per cob.
		Kumar *et al.* (2014)	Line x Tester	Showed desirable significant heterosis for grain yield per plant, number of grain rows per cob, number of kernel rows per ear and ear length. Exhibited positive significant heterosis for number of grain rows per cob.
10	**100-grain weight**	Avinashe *et al.* (2013)	Line x Tester	Identified as superior hybrids as these recorded high per centage of relative heterosis, heterobeltiosis and standard heterosis for grain yield per plant and 100-grain weight along with other characters.
		Rajesh *et al.* (2014)	Line x Tester	*The crosses 5050 × BML 10, 3511 × BML 7, 1234 × BML 10, 1234 × BML 13 and 5050 × BML 7 had high mean performance and standard heterosis over check DHM 117 for grain yield per plant and other yield contributing characters like number of grain row per cob, 100-grain weight, number of kernel rows per ear, ear girth and ear length. Thus these crosses possess high heterosis which can be exploited commercially for higher yield in maize.*
		Verma *et al.* (2014)	Line x Tester	The crosses 5050 × BML 10, 3511 × BML 7, 1234 × BML 10, 1234 × BML 13 and 5050 × BML 7 had high mean performance and standard heterosis over check DHM 117 for grain yield per plant and other yield contributing characters like number of kernels per row, 100-kernel weight, number of kernel rows per ear, ear girth and ear length. Thus these crosses possess high heterosis which can be

S. No	Characters	Name of Author	Design of experiment	Remarks
				exploited commercially for higher yield in maize.
11	**Harvest index**	Gautam *et al.* (2013)	Line x Tester	Thirty nine hybrids showed positive heterosis for grain yield among the 40 crosses. The best positive mid-parent heterosis was found 880 % in cross between RML-32 and RML-17, followed by RL-98 x RML-17 (507 %).
		Khan *et al*. (2014)	Diallel	The hybrid P_2 x P_5 exhibited maximum positive significant economic heterosis for hervest index over the best check PHEM-2. Heterobeltiosis for grain yield per plant was exhibited by twenty six hybrids with maximum heterobeltiosis depicted by the hybrid P_2 x $P_{4.}$
		Ruswandi *et al.* (2015)	Line x Tester	The cross combination M5BR 153.1.2×DR 4 followed by M5DR 3.1.2×DR 6, M5DR 3.1.2×DR 8, M5DR 1.6.3×DR 8, M5DR 4.8.8×DR 4 and M5DR 18.4.1×DR 8 revealed higher magnitude of economic heterosis for grain yield. So, the crosses M5 DR 16.2.1×DR 4 and M5BR 153.1.2×DR 4 can be utilized for developing high yielding hybrid varieties as well as for exploiting hybrid vigor.
12	**Grain yield per plant**	Kapoor *et al.* (2014)	Line x Tester	The cross KI-16 x CM200 exhibited economic heterosis and *per se* performance for grain yield, cob placement height, cob length, cob girth and harvest index.
		Khan *et al*. (2014)	Diallel	The hybrid P_2x P_6 exhibited maximum positive significant heterosis at all the three levels with highest per se performance (11.41%) for protein content. Hybrid P_5 x P_6 exhibited maximum economic heterosis with highest per se performance (149.00) for grain yield per plant (g).
		Praveen *et al.* (2014)	Line x Tester	Over standard check NK 6240, it showed desirable significant heterosis for grain yield per plant, number of kernels per row, number of kernel rows per ear and ear length.

S. No	Characters	Name of Author	Design of experiment	Remarks
		Verma *et al.* (2014)	Line x Tester	The crosses 5050 × BML 10, 3511 × BML 7, 1234 × BML 10, 1234 × BML 13 and 5050 × BML 7 had high mean performance and standard heterosis over check DHM 117 for grain yield per plant and other yield contributing characters like number of grains per row, 100-grain weight, and ear girth. Thus these crosses possess high heterosis which can be exploited commercially for higher yield in maize.
		Ruswandi *et al.* (2015)	Line x Tester	The cross M5BR 153.1.2×DR 4 followed by M5DR 3.1.2×DR 6, M5DR 3.1.2×DR 8, M5DR 1.6.3×DR 8, M5DR 4.8.8×DR 4 and M5DR 18.4.1×DR 8 revealed higher magnitude of economic heterosis for grain yield.
13	**Oil content**	Sinha *et al.* (2013)	Line x Tester	The hybrids L_5 X T_3 and L_6 X T_3 were exhibited highest standard heterosis and per se performance for oil and protein content respectively.
		Kumar *et al.* (2014)	Line x Tester	Stated that all the 60 hybrids showed for days to 50 per cent tasseling and days to 50 per cent silking over standard checks for days to maturity, over standard check NK 6240, it showed desirable significant heterosis for grain yield per plant, number of grains per row, oil content, protein and starch content.
14	**Protein content**	Bekele and Rao (2013)	Line x Tester	All the other crosses gave negative and significant standard heterosis for oil and protein contents over best check. Heterobeltiosis studies revealed that the five hybrids showed positive and significance performance for grain yield. Further three hybrids recorded positive and significant heterobeltiosis for protein content.
		Rajesh *et al.* (2014)	Line x Tester	The five crosses had high mean performance and standard heterosis over check DHM 117 for grain yield per plant and other quality contributing traits oil content,

S. No	Characters	Name of Author	Design of experiment	Remarks
				protein and starch content.
		Kumar and Babu (2016)	Line x Tester	Cross combinations L_1 x T_2, L_7 x T_1, L_{22} x T_2, L_{14} x T_3, L_8 x T_3, L_9 x T_1, L_{19} x T_1 and L_{21} x T_3 exhibited significant heterosis for protein content,oil content and starch content.
15	**Starch content**	Dubey *et al.* (2009)	Line x Tester	The relative heterosis, heterobetiosis and economic heterosis was observed for seed oil content, starch content and grain yield per plant L_{10} x T_1-VC revealed highest *per se* performance for oil content (7.02 per cent) and grain yield per plant (76.25 g/p). 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.
		Rajesh *et al.* (2014)	Line x Tester	The five crosses had high mean performance and standard heterosis over check DHM 117 for grain yield per plant and other quality contributing traits oil content, protein and starch content.

2.2 Combining Ability and Gene Action:

Any crop improvement programme basically depends on the selection of appropriate genotypes. Combining ability analysis through line x tester mating design is most important and efficient tool available with plant breeders which enable them to select the desirable parents and crosses. This method provide information about general combining ability, specific combining ability and nature of gene action with maximum precision, which of great importance in developing an efficient breeding programme.

Sprague and Tatum (1942) formulated the concepts of combining abilities. General combining ability is "the average performance of a strain in series of cross combinations, estimated from the performance of F_1's from the crosses", whereas specific combining ability is "deviation in performance of a cross combination from that predicted on the basis of general combining abilities of the parents involved in the crosses".

The gca variance is due to additive variance and additive x additive interaction variance, while, the sca variance is due to dominance variance, additive x additive variance, additive x dominance variance and dominance x dominance variance components. Literatures on this aspect reviewed are furnished in tabular from in Table: 2.2.

Table 2.2: Review of literature for combining ability and gene action for fifteen characters in maize

S. No	Characters	Name of Author	Design of experiment	Remarks
1	**Days to 50 per cent tasseling**	Singhal *et al.* (2006)	Line x Tester	Reported the importance of both gca and sca for days to 50 per cent tasseling, days to 50 per cent silking, grain yield, 100-grain weight and cob girth. The gca effects of the parents showed that among lines, L_8 was good for cob length, cob girth, grain rows per cob, 100-grain weight and grain yield.
		Jain and Bhardwaj (2014)	Line x Tester	Inbred line showed negative significant gca for days to 50 per cent tasseling. The hybrid $L_6 \times T_1$ exhibited negative significant sca for days to 50 per cent tasseling.
2	**Days to 50 per cent silking**	Dar *et al.* (2007)	Line x Tester	Based on estimated, higher magnitude of σ^2sca in relation to σ^2gca implied the greater importance of non-additive gene effect than additive gene effect for all the traits thus favor by hybrid production. 12 crosses observations were recorded on days to 50 per cent tasselling and silking, plant height, grain rows per cob, 100-grain weight and grain yield estimated.
		Aliu *et al.* (2008)	Diallel	Additive gene effects were more important than non-additive since the ratio was 0.25 among gca and sca. The highest value for maximal EW was a heterozygote combination from the inbred lines L_6 x L_{10} (xg = 376.2 g/ear), while the minimal average value obtained for the

S. No	Characters	Name of Author	Design of experiment	Remarks
				hybrid.
		Motamedi *et al.* (2014)	Line x Tester	Inbred line shows negative significant general combining ability. The hybrids $L_1 \times T_1$ and $L_6 \times T_1$ showed significant negative sca effects for day to50 per cent silking.
3	**anthesis-silking interval (ASI)**	Lata *et al.* (2008)	Line x Tester	The cross L_5 x KH 2001 showed high *per se* performance, sca effects and heterosis for grain yield and medium maturity and thus characters, can be tested over the locations for its consistent performance. Other crosses *viz.*, L_1 x KH 517, L_3 x KH 517, L_7 x KH 2001, L_2 x KH 2001 and L_4 x KH 2001 also showed high heterosis, sca effects and *per se* performance.
		Amiruzzaman *et al.* (2013)	Diallel	Standard heterosis for grain yield ranged from -17.60 to 9.71 percent. For other traits, desirable heterosis varied from -0.10 to -4.42 percent, -0.03 to -4.20 percent, -2.44 to -42.11 percent and -1.33 to -21.87 percent for days to tasseling, days to silking, plant height and ear height, respectively.
4	**Days to 75 per cent brown husk**	Miranda *et al.* (2008)	Diallel	They cited that the general combining ability estimates exhibited significant for day's to 75 per cent brown husk, grain yield, plant height, ear height and degree of husk covering. In addition the specific combining ability observed to be significant for all the traits excluding ear height.

S. No	Characters	Name of Author	Design of experiment	Remarks
		Rashmi *et al.* (2013)	Full Diallel	Data were recorded for seven quantitative traits *viz.,* days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent dry husk, ear length, ear girth, 100 grain weight and grain yield. CM152× CM212 for days to 75 per cent brown husk.
		Rastgari *et al.* (2014)	Diallel	The hybrid L6 × A679 hybrid showed negative significant sca for days to 75 per cent brown husk.
5	**Plant height**	Singh and Kumar (2009)	Line x Tester	Observation days to 50 per cent tasseling, days to 50 per cent silking, plant height, ear height, and days to maturity, ear length, cob girth and grain yield were used to estimate the correlation coefficient of gca with top cross progenies and genotypic medium maturity inbred lines of maize.
		Yousif and Sedeeq (2011)	Line x Tester	The lines (ZP) and (OH40) showed better gca for plant height, but they showed poor combiner with negative gca values for ear height. While the line (R153) showed better gca for ear height.
		Mural and Chikkalingaiah (2012)	Line x Tester	Among the crosses, QPM 35 x T 295 was found superior with positive significant sca effects and better mean performance for grain yield and plant height.
6	**Ear height**	Jebaraj *et al.* (2010)	Line x Tester	Both gca and sca effects were found to be significant for days to 50 per cent silking, days to 50

S. No	Characters	Name of Author	Design of experiment	Remarks
				per cent tasseling, ear height and plant height, but for ear height only gca effects were found to be significant among the tester, Among the crosses, QPM 35 x T 295 was superior with positive significant sca effects and better mean performance for grain yield and plant height.
		Yousif and Sedeeq (2011)	Line x Tester	The lines (ZP) and (OH40) showed better gca for plant height, but they showed poor combiner with negative gca values for ear height. While the line (R153) showed better gca for ear height
7	**Number of leaves per plant**	Jabeen *et al.* (2007)	Half diallel	Showed positive signinficant gca and sca for number of leaves per plant and plant height and ear height.
		Reddy *et al.* (2011)	Line x Tester	Gave greater importance for gca x environment interaction than sca x environment interaction was revealed for cob length and number of leaves per plant. However, only sca x environment was important for grain rows per cob and 100-grain weight. But G x E interactions was of no importance for grain yield and grain row per cob.
8	**Cob girth**	Singh and Kumar (2009)	Line x Tester	Observation days to 50 per cent tasseling, days to 50 per cent silking, plant height, ear height, ear length, ear diameter and grain yield were used to estimate the correlation coefficient of gca with top cross

S. No	Characters	Name of Author	Design of experiment	Remarks
				progenies and genotypic medium maturity inbred lines of maize.
		Patil *et al.* (2012)	Line x Tester	Reported significant gca and sca effects for days to 75 per cent silking, plant height and cob girth. However, Mean squares due to gca and sca in pooled analysis were significant for cob girth. Only two crosses NM-099 x NM-0973 and NM-0984 x NM-0914 were found to be the best crosses based on high significant sca effects.
9	**Number of grain rows per cob**	Abrha *et al.* (2013)	Line x Tester	They cited that there were significant mean square differences due to line gca for all the traits analyzed while tester gca was significant only for grain yield and cob height. Mean squares due to sca were highly significant for grain yield plant and number of grains row per cob and 100 grain weight.
		Verma *et al.* (2014)	Line x Tester	Mean squares due to sca were highly significant for grain yield per plant and other yield contributing characters like number of grain rows per cob, 100-grain weight, ear girth and ear length.
10	**100-grain weight**	Gautam *et al.* (2013)	Line x Tester	Studied the significant gca estimates for cob length, cob girth, cob weight per plant and 100 grain weight while, significant sca estimates were reported for cob girth.
		Jebaraj *et al.*	Line x	Among the parents studied the

S. No	Characters	Name of Author	Design of experiment	Remarks
		(2010)	Tester	following parents *viz.*, UMI 112, UMI 264, UMI 278, UMI 285 and Co 1 were good general combiners with higher mean values for seed yield and different yield components *viz.*, plant height, ear length, kernel rows and 100 grain weight.
12	**Grain yield per plant**	Vijayabharathi *et al.* (2009)	Line x Tester	Based on both *per se* and gca, the genotypes UPC 5, UPC 4 and UPC 1 among lines and Amber popcorn, Bangalore popcorn among the testers were proved as good general combiners for yield and quality traits.
		Abrha *et al.* (2013)	Line x Tester	They cited that there were significant mean square differences due to line gca for all the traits analyzed while tester gca was significant only for grain yield and cob height. Mean squares due to sca were highly significant for grain yield plant and number of grains row per cob and 100 grain weight.
		Panwar *et al.* (2013)	Diallel	They cited that the ratio of sca / gca variance was greater than one for all the traits, thereby indicating the preponderance of non-additive gene effects. Inbred line P6 was good general combiner for days to 50 per cent silking, 100- grain weight, grain yield per plant and protein content. One hybrid showed positive significant sca effects for grain yield per plant and protein content with highest estimate of sca effects.

S. No	Characters	Name of Author	Design of experiment	Remarks
13	**Oil content**	Shanthi *et al.* (2010)	Diallel	From this study it is inferred that, the three hybrids P_4 x P_7, P_2 x P_6 and P_5 x P_{10} were considered as most stable and good specific combiners for grain yield and quality parameters (protein, oil and starch content) along with higher *per se* values for the characters studied
		Sharma *et al.* (2015)	Line x Tester	They reported that the gca interaction effects were significant for plant height, ASI and grain yield. The sca effects were significant for days taken to tasseling. Based on gca effects (g_i), $\sigma^2 g_i$, $\sigma^2 s_i$ and per se performance for each parent, SD/17 line for 100 grain weight, SD/15 line for number of rows per cob, SD/10 line oil and protein content.
14	**Protein content**	Elmyhum *et al.* (2013)	Line x Tester	For grain yield trait significant and highest gca effect was recorded in parental line LN5 and it showed significant gca effects for plant height, protein content and oil content. Line LN6 revealed significant positive gca effect for starch content. However; hybrid HN3, HN8 and HN10 were good specific combiners for protein content.
		Khan *et al.* (2014)	Diallel	Hybrid P_6 x P_7 exhibited highest positive significant economic heterosis (10.23 %) along with positive significant sca effects for grain yield per plant and

S. No	Characters	Name of Author	Design of experiment	Remarks
				protein content.
15	**Starch content**	Sharma *et al.* (2015)	Line x Tester	The maximum significant positive sca effects exhibited by Hybrid L_{12} x T_1 for grain yield per plant and by hybrid L_2 x T_1 for starch content
		Khan *et al.* *(*2016)	Diallel	They concluded variance due to sca was higher than gca by the σ^2 gca/σ^2 sca ratio being less than one for the all characters. Parents were the good general combiners and genetically worthy parents as they contributed favorable genes for grain yield and quality traits *viz*, oil, protein and starch content.

3. MATERIALS AND METHODS

The present investigation entitled **“Heterosis and Combining Ability Analysis in Medium Maturing Yellow Seeded Maize (*Zea mays* L.) Hybrids**” was carried out at the Instructional farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur *Kharif* -2016.

The details of experimental site, materials used and techniques adopted during the course of present investigation are described in this chapter.

3.1 Experimental Site and Conditions:

Geographically, Udaipur is situated at 24^0-35’ N latitude and 73^0-42’ E longitude and at an elevation of 582.17 meters above mean sea level. The climatic conditions of the area represent subtropical condition with humid climate. The meteorological data on temperature, rainfall, and relative humidity during crop growth period *Kharif*-2016, recorded at Agro-meteorological Observatory, Instructional farm, Rajasthan College of Agriculture, MPUAT, Udaipur are given in Table 3.1 and graph Fig. 3.1. The soil of experimental field was clay loam, deep, well drained, alluvial in origin and has fairly good moisture holding capacity. The physico-chemical characteristics of the soil of the experimental site are presented in Table 3.2.

3.2 Experimental Material:

In this experiment12 inbred lines medium maturing yellow seeded maize were crossed with three testers *viz*., (EI-586-2, EI-1155 and BML-6) in line x tester design to develop 36 hybrids and four checks were evaluated in randomized block design with three replications during *kharif*-2016 (**Table 3.3).**

3.3 Experimental Design:

The experimental material consisted of a total of 55 entries (36 F_1 hybrids, 12 parents and 4 checks) were planted in randomized block design with three replications with a single row plot of four meter length, maintaining crop geometry of 60 x 25 cm. The recommended agronomical package of practices in zone IVA of Rajasthan were used to raise a healthy crop.

