GENE ACTION AND COMBINING ABILITY STUDIES IN SINGLE CROSS HYBRIDS OF MAIZE (*Zea mays* L.)

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1. INTRODUCTION

Maize (*Zea mays* L., 2n=20) is an important cereal crop belonging to tribe *Maydeae*, of the grass family, *Poaceae*. The plant is native to Central America. *Zea mays* is the only species in the genus Zea with chromosome number 2n=20. It has two close relatives among the American *Maydeae viz*., genus *Tripsacum* (gamagrass) and *Teosinte* (Euchalaena) which is regarded as the closest relative and five among Asiatic *Maydeae* viz *Chinonachne, Sclerachne, Coix, Trilobachene and Polytoca.*

In world, it ranks third next to wheat and rice in production. The suitability of maize to diverse environments is unmatched by any crop as the expansion of maize to new areas and environment still continues, as it has a range of plasticity. It is grown from latitude 58°N to 40°S, from sea level to higher than 3000 m altitude and in areas receiving yearly rainfall of 250 to 5000 mm (Downsell *et al*., 1996). Most of the area under this crop is however in the warmer parts of temperate regions and in humid subtropical climate. Highest production is in area having the warmest month isotherms from 21°C to 27°C and a frost free season of 120 to180 days duration.

Maize is one of the staple food crop and widely cultivated crop throughout the world. The United States produces almost half of the world’s production; other top producing countries are China, Brazil, France, Indonesia and South Africa.

In world, maize grown with a production 590 million tonnes and productivity 4229 kg per ha and occupies an area of 139 million ha. Maize is known as king of cereals because of its high production potential and wider adaptability. About 30% of world production is used for direct human consumption and as an industrial input, while 70% is used as animal feed. In India, maize is fourth most important cereal crop next to rice, wheat and sorghum. India ranks fourth in maize production with 19.31 million tonnes grown on an area of 8.26 million hectares with productivity of 2337 kg per hectare (Anon., 2009).

Karnataka is one of the major maize producing states in the country and it ranked first in production. During 2007-08, a total of 11.70 lakh hectares of maize was grown with a production of 35.80 lakh tonnes and average productivity of 3060 kg per hectare was realized with almost cent percent adoption of modern maize production technology. Karnataka state ranked first in yield realization till 1996-97 now lagging behind to Andhra Pradesh. The average productivity of state is much higher than the national productivity. Area under maize is increasing rapidly in the state, because of better environment. Thus there is a greater scope to increase maize productivity to a global level (Anon., 2009).

Rabi cultivation of maize is a relatively new practice which was first started in Bihar. *Rabi* maize has the clear–cut comparative advantage of low incidence of diseases and insect pests, crop do not suffer on account of heavy rainfall, slow growth of weeds, effective use of light *etc.* and hence preferred by farmers. These factors singly and in combination favoured the adoption of *rabi* maize cultivation in Bihar. Later it caught the attention in other parts of country like West Bengal, Uttar Pradesh, Madhya Pradesh, Tamil Nadu, Karnataka, and Punjab, where it is grown successfully.

Corn is increasingly used as an animal feed and fodder crop for both green forage and silage. About 26 per cent of maize production in India is consumed as food, 45 per cent goes to poultry, piggery and fish meal, 12 per cent goes to animal feed, 12 per cent in wet industry for making starch and oil, three per cent in dry milling for traditional requirements like Dalia, Sattu and other food products such as corn bread corn chips, brewery one per cent and seed one percent (Fig. 1).

Maize kernel contains about 77 per cent starch, 2 per cent sugar, 9 per cent protein, 2 per cent ash on a water free basis, 5 per cent pentosan and 5 per cent oil. It has more than 1000 industrial uses and mainly used for production of starch due to its high starch content of 77 per cent. Maize seed oil contains highest polyunsaturated fatty acids (PUFA), Linoleic acid (61.99%) and it remains as liquid at fairly low temperature which is helpful in combating heart disease. Maize seed oil is also low in linolenic acid (0.7%) and contains a high level of natural flavor. Maize is primarily used as food for human in African and Asian sub continents, while in United States about 85 per cent of the crop is used as cattle feed.