Table 3.1: Meteorological parameters (weakly average) during the crop growth period for *Kharif* -2016

Standard Week No.	Date	Temperature (°C)		Relative humidity (per cent)		Total Rainfall of week (mm)
		Max.	**Min.**	**Max.**	**Min.**	
27.	2 July- 8 July	32.2	25.1	80.9	60.0	39.2
28.	9 July- 15 July	31.0	23.9	86.7	70.9	91.6
29.	16 July - 22July	29.9	24.3	78.0	67.1	5.4
30.	23 July- 29 July	30.8	23.6	89.7	70.0	157.6
31.	30 July -5Aug	27..9	23.3	92.0	83.0	124.2
32.	6 Aug-12 Aug	26.8	23.5	95.0	89.0	104.5
33.	13 Aug-19 Aug	30.0	23.0	83.6	65.6	0.6
34.	20 Aug-26 Aug	27.6	23.2	91.1	78.9	61.2
35.	27 Aug-2 Sept	30.4	23.5	89.4	71.1	14.4
36.	3 Sept -9 Sept	29.9	22.2	78.7	57.7	0.0
37.	10 Sept-16 Sept	31.7	21.8	78.1	49.3	0.0
38.	17 Sept - 23 Sept	34.6	23.3	81.6	47.6	3.4
39.	24 Sept- 30 Sept	35.3	22.1	74.0	42.7	0.0
40.	1 Oct – 7 Oct	31.7	23.2	88.4	65.1	62.4
41.	8 Oct-14 Oct	32.0	19.5	81.1	41.9	0.0
42.	15 Oct-21 Oct	32.4	17.9	72.0	30.4	0.0
43	22 Oct- 28 Oct	30.8	15.7	76.0	32.0	0.0

Source: Agro-met observatory, Instructional farm, Rajasthan College of Agriculture, Udaipur

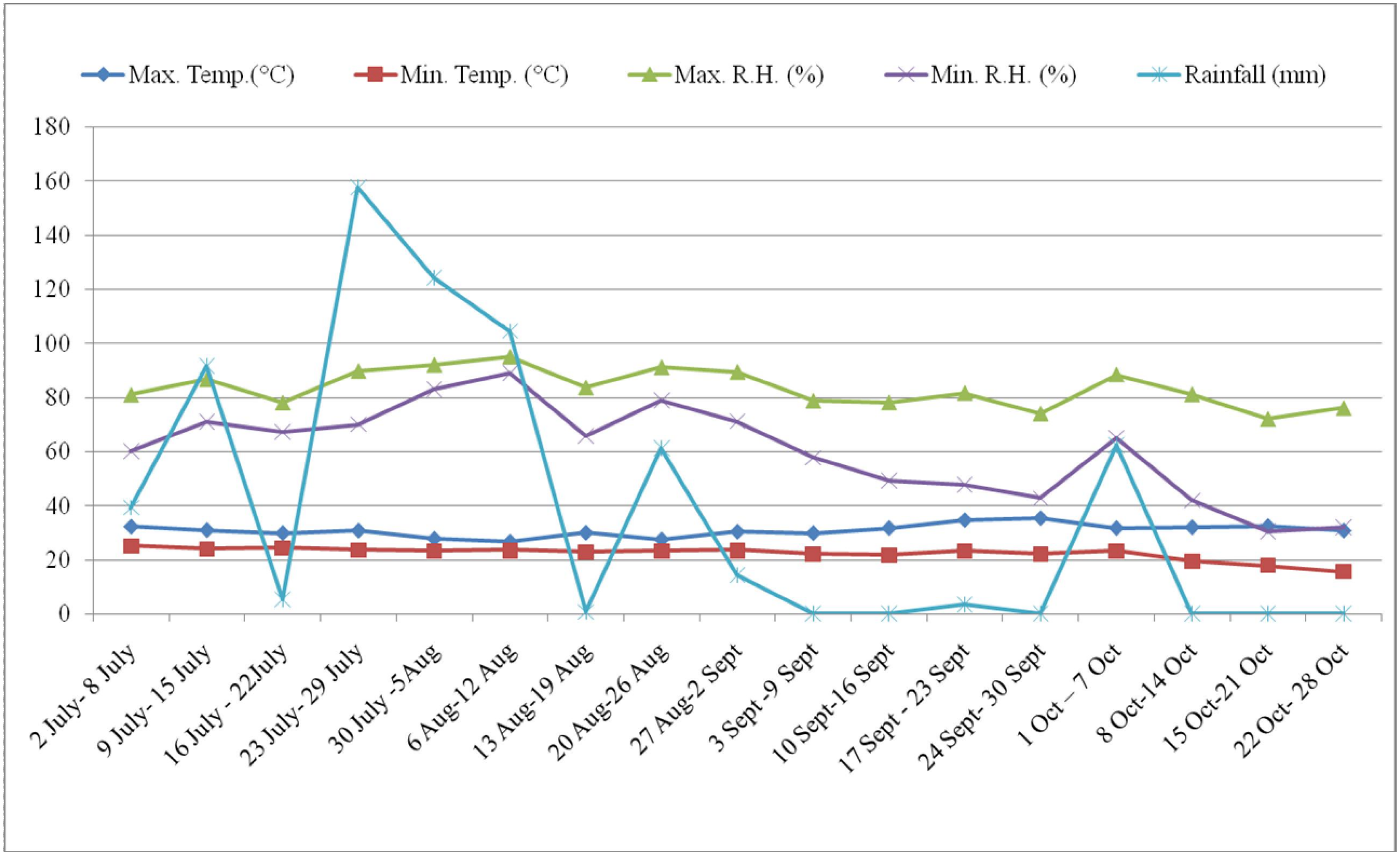

Fig.3.1: Meteorological parameters (weekly average) during crop growth period 8 July to 15 October for *Kharif*-2016

Table 3.2: Physico-chemical characteristics of the soil of the experimental site

	Soil Characteristics	Instructional Farm, RCA, Udaipur
A.	**Mechanical**	
	(a) Coarse sand (%)	10.42
	(b) Fine sand (%)	27.13
	(c) Silt (%)	29.95
	(d) Clay (%)	27.55
	(e) Textural class	Clay loam
B.	**Physical**	
	(a) Bulk density (g/cc)	1.52
	(b) Particle density (g/cc)	2.65
	(c) Porosity (%)	43.39
	(d) Field capacity (%)	25.73
	(e) Permanent wilting capacity	12.53
C.	**Chemical**	
	(a) Organic carbon (%)	0.58
	(b) Total nitrogen (%)	0.09
	(c) Available P (kg / ha)	81.00
	(d) Available K (kg / ha)	836.00
	(e) pH	7.5
	(f) EC do / m (250^0C)	1.92

Table 3.3: List of materials (inbred lines, testers and checks) used under study

S.No.	Inbred line	Pedigree	Source	Level of inbreeding
1.	L_1	(EI-2522)	MPUAT, Udaipur	S_6
2.	L_2	(EI-2531)	MPUAT, Udaipur	S_6
3.	L_3	(EI-2533)	MPUAT, Udaipur	S_6
4.	L_4	(EI-2535)	MPUAT, Udaipur	S_6
5.	L_5	(EI-2536)	MPUAT, Udaipur	S_6
6.	L_6	(EI-2538)	MPUAT, Udaipur	S_6
7.	L_7	(EI-2540)	MPUAT, Udaipur	S_6
8.	L_8	(EI-2541)	MPUAT, Udaipur	S_6
9.	L_9	(EI-2542)	MPUAT, Udaipur	S_6
10.	L_{10}	(EI-2544)	MPUAT, Udaipur	S_6
11.	L_{11}	(EI-2550)	MPUAT, Udaipur	S_6
12.	L_{12}	(EI-2552)	MPUAT, Udaipur	S_6
13.	T_1	(EI-586-2)	MPUAT, Udaipur	S_6
14.	T_2	(EI-1155)	MPUAT, Udaipur	S_7
15.	T_3	(BML-6)	Hyderabad	S_7
16.	Pratap Hybrid Maize-3	-	MPUAT, Udaipur	Hybrid variety
17.	Vivek Hybrid-43	-	VPKAS, Almora	Hybrid variety
18.	Pratap Makka-9	-	MPUAT, Udaipur	Composite variety
19.	HM-11	-	CCSHAU, Hissar	Hybrid variety

Where,

MPUAT- Maharana Pratap University of Agriculture and Technology, Udaipur

VPKAS- Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora

CCSHAU- Chaudhary Charan Singh Haryana Agricultural University, Hissar

3.4 Traits under Study:

Observations for all the traits were recorded on ten randomly selected competitive plants of each entry in each replication except for days to 50 per cent tasseling, days to 50 per cent silking and days to 75 per cent brown husk where observations were recorded on plot basis.

3.4.1 Days to 50 per cent tasseling:

The numbers of days were counted from date of sowing to the date of emergence of tassel shedding pollen in 50 per cent plants of a treatment.

3.4.2 Days to 50 per cent silking:

The numbers of days were counted from date of sowing to the date when 50 per cent plants in a treatment have appearance of 2-3 cm long silk.

3.4.3 Anthesis-silking interval (ASI):

It is calculated as a difference (in days) between days to 50 per cent tasseling and days to 50 per cent silking.

3.4.4 Days to 75 per cent brown husk:

This phonological observation was recorded on population basis. The numbers of days were counted from date of sowing to the date when 75 per cent plants in a plot exhibit brown husk of ears.

3.4.5 Plant height (cm):

Height of plant was recorded in centimeters at maturity from the base of the plant to flag leaf.

3.4.6 Ear height (cm):

Ear height was measured in centimeters at maturity of tagged ten plants from the base of plant to the base of first ear placement.

3.4.7 Number of leaves per plant:

Total numbers of leaves were counted after pollination on each selected plant and average was calculated.\

3.4.8 Cob girth (cm):

After removing the ear husk, girth diameter of ear of ten randomly selected competitive plants was measured in centimeters as the thickness of the ear at the middle of the ear and mean girth diameter of per cob.

3.4.9 Number of grain rows per cob:

The number of grain rows in middle of cob was counted in each cob separately in tagged plant and average was taken.

3.4.10 100-grain weight (g):

Two samples of 100 grain from each treatment in every replication were taken randomly (at 15 per cant moisture) and weighted in grams and average was taken.

3.4.11 Harvest index (per cent):

Harvest index is the ratio of economic (grain yield) to biological yield (Stover and grain yield) and was calculated using the formula of Donald and Hamblin (1976).

$$Harvest\ index = \frac{Economic\ (grain)\ yield\ per\ plant}{Biological\ yield\ per\ plant} \times 100$$

3.4.12 Grain yield per plant (g):

The dried cobs of selected plants were shelled separately and then the yield was determined in grams (at 15 per cant moisture) and averaged.

3.4.13 Oil content (per cent):

The Soxhlet's Ether Extraction method developed by A.O.A.C. (1965) was used for estimation of oil content. Two samples per treatment per replication were analyzed and oil content was estimated in per cent and average was determined. The detailed procedure used is given in Appendix III.

3.4.14 Protein content (per cent):

Protein content of the seeds was estimated by using Micro kjeldahl's method given by Linder (1944). Two samples of maize grains per treatment per replication were analyzed and average was taken. The detailed procedure is given in Appendix IV.

3.4.15 Starch content (per cent):

Two samples of maize grains per treatment per replication were analyzed and average was taken. The starch content was determined by Anthrone Reagent method. The details of the method used are given in Appendix V.

3.5 Statistical Analysis:

The statistical analysis were subjected to estimated heterosis and combining ability, using replication mean values on ten randomly selected plants. The statistical procedure adopted was as under**:**

3.5.1 Analysis of variance:

The analysis of variance was carried out for randomized block design separately for all the traits under study on plot mean basis as per standard statistical procedure described by Panse and Sukhatme (1985). The general structure of ANOVA is given in Table 3.4.

The Statistical model for randomized block design is-

$$Y_{ij} = \mu + \beta_i + \tau_j + \Sigma_{ij}$$

Where, Y_{ij} = Mean phenotypic value of j^{th} genotype in i^{th} replication,

μ = General mean,

β_i = Effect due to i^{th} replication,

τ_j = Effect due to j^{th} genotype and

Σ_{ij} = Uncontrolled variation associated with j^{th} genotype in i^{th} replication.

Table 3.4: Analysis of variance and expectation of mean squares

Source of variation	DF	S.S.	M.S.	Expected mean squares
Replications	r-1	SS_1	M_1	$\sigma^2_E + g\,\sigma^2_r$
Genotypes	g-1	SS_2	M_2	$\sigma^2_E + r\,\sigma^2_g$
Parents	p-1	SS_3	M_3	$\sigma^2_E + r\,\sigma^2_p$
Crosses	h-1	SS_4	M_4	$\sigma^2_E + r\,\sigma^2_h$
Parents vs Crosses	1	SS_5	M_5	-
Error	(g-1)(r-1)	SS_6	M_6	σ^2_E

Where,

r = number of replications,

g = number of genotypes,

p = number of parents

h = number of hybrids.

Test of significance

The F ratio was calculated for each source of variation by dividing M_6 (error mean square) to their respective mean squares:

$$F = \frac{Mi}{M_6}$$

Where,

Mi = Mean squares due to i[th] source.

Standard error of mean

The standard error of mean was calculated by the following formula:

$$SEm \pm = \sqrt{\frac{M_6}{r}}$$

Critical difference

Critical difference for each character was calculated as follows:

$$C.D. = \sqrt{\frac{2M_6}{r}} \times t_{[(r-1)(g-1)]}$$ at 5 per cent or 1 per cent level of significance

Coefficient of variation

The co-efficient of variation for each character was calculated as follows:

$$C.V. \text{ (per cent)} = \frac{\sqrt{M_6}}{\bar{X}} \times 100$$

Where,

$\bar{X}$ = Mean over genotypes and replications

3.5.2 Estimation of heterosis, Heterobeltiosis and economic herterosis

Heterosis was expressed as per cent deviation from mid parent, where as heterobeltiosis and economic heterosis as per cent deviation towards desirable direction over better parent and standard check respectively. The formulas used for their estimation and for testing significance were as follows.

(a) Heterosis (per cent)

Relative heterosis / mid parent heterosis was calculated as per procedure suggested by Turner (1953).

$$\text{Relative heterosis (per cent)} = \frac{(\overline{F}_1 - \overline{MP})}{\overline{MP}} \times 100$$

Its significance was tested by ‘t’ as follows:

$$t_{[(r-1)\,(g-1)]} = \frac{(\overline{F}_1 - \overline{MP})}{SE(\overline{F}_1 - \overline{MP})}$$

$$SE\,(F_1 - MP) = \sqrt{\frac{3\ Mse}{2r}}$$

Where,

$\overline{MP} =$ Mean value of two parents of corresponding F_1 i.e. $(P_1 + P_2)/2$,

$\overline{F_1} =$ Mean performance of hybrid

(b) Heterobeltiosis (per cent)

Heterobeltiosis / better parent heterosis was calculated as per procedure suggested by Fonesca and Patterson (1968).

$$\text{Heterobeltiosis (per cent)} = \frac{(\overline{F}_1 - \overline{BP})}{\overline{BP}} \times 100$$

Its significance was tested by ‘t’ test as follows:

$$t_{[(r-1)\,(g-1)]} = \frac{(\overline{F}_1 - \overline{BP})}{SE(\overline{F}_1 - \overline{BP})}$$

$$SE(\overline{F}_1 - \overline{BP}) = \sqrt{\frac{2\ Mse}{r}}$$

Where,

$\overline{BP} =$ Mean performance of better parent in desired direction,

$\overline{F_1} =$ Mean performance of F_1 hybrid

(c) Economic heterosis (per cent)

Economic heterosis / standard check heterosis was calculated as per procedure suggested by Briggle (1963).

Economic heterosis = $\frac{(\overline{F}_1 - \overline{BC})}{\overline{BC}}$ x 100

It's significance was tested by't' test as follows:

$$t_{[(r-1)\,(g-1)]} = \frac{(\overline{F}_1 - \overline{BC})}{SE(\overline{F}_1 - \overline{BC})} \; x \; 100$$

$$SE(\overline{F}_1 - \overline{BC}) = \sqrt{\frac{2Mse}{r}}$$

The critical difference (C.D.) was estimated as under:

C.D. (5 per cent or 1 per cent level of significance) = SE x t (5 per cent or 1 per cent level of significance)

Where,

$\overline{BC}$	=	Mean performance of best check in desired direction
$\overline{F}_1$	=	Mean performance of F_1 hybrid,
P_1	=	Mean value of first parent,
P_2	=	Mean value of second parent,
r	=	Number of replications,
M_{se}	=	Error mean square and
t	=	Table value of 't' for error degree of freedom at 5 per cent or 1 per cent level.

Heterosis in positive direction was considered desirable for all the characters except traits like days to 50 per cent tasseling, days to 50 per cent silking, Anthesis-silking interval, days to 75 per cent brown husk, plant height and ear height, where negative direction was considered desirable.

3.5.3 Combining ability analysis:

The combining ability analysis for line x tester mating design was performed as per method suggested by Kempthorne (1957). The analysis of variance for combining ability through line x tester mating design (including parents) is given in Table 3.5. From the expectation or mean squares covariance o full sibs and half sibs were estimated using the sum of square due to female as a line (MS_1), male as a tester (MS_2) and female x male (MS_3).

Table 3.5: Analysis of variance for combining ability

Source of variation	**D.F.**	**M.S.**	**Expectations of mean squares**	
			Components	**Covariance**
Replications	**r -1**	**-**	**-**	**-**
Crosses	**lt -1**	**-**	**-**	**-**
Lines	**l -1**	M_1	$\sigma^2_E + r\,\sigma^2_{LT} + rt\,\sigma^2_L$	σ^2_E**+r.Cov.(FS) -2 Cov. (H.S.) + lt Cov. (H.S.)**
Testers	**t -1**	M_2	$\sigma^2_E + r\,\sigma^2_{LT} + rl\,\sigma^2_T$	σ^2_E**+r.Cov.(FS) -2 Cov. (H.S.) + Cov. (H.S.)**
Line x Tester	**(l -1) (t -1)**	M_3	$\sigma^2_E + r\,\sigma^2_{LT}$	σ^2_E**+r.Cov.(FS) -2 Cov. (H.S.)**
Error	**(r -1) (lt - 1)**	M_4	σ^2_E	σ^2_E

Test of Significance

The F for each source was calculated by dividing M_4 to mean square (M_1 to M_3) of each source.

Where,

l, t, r = Number of lines, tester and replications,

σ^2_E = Variance among the individual from the same mating

σ^2_T = Progeny variance arising from difference among testers,

σ^2_L = Progeny variance arising from difference among lines,

σ^2_{LT} = Progeny variance arising from interactions of lines and testers.

Estimation of variance components

$\sigma^2_L = (M_1 - M_3) / rt$

σ^2_T = $(M_2 – M_3) / rl$

σ^2_{LT} = $(M_3 – M_4) / r$

Estimation of Cov. H. S. and Cov. F. S.

Cov. $HS._{(line)}$ = $(M_1 – M_3) / rt$

Cov. $H.S._{(tester)}$ = $(M_2 – M_3) / rl$

Cov. $H.S._{(average)}$ = $[(l-1) M_1 + (t-1) M_2 / \{(l+t-2)\} – M_3] / [r(2\ lt-l-t)]$

Cov.F.S. = $M_1 + M_2 + M_3 – 3M_4$ + 6r.Cov.H.S. (Average) – r (1 + t) Cov.H.S. (average)] / 3r

σ^2_{gca} L = σ^2L

σ^2_{gca} T = σ^2T

σ^2_{gca} = Cov. $H.S._{(average)}$

σ^2_{sca} = σ^2LT = (Cov. F.S. – 2 Cov. H.S.)

Genetic Component of Variation

$$\sigma^2_A = \frac{4}{1+F}\ \sigma^2_{gca}$$

$$\sigma^2_D = \left(\frac{2}{1+F}\right)^2\ \sigma^2_{gca}$$

Where,

F = Inbreeding coefficient (in present case it was assumed to be 1)

Estimation of General and Specific Combining Ability Effects

The following model was used to estimate general and specific combining ability effects of the ijth observations.

$$Y_{ijk} = \mu + G_i + G_j + S_{ij} + R_k + \Sigma e_{ijk}$$

Where,

Y_{ijk} = Phenotypic expression of ijth genotype in kth replication.

μ = Population mean,

G_i = g.c.a. effects of ith line,

G_j = g.c.a. effects of j^{th} tester,

S_{ij} = s.c.a. effects of cross between i^{th} line and j^{th} tester,

R_k = Effect of k^{th} replication and

Σe_{ijk} = Uncontrolled variation/error associated with ij cross in k^{th} replication

i = Varies from 1, 2, 3,…..l

j = Varies from 1, 2, 3,…..t

k = Varies from 1, 2, 3,…..r.

The individual effects were measured as explained below

μ = X…/ ltr

Where,

X… is the total of hybrid combinations

g_i = (X_i … / lr) - (x… / ltr)

Where,

X_i… is the total of i^{th} male parents over all lines and replications.

g_j = (X_j / tr) – (X… / ltr)

Where,

X_j = is the total of j^{th} female parent over all testers and replications.

S_{ij} = (X_{ij} / r) – (X_i… / lr) – (X_j / tr)n + (X… /ltr)

Where,

X_{ij} = ij^{th} combination total over all replications.

Standard error of combining ability effects

S.E. (g.c.a. for lines) = $(MSe/rt)^{1/2}$

S.E. (g.c.a. for testers) = $(MSe/rl)^{1/2}$

S.E. (g.c.a. for effects) = $(MSe/r)^{1/2}$

S.E. (g_i - g_j for lines) = $(2MSe/rt)^{1/2}$

S.E. (g_i - g_j for testers) = $(2MSe/ri)^{1/2}$

$$S.E. (S_{ij} - S_{ki}) = (2MSe/r)^{1/2}$$

4. EXPERIMENTAL RESULTS

The experimental results of tha present investigation entitled '**Heterosis and Combining Ability Analysis in Medium Maturing Yellow Seeded Maize (***Zea mays* L**.) Hybrids**' are discussed under the following heads:

4.1 Analysis of variance for experimental design

4.2 *Per se* performance of parents and their hybrids

4.3 Heterosis, heterobeltiosis and economic heterosis

4.4 Combining ability analysis

4.1 Analysis of Variance for Experimental Design (Table 4.1)

The analysis of variance for experimental design was carried out for all the fifteen characters *viz.*, days to 50 per cent tasseling, days to 50 per cent silking, anthesis-silking interval, days to 75 per cent brown husk, plant height, ear height, number of leaves per plant, cob girth, number of grain row per cob, 100-grain weight, harvest index, grain yield per plant, oil content, protein content, and starch content.

The analysis of variance indicated that mean squares due to genotypes, parents, crosses and parents v/s crosses were significant for all the characters except for days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent brown husk, no. of leaves per plant, cob girth and number of grain row per cob due to genotypes, days to 75 per cent brown husk and number of leaves per plant due to parents, anthesis-silking interval, days to 75 per cent brown husk, number of leaves per plant, cob girth, number of grain row per cob and 100-grain weight due to parents v/s crosses and anthesis-silking interval, days to 75 per cent brown husk and number of leaves per plant due to crosses (Table 4.1). The significant mean square of different character indicated the existence of appreciable amount of genetic variability under research experimental materials.

Table 4.1: Analysis of variance for fifteen traits in maize

Source of variance	Df	Mean Squares														
		Days to 50 per cent tasseling	Days to 50 per cent silking	Anthesis-silking interval	Days to 75 per cent brown husk	Plant height	Ear height	Number of leaves per plant	Cob girth	Number of grains rows per cob	100-grain weight	Harvest index	Grain yield (g/plant)	Oil content	Protein content	Starch content
Replication	2	19.98**	10.85	1.77*	6.62	58.93	61.07	0.23	1.81	4.06	4.95	0.68	20.77	0.09	0.10	0.09
Genotypes	54	22.87	18.94	0.72*	12.03	936.05**	339.11**	1.41	3.58	3.22	8.39**	27.98**	1264.08**	0.95**	1.75**	14.60**
Parents	14	24.81**	16.79**	0.95*	14.61	496.46**	122.05**	2.07	7.84**	4.65**	7.80**	19.12**	1071.77**	0.91**	1.88**	13.56**
Crosses	35	13.48**	12.46**	0.56	11.47	241.82**	141.55**	1.11	2.07**	2.60**	9.22**	28.97**	1149.30**	1.03**	1.72**	15.82**
Parents v/s Crosses	1	385.01**	303.80**	0.55	16.06	33052.95**	9689.48**	2.09	0.07	0.41	3.45	180.43**	11882.95**	0.30**	1.85**	22.18**
Error	108	3.44	4.47	0.53	18.78	51.24	26.24	1.31	0.78	1.40	1.66	1.60	27.60	0.07	0.05	0.49

*, ** Significant at 5 per cent and 1 per cent level of significance, respectively

4.2 *Per Se* performance of parents and their hybrids:

The parent hybrids and checks of fifteen characters studied are presented in Appendix I and Appendix II. The character wise results are presented as here under.

4.2.1 Days to 50 per cent tasseling (Appendix I)

Days to 50 per cent tasseling ranged from 65.67 (T_3) to 67.00 days (T_1), from 61.67 (L_{12}) to 68.33 days (L_2) and from 59.33 (L_7 x T_3) to 70.33 days (L_9 x T_2) among testers, inbred lines and hybrids, respectively. The days to 50 per cent tasseling among the check it was ranged from 60.33 (Pratap Hybrid Maize-3) to 63.33 days (Pratap Makka-9).

4.2.2 Days to 50 per cent silking (Appendix I)

The data revealed that days to 50 per cent silking ranged from 67.67 (T_3) to 70.00 days (T_1), from 64.67 (L_{12}) to 71.33 days (L_2), form 62.33 (L_7 x T_3) to 71.33 days (L_9 x T_2) and 62.00 (Pratap Hybrid Maize-3) to 66.00 days (HM-11) among testers, inbred lines, hybrids and checks, respectively.

4.2.3 Anthesis-silking interval (Appendix I)

The data of anthesis-silking interval ranged from 1.33 (T_2) to 3.00 days (T_1), from 2.00 (L_{10}) to 3.33 days (L_5 and L_6) and from 1.33 (L_8 x T_2) to 3.67 days (L_1 x T_2) among testers, inbred lines and hybrids, respectively. The data of anthesis-silking interval among the check varied from 1.67 (Pratap Hybrid Maize-3) to 3.33 days (Vivek Hybrid-43).

4.2.4 Days to 75 per cent brown husk (Appendix I)

The mean values revealed that days to 75 per cent brown husk ranged among testers from 89.00 (T_2) to 96.00 days (T_3), among inbred lines form 88.67 (L_{11}) to 94.33 days (L_7), among hybrids from 88.00 (L_{11} x T_2) to 95.00 days (L_{10} x T_2) and among checks from 89.33 (Vivek Hybrid-43) to 93.00 days (HM-11).

4.2.5 Plant height (Appendix I)

The mean values of plant height ranged among testers from 107.83 (T_2) to 124.17 cm (T_3), among inbred lines form 107.83 (L_3) to 156.06 cm (L_1), among hybrids from 135.62 (L_6 x T_2) to 172.98 cm (L_2 x T_3), and among checks from 118.72 (Pratap Hybrid Maize-3) to 147.34 cm (Pratap Makka-9).

4.2.6 Ear height (Appendix I)

The data for this trait revealed that ear height ranged among testers from 46.45 (T_1) to 57.72 cm (T_3), among inbred lines from 48.05 (L_4) to 69.92 cm (L_9), among hybrids from 57.25 (L_6 x T_2) to 87.79 cm (L_{12} x T_3) and among checks 42.78 (Pratap Hybrid Maize-3) to 71.85 cm (Pratap Makka-9).

4.2.7 Number of leaves per plant (Appendix I)

The number of leaves per plant ranged among testers from 14.47 (T_1) to 15.47 (T_2), among inbred lines from 12.15 (L_3) to 15.30 (L_1), among hybrids from 13.27 (L_4 x T_1) to 16.00 (L_{11} x T_2) and among checks 14.47 (Pratap Makka-9) to 15.70 (Vivek Hybrid-43).

4.2.8 Cob girth (Appendix I)

Cob girth is ranged from 10.52 (T_3) to 11.75 cm (T_2) among testers, from 9.32 (L_7) to 14.42 cm (L_{12}) among inbred lines, from 9.75 (L_8 x T_3) to 13.02 cm (L_{10} x T_3) among hybrids and from 11.45 (Pratap Hybrid Maize-3) to 12.75 cm (HM-11) among checks.

4.2.9 Number of grains rows per cob (Appendix II)

The data revealed that number of grams rows per cob is ranged from 12.87 (T_3) to 12.93 cm (T_1) among testers, from 11.40 (L_7) to 15.80 cm (L_{12}) among inbred lines, from 11.20 (L_8 x T_3) to 15.33 cm (L_9 x T_3) among hybrids and from 13.80 (Vivek Hybrid-43) to 15.07 cm (Pratap Makka-9) among checks.

4.2.10 100 grain weight (Appendix II)

The perusal of mean data revealed that among tester 100 grain weight range varied from 32.64 (T_3) to 34.31 grams (T_1), among inbred lines from 30.64 (L_3) to 35.98 grams (L_{10}), among hybrids from 27.64 (L_6 x T_1) to 35.64 grams (L_5 x T_1) and among checks from 30.64 (Pratap Hybrid Maize-3) to 33.98 grams (Vivek Hybrid-43).

4.2.11 Harvest index (%) (Appendix II)

The range of harvest index varied among testers from 29.33 (T_1) to 32.87 per cent (T_3), among inbred lines from 28.20 (L_2) to 36.80 per cent (L_{12}), among hybrids from 28.73 (L_{12} x T_1) to 29.40 per cent (L_{12} x T_3) and among checks from 29.93 (Vivek Hybrid-43) to 35.00 per cent (Pratap Makka-9).

4.2.12 Grain yield per plant (g) (Appendix II)

The perusal of mean data revealed that grain yield per plant ranged among testers from 59.95 (T_1) to 96.55 grams per plant (T_3), among inbred lines from 57.42 (L_2) to 120.07 grams per plant (L_{12}), among hybrids from 67.22 (L_1 x T_1) to 151.48 grams per plant (L_{12} x T_3) and among checks from 78.28 (Vivek Hybrid-43) to 105.08 grams per plant (Pratap Makka-9).

4.2.13 Oil content (%) (Appendix II)

The magnitude of variation for oil content varied from 3.72 (T_1) to 4.96 per cent (T_3), from 3.50 (L_1) to 4.76 per cent (L_{10} from 3.19 (L_2 x T_2) to 4.88 per cent (L_{11} x T_3) and from 3.52 (Pratap Makka-9) to 4.55 per cent (HM-11) among testers, inbred lines, hybrids and check, respectively.

4.2.14 Protein content (%) (Appendix II)

The range of protein content varied from 8.25 (T_1) to 9.46 per cent (T_3), from 7.48 (L_{12}) to 9.52 per cent (L_4), from 7.33 (L_8 x T_3) to 10.08 per cent (L_2 x T_3) and from 8.62 (Vivek Hybrid-43) to 9.92 per cent (HM-11) among testers, inbred lines, hybrids and check, respectively.

4.2.15 Starch content (%) (Appendix II)

The magnitude of variation for starch content ranged from 63.90 (T_3) to 67.74 per cent (T_2) among testers, from 62.01 (L_9) to 68.99 per cent (L_2) among inbred lines, from 61.36 (L_1 x T_2) to 69.03 per cent (L_2 x T_3) among hybrids and from 63.16 (Pratap Makka-9) to 66.74 per cent (Pratap Hybrid Maize-3) among checks.

4.3 Heterosis, Heterobeltiosis and Economic Heterosis:

The manifestation of heterosis in crop plants is one of the major objective to plant breeders in present situation of uncontrolled population growth of the country as well as world to mitigate present in future food requirement.

The concept of heterosis given by Fonesca and Patlerson (1968) was for superiority of hybrids over better parent. According to modern concept, heterosis is the expression of joint action of favourable genes and interaction among allelic, non-allelic and mitochondrial genes, brought together from the parents to hybrids.

Heterosis is being exploited commercially in important cross pollinated crops and to limited extent in self pollinated crops. The measures of heterosis over mid-parent have relatively limited importance and is more of academic interest rather than of practical significance.

In present investigation, the extent of heterosis, heterobeltiosis and economic heterosis were expressed as pre cent increase in hybrid performance in relation to mid-parent, better parent and standard check. Out of four standard checks, the best one on the basis of performance was used to compare the genotypes, considering the economic importance of that trait in desirable direction. Tha trait wise results are discussed as under:

4.3.1 Days to 50 per cent tasseling (Table 4.3.1)

Heterosis for days to 50 per cent tasseling ranged from -13.13 (L_3 x T_2) to 0.96 per cent (L_9 x T_2). Out of 36 hybrids, 31 hybrids depicted negative heterosis. Heterobeltiosis significant in negative direction was expressed by 14 hybrids. It ranged from -10.78 (L_3 x T_2) to -4.9 per cent (L_3 x T_1). None of the hybrid depicted significant negative economic heterosis for this trait against the best check HM-11.

4.3.2 Days to 50 per cent silking (Table 4.3.1)

The estimates of heterosis for days to 50 per cent silking ranged from -11.57 (L_3 x T_2) to -0.48 per cent (L_1 x T_2). 25 hybrids showed negative significant heterosis. The heterosis over better parent was negative significant is 7 hybrids. Hybrid L_3 x T_3 (11.55 per cent) had highest heterobeliosis followed by L_4 x T_2 (-9.95 per cent) and L_7 x T_2 (-9.83 per cent). None of the hybrid depicted negative significant economic heterosis against the best check Pratap Hybrid Maize-3.

4.3.3 Anthesis-silking interval (Table 4.3.2)

Heterosis for anthesis-silking interval ranged from -38.46 (L_9 x T_2) to 69.23 per cent (L_1 x T_2). Three hybrids showed significant heterosis out of which only one hybrid L_6 x T_1 (-36.84 %) showed negative significant heterosis for this trait. None of hybrid showed better parent and economic heterosis.

4.3.4 Days to 75 per cent brown husk (Table 4.3.2)

Only one hybrid namely L_5 x T_3 (-7.02 %) depicted negative significant heterosis for 75 per cent brown husk. None of the hybrids depicted significant heterobeltiosis and economic heterosis over the batter parent and best check Vivek Hybrid-43, respectively.

Table 4.3.1 Extent of heterosis, heterobeltiosis and economic heterosis for days to 50 per cent tasseling and days to 50 per cent silking in maize

SN.	Crosses	Days to 50 per cent tasseling			Days to 50 per cent silking		
		Het	Hb	EH	Het	Hb	EH
1.	L1 x T1	-7.46**	-4.26	-0.55	-7.13**	-4.06	-
2.	L2 x T1	-8.07**	-6.47**	-	-5.54*	-4.39	-
3.	L3 x T1	-5.68**	-4.98*	-	-5.44*	-4.76	-
4.	L4 x T1	-6.06**	-4.62	-	-5.57*	-3.94	-
5.	L5 x T1	-6.94**	-3.72	0.00	-7.35**	-4.55	-
6.	L6 x T1	-5.94**	-2.15	-	-7.39**	-4.08	-
7.	L7 x T1	-6.91**	-4.21	-	-6.37**	-3.54	-
8.	L8 x T1	-8.04**	-7.11**	-	-8.65**	-7.77**	-
9.	L9 x T1	-5.94**	-5.47*	-	-5.21*	-4.76	-
10.	L10 x T1	-1.49	-1.49	-	-1.20	-0.48	-
11.	L11 x T1	-5.53**	-4.57	-	-4.83*	-3.43	-
12.	L12 x T1	-4.15*	0.00	-	-3.96	0.00	-
13.	L1 x T2	-2.73	-	-	-0.48	-	-
14.	L2 x T2	-9.69**	-8.17**	-	-5.66**	-2.44	-
15.	L3 x T2	-13.13**	-10.78**	-	-11.57**	-10.33**	-
16.	L4 x T2	-11.71**	-7.18**	0.00	-9.95**	-6.40*	-
17.	L5 x T2	-7.20**	-0.53	-	-6.00**	-1.01	-
18.	L6 x T2	-9.23**	-2.15	-	-8.43**	-3.06	-
19.	L7 x T2	-10.62**	-4.74	0.00	-9.83**	-5.05	-
20.	L8 x T2	-9.71**	-5.58*	-	-8.71**	-5.83*	-
21.	L9 x T2	0.96	-	-	-0.70	-	-
22.	L10 x T2	-9.13**	-5.97**	-	-7.98**	-5.31*	-
23.	L11 x T2	-4.85*	-0.51	-	-3.07	-	-
24.	L12 x T2	-7.00**	-	-	-5.57*	-	-
25.	L1 x T3	-3.38	-1.06	-	-3.50	-2.03	-
26.	L2 x T3	-7.16**	-4.57	-	-2.94	-2.46	-
27.	L3 x T3	-7.73**	-6.09**	-	-6.73**	-4.43	-
28.	L4 x T3	-7.14**	-6.67**	-	-5.42*	-5.42*	-
29.	L5 x T3	-4.94*	-2.66	-	-4.24	-3.03	-
30.	L6 x T3	-6.01**	-3.23	-0.55	-5.76*	-4.08	-
31.	L7 x T3	-8.01**	-6.32**	-1.66	-6.73**	-5.56*	-
32.	L8 x T3	-6.09**	-6.09**	-	-5.13*	-4.43	-
33.	L9 x T3	-6.00**	-4.57	-	-5.54*	-3.45	-
34.	L10 x T3	-3.52	-2.54	-	-1.46	-0.49	-
35.	L11 x T3	-6.09**	-6.09**	-	-4.18	-3.94	-
36.	L12 x T3	-4.71*	-1.62	-	-4.28	-2.06	-