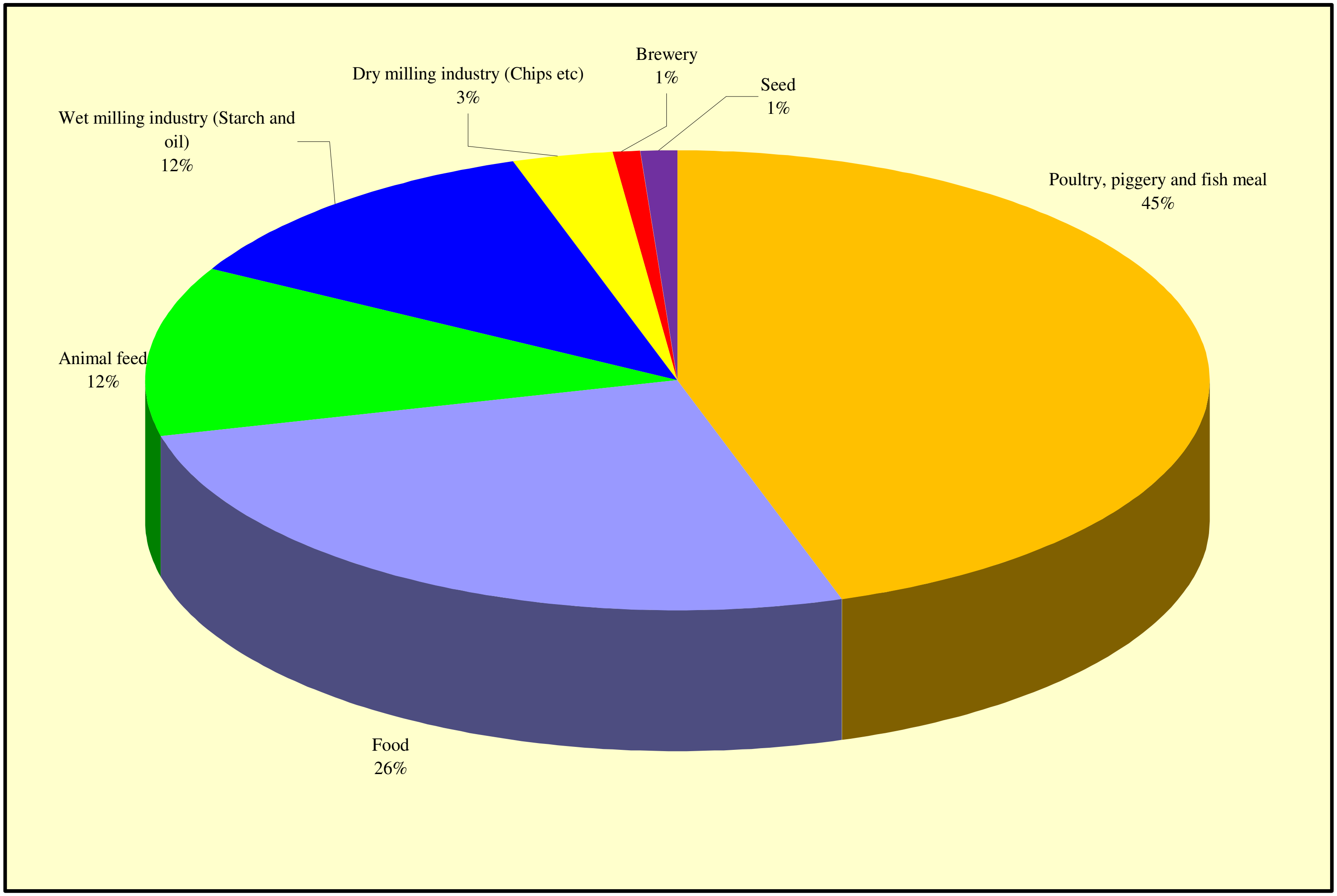

Fig.1. Utilization pattern of maize in India

However, now a day's corn grain is also a key raw material used for making starch, glucose and oil. Corn starch is used to make sweeteners, as well as such items as disposable forks and spoons. Corn starch is widely used in industrial purposes such as coating for paper and paper products and wallboards for buildings. The pharmaceutical industry also uses corn starch to make pills and other similar products. Recently, high fructose corn syrup has also been made from corn starch. This is mostly used in manufacture of coal and other drinks. In some countries, alcohol made from corn is blended in fuel for gasoline-powered vehicles to reduce emission of pollutants.

Principal types of maize are dent, flint, pod, pop, soft or flour, sweet and waxy corn. The floury and opaque are nutritional quality types with high tryptophan and lysine content respectively. Maize is the only cereal which can be used as food at various stages of its plant development. It is used as baby corn as soon as the plant flowers. Green ears of maize are used on large scale for roasting and boiling and consumed as food at dough stage.

The potential of heterosis is just beginning to be exploited in developing countries through expansion of hybrid seeds. It has the highest potential of per day carbohydrate productivity. Thus, the father of green revolution, the renowned Nobel Laureate, Dr. Norman E. Borlaug, believes that "after the last two decades saw the revolution in rice and wheat, the next few decades will be known as maize era".

The invention of heterosis phenomenon, the development of hybrid breeding technology and successful commercial exploitation of heterosis in maize are considered to be significant achievements and land marks in the history of biological sciences during the present century. A number of genotypes e.g., single crosses, three way crosses, double crosses, varietal hybrids, multiple hybrids, composites, synthetics, pools, populations etc. are feasible to maize growing farmers for commercial cultivation by virtue of the crop being a highly cross pollinated species.