*, ** Significant at 5 per cent level and 1 per cent level of significance, respectively

Table 4.3.2 Extent of heterosis, heterobeltiosis and economic heterosis for anthesis silking interval and days to 75 per cent brown husk in maize

		Anthesis Silking Interval			Days to 75 per cent Brown Husk		
SN.	Crosses	Het	Hb	EH	Het	Hb	EH
1.	L1 x T1	0.00	0.00	-	0.74	-	-
2.	L2 x T1	-11.11	-11.11	-	2.20	-	-
3.	L3 x T1	0.00	0.00	-	2.20	-	-
4.	L4 x T1	5.88	-	-	4.81	-	-
5.	L5 x T1	-15.79	-11.11	-	0.18	-	-
6.	L6 x T1	-36.84*	-33.33	-	0.73	-	-
7.	L7 x T1	5.88	-	-	0.00	-	-
8.	L8 x T1	-22.22	-22.22	-	0.92	-	-
9.	L9 x T1	11.11	-	-	-2.74	-2.56	0.00
10.	L10 x T1	6.67	-	-	1.29	-	-
11.	L11 x T1	12.50	-	-	2.78	-	-
12.	L12 x T1	0.00	0.00	-	-0.73	0.00	-
13.	L1 x T2	69.23**	-	-	5.24	-	-
14.	L2 x T2	38.46	-	-	4.07	-	-
15.	L3 x T2	38.46	-	-	1.48	-	-
16.	L4 x T2	50.00	-	-	1.87	-	-
17.	L5 x T2	28.57	-	-	0.18	-	-
18.	L6 x T2	14.29	-	-	0.74	-	-
19.	L7 x T2	16.67	-	-	2.55	-	-
20.	L8 x T2	23.08	-	-	-0.93	-0.37	0.00
21.	L9 x T2	-38.46	0.00	0.00	3.51	-	-
22.	L10 x T2	40.00	-	-	6.54	-	-
23.	L11 x T2	63.64*	-	-	-0.94	-0.75	-0.75
24.	L12 x T2	38.46	-	-	-2.21	-0.37	0.00
25.	L1 x T3	-6.67	-	-	-3.06	-	-
26.	L2 x T3	33.33	-	-	-0.53	-	-
27.	L3 x T3	20.00	-	-	0.53	-	-
28.	L4 x T3	42.86	-	-	-1.26	-	-
29.	L5 x T3	12.50	-	-	-7.02*	-6.03	-0.38
30.	L6 x T3	-0.00	-	-	-4.80	-2.55	-
31.	L7 x T3	28.57	-	-	-3.33	-2.47	-
32.	L8 x T3	20.00	-	-	1.79	-	-
33.	L9 x T3	6.67	-	-	0.71	-	-
34.	L10 x T3	66.67*	-	-	-1.08	-	-
35.	L11 x T3	53.85*	-	-	0.72	-	-
36.	L12 x T3	6.67	-	-	-0.18	-	-

*, ** Significant at 5 per cent level and 1 per cent level of significance, respectively

4.3.5 Plant height (Table 4.2.3)

Heterosis for plant height ranged from 7.19 (L_1 xT_3) to 47.78 per cent (L_8 xT_1). The heterotic effect was significant in all 36 hybrids, Out of which none of the hybrids showed negative significant heterosis. The data revealed that none of the hybrids showed negative significant better parents heterosis and economic heterosis for this trait.

4.3.6 Ear height (Table 4.2.3)

The estimates of heterosis for ear height ranged from 5.35 (L_6 x T_2) to 60.28 per cent (L_7 x T_1). 35 hybrids showed significant heterosis out of which none of the hybrid showed negative significant heterosis for this trait. The data revealed that none of the hybrid depicted significant heterobeltiosis and economic heterosis for this trait.

4.3.7 Number of leaves per plant (Table 4.3.4)

The estimates of heterosis for number of leaves per plant revealed that none of the hybrids depicted significant all three type of heterosis for this trait.

4.3.8 Cob girth (Table 4.3.4)

Heterosis for cob girth ranged from -15.16 (L_6 x T_2) to 27.68 per cent (L_1 x T_3). 12 hybrids depicted significant heterosis out of which the heterosis was positive in 6 hybrids. The maximum heterosis was expressed by hybrid L_1 x T_3 (27.68 %) followed by L_{10} x T_3 (18.69 %) and L_2 x T_1 (18.04 %). Only two hybrids viz., L_1 x T_3 (22.82 %) and L_{10} x T_3 (14.01 %) depicted significant and positive heterosis over better parent. None of the hybrid showed significant economic heterosis for this trait over the best check Pratap Hybrid Maize-3.

4.3.9 Number of grain rows per cob (Table 4.3.5)

The estimates of relative heterosis for number of grain rows per cob revealed that out of 36 hybrids, one hybrid exhibited positive significant relative heterosis for this trait with the magnitude ranged 17.93 (L_1 x T_3). None of the hybrids exhibited positive significant heterobeltiosis and economic heterosis for this trait over the better parent and best check Vivek Hybrid-43, respectively.

4.3.10 100-grain weight (Table 4.3.5)

Heterosis for 100 grain weight ranged from -18.24 (L_6 x T_1) to 9.38 per cent (L_8 x T_2). 14 hybrids showed significant heterosis, out of which 6 hybrids depicted positive significant heterosis for this trait. The maximum heterosis was depicted by hybrid L_8 x T_2 (9.38 %) followed by L_7 x T_2 (7.86 %), L_9 x T_2 (7.78 %), L_{12} x T_2 (7.70 %) and L_4 x T_2 (5.65 %). None of the hybrids depicted significant heterobeltiosis as well as economic heterosis for this trait better parent and best check Pratap Hybrid Maize-3, respectively.

4.3.11 Harvest index (Table 4.3.6)

The estimates of heterosis for harvest index ranged from -13.10 (L_2 x T_1) to 28.64 per cent (L_{11} x T_2). 22 hybrids showed significant and positive heterosis for this trait. Hybrid L_{11} x T_2 (28.64 %) exhibited maximum heterosis followed by hybrids L_{l2} x T_1 (27.69 %), L_9 x T_3 (26.72 %) and L_1 xT_2 (24.67 %). 17 hybrids showed significant heterobeltiosis out of which all 17 hybrids depicted positive significant heterobeltiosis, whereas only two hybrids *viz.*, L_{12} xT_3 (7.07 %) and L_9 xT_3 (6.52 %) showed significant and positive economic heterosis over the best check Vivek Hybrid-43.

4.3.12 Grain yield per plant (Table 4.3.6)

The estimates of heterosis for grain yield per plant ranged from -25.25 (L_{12} x T_2) to 98.61 per cent (L_2 x T_1). Out of 36 hybrids, 27 hybrids showed significant heterosis out of which 23 hybrids exhibited significant and positive heterosis for this trait. Out of 36 hybrids 17 hybrids showed positive and significant hetebeltiosis. It range from 15.85 (L_8 x T_1) to 94.41 per cent (L_2 x T_1). The maximum heterobeltiosis was expressed by hybrids L_2 x T_1 (94.41%) followed by L_7 x T_1 (80.18%), L_9 x T_1 (66.89%), L_{11} x T_2 (63.67%) and L_7 xT_1 (48.26%). These above hybrids also exhibited positive significant heterosis for this trait.

Only three hybrids *viz.*, L_{12} x T_3 (26.17%), L_{11} x T_2 (12.62%) and L_9 x T_3 (11.56%) showed significant and positive economic heterosis for grain yield per plant over the best check Vivek Hybrid-43. These hybrids also showed significant and positive better parent and mid parent heterosis for this trait.

Table 4.3.3 Extent of heterosis, heterobeltiosis and economic heterosis for plant height and ear height in maize

SN.	Crosses	Plant height (cm)			Ear height (cm)		
		Het	Hb	EH	Het	Hb	EH
1.	L1 x T1	12.65**	-	-	22.53**	-	-
2.	L2 x T1	38.91**	-	-	40.79**	-	-
3.	L3 x T1	42.26**	-	-	57.18**	-	-
4.	L4 x T1	32.68**	-	-	44.03**	-	-
5.	L5 x T1	33.04**	-	-	20.78**	-	-
6.	L6 x T1	23.94**	-	-	25.49**	-	-
7.	L7 x T1	33.65**	-	-	60.28**	-	-
8.	L8 x T1	47.78**	-	-	37.45**	-	-
9.	L9 x T1	35.08**	-	-	26.24**	-	-
10.	L10 x T1	19.76**	-	-	29.52**	-	-
11.	L11 x T1	25.50**	-	-	24.39**	-	-
12.	L12 x T1	30.43**	-	-	55.49**	-	-
13.	L1 x T2	11.25**	-	-	16.61*	-	-
14.	L2 x T2	42.25**	-	-	40.52**	-	-
15.	L3 x T2	33.40**	-	-	34.19**	-	-
16.	L4 x T2	30.70**	-	-	36.07**	-	-
17.	L5 x T2	49.18**	-	-	44.58**	-	-
18.	L6 x T2	17.34**	-	-	5.35	-	-
19.	L7 x T2	34.41**	-	-	41.97**	-	-
20.	L8 x T2	47.08**	-	-	38.86**	-	-
21.	L9 x T2	26.88**	-	-	25.19**	-	-
22.	L10 x T2	32.21**	-	-	27.28**	-	-
23.	L11 x T2	31.25**	-	-	25.80**	-	-
24.	L12 x T2	36.96**	-	-	57.93**	-	-
25.	L1 x T3	7.19*	-	-	25.68**	-	-
26.	L2 x T3	36.61**	-	-	32.67**	-	-
27.	L3 x T3	27.98**	-	-	16.84*	-	-
28.	L4 x T3	22.76**	-	-	37.63**	-	-
29.	L5 x T3	30.73**	-	-	34.50**	-	-
30.	L6 x T3	25.68**	-	-	34.90**	-	-
31.	L7 x T3	31.88**	-	-	57.48**	-	-
32.	L8 x T3	37.22**	-	-	29.96**	-	-
33.	L9 x T3	26.51**	-	-	26.17**	-	-
34.	L10 x T3	17.03**	-	-	31.39**	-	-
35.	L11 x T3	21.94**	-	-	39.42**	-	-
36.	L12 x T3	24.52**	-	-	58.70**	-	-

*, ** Significant at 5 per cent level and 1 per cent level of significance, respectively

Table 4.3.4 Extent of heterosis, heterobeltiosis and economic heterosis for number of leaves per plant and cob girth in maize

SN.	Crosses	Number of leaves per plant			Cob girth (cm)		
		Het	Hb	EH	Het	Hb	EH
1.	L1 x T1	-3.02	-	-	-1.65	-	-
2.	L2 x T1	4.98	2.07	-	18.04**	10.11	-
3.	L3 x T1	10.28	1.38	-	-2.32	-	-
4.	L4 x T1	-7.44	-	-	-13.61**	-	-
5.	L5 x T1	-0.45	-	-	-8.25	-	-
6.	L6 x T1	-6.74	-	-	-4.47	-	-
7.	L7 x T1	2.38	-	-	15.82*	7.33	-
8.	L8 x T1	5.80	5.07	-	12.56*	7.94	-
9.	L9 x T1	2.10	0.92	-	5.92	-	-
10.	L10 x T1	3.26	2.30	-	14.78**	12.26	-
11.	L11 x T1	1.16	0.46	-	7.12	6.01	-
12.	L12 x T1	0.22	-	-	-8.55	-	-
13.	L1 x T2	-6.39	-	-	-0.82	-	-
14.	L2 x T2	2.29	-	-	2.00	-	-
15.	L3 x T2	-1.45	-	-	-7.24	-	-
16.	L4 x T2	2.47	-	-	-7.49	-	-
17.	L5 x T2	0.66	-	-	-6.92	-	-
18.	L6 x T2	-2.92	-	-	-15.16**	-	-
19.	L7 x T2	-5.29	-	-	0.78	-	-
20.	L8 x T2	-3.59	-	-	-0.64	-	-
21.	L9 x T2	-3.60	-	-	-14.08**	-	-
22.	L10 x T2	-2.92	-	-	6.60	5.08	-
23.	L11 x T2	7.62	3.45	1.91	7.86	5.08	-
24.	L12 x T2	-5.22	-	-	-5.11	-	-
25.	L1 x T3	-1.21	-	-	27.68**	22.82**	-
26.	L2 x T3	6.29	1.79	-	11.02	5.39	-
27.	L3 x T3	5.91	-	-	2.75	-	-
28.	L4 x T3	-2.52	-	-	-4.34	-	-
29.	L5 x T3	-6.04	-	-	6.26	2.35	-
30.	L6 x T3	-0.69	-	-	-11.69*	-	-
31.	L7 x T3	9.13	4.02	-	17.45**	10.74	-
32.	L8 x T3	3.42	1.12	-	-5.05	-	-
33.	L9 x T3	-3.21	-	-	0.70	-	-
34.	L10 x T3	5.72	3.13	-	18.69**	14.01*	-
35.	L11 x T3	4.57	2.23	-	7.86	4.81	-
36.	L12 x T3	-7.96	-	-	-10.83*	-	-

*, ** Significant at 5 per cent level and 1 per cent level of significance, respectively

Table 4.3.5 Extent of heterosis, heterobeltiosis and economic heterosis for number of grains rows per cob and 100-grain weight in maize

SN.	Crosses	Number of grains rows per Cob			100-Grain weight		
		Het	Hb	EH	Het	Hb	EH
1.	L1 x T1	-1.90	-	-	-11.77**	-	-
2.	L2 x T1	9.09	5.15	-	-4.95	-	-
3.	L3 x T1	-3.03	-	-	-0.51	-	-
4.	L4 x T1	-9.80	-	-	-10.56**	-	-
5.	L5 x T1	-11.71	-	-	3.38	2.89	-
6.	L6 x T1	-1.22	-	-	-18.24**	-	-
7.	L7 x T1	11.78	5.15	-	-5.65*	-	-
8.	L8 x T1	6.49	5.67	-	3.06	-	-
9.	L9 x T1	5.24	-	-	-2.54	-	-
10.	L10 x T1	11.79	11.22	-	-6.17*	-	-
11.	L11 x T1	3.02	0.49	-	-5.32*	-	-
12.	L12 x T1	-7.66	-	-	-3.52	-	-
13.	L1 x T2	0.27	-	-	-4.00	-	-
14.	L2 x T2	1.60	-	-	3.03	3.03	-
15.	L3 x T2	-3.54	-	-	-1.57	-	-
16.	L4 x T2	-0.98	-	-	5.65*	4.04	-
17.	L5 x T2	-8.29	-	-	-5.42*	-	-
18.	L6 x T2	-7.06	-	-	-6.54*	-	-
19.	L7 x T2	2.47	-	-	7.86**	4.04	-
20.	L8 x T2	-0.78	-	-	9.38**	6.06	-
21.	L9 x T2	-9.05	-	-	7.78**	5.05	-
22.	L10 x T2	10.26	9.69	-	-6.28*	-	-
23.	L11 x T2	10.55	7.84	-	2.46	0.00	-
24.	L12 x T2	-1.16	-	-	7.70**	6.06	-
25.	L1 x T3	17.93**	12.44	-	-0.50	-	-
26.	L2 x T3	2.41	-	-	6.60*	6.06	-
27.	L3 x T3	-0.76	-	-	3.16	0.00	-
28.	L4 x T3	-3.19	-	-	-1.03	-	-
29.	L5 x T3	-2.69	-	-	-2.97	-	-
30.	L6 x T3	-7.80	-	-	-5.05	-	-
31.	L7 x T3	5.49	-	-	-2.11	-	-
32.	L8 x T3	-12.50	-	-	3.67	1.02	-
33.	L9 x T3	9.79	1.77	-	-5.21	-	-
34.	L10 x T3	12.08	11.22	-	0.00	-	-
35.	L11 x T3	8.82	5.88	-	-4.95	-	-
36.	L12 x T3	-12.09*	-	-	-1.03	-	-

*, ** Significant at 5 per cent level and 1 per cent level of significance, respectively

Table 4.3.6 Extent of heterosis, heterobeltiosis and economic heterosis for harvest index and grain yield per plant in maize

SN.	Crosses	Harvest Index			Grain yield per plant		
		Het	Hb	EH	Het	Hb	EH
1.	L1 x T1	0.91	0.91	-	2.80	-	-
2.	L2 x T1	27.69**	25.23**	-	98.61**	94.41**	-
3.	L3 x T1	13.48**	12.22**	-	57.10**	48.26**	-
4.	L4 x T1	-10.05**	-	-	-12.83**	-	-
5.	L5 x T1	14.66**	11.35**	-	41.99**	19.17**	-
6.	L6 x T1	12.28**	10.31**	-	45.69**	28.25**	-
7.	L7 x T1	18.39**	16.19**	-	83.23**	80.18**	-
8.	L8 x T1	13.03**	9.09**	-	38.82**	15.85**	-
9.	L9 x T1	20.91**	20.23**	-	72.19**	66.89**	-
10.	L10 x T1	2.98	0.22	-	16.89**	0.08	-
11.	L11 x T1	9.38**	8.64*	-	42.89**	31.70**	-
12.	L12 x T1	-13.10**	-	-	-19.47**	-	-
13.	L1 x T2	24.67**	21.96**	1.63	56.44**	45.27**	-
14.	L2 x T2	14.84**	10.22**	-	41.61**	20.01**	-
15.	L3 x T2	-3.74	-	-	-4.88	-	-
16.	L4 x T2	10.45**	1.83	0.54	20.77**	5.35	-
17.	L5 x T2	3.99	3.21	-	7.41	3.92	-
18.	L6 x T2	0.66	0.22	-	7.64	5.16	-
19.	L7 x T2	-3.60	-	-	8.25	-	-
20.	L8 x T2	19.19**	17.55**	0.72	42.00**	36.45**	1.85
21.	L9 x T2	4.80	1.96	-	21.34**	7.59	-
22.	L10 x T2	12.65**	12.04**	-	24.67**	23.53**	-
23.	L11 x T2	28.64**	25.00**	4.17	75.95**	63.67**	12.62**
24.	L12 x T2	-12.25**	-	-	-25.25**	-	-
25.	L1 x T3	2.89	-	-	14.58**	-	-
26.	L2 x T3	18.34**	9.94**	-	39.62**	11.32*	-
27.	L3 x T3	4.77	0.20	-	19.70**	1.73	-
28.	L4 x T3	-4.82	-	-	-7.78*	-	-
29.	L5 x T3	-3.54	-	-	-7.82	-	-
30.	L6 x T3	-2.21	-	-	-3.42	-	-
31.	L7 x T3	-4.21	-	-	4.53	-	-
32.	L8 x T3	-2.28	-	-	-1.86	-	-
33.	L9 x T3	26.72**	19.27**	6.52*	66.99**	38.74**	11.56**
34.	L10 x T3	19.00**	15.62**	3.26	38.59**	29.69**	4.29
35.	L11 x T3	12.62**	5.88	-	24.02**	7.66	-
36.	L12 x T3	13.11**	7.07*	7.07*	39.86**	26.17**	26.17**

*, ** Significant at 5 per cent level and 1 per cent level of significance, respectively

4.3.13 Oil content (Table 4.3.7)

The estimates of heterosis for oil content in grain ranged from -30.28 (L_6 x T_3) to 34.36 per cent (L_5 x T_1). 24 hybrid depicted significant heterosis out of which 8 hybrids showed positive and significant heterosis. Out of 36 hybrids only 3 hybrids *viz.*, L_5 x T_1 (32.32%), L_7 x T_1 (22.47%) and L_1 x T_1 (18.44%) showed positive and significant better parent heterosis. These hybrids also exhibited positive significant heterosis for this trait. None of the hybrid showed positive significant economic heterosis for this trait over the best check Pratap Makka-9.

4.3.14 Protein content (Table 4.3.7)

Heterosis for protein content in grain ranged from -23.80 (L_8 x T_3) to 27.72 per cent (L_{12} x T_1). 21 hybrids showed significant heterosis out of which 12 hybrids showed positive and significant hereosis for this trait. Out of 36 hybrids, 9 hybrids depicted positive and significant heterobeltiosis. The maximum positive significant heterobeltiosis expressed by hybrid L_{12} x T_2 (21.70%), followed by L_7 x T_1 (15.72%), L_{11} x T_1 (14.87%), L_7 x T_2 (12.98%) and L_{11} x T_2 (12.21%). These hybrids also showed positive significant heterosis for this trait. None of the hybrid showed significant economic heterosis over the best check Vivek Hybrid-43.

4.3.15 Starch content (Table 4.3.7)

The estimates of heterosis for starch content in grain ranged from -6.36 (L_1 x T_1) to 6.42 per cent (L_9 x T_1). 27 hybrid depicted significant heterosis out of which only 8 hybrids showed positive and significant heterosis. Out of 36 hybrids only two hybrids *viz.*, L_{12} x T_3 (4.53%) and L_9 x T_1 (3.39%) showed positive and significant better parent heterosis. These hybrids also showed positive significant heterosis for this trait. None of the hybrid depicted positive significant economic heterosis for this trait over the best check Pratap Makka-9.

Table 4.3.7 Extent of heterosis, heterobeltiosis and economic heterosis for oil content, protein content and starch content in maize

SN.	Crosses	Oil Content in grain			Protein Content in grain			Starch Contain in grain		
		Het	Hb	EH	Het	Hb	EH	Het	Hb	EH
1.	L1 x T1	22.05**	18.44**	-	0.10	-	-	-6.36**	-	-
2.	L2 x T1	-12.90**	-	-	-2.18	-	-	-5.28**	-	-
3.	L3 x T1	-3.62	-	-	-8.89**	-	-	-1.37	-	-
4.	L4 x T1	-17.90**	-	-	-10.98**	-	-	-0.35	-	-
5.	L5 x T1	34.36**	32.32**	-	1.65	-	-	-4.71**	-	-
6.	L6 x T1	7.27	-	-	7.49**	2.67	-	0.82	-	-
7.	L7 x T1	26.14**	22.47**	-	20.85**	15.72**	-	-2.39**	-	-
8.	L8 x T1	-16.97**	-	-	5.79**	-	-	-0.60	-	-
9.	L9 x T1	16.92**	7.78	-	1.94	-	-	6.42**	3.39**	-
10.	L10 x T1	-0.86	-	-	-4.11*	-	-	-3.88**	-	-
11.	L11 x T1	-4.21	-	-	20.32**	14.87**	-	-2.29**	-	-
12.	L12 x T1	-2.17	-	-	27.72**	21.79**	1.48	-4.72**	-	-
13.	L1 x T2	-15.50**	-	-	-12.21**	-	-	-4.00**	-	-
14.	L2 x T2	-26.87**	-	-	12.10**	11.85**	-	0.93	0.01	0.01
15.	L3 x T2	8.46	-	-	8.14**	6.64**	-	1.84*	-	-
16.	L4 x T2	1.59	-	-	-1.61	-	-	-3.31**	-	-
17.	L5 x T2	13.16**	2.00	-	0.52	0.38	-	-9.20**	-	-
18.	L6 x T2	-7.52	-	-	-6.90**	-	-	-1.25	-	-
19.	L7 x T2	18.45**	5.41	-	20.89**	12.98**	-	0.03	-	-
20.	L8 x T2	-20.96**	-	-	2.31	-	-	0.82	0.05	-
21.	L9 x T2	-25.18**	-	-	-1.83	-	-	-1.84*	-	-
22.	L10 x T2	-17.64**	-	-	-12.76**	-	-	-6.37**	-	-
23.	L11 x T2	-18.05**	-	-	20.41**	12.21**	-	-6.35**	-	-
24.	L12 x T2	-11.95*	-	-	16.81**	8.71**	-	-2.54**	-	-
25.	L1 x T3	8.35	-	-	2.88	-	-	2.61**	1.51	-
26.	L2 x T3	-21.75**	-	-	10.89**	6.55**	1.89	3.89**	0.06	0.06
27.	L3 x T3	10.24*	-	-	-2.98	-	-	-3.76**	-	-
28.	L4 x T3	-14.59**	-	-	-8.82**	-	-	2.28**	1.54	-
29.	L5 x T3	-19.38**	-	-	-2.11	-	-	3.27**	0.14	-
30.	L6 x T3	-30.28**	-	-	1.75	-	-	-2.06**	-	-
31.	L7 x T3	-12.17**	-	-	0.57	-	-	-2.80**	-	-
32.	L8 x T3	-1.07	-	-	-23.80**	-	-	-4.98**	-	-
33.	L9 x T3	-3.52	-	-	-14.76**	-	-	1.76*	0.26	-
34.	L10 x T3	-0.82	-	-	-1.05	-	-	4.50**	1.48	-
35.	L11 x T3	13.52**	-	-	13.15**	1.41	-	-1.80*	-	-
36.	L12 x T3	-13.59**	-	-	-1.32	-	-	4.58**	4.53**	-

*, ** Significant at 5 per cent level and 1 per cent level of significance, respectively

4.4 Combining Ability Analysis

Combining ability analysis provides estimates of variance due to general combining ability and specific combining ability. It also leads to identification of parents with good combining ability effects and in allocating cross combinations, sowing high specific combining ability effects.

The analysis of variance for combining ability and estimation of variance components for various traits was done as per line x tester analysis following the procedure suggested by Kempthrone (1957). The salient features of the results obtained are presented below.

4.4.1 Analysis of variance: (Table 4.4.1)

The data on 36 crosses were analysed and the total variance was partitioned into component *viz.,* variance due to lines, testers and line x testers. The data on crosses were further analysed to determine the lines and testers (gca) and line x testers (sca) variance components for all the traits (Table 4.4.1)

The mean squares value for hybrids were significant for all the characters except anthesis-silking interval, days to 75 per cent brown husk and number of leaves per plant. The mean square of its further partition *viz.,* due to lines, testers and line x tester were significant for all the characters except for anthesis-silking interval, days to 75 per cent brown husk and number of leaves per plant due to lines, anthesis-silking interval, days to 75 per cent brown husk, plant height, number of leaves per plant, cob girth, number of grain row per cob due to tester and anthesis-silking interval, days to 75 per cent brown husk, number of leaves per plant and number of grain row per cob due to line x tester indicated significant contribution lines and testers towards general combining ability variance components for these traits. The significant line x tester indicated significant contribution of hybrids for specific combining ability variance components.

Comparison of the magnitude of unbiased estimates of variance due to lines and testers indicated that the contribution lines (female) was higher than that of testers (male) for all the characters except for anthesis-silking interval, ear height, 100-grain weight, grain yield per plant and oil content. The contribution of lines (female) towards σ^2gca was greater.

Variance due to testers was of higher magnitude than that of lines for, anthesis-silking interval, ear height, 100-grain weight, and grain yield per plant. This indicated greater the contribution of testers for these traits towards σ^2gca.

The ratio of σ^2sca/ σ^2gca was greater than one for all the traits except anthesis-silking interval, number of leaves per plant, harvest index, grain yield per plant, oil content, starch content, protein content. This indicated that the preponderance of non-additive gene effects in the expression of these traits.

Table 4.4.1: Analysis of variance for combining ability for fifteen traits in maize

Source of Variation	d.f.	Days to 50 per cent tasseling	Days to 50 per cent silking	Anthesis-silking interval	Days to 75 per cent brown husk	Plant height	Ear height	Number of leaves per plant	Cob girth	Number of grains rows per cob	100 -Grain weight	Harvest index	Grain yield(g/plant)	Oil content	Protein content	Starch content
Replication	2	19.98**	10.85	1.77*	6.62	58.93	61.07	0.23	1.81	4.06	4.95	0.68	20.77	0.09	0.10	0.09
Crosses	35	13.48**	12.46**	0.56	11.47	241.82**	141.55**	1.11	2.07**	2.60**	9.22**	28.97**	1149.30**	1.03**	1.72**	15.82**
Lines	11	22.65**	21.84**	0.47	6.53	587.92**	213.53**	1.15	2.75**	4.07**	10.58**	18.13**	597.83**	0.81**	1.93**	11.98**
Testers	2	20.70**	14.73*	0.48	2.03	59.32	494.60**	0.54	1.01	0.47	23.59**	13.28**	907.41**	0.69**	0.21**	7.03**
Lines x Testers	22	8.23**	7.56*	0.61	14.80	85.37*	73.46**	1.13	1.83**	2.06	7.24**	35.81**	1447.03**	1.17**	1.76**	18.54**
Error	108	3.44	4.47	0.53	18.78	51.24	26.24	1.31	0.78	1.40	1.66	1.60	27.60	0.07	0.05	0.49
Variance																
σ^2_L		1.60	1.59	-0.02	-0.92	55.84	15.56	0.00	0.10	0.22	0.37	-1.96	-94.35	-0.04	0.02	-0.73
σ^2_t		0.35	0.20	-0.00	--0.35	-0.72	11.70	-0.02	-0.02	-0.04	0.45	-0.63	-14.99	-0.01	-0.04	-0.32
σ^2_{SCA}		1.60	1.03	0.03	-1.33	11.38	15.56	-0.06	0.35	0.22	1.86	11.40	473.14	0.37	0.57	6.02
σ^2_{GCA}		0.33	0.31	-0.00	-0.21	9.85	4.29	-0.00	0.02	0.03	0.13	-0.43	-18.75	-0.01	-0.00	-0.17
$\sigma^2_{SCA / GCA}$		4.48	4.19	-	6.33	1.15	3.62	-	17.5	7.33	1.23	-26.51	-25.23	-37	-	-35.41

*, ** Significant at 5 per cent and 1 per cent level of significance, respectively

4.4.2 Estimates of combining ability effects (Table 4.4.2 and 4.4.3)

The combining ability analysis was performed to obtain information on selection of better parents and crosses for their further use in breeding programme. The estimates of gca effects of the parents and sca effects of the hybrids for different traits are presented in Table 4.4.2 and 4.4.3.

The character wise results on combining ability effects are presented as under:

1. Days to 50 per cent tasseling (Table 4.4.2**)**

Four inbred lines showed significant gca effect out of which two inbred lines *viz.,* L_7 (-2.07) and L_6 (-1.74) expressed negative significant gca effects for days to 50 per cent teaselling. None of the testers and hybrids showed significant negative gab and sac effects, respectively.

2. Days to 50 per cent sulking (Table 4.4.2**)**

Two inbred lines *viz.,* L_6 and L_7 (-2.13) expressed negative significant gca effect for this trait. These lines were also showed negative significant gca effect for 50 per cent tasseling. None of the testers and hybrids showed significant negative gca and sca effects, respectively for this trait.

3. Anthesis-silking interval (Table 4.4.2**)**

None inbred line and tester expressed significant gca effects. Only one hybrid L_9 x T_2 (-1.08) sowed significant negative sca effects for Anthesis-silking interval**.**

4. Days to 75 per cent brown husk (Table 4.4.2**)**

None of the inbred lines, tester and hybrid showed significant gca and sca effects, respectively for this trait.

5. Plant height (Table 4.4.2**)**

Out of twelve inbred lines, five inbred lines expressed negative significant gca effects with magnitude varied from -11.56 (L_{10}) to -5.30 (L_3). None of the testers and hybrids showed significant gca and sca effects, respectively for plant height.

6. Ear height (Table 4.4.2**)**

Out of twelve inbred lines, 7 inbred lines showed significant gca effect out of which three inbred lines *viz.,* L_6 (-6.41), L_1 (-5.59) and L_3 (-4.25). Among the testers, only one tester T_1 (-2.29) showed significant negative gca effects for this trait. Three hybrids *viz.*, L_3 x T_3 (-10.21), L_5 x T_1 (-7.26) and L_6 x T_2 (-7.89) showed significant and negative sca effect for ear height.

7. Number of leaves per plant (Table 4.4.2**)**

None of the inbred lines, tester and hybrid showed significant gca and sca effects, respectively for this trait.

8. Cob girth (Table 4.4.2**)**

Only one inbred line L_{10} (1.30) showed positive significant gca effects. None of the tester showed significant gca effects. Only one hybrid L_1 x T_1 (1.58) showed significant positive sca effects for this trait.

9. Number of grain rows per cob (Table 4.4.3**)**

Out of twelve inbred lines only three inbred lines *viz.*, L_{10} (1.20), L_9 (1.0) and L_{11} (0.98) showed significant and positive gca effect Among the tester and hybrids none of tester and hybrid showed significant positive gca and sca effects , respectively for this trait.

10. 100-grain weight (Table 4.4.3**)**

The estimates of positive significant gca effects for 100-grain weight revealed that out of twelve inbred lines, only two inbred lines *viz.*, L_8 (1.35) and L_2 (1.13) showed positive and significant gca effects. Among the three testers, only one tester T_2 (0.85) showed significant gca effect, where as only one hybrid L_5 x T_1 (2.98) depicted positive and significant sca effect for 100-grain weight.

11. Harvest index (Table 4.4.3**)**

Nine inbred lines showed positive significant gca effects out which four inbred lines depicted significant and positive gca effect with ranged from 1.15 (L_{10}) to 2.11 (L_2). Among the testers, only one tester T_3 (0.63) showed significant gca effect. 24 hybrid showed significant sca effects ranged from -3.92 (L_9 x T_2) to 6.19 (L_{12} x T_3). 12 hybrids showed positive significant sca effects for this trait. The maximum significant and positive sca effects expressed by hybrid L_{12} x T_3 (6.19), followed by L_1 x T_2 (4.46), L_7 x T_1 (4.24), L_4 x T_2 (3.90) and L_{11} x T_2 (3.39).

Table 4.4.2 Estimates gca and sca effects for days to 50 per cent tasseling days to 50 per cent silking, anthesis-silking interval, days to 75 per cent brown husk, plant height, ear height, number of leaves per plant and gob girth in maize

SN	Genotype	Days to 50per cent tasseling	Days to 50per cent silking	Anthesis Silking Interval	Days to 75 per cent Brown Husk	Plant height (cm)	Ear height (cm)	Number of leaves per plant	Cob girth(cm)
1	T1	-0.13	-0.16	-0.04	0.03	-0.55	-2.79**	-0.13	0.09
2	T2	0.81*	0.70	-0.09	-0.25	-0.91	-1.42	0.01	-0.19
3	T3	-0.69	-0.55	0.13	0.22	1.47	4.21**	0.12	0.10
4	L1	0.26	0.43	0.16	-0.56	-5.48*	-5.59**	0.01	-0.19
5	L2	0.81	0.98	0.16	1.33	14.79**	4.48*	0.38	-0.13
6	L3	-0.19	-0.02	0.16	0.89	-5.30*	-4.25*	-0.38	-0.34
7	L4	-1.19	-0.91	0.27	0.22	-6.42*	-3.43	-0.36	-0.26
8	L5	-0.96	-0.91	0.05	-1.00	0.56	-2.28	0.04	-0.57
9	L6	-1.74**	-2.13**	-0.40	-1.11	-9.16**	-6.41**	-0.50	-0.32
10	L7	-2.07**	-2.13**	-0.06	1.00	1.76	4.68*	-0.05	-0.10
11	L8	-0.63	-0.80	-0.18	-0.33	8.89**	-1.97	0.30	-0.65*
12	L9	3.26**	2.76**	-0.40	0.22	6.30*	3.70*	-0.27	0.49
13	L10	2.15**	2.09**	-0.06	0.78	-11.56**	-0.17	0.29	1.30**
14	L11	1.04	1.31	0.27	-0.78	-1.94	1.70	0.69	0.52
15	L12	-0.74	-0.69	0.05	-0.67	7.57**	9.55**	-0.16	0.27
16	L1 x T1	-2.31	-2.29	0.04	-0.69	1.78	-0.08	-0.03	-1.18
17	L2 x T1	-0.20	-0.51	-0.30	-0.25	-2.18	0.59	-0.06	0.62
18	L3 x T1	1.80	1.82	0.04	0.19	6.81	9.59**	0.59	-0.16
19	L4 x T1	1.13	1.05	-0.07	2.19	2.98	1.30	-0.83	-0.78
20	L5 x T1	-0.76	-0.95	-0.19	1.75	-6.73	-7.26*	0.10	-0.74
21	L6 x T1	0.35	-0.06	-0.41	1.19	0.24	1.21	-0.59	0.59
22	L7 x T1	0.69	0.94	0.26	-0.25	-1.32	1.99	-0.07	0.30
23	L8 x T1	-0.43	-0.73	-0.30	-0.25	2.44	0.17	0.45	0.91
24	L9 x T1	-1.98	-0.95	0.93	-3.47	5.23	-0.43	0.41	0.88
25	L10 x T1	1.80	1.71	-0.07	-1.36	-5.10	-0.70	0.06	-0.00
26	L11 x T1	-0.43	-0.51	-0.07	1.19	-2.37	-3.90	-0.61	-0.22
27	L12 x T1	0.35	0.49	0.15	-0.25	-1.78	-2.48	0.57	-0.21
28	L1 x T2	2.07	2.85	0.76	2.58	-1.40	-1.58	-0.20	-0.40
29	L2 x T2	-0.15	-0.04	0.09	0.69	0.04	2.68	-0.06	-0.30
30	L3 x T2	-2.15	-2.04	0.09	-1.19	-4.52	0.62	-0.61	-0.04
31	L4 x T2	-1.48	-1.48	-0.02	-1.19	-0.87	-0.34	0.97	0.64
32	L5 x T2	0.30	0.52	0.20	1.03	9.33	7.04	0.64	0.08
33	L6 x T2	-0.59	-0.26	0.31	0.47	-8.89	-7.89*	0.31	-0.09
34	L7 x T2	-0.59	-0.93	-0.35	1.36	-2.09	-4.52	-0.81	-0.52
35	L8 x T2	-0.37	-0.26	0.09	-2.64	-0.20	3.06	-0.55	0.23
36	L9 x T2	4.07**	2.85	-1.02*	1.47	-6.37	0.79	-0.05	-0.91
37	L10 x T2	-2.15	-2.48	-0.35	2.58	7.55	-0.01	-0.47	-0.18

SN	Genotype	Days to 50per cent tasseling	Days to 50per cent silking	Anthesis Silking Interval	Days to 75 per cent Brown Husk	Plant height (cm)	Ear height (cm)	Number of leaves per plant	Cob girth(cm)
38	L11 x T2	1.30	1.30	-0.02	-2.86	2.88	-1.27	0.73	0.59
39	L12 x T2	-0.26	-0.04	0.20	-2.31	4.52	1.42	0.10	0.90
40	L1 x T3	0.24	-0.56	-0.80	-1.89	-0.38	1.66	0.23	1.58*
41	L2 x T3	0.35	0.55	0.20	-0.44	2.14	-3.27	0.13	-0.32
42	L3 x T3	0.35	0.21	-0.13	1.00	-2.29	-10.21**	0.01	0.20
43	L4 x T3	0.35	0.44	0.09	-1.00	-2.11	-0.96	-0.14	0.14
44	L5 x T3	0.46	0.44	-0.02	-2.78	-2.60	0.22	-0.74	0.65
45	L6 x T3	0.24	0.32	0.09	-1.67	8.64	6.68	0.27	-0.49
46	L7 x T3	-0.09	-0.01	0.09	-1.11	3.41	2.53	0.88	0.22
47	L8 x T3	0.80	0.99	0.20	2.89	-2.25	-3.23	0.10	-1.14
48	L9 x T3	-2.09	-1.90	0.09	2.00	1.14	-0.36	-0.36	0.03
49	L10 x T3	0.35	0.77	0.43	-1.22	-2.45	0.71	0.41	0.19
50	L11 x T3	-0.87	-0.79	0.09	1.67	-0.51	5.17	-0.12	-0.37
51	L12 x T3	-0.09	-0.45	-0.35	2.56	-2.74	1.06	-0.67	-0.69
	Standard error								
	Ti	0.36	0.41	0.14	0.83	1.38	1.00	0.22	0.17
	Lj	0.64	0.73	0.25	1.50	2.48	1.80	0.40	0.31
	Sij	1.29	1.47	0.50	3.01	4.97	3.59	0.80	0.61
	Ti-j	0.44	0.50	0.17	1.02	1.69	1.22	0.27	0.21
	Li-j	0.87	1.00	0.34	2.04	3.37	2.44	0.54	0.42
	Ti-Lj	0.69	0.79	0.27	1.61	2.67	1.93	0.43	0.33
	STi-Tj	1.58	1.80	0.62	3.68	6.08	4.40	0.97	0.75
	SiL-jL	1.75	1.99	0.69	4.09	6.75	4.88	1.08	0.83
	Sij-kl	1.80	2.05	0.71	4.21	6.96	5.03	1.11	0.86

*, ** Significant at 5 per cent level and 1 per cent level of significance, respectively

12. Grain yield per plant (Table 4.4.3**)**

The gca effect for grain yield per plant ranged from -11.40 (L_7) to 11.60 (L_{11}). 11 inbred lines showed significant gca effect out of which five inbred lines *viz.*, L_{11} (11.60), L_9 (10.49), L_2 (8.40), L_8 (6.49) and L_{10} (5.14) depicted significant and positive gca effect for this trait. Whereas tester T_3 (5.16) had positive and significant gca effect for this trait. Among the hybrids sca effects ranged from -23.86 (L_{12} x T_2) to 46.41 (L_{12} x T_3). 27 hybrids depicted significant sca effect out of which twelve hybrids showed positive and significant sca effect for grain yield per plant. The maximum sca effects expressed by hybrid L_{12} x T_3 (46.41) followed by L_1 x T_2 (24.60), L_{11} x T_2 (24.59), L_7 x T_1 (24.60) and L_4 x T_2 (21.50). These hybrids were also expressed positive and significant sca effects for harvest index.

13. Oil content (Table 4.4.3**)**

The gca effect for oil content in grain ranged from -0.62 (L_2) to 0.30 (L_7). 7 inbred lines showed significant gca effect out of which, four inbred lines expressed positive and significant gca effect. Among the testers only one tester T_3(0.14)showed positive and significant gca effect tester T_3 also showed positive significant gca effect for harvest index , grain yield per plant and starch content. Among the hybrids 10 hybrids showed positive and significant sca effect for this trait. The maximum sca effects for oil content depicted by hybrid L_{11} x T_3 (0.83) followed by L_4 x T_2 (0.72), L_8 x T_3 (0.65), L_5 x T_1 (0.61) and L_9 x T_1 (0.56).

14. Protein content (Table 4.4.3**)**

The perusal estimates of significant positive gca effects for protein content in grain revealed that out of twelve inbred lines four lines were significant ranged from 0.47 (L_{12}) to 0.79 (L_{11}). Among the three testers, only one tester T_2 (0.09) showed significant positive gca effects. The perusal of sca effects for this trait revealed that eleven hybrids expressed positive significant sca effects the range from 0.36 (L_4 x T_2) to 0.90 (L_1 x T_3).

15. Starch content (Table 4.4.3**)**

The gca effect for starch content ranged from -1.75 (L_{11}) to 2.50 (L_2). 8 inbred lines showed significant gca effect out of which as three inbred lines *viz.*,L_2 (2.50), L_8 (1.45) and L_{10} (0.70) showed positive and significant gca effect. Only tester T_3 (0.36) depicted positive and significant gca effect, sca effect for this trait ranged from-3.57

(L_8 x T_3) to 3.26 (L_5 xT_3). 26 hybrids showed significant sca effects out of which 13 hybrids expressed positive and significant sca effects. The maximum sca effects showed by hybrid L_5 x T_3 (3.26) followed by L_9 x T_1 (2.74), L_{12} x T_3 (2.22), L_3 x T_2 (2.74) and L_1 x T_3 (2.09).

Table 4.4.3 Estimates gca and sca effects for number of grains rows per cob, 100 -grain weight, harvest index, grain yield per plant, oil content, protein content and starch content (%) in maize

SN	Genotype	Number of grains rows per Cob	100 - Grain weight	Harvest Index	Grain yield per plant	Oil Content	Protein Content	Starch Content
1	T1	0.05	-0.76**	-0.58*	-4.86**	-0.01	-0.05	-0.49**
2	T2	-0.13	0.85**	-0.06	-0.30	-0.13**	0.09*	0.13
3	T3	0.08	-0.09	0.63*	5.16**	0.14**	-0.04	0.36**
4	L1	-0.31	-0.87	-0.45	-4.95**	0.08	-0.26**	-0.95**
5	L2	-0.26	1.13*	2.11**	8.40**	-0.62**	0.57**	2.50**
6	L3	-0.40	-0.43	-1.52**	-9.40**	0.24**	-0.30**	-0.63*
7	L4	-0.31	-0.54	-0.29	-3.64*	0.05	-0.31**	0.22
8	L5	-0.64	0.91*	-0.89*	-5.22**	0.28**	-0.06	-0.29
9	L6	-0.31	-2.54**	-1.72**	-8.44**	0.07	-0.60**	-0.34
10	L7	-0.31	-0.54	-1.72**	11.04**	0.30**	0.49**	-0.86**
11	L8	-0.73	1.35**	0.86	6.49**	-0.20*	-0.04	1.45**
12	L9	1.00*	-0.20	1.79**	10.49**	0.16	-0.54**	0.45
13	L10	1.20**	0.69	1.15*	5.14**	0.24*	-0.20**	0.70**
14	L11	0.98*	0.57	1.55**	11.60**	-0.13	0.79**	-1.75**
15	L12	0.09	0.46	-0.87*	0.58	-0.47**	0.47**	-0.51*
16	L1 x T1	-0.94	-0.91	-2.82**	22.29**	0.29	0.05	-1.98**
17	L2 x T1	0.55	-0.91	1.76*	13.69**	0.05	-1.03**	-2.97**
18	L3 x T1	-0.12	0.98	2.31**	15.09**	-0.68**	-0.86**	0.28
19	L4 x T1	-0.74	-1.57	-3.04**	-16.34**	-0.62**	-0.55**	0.56
20	L5 x T1	-0.61	2.98**	2.69**	16.04**	0.61**	-0.08	-0.27
21	L6 x T1	0.53	-1.57	2.38**	15.06**	0.49**	0.30	1.54**
22	L7 x T1	0.59	-0.57	4.24**	24.60**	0.23	0.29	0.02
23	L8 x T1	1.08	0.54	0.67	2.86	-0.46*	0.81**	1.12*
24	L9 x T1	0.41	0.43	0.60	1.66	0.56**	0.38*	3.23**
25	L10 x T1	0.01	0.54	-2.96**	-15.38**	-0.07	-0.05	-0.81
26	L11 x T1	-0.63	0.31	-2.56**	-12.45**	-0.38*	-0.08	1.27*
27	L12 x T1	-0.14	-0.24	-3.27**	-22.56**	-0.03	0.81**	-1.99**
28	L1 x T2	-0.49	-0.52	4.46**	25.94**	-0.61**	-0.95**	-0.11
29	L2 x T2	-0.20	-0.52	-1.70	-8.28*	-0.09	0.29	1.59**
30	L3 x T2	-0.00	-1.63	-2.68**	-18.21**	0.32	0.66**	2.74**
31	L4 x T2	0.64	1.48	3.90**	21.50**	0.72**	0.36*	-1.03*
32	L5 x T2	0.04	-2.30*	-0.37	-1.99	0.40*	-0.10	-2.99**
33	L6 x T2	-0.09	0.15	-0.94	-3.70	0.34	-0.76**	0.55
34	L7 x T2	-0.36	1.48	-2.21*	-11.90**	0.54**	0.42**	1.97**
35	L8 x T2	0.33	0.26	2.81**	16.76**	-0.19	0.59**	2.45**
36	L9 x T2	-1.40	1.48	-3.92**	-20.64**	-0.74**	0.14	-1.69**
37	L10 x T2	-0.00	-1.74	0.19	-0.21	-0.33	-0.76**	-2.16**

SN	Genotype	Number of grains rows per Cob	100 - Grain weight	Harvest Index	Grain yield per plant	Oil Content	Protein Content	Starch Content
38	L11 x T2	0.55	0.70	3.39**	24.59**	-0.45*	0.05	-1.08*
39	L12 x T2	0.98	1.15	-2.92**	-23.86**	0.09	0.07	-0.23
40	L1 x T3	1.43	1.43	-1.63	-3.65	0.32	0.90**	2.09**
41	L2 x T3	-0.35	1.43	-0.06	-5.41	0.04	0.74**	1.39**
42	L3 x T3	0.12	0.65	0.37	3.13	0.37*	0.21	-3.02**
43	L4 x T3	0.10	0.09	-0.86	-5.16	-0.10	0.19	0.47
44	L5 x T3	0.56	-0.69	-2.32**	-14.05**	-1.01**	0.18	3.26**
45	L6 x T3	-0.44	1.43	-1.43	-11.36**	-0.84**	0.46**	-2.09**
46	L7 x T3	-0.24	-0.91	-2.03*	-12.70**	-0.76**	-0.71**	-1.99**
47	L8 x T3	-1.41	-0.80	-3.48**	-19.63**	0.65**	-1.40**	-3.57**
48	L9 x T3	0.99	-1.91*	3.32**	18.97**	0.18	-0.52**	-1.54**
49	L10 x T3	-0.01	1.20	2.77**	15.59**	0.40*	0.81**	2.97**
50	L11 x T3	0.08	-1.02	-0.83	-12.14**	0.83**	0.03	-0.19
51	L12 x T3	-0.84	-0.91	6.19**	46.41**	-0.06	-0.88**	2.22**
	Standard error							
	Ti	0.23	0.25	0.24	1.01	0.05	0.04	0.13
	Lj	0.41	0.45	0.44	1.82	0.09	0.08	0.24
	Sij	0.82	0.89	0.88	3.65	0.18	0.15	0.48
	Ti-j	0.28	0.30	0.30	1.24	0.06	0.05	0.16
	Li-j	0.56	0.61	0.60	2.48	0.12	0.11	0.33
	Ti-Lj	0.44	0.48	0.47	1.96	0.10	0.08	0.26
	STi-Tj	1.00	1.09	1.08	4.46	0.22	0.19	0.59
	SiL-jL	1.11	1.21	1.19	4.95	0.25	0.21	0.66
	Sij-kl	1.15	1.25	1.23	5.11	0.25	0.22	0.68

*, ** Significant at 5 per cent level and 1 per cent level of significance, respectively

5. DISCUSSION

Maize (*Zea mays* L.) is an important multipurpose cross pollinated crop. It is third most widely distributed crop of the world being grown in diverse and ecologies with highest production and productivity among cereals. In India productivity of maize is numerically low in Rajasthan (1318kg/ha) as compared to the productivity at national level (2509kg/ha). These yield level are very low as compared to world productivity (5519kg/ha).This clearly indicate tremendous scope of increasing the productivity of maize both at national and state level.

For improving yield potential of varieties and hybrids, selection of right type of parents is very important. This can only do by testing the genetic worth of potential lines, because many times the high yielding parents may not nick well to give desirable segregates.

Genetic parameters like heterosis and combining ability provide adequate guide lines for selection of parents/crosses for getting desirable segregants/exploitation of heterosis. various mating design are available to derive information about the combining ability but for present study Line x Tester was used because in this design more number of lines can be evaluated for their genetic worth.

The analysis of variance for experimental design (Table 4.1) revealed mean squares due to genotypes, parents, crosses and parents v/s crosses were significant for all the characters except for days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent brown husk, number of leaves per plant, cob girth and number of grain row per cob due to genotypes, days to 75 per cent brown husk and number of leaves per plant due to parents, anthesis-silking interval, days to 75 per cent brown husk, number of leaves per plant, cob girth, number of grain row per cob and 100-grain weight due to parents v/s crosses and anthesis-silking interval, days to 75 per cent brown husk and number of leaves per plant due to crosses. The significant mean square of different traits indicated the existence of appreciable amount of genetic variability under research experimental materials.

Similar trends for variance and its components were also reported by Dubey *et al.* (2009), Premlatha and Kalamani (2010), Sumalini and Rani (2010), Kumar and Bharathi (2011), Pavan *et al.* (2011), Singh and Singh (2011), Sundararajan and

Kumar (2011), Abuali *et al.* (2012), Sumalini (2012), Avinashe *et al.* (2013), Gautam et al. (2013), Khan *et al.* (2014), Kumar et al. (2014), Rajesh *et al.* (2014), Singh (2015), and Zeleke (2015).

***Per se* performance:**

The *per se* performance was advocated by Genter and Alexander (1962) as one of the method useful in evaluating parents for heterosis breeding in maize. The *per se* performance of parents and their hybrids along with checks for fifteen characters are presented in Appendix I and II for various traits under investigation revealed that inbred line L_{12} exhibited maximum mean values for grain yield per plant (120.07 g), number of grain row per cob (15.80), harvest index (36.38%), cob girth (14.42 cm) and minimum mean values for days to 50 per cent tasseling (64.67 days) and days to 50 per cent silking (64.67 days). Whereas inbred line L_4 for oil content (4.77%) and protein content (9.82%), L_8 for starch content (9.52%) and L_{10} for 100-grain weight (35.98 g) exhibited maximum mean values (Appendix I and II).

Among testers, T_3 exhibited maximum values of grain yield per plant (96.55g), oil content (4.96%), protein content (9.46%), harvest index (32.87 per cent), and minimum mean values for days to 50 per cent tasseling (65.67 days) and days to 50 per cent silking (67.67 days). Whereas tester T_2 exhibited maximum mean values for starch content (67.74%), 100-grain weight (32.98 gm), number of grain rows row per cob (12.93), cob girth (11.75 cm), number of leaves per plant (15.47) and depicted minimum values for anthesis-silking interval (1.00 days) and days to 75 per cent brown husk (89.00 days).

Hybrid L_{12} x T_3 exhibited maximum mean value for grain yield per plant (151.48 g) and harvest index (39.40%). Another hybrid L_{11}x T_3 showed maximum value for oil content (4.88%) and protein content (9.60%). Whereas hybrid L_{10} x T_3 depicted maximum mean value for cob girth (13.02 cm), 100-grain weight (34.31 g) and starch content (68.82%). The hybrid L_7 x T_3 recorded minimum mean values for days to 50 per cent tasseling (59.33 days), days to 50 per cent silking (62.33 days).

Among the checks check-3(Pratap Makka-9) exhibited maximum mean values for grain yield per plant (105.08 gm), harvest index (35.00%) and number of grain row per cob (15.07%). Whereas check-1(Pratap Hybrid Maize-3) showed maximum mean values for protein content (9.90%) and starch content (66.74%) and minimum mean values for days to 50 per cent tasseling (60.33 days), days to 50 per cent silking (62.00 days), anthesis-silking interval (1.67 days), plant height (118.72 cm), number of leaves per plant (11.45).

Heterosis:

Commercial exploitation of heterosis is considered to be an outstanding application of principles of genetics into the field of plant breeding. The aim of heterosis analysis in present study was to identify best cross combination which may give high degree of useful heterosis and characterization of their parents for their utilization in future breeding programme. For any hybrid to be acceptable for commercial cultivation, it must have sufficient level of superiority over the stander/best check. Such as superiority is referred as standard heterosis. In present study the standered heterosis was calculated over best check of specific traits.

Out of 36 hybrids three hybrids *viz,* L_{12} x T_3 (26.17%), L_{11} x T_2 (12.62%) and L_9 x T_3 (11.56%) were exhibited significant and positive economic heterosis for grain yield per plant over the best check Vivek Hybrid-43. These hybrids were also significant and positive yield contributing trait like harvest index. These hybrids also depicted good *per se* performance for grain yield per plant (Table.5.1). Thus, it may be concluded that for commercial exploitation these hybrids are most appropriate. These findings are in agreements with the reports Dubey *et al.* (2009), Premlatha and Kalamani (2010), Sumalini and Rani (2010), Kumar and Bharathi (2011), Pavan *et al.* (2011), Singh and Singh (2011), Sundararajan and Kumar (2011), Khan *et al.* (2014), Kumar et al. (2014), Rajesh *et al.* (2014), and Singh (2015) also reported economic heterosis in maize for yield and its contributing traits.

Relative heterosis and heterobeltiosis are important as they provide an idea about role of dominance and over dominance type of gene action.

In this study number of hybrids depicting significant an positive relative heterosis ranged from 1 (number of grain row per cob), 6 (cob girth and 100-grain weight), 8 (oil content and starch content), 12 (protein content), 22 (harvest index) and 23 (grain yield per plant). The significant positive relative heterosis of these traits, indicating that for these traits the genes with positive effects were dominant, on the contrary in almost all other characters variable number of crosses depicted heterosis in both positive and negative direction, indicating that genes with negative as well as positive effects were dominant. Dar *et al*. (2007), Lal *et al*. (2007), Dubey *et al*. (2009), Premlatha and Kalamani (2010), Sundararajan and Kumar (2011), Kumar *et al*. (2013), Singh *et al*. (2013) Khan *et al*. (2014), Kumar et al. (2014), Rajesh *et al*. (2014), Singh (2015), Zeleke (2015) and Ruswandi *et al*. (2015) reported economic heterosis for quality traits in maize.

The number of hybrids showing significant hereobeltiosis was also as high as depicting relative hetterosis, but the number of hybrids showing significant heterobeltiosis in desirable direction ranged from 2 (number of leaves per plant and starch content), 3 (oil content), 9 (protein content) and 17 (grain yield per plant and harvest index). The maximum significant positive better parent heterosis for grain yield per plant was expressed by hybrid L_2 x T_1 (94.41%) followed by L_7 x T_1 (80.18%), L_9 x T_1 (66.80%), L_{11} x T_2 (63.67%) and L_3x T_1 (48.26%). The presence of heterobeltiosis indicates that over dominance also existed for most of the characters. However, its magnitude and the number of hybrids depicting the same was variable. Heterosis over better parent for grain yield was also reported by , Dubey et al. (2009), Viera *et al*. (2009), Amanullah *et al*. (2011), Bedhendi *et al*. (2011), Silva *et al*. (2011), Raghu *et al*. (2012), Avinashe *et al*. (2013), Netravarti *et al*. (2013), Ali *et al*. (2014), Rajesh *et al*. (2014), Khan *et al*. (2014), Ruswandi *et al*. (2015).), Singh (2015) and Zeleke (2015).

For maturity traits like days to 50 per cent tasseling, days to 50 per cent silking, anthesis-silking interval, day to 75 per cent brown husk and plant type traits like plant height and ear height, number of hybrids showed negative significant relative heterosis ranged from 1(anthesis-silking interval and day to 75 per cent brown husk), 14 (days to 50 per cent tasseling) and 25 (days to 50 per cent silking). The negetive significant relative heterosis for maturity traits also reported by Dubey *et al*. (2009), Premlatha and Kalamani (2010), Sumalini and Rani (2010), Kumar and Bharathi (2011), Pavan *et al*. (2011), and Singh and Singh (2011). Sundararajan and Kumar (2011), Khan *et al*. (2014), Kumar et al. (2014), Rajesh *et al*. (2014), Singh (2015), and Zeleke (2015).

Combining ability:

Besides, heterosis the information about combining ability is of immenses help to the plant breeder in the choice suitable parents. Sprague and Tatum (1942) defined general combining ability as average performance of a line in a series of crosses and specific combining ability as deviation in a performance of a cross combination from that predicated on the basis of the general combining ability is attributed to additive and additive x additive interaction effects, which are fixable, while specific combing ability is attribute to non-additive gene action, which may be due to dominance or/and epitasis.

Analysis of variance for combining ability indicated that the mean square due to lines and testers were significant for all the characters except anthesis-silking interval, days to 75 per cent brown husk and number of leaves per plant due to the lines, anthesis-silking interval, days to 75 per cent brown husk, number of leaves per plant, plant height, cob girth and number of grain row per cob due to tester. The mean square due to line x tester interactions were significant for all characters except anthesis-silking interval, days to 75 per cent brown husk, number of leaves per plant and number of grain row per cob, which indicates that the experimental material possessed considerable variability and that both gca and sca were involve in the genetic control of various characters.

The ratio of $\sigma^2_{sca} / \sigma^2_{gca}$ was greater than one for all the traits except anthesis-silking interval, number of leaves per plant, harvest index, grain yield per plant, oil content, starch content and protein content. This indicated that the preponderance of non-additive gene effects in the expression of these traits. These result are accordance with the findings of Singh and Kumar (2009), Jebaraj *et al.* (2010), Reddy *et al.* (2011), Vieira *et al.* (2011), Patil *et al*. (2012), Abrha *et al.* (2013), Gautam *et al* (2013), Kambe *et al.* (2013), Singh *et al*. (2013), Panwar *et al*. (2013), Khan *et al.* (2014), Sharma *et al.* (2015) and Khan *et al.* (2016).

Estimates of gca effects revealed that among the inbred lines none of the inbred line was found good general combiner for all the characters. Inbred line L_{10} was found good general combiners for grain yield per plant and majority of yield contributing traits and quality traits like cob girth, number of grain rows per cob, harvest index, oil content and starch content, whereas inbred line L_{11} was found good general combiners for grain yield plant, harvest index, plant height and protein content. The inbred lines L_6 and L_7 were found good general combiners for maturity and plant type traits (Table 5.2).

Among the testers T_3 was found good general combiners most of the traits *viz*, grain yield per plant, harvest index, oil content, protein content and starch content (Table 5.2). The general combining ability is due to additive and additive x additive gene effects (Griffing, 1956) which are the fixable component of genetic variation. Therefore, it would be worthwhile to use above parental lines in hybridization, aimed at getting desirable segregates in the segregating generations.

Twelve hybrids showed significant positive sca effects for grain yield per plant (Table 5.3). The maximum significant positive sca effects for grain yield per plant L_{12} x T_3 (46.41) followed by hybrids L_1 x T_2 (24.60), L_{11} x T_2 (24.59), L_7 x T_1 (24.60), Hybrid L_4 x T_2 (21.50) (Table 5.4). These above said cross are between average x good, poor x average, good x average, poor x poor and poor x average gca effects parents, respectively for grain yield per plant.

Hybrid L_{12} x T_3 showed highest significant positive sca effects along with higest *per se* performance and economic heterosis for grain yield per plant. This was cross between average x good gca effect parents for grain yield per plant. Another important hybrid was L_{11} x T_2 the sca effects of this hybrid were significant in desirable direction for grain yield per plant. This hybrid also showed good *per se* performance and significant economic heterosis for grain yield per plant. This was cross between poor x average sca effect parents for grain yield per plant.

For oil content ten hybrids *viz*, L_5 x T_1, L_6 x T_1, L_9 x T_1, L_4 x T_2, L_5 x T_2, L_7 x T_2, L_3 x T_3, L_8 x T_3, L_{10} x T_3 and L_{11} x T_3 showed significant positive sca effect for this trait. Whereas 11 and 13 hybrids depicted significant and positive sca effects for protein and starch content, respectively (Table 5.3).

Similar findings for identification of superior inbred lines and hybrids based on gca and sca effects for grain yield and its components in maize were also reported Singh and Kumar (2009), Vijayabharathi *et al.* (2009), Shanthi *et al.* (2010), Yousif and Sedeeq (2011), Reddy *et al.* (2011), Patil *et al.* (2012), Abrha *et al.* (2013), Gautam *et al.* (2013), Panwar *et al.* (2013), Verma *et al.* (2014),Sharma et al. (2015) and Khan *et al.* (2016).

The study under discussion finally revealed that some of inbred lines and testers used in the present investigation can be selected for the successful development of single cross hybrids since they possessed high to good *per se* performance with good general combining ability for grain yield per plant and other yield contributing and quality traits. Characters inhibited through additive mode of inheritance can be improved by selection method.

Some of the selected hybrids under study revealed good economic heterotic response to the tune of 11.56 to 26.17 per cent and good *per se* performance with high significant positive sca effects for grain yield per plant. Hence, these hybrids may be concluded for commercial exploitation and could be recommended for testing in multi-location trials.

Table 5.1: Best hybrids and parents identified on the basis of *per se* performance and economic heterosis (%) for grain yield per plant, harvest index

S.N	Hybrids and parents	*Per se* performance for grain yield per plant (g)	Economic heterosis (%) for grain yield per plant over the best check Vivek Hybrid-43	Economic heterosis (%) for harvest index per plant over the best check Vivek Hybrid-43	Days to 50 per sent silking
1.	L_{12} x T_3	151.48	26.17**	7.07*	63.33
2.	L_{11}x T_2	135.22	12.62**	4.17	68.33
3.	L_9 x T_3	133.95	11.56**	6.52*	65.33
4.	L_{10} x T_3	125.22	4.29	-	67.33
5.	L_8 x T_2	122.28	1.85	-	64.67
6.	L_{12}	120.07	-	-	67.67
7.	L_4	110.95	-	-	67.67
8.	L_8	89.62	-	-	68.67
9.	L_5	88.35	-	-	66.00
10.	L_{10}	84.15	-	-	69.00

*, ** Significant at 5 per cent level and 1 per cent level of significance, respectively

Table 5.2: Classification of parental lines based on general combining ability effects for fifteen traits in maize

Parental inbred lines	Days to 50 per cent tesselin	Days to 50 per cent sil	Anthesis Silking Interval	Days to 75 per cent Br	Plant height (cm)	Ear height (cm)	Number of leaves per pla	Cob girth (cm	Number of grains rows per	100-Grain weight	Harvest Index	Grain yield per pla	Oil Content	Protein Content	Starch Content

	g	kin g		ow n Hu sk			nt	)	Cob			nt			
L_1	A	A	A	A	G	G	A	A	A	A	A	P	A	P	P
L_2	A	A	A	A	P	A	A	A	A	G	G	G	P	G	G
L_3	A	A	A	A	G	G	A	A	A	A	P	P	G	P	P
L_4	A	A	A	A	G	A	A	A	A	A	A	P	A	P	A
L_5	A	A	A	A	A	A	A	A	A	G	P	P	G	A	A
L_6	G	G	A	A	G	G	A	A	A	P	P	P	A	P	A
L_7	G	G	A	A	A	P	A	A	A	A	P	P	G	G	P
L_8	A	A	A	A	P	A	A	P	A	G	A	G	P	A	G
L_9	P	A	A	A	P	P	A	A	G	A	G	G	A	P	A
L_{10}	P	P	A	A	G	A	A	G	G	A	G	G	G	P	G
L_{11}	A	A	A	A	G	A	A	A	A	A	G	G	P	G	P
L_{12}	A	A	A	A	A	P	A	A	A	A	P	A	P	G	P
T_1	A	A	A	A	A	G	A	A	A	P	P	P	A	A	P
T_2	P	A	A	A	A	A	A	A	A	G	A	A	P	P	A
T_3	A	A	A	A	A	P	A	A	A	A	G	G	G	G	G

G = Good, A = Average and P= Poor

Table 5.3: Inbred lines and hybrids possessing good gca and sca effects for fifteen traits in maize

S.No.	Characters	Inbred lines	Testers	Hybrids
1.	Days to 50 per cent tasseling	L_6, L_7	-	-
2.	Days to 50 per cent silking	L_6, L_7	-	-
3.	Days to 75 per cent brown husk	-	-	L_9 x T_2
4.	Anthesis silking interval	-	-	-
5.	Plant height	L_1, L_3, L_4, and L_6	-	-
6.	Ear height	L_1, L_3, and L_6	T_1	L_5 x T_1, L_6 x T_2 and L_3 x T_3
7.	Number of leaves per plant	-	-	-
8.	Cob girth	L_{10}	-	L_1 x T_3
9.	Grain rows per cob	L_{10}, L_{11}	-	-
10.	100 -Grain weight	L_2, L_5, and L_8	T_2	L_5 x T_1
11.	Harvest index	L_2, L_9, L_{10} and L_{11}	T_3	L_2 x T_1, L_3 x T_1, L_5 x T_1, L_6 x T_1, L_7 x T_1, L_1 x T_2, L_4 x T_2, L_8 x T_2, L_{11} x T_2, L_9 x T_3, L_{10} x T_3 and L_{12} x T_3
12.	Grain yield per plant	L_2, L_9, L_{10} and L_{11}	T_3	L_2 x T_1, L_3 x T_1, L_5 x T_1, L_6 x T_1, L_7 x T_1, L_1 x T_2, L_4 x T_2, L_8 x T_2, L_{11} x T_2, L_9 x T_3, L_{10} x T_3 and L_{12} x T_3
13.	Oil content	L_3, L_5, L_7 and L_{10}	T_3	L_5 x T_1, L_6 x T_1, L_9 x T_1, L_4 x T_2, L_5 x T_2, L_7 x T_2, L_3 x T_3, L_8 x T_3, L_{10} x T_3 and L_{11} x

				T_3
14.	Protein content	L_2, L_6, , L_{11} and L_{12}	T_2	L_8 x T_1, L_9 x T_1, L_{12} x T_1, L_3 x T_2, L_4 x T_2, L_7 x T_2, L_8 x T_2, L_1 x T_3, L_2 x T_3, L_6 x T_3 and L_{10} x T_3
15.	Starch content	L_2, L_8 and L_{10}	T_3	L_6 x T_1, L_8 x T_1, L_9 x T_1, L_{11} x T_1, L_2 x T_2 , L_3 x T_2, L_7 x T_2, L_8 x T_2, L_1 x T_3, L_2 x T_3, L_5 x T_3, L_{10} x T_3 and L_{12} x T_3

Table 5.4 Best hybrids and parents identified on the basis of *per se* performance and their gca/sca effects for grain yield per plant, harvest index, 100-grain weight and quality traits.

S.N	Hybrids and parents	*Per se* performance for grain yield per plant (g)	sca/gca effects				
			Grain yield per plant	Harvest index	100-grain weight	Oil content	Protein
1.	L_{12} x T_3	151.48	46.41**	6.19**	-0.91	-0.06	-0
2.	L_{11}x T_2	135.22	24.59**	3.39**	0.70	0.45*	
3.	L_9 x T_3	133.95	18.97**	3.32**	-1.91*	0.18	-0
4.	L_{10} x T_3	125.22	15.59**	2.77**	1.20	0.40*	0
5.	L_8 x T_2	122.28	16.76**	2.81**	0.26	-0.19	0
6.	L_{12}	120.07	0.58	-0.87*	0.46	-0.47**	0
7.	L_4	110.95	-3.64*	-0.29	-0.54	0.05	-0
8.	L_8	89.62	6.49**	0.86	1.35**	-0.20*	
9.	L_5	88.35	-5.22**	-0.89*	0.91*	0.28**	
10.	L_{10}	84.15	5.14**	1.15*	0.69	0.24**	-0

*, ** Significant at 5 per cent level and 1 per cent level of significance, respectively

6. SUMMARY

For generating the experimental material of present investigations entitled. **"Heterosis and Combining Ability Analysis in Medium Maturing Yellow Seeded Maize (***Zea mays* L**.) Hybrids"** the crossing programme was undertaken during *Rabi* 2015-16 by adopting line x tester mating design using 12 inbred lines and 3 testers. The resultant 36 hybrids along with their 15 parents and four checks were evaluated in randomized block design with three replications during *Kharif*-2016. The data were recorded and subjected to statistical analysis.

The salient features of results are summarized here under.

1. The analysis of variance indicated that mean squares due to genotypes, parents, crosses and parents v/s crosses were significant for all characters except for days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent brown husk, number of leaves per plant, cob girth and number of grain rows per cob due to genotypes, days to 75 per cent brown husk and number of leaves per plant due to parents, anthesis-silking interval, days to 75 per cent brown husk, number of leaves per plant, cob girth, number of grain rows per cob and 100-grain weight due to parents v/s crosses and anthesis-silking interval, days to 75 per cent brown husk and number of leaves per plant due to crosses. The significant mean squares or different traits, indicated the existence of appreciable amount of genetic variability under research experimental materials.

2. Inbred line L_2 exhibited maximum mean values for grain yield per plant, number or grain rows per cob, harvest index and minimum mean values for days to 50 per out tassseling and days to 50 per cent silking. Whereas tester T_3 showed maximum mean values for grain yield per plant, harvest index, oil content and protein content and minimum mean values for days to 50 per cent tasseling and days to 50 per cent silking.

3. Hybrid L_{12} xT_3 showed maximum mean values for grain yield per plant and harvest index. Where hybrid L_{11} x T_3 depicted maximum mean values for oil content and protein content.

4. There was close association between *per se* performance of hybrids and heterosis, *per se* performance on hybrids and sca effects and *per se* performance or parents and gca

effects. It would, therefore, be desirable to give due weightage to mean performance along with other parameters while selecting the parents for hybrization.

5. Out of 6 hybrids three hybrids *viz.*, L_{12} x T_3, L_{11} x T_2 and L_9 x T_3 were showed significant positive economic heterosis for grain yield per plant over the best check Vivek Hybrid-43. There hybrids also depicted significant positive economic heterosis for harvest index.

6. Number of hybrids depicting significant positive relative heterosis ranged from 1 (number of grain rows per cob) to 23 (grain yield per plant).

7. The number of hybrids showing significant heterobeltiosis in desirable direction ranged from 2 (number of leaves per plant) to 17 (grain yield per plant and harvest index). The maximum significant positive better parent heterosis for grain yield per plant was showed by hybrid L_2 x T_1 followed by hybrids L_7x T_1, L_9 x T_1, L_{11} x T_2 and L_7 x T_1.

8. Analysis of variance for combining ability indicated that mean square due to lines and testers were significant for all the traits except for anthesis-sliking interval, days to 75 per cent brown husk and number of leaves per plant due to lines, anthesis-silking interval, days to 75 per cent brown husk plant height, number of leaves per plant, cob girth and number or grain rows per cob due to testers. The man square due to line x tester interactions were significant for all the characters except anthesis-silking interval, days to 75 per cent brown husk, number or leaves per plant and number or grain rows per cob which indicated that experimental materials possessed considerable variability and that both gca and sca were involved in the genetic control of various traits.

9. The ratio of σ^2_{sca} / σ^2_{gca} was greater than over for all the traits except anthesis-silking interval, number of leaves per plant, harvest index, grain yield per plant, oil content protein content and starch content. This indicated that the preponderance of non-additive gave effects in the expression of these traits.

10. Inbred line L_{10} was found good general combiners for grain yield per plant, cob girth, number of grain rows per cob, harvest index oil content and starch content, whereas inbred line L_{11} was good general combines for grain yield per plant and protein content.

11. Among the testers T_3 was good general combines for yield and majority of traits *viz.*, grain yield per plant, harvest index, oil content, protein content and starch content. The general combing ability due to additive and additive x additive gene effects. Which are the fixable component of genetic variation.

12. Twelve hybrids showed significant positive sca effects for grain yield per plant. The maximum significant positive sca effects for grain yield per plant was depicted by hybrid L_{12} x T_3, followed by hybrids L_1 x T_2, L_{11} x T_2, L_7 x T_1 and L_4 x T_2.

13. Hybrid L_{12} x T_3 showed highest significant positive sca effects along with highest *per se* performance and economic heterosis for grain yield per plant. This was cross between average x good gca effects parents for grain yield per plant.

14. Some of selected hybrids under study revealed good economic heterotic response to the tone of 11.56 to 26.17 per cent and good per se performance with high significant positive sca effects for grain yield per plant. Hence, there hybrids may be recommended for testing in multi-location trials.

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Appendix I Mean values for Days to 50 per cent tesseling Days to 50 per cent silking Anthesis-silking interval Days to 75 per cent Brown Husk Plant height (cm) Ear height (cm) Number of leaves per plant Cob girth(cm)

SN	Genotype	Days to 50 per cet tesseling	Days to 50 per cent silking	Anthesis Silking Interval	Days to 75 per cent Brown Husk	Plant height (cm)	Ear height (cm)	Number of leaves per plant	Cob girth (cm)
1	T1	67.00	70.00	3.00	91.00	110.84	46.45	14.47	10.92
2	T2	68.67	70.00	1.33	89.00	107.83	51.58	15.47	11.75
3	T3	65.67	67.67	2.00	96.00	124.17	57.72	14.93	10.52
4	L1	62.67	65.67	3.00	89.00	156.06	58.85	15.30	9.72
5	L2	68.33	71.33	3.00	91.00	129.08	60.45	13.67	9.45
6	L3	68.00	71.00	3.00	91.00	107.83	49.65	12.13	11.65
7	L4	65.00	67.67	2.67	89.00	116.17	48.05	14.20	13.35
8	L5	62.67	66.00	3.33	94.00	111.44	53.98	14.87	11.35
9	L6	62.00	65.33	3.33	91.67	123.34	57.11	14.20	13.75
10	L7	63.33	66.00	2.67	94.33	120.32	49.45	13.53	9.32
11	L8	65.67	68.67	3.00	90.00	112.95	53.05	14.27	10.02
12	L9	67.67	70.67	3.00	91.33	134.29	69.92	14.13	13.42
13	L10	67.00	69.00	2.00	89.33	118.57	60.58	14.20	11.42
14	L11	65.67	68.00	2.33	88.67	127.76	62.85	14.27	11.15
15	L12	61.67	64.67	3.00	92.33	134.22	52.92	15.20	14.42
16	L1 x T1	60.00	63.00	3.00	90.67	150.33	64.51	14.43	10.15
17	L2 x T1	62.67	65.33	2.67	93.00	166.63	75.25	14.77	12.02
18	L3 x T1	63.67	66.67	3.00	93.00	155.54	75.52	14.67	11.02
19	L4 x T1	62.00	65.00	3.00	94.33	150.59	68.05	13.27	10.48
20	L5 x T1	60.33	63.00	2.67	92.67	147.86	60.65	14.60	10.22
21	L6 x T1	60.67	62.67	2.00	92.00	145.12	64.98	13.37	11.78
22	L7 x T1	60.67	63.67	3.00	92.67	154.47	76.85	14.33	11.72
23	L8 x T1	61.00	63.33	2.33	91.33	165.36	68.38	15.20	11.78
24	L9 x T1	63.33	66.67	3.33	88.67	165.56	73.45	14.60	12.89
25	L10 x T1	66.00	68.67	2.67	91.33	137.37	69.32	14.80	12.82
26	L11 x T1	62.67	65.67	3.00	92.33	149.72	67.98	14.53	11.82
27	L12 x T1	61.67	64.67	3.00	91.00	159.81	77.25	14.87	11.58
28	L1 x T2	65.33	69.00	3.67	93.67	146.78	64.39	14.40	10.65
29	L2 x T2	63.67	66.67	3.00	93.67	168.50	78.72	14.90	10.81
30	L3 x T2	60.67	63.67	3.00	91.33	143.85	67.92	13.60	10.85
31	L4 x T2	60.33	63.33	3.00	90.67	146.39	67.78	15.20	11.61
32	L5 x T2	62.33	65.33	3.00	91.67	163.56	76.32	15.27	10.75
33	L6 x T2	60.67	63.33	2.67	91.00	135.62	57.25	14.40	10.82
34	L7 x T2	60.33	62.67	2.33	94.00	153.33	71.72	13.73	10.62
35	L8 x T2	62.00	64.67	2.67	88.67	162.36	72.65	14.33	10.82
36	L9 x T2	70.33	71.33	1.33	93.33	153.60	76.05	14.27	10.81
37	L10 x T2	63.00	65.33	2.33	95.00	149.66	71.38	14.40	12.35
38	L11 x T2	65.33	68.33	3.00	88.00	154.60	71.98	16.00	12.35
39	L12 x T2	62.00	65.00	3.00	88.67	165.76	82.52	14.53	12.42
40	L1 x T3	62.00	64.33	2.33	89.67	150.19	73.25	14.93	12.92
41	L2 x T3	62.67	66.00	3.33	93.00	172.98	78.39	15.20	11.08
42	L3 x T3	61.67	64.67	3.00	94.00	148.46	62.72	14.33	11.39
43	L4 x T3	60.67	64.00	3.33	91.33	147.52	72.78	14.20	11.42
44	L5 x T3	61.00	64.00	3.00	88.33	154.00	75.12	14.00	11.62
45	L6 x T3	60.00	62.67	2.67	89.33	155.54	77.45	14.47	10.72
46	L7 x T3	59.33	62.33	3.00	92.00	161.22	84.38	15.53	11.65
47	L8 x T3	61.67	64.67	3.00	94.67	162.69	71.98	15.10	9.75
48	L9 x T3	62.67	65.33	2.67	94.33	163.49	80.52	14.07	12.05
49	L10 x T3	64.00	67.33	3.33	91.67	142.04	77.72	15.40	13.02
50	L11 x T3	61.67	65.00	3.33	93.00	153.60	84.05	15.27	11.68
51	L12 x T3	60.67	63.33	2.67	94.00	160.88	87.79	13.87	11.12

SN	Genotype	Days to 50 per cet tesseling	Days to 50 per cent silking	Anthesis Silking Interval	Days to 75 per cent Brown Husk	Plant height (cm)	Ear height (cm)	Number of leaves per plant	Cob girth (cm)
52	Check 1	60.33	62.00	1.67	92.67	118.72	42.78	15.30	11.45
53	Check 2	61.67	65.00	3.33	89.33	145.98	71.05	15.70	12.42
54	Check 3	63.33	65.67	2.33	90.67	147.34	71.85	14.47	12.58
55	Check 4	63.00	66.00	3.00	93.00	143.38	69.78	14.87	12.75
	GM	63.13	65.84	2.79	91.66	144.64	67.55	14.55	11.51
	PM	65.67	68.11	2.71	91.18	122.32	55.51	14.32	11.48
	F1 M	62.19	65.02	2.84	91.89	154.58	72.97	14.58	11.43
	Check M	62.08	64.67	2.58	91.42	138.85	63.87	15.08	12.30
	Se	1.07	1.22	0.42	2.50	4.13	2.99	0.66	0.51
	CD5%	3.00	3.42	1.18	7.01	11.59	8.38	1.86	1.43
	CD1%	3.97	4.53	1.56	9.28	15.33	11.08	2.46	1.89
	CV	2.94	3.21	26.09	4.73	4.95	7.66	7.88	7.68

*, ** Significant at 5 per cent level and 1 per cent level of significance, respectively

Appendix II. Mean values for No. of grains rows per Cob, 100 -Grain weight, Harves Index Grain yield per plant, Oil content (%), Protein content (%), Starch content (%)

SN	Genotype	Number of grains rows per Cob	100 - Grain weight	Harvest Index	Grain yield per plant	Oil content (%)	Protein Content (%)	Starch Content (%)
1	T1	12.93	34.31	29.33	59.95	3.72	8.25	65.76
2	T2	12.93	32.98	30.67	82.62	4.50	8.68	67.74
3	T3	12.87	32.64	32.87	96.55	4.96	9.46	63.90
4	L1	11.67	33.64	29.33	70.82	3.50	8.85	65.30
5	L2	12.00	32.98	28.20	57.42	4.24	8.72	68.99
6	L3	13.47	30.64	30.00	67.55	3.73	8.44	63.92
7	L4	14.27	31.98	36.33	110.95	4.73	9.52	64.84
8	L5	14.40	34.64	31.13	88.35	3.61	8.71	68.03
9	L6	14.47	33.31	30.40	78.82	4.85	7.51	64.18
10	L7	11.40	30.64	30.47	57.95	3.51	7.55	64.28
11	L8	12.73	30.98	31.53	89.62	4.41	9.78	68.78
12	L9	15.07	31.31	29.00	63.88	4.41	8.63	62.01
13	L10	13.07	35.98	31.00	84.15	4.76	9.50	67.82
14	L11	13.60	34.64	28.93	71.08	3.65	7.50	64.85
15	L12	15.80	31.98	36.80	120.07	3.51	7.48	63.97
16	L1 x T1	12.07	29.98	29.60	67.22	4.41	8.56	61.36
17	L2 x T1	13.60	31.98	36.73	116.55	3.47	8.30	63.82
18	L3 x T1	12.80	32.31	33.67	100.15	3.59	7.60	63.95
19	L4 x T1	12.27	29.64	29.53	74.48	3.47	7.91	65.07
20	L5 x T1	12.07	35.64	34.67	105.28	4.93	8.62	63.74
21	L6 x T1	13.53	27.64	33.53	101.08	4.60	8.47	65.50
22	L7 x T1	13.60	30.64	35.40	108.02	4.56	9.54	63.46
23	L8 x T1	13.67	33.64	34.40	103.82	3.38	9.53	66.87
24	L9 x T1	14.73	31.98	35.27	106.62	4.76	8.60	67.98
25	L10 x T1	14.53	32.98	31.07	84.22	4.21	8.51	64.19
26	L11 x T1	13.67	32.64	31.87	93.62	3.53	9.47	63.81
27	L12 x T1	13.27	31.98	28.73	72.48	3.54	10.04	61.80
28	L1 x T2	12.33	31.98	37.40	120.02	3.38	7.70	63.86
29	L2 x T2	12.67	33.98	33.80	99.15	3.19	9.76	69.00
30	L3 x T2	12.73	31.31	29.20	71.42	4.46	9.26	67.04
31	L4 x T2	13.47	34.31	37.00	116.88	4.69	8.95	64.10
32	L5 x T2	12.53	31.98	32.13	91.82	4.59	8.74	61.64
33	L6 x T2	12.73	30.98	30.73	86.88	4.32	7.54	65.13
34	L7 x T2	12.47	34.31	29.47	76.08	4.74	9.81	66.03
35	L8 x T2	12.73	34.98	37.07	122.28	3.52	9.44	68.82
36	L9 x T2	12.73	34.64	31.27	88.88	3.33	8.50	63.68
37	L10 x T2	14.33	32.31	34.73	103.95	3.81	7.93	63.46
38	L11 x T2	14.67	34.64	38.33	135.22	3.34	9.74	62.09
39	L12 x T2	14.20	34.98	29.60	75.75	3.52	9.44	64.18
40	L1 x T3	14.47	32.98	32.00	95.88	4.58	9.42	66.29
41	L2 x T3	12.73	34.98	36.13	107.48	3.60	10.08	69.03
42	L3 x T3	13.07	32.64	32.93	98.22	4.79	8.69	61.50
43	L4 x T3	13.13	31.98	32.93	95.68	4.14	8.65	65.84
44	L5 x T3	13.27	32.64	30.87	85.22	3.45	8.89	68.12
45	L6 x T3	12.60	31.31	30.93	84.68	3.42	8.63	62.72
46	L7 x T3	12.80	30.98	30.33	80.75	3.72	8.55	62.30
47	L8 x T3	11.20	32.98	31.47	91.35	4.63	7.33	63.04
48	L9 x T3	15.33	30.31	39.20	133.95	4.52	7.71	64.06
49	L10 x T3	14.53	34.31	38.00	125.22	4.82	9.38	68.82
50	L11 x T3	14.40	31.98	34.80	103.95	4.88	9.60	63.21
51	L12 x T3	12.60	31.98	39.40	151.48	3.66	8.36	66.86

SN	Genotype	Number of grains rows per Cob	100 - Grain weight	Harvest Index	Grain yield per plant	Oil content (%)	Protein Content (%)	Starch Content (%)
52	Check 1	14.20	30.64	31.07	89.62	4.21	9.90	66.74
53	Check 2	13.80	33.98	29.93	78.28	3.62	8.62	63.96
54	Check 3	15.07	32.31	35.00	105.08	3.52	8.83	63.16
55	Check 4	14.67	32.64	31.93	94.28	4.55	9.62	65.21
	GM	13.38	32.59	32.69	93.50	4.06	8.78	65.02
	PM	13.38	32.84	31.07	79.98	4.14	8.57	65.62
	F1 M	13.26	32.51	33.45	99.33	4.04	8.81	64.79
	Check M	14.43	32.39	31.98	91.82	3.98	9.24	64.77
	Se	0.68	0.74	0.73	3.03	0.15	0.13	0.40
	CD5%	1.91	2.08	2.05	8.50	0.42	0.36	1.13
	CD1%	2.53	2.75	2.71	11.25	0.56	0.48	1.49
	CV	8.83	3.95	3.87	5.62	6.43	2.54	1.07

*, ** Significant at 5 per cent level and 1 per cent level of significance, respectively

APPENDIX- III

ESTIMATION OF OIL CONTENT BY SOXHLET'S ETHER EXTRACTION METHOD (A. O. A. C., 1965)

PROCEDURE:

1. Grind 2 g of pre dried seed materials and transfer it in thimble. Pug the mouth of the thimble with fallow free absorbant cotton.
2. Take the clean, dry receiver flask from the Soxhlet assembly and weigh it accurately (W).
3. Introduce the thimble with sample into the Soxhlet.
4. Assemble apparatus and fill the Soxhlet with petroleum ether (b.p. 40-60^{o}C) by pouringit through the condenser at the top. The amount of solvent taken is about 1.5 times the capacity of the Soxhlet.
5. Place the apparatus on a water bath at 60^{o}C and start cold watercirculation in the condenser.
6. Extract for 8 hrs (roughly 250 times).
7. After extraction is over, remove the thimble with material from Soxhelt.
8. Assemble the apparatus again and heat it on water bath to recover all the ether from the receiver flask. The flask now contains only the crude fat.
9. Disconnect the receiver flask, wipe the outside of flask thoroughly with a clean dry cloth to remove the film of moisture and dust and dry it in a hot air oven at 100^{o}C for 1 hr.
10. Cool in desiccator and weigh (W_1).

CALCULATION:

Oil content (%) = $\frac{W_1 - W}{M} \times 100$ where,

W_1 = Weight of oil flask after extraction

W = Weight of empty flask

M = Weight of dried material taken

APPENDIX-IV

ESTIMATION OF STARCH CONTENT BY ANTHRONE REAGENT METHOD

PRINCIPLE:

The sample is treated with 80% alcohol to remove sugars and then starch is extracted with perchloric acid. In hot acidic medium starch is hydrolysed to glucose and dehydrated to hydroxymethyl furfural. This compound forms a green coloured product with anthrone.

MATERIALS:

1. Anthrone: Dissolve 200 mg anthrone in 100 ml of ice cold 95% sulphuric acid.
2. 80% alcohol (ethanol).
3. 52% perchloric acid.
4. Standard glucose: a) Stock solution-dissolve 100 mg of glucose in 100 ml of distill water, b) 10 ml of stock solution diluted to 100 ml with distill water.

PROCEDURE:

1. Homogenize 0.1 g of the sample in hot 80 % alcohol (ethanol) to remove sugars. Centrifuge and retain the residue. Wash the residue repeatedly with hot 80% ethanol till the washing do not give color with Anthrone reagent. Dry the residue well over the water bath.
2. To the residue add 5 ml of distil water and 6.5 ml of 52% perchloric acid.
3. Extract at 0^0C for 20 min. Centrifuge and save the supernatant.
4. Repeat the extraction using fresh perchloric acid. Centrifuge and pool the supernatant and make upto 100 ml.
5. Pipette out 0.1 or 0.2 ml of supernatant and make up the volume to 1 ml with water.
6. Prepare the standards by taking 0.2, 0.4, 0.6, 0.8 and 1.0 ml of the working standard and make the volume to 1 ml in each tube with distil water.
7. Add 4 ml of Antrhone reagent to each tube.
8. Heat for 8 minutes in a boiling water bath.

9. Cool rapidly and read the intensities of green to dark green colour at 630 nm.

CALCULATION:

Find out glucose content in the sample using the standard graph. Multiply the value by a factor 0.9 to arrive at starch content.

APPENDIX- V

ESTIMATION OF PROTEIN CONTENT BY MICRO-KJELDHAL'S METHOD, LINDER (1944)

PRINCIPLE:

Nessler's reagent is an alkaline aqueous solution of potassium mercuric iodide (Kl. Hgl2). It reacts with NH3 (or NH4- salts) to give reddish brown colour or precipitate. In the presence of sodium silicate the coloured precipitate are rapidly and completely removed from solution. The colour developed remains stable upto 15 heat room temperature (20-40 °C), its intensity is proportional to the initial concentration of NH3 nitrogen by Nesslerization. The colour can be read at 440-650 nm but sensitivity is more at shorter wave length.

PROCEDURE:

(B) Digestion:

1. Grind the seed material and weight 0.1g of sample and put in a dried Kjeldhal's Flask.
2. Add 2 ml of concentrated H_2SO_4 (Analar) and digest on heater for 1.30 h (a short funnel may be used as a reflux).
3. To this add 0.5 ml of H_2O_2 (30%) with alternate heating and cooling till the colour disappears. Heat further until H_2SO_2 fumes escape.
4. Transfer the contents of Kjeldhal's flask to 100 ml volumetric flask and make volume.

(B) Color Development:

5. Take 5 ml. volumetric flask, add 2 ml. and 1 ml. of 10% of NaOH and Sodium Silicate, respectively. Add 1.6 ml Nessler's reagent and finally make volume with distilled water. Allow 10 min. for color to develop.
6. Run a control with distilled water by the same procedure.

7. Adjust colorimeter using control and take absorbance (O.D.) readings at 540 nm. In this study, calorimetric readings were taken at 630 nm.

(C) Standard curve:

8. Dissolve 0.1179 g of ammonium sulphate in distilled and make the volume to 11 (25 ppm NH_2 –N solution), pipette out 1,2,3,4,5,6,7 and 8 ml (or 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5and 4.0 ppm) of this solution in 50 ml volumetric flask. Develop colour by procedure givenabove and read absorbance at same wave length draw a standard graph between ppm NH_3-Nand absorbance value.

(D) Estimation of Protein:

9. Determine the N-content of sample using the standard curve. The crude protein content is calculated by multiplying the N-content with 6.5 for maize.