Shull (1908 and 1911) gave the original concept for production and growing of single cross hybrids, but the cost of seed production has limited its utility. Jones (1918) suggested that double cross hybrids can be produced from two single cross hybrids to reduce the cost of seed production subsequently with the improvement in vigour and yield potential of inbred lines and development of better cultural practices, single crosses were adapted for commercial cultivation in the advanced countries. The recent trends even in the developing and under developed countries single cross hybrids are more popular due to their higher yield levels under favourable environment and uniformity in expression. Hence, there is a greater scope for the exploitation of heterosis through single cross hybrids, than double cross hybrids.

The hybrid development programme in maize involves development and evaluation of inbred lines, crossing of selected inbreds based on their combining ability and production of hybrids. In this context, a programme on development of inbred lines was initiated by using inbreeding system utilizing yellow pool as base population at Agricultural research station, Arabhavi. The experimental hybrids developed from S_4 lines derived from yellow pool and three testers by line x tester (L x T) method were evaluated in *rabi* season to assess their crossbred performance, combining ability and nature of inheritance for different qualitative traits.

In heterosis breeding programme, the selection of parents/inbreds based on their morphological diversity with good combining ability is very important in producing superior hybrids. The analysis of general combining ability and specific combining ability helps in identifying potential parents/inbreds for the production of superior hybrids. The line × tester analysis (Kempthorne, 1957) is one of the simplest and efficient methods of evaluating large number of inbreds/parents for their combining ability.

With this in view, an attempt was made to evaluate 87 single cross hybrids, 29 S_4 lines, 3 testers along with 5 checks with the following objectives.

1. To evaluate the performance of single cross experimental maize hybrids for grain and fodder yield.
2. To estimate the gca and sca effects in respect to grain yield and its components.
3. Assessing of combining ability of single cross experimental hybrids and parents by involving line x tester analysis.

2. REVIEW OF LITERATURE

The research carried out in the past on maize to study the gene action, heterosis, combining ability, correlation and path analysis in respect of qualitative and quantitative characters relevant to the present study is reviewed below.

Study of the behaviour of quantitative traits in maize is important because traits like maturity, plant height, ear length, ear circumference, number of kernel rows per cob, number of kernels per row, 100-grain weight, and grain yield are under polygenic control. The available literature on these aspects are reviewed under the following headings

2.1 Evaluation of lines by hybrid and mean inbred performance

2.2 Heterosis

2.3 Combining ability and gene action

2.4 Relationship between heterosis and combining ability

2.5 Association between yield and its components

2.1 Evaluation of lines by hybrid and mean inbred performance

The final evaluation of inbred lines can be determined by hybrid and mean inbred performance. In the earlier years of the corn breeding programmes, usually inbred lines were not evaluated in hybrid combinations until they had been inbred for several generations. A very large number of hybrids can be produced from a relatively few inbred lines. The lines can be saved or discarded on the basis of the mean performance of the crosses or based on mean performance of the inbred lines.

Jones (1922) reported on the relative performance of top crosses. Davis (1927) used top crosses to estimate the combining ability of S2 lines. Lindstorm (1931) suggested the commercial use of top crosses. He found that certain inbred lines were very preponderant for ear type, disease resistance, stability and uniformity in maturity.

Jenkins and Brunson (1932) noticed significant correlation between yields of intercrossed inbred lines and the same lines as top crosses. They reasoned that the most valuable lines for use in double crosses, multiple crosses or synthetic varieties are those, which on an average produce the best hybrids when tested with wide range of germplasm. They concluded from their study that crosses with standard open pollinated varieties provide efficient method for the preliminary testing of inbred lines for later use in other types of hybrid combinations. The use of top crosses provides an efficient method for the preliminary evaluation of inbred lines. They are especially useful for determining general combining ability for a large number of lines. The procedure permits the testing of a large number of inbred lines at one time and eliminates the need for preliminary evaluation of inbred lines in top crosses.

A simple inexpensive performance test was designed by Jugenheimer (1949) for the preliminary screening of large number of entries. Each three way cross was planted in replicated, single-hill plots. Its performance was compared to that of the single cross tester grown adjacent to it. The better lines obtained by the preliminary tests might be grown in larger populations for additional selection within families if seemed desirable. The remaining material may also be evaluated in standard yield tests to determine the superior inbred lines and hybrids.

Russell (1968) believed that older methods of evaluating inbred lines may need modification. The current yield levels are much higher and source materials diversified. Inbred lines for use in double cross hybrids were usually evaluated for general combining ability or additive effects. Because of the change to single cross and three way cross hybrids, testing procedures having maximum efficiency require greater emphasis on non-additive effects. The relative importance of additive and nonadditive type of gene action is changing in breeding programmes. He also pointed out that visual selection among and within inbred line progeny permits the breeder to evaluate many more progenies than is possible in replicated yield trials and at a much lower cost. He suggested that visual selection could be carried out for about three generations of progeny evaluation. It may be more logical to test immediately for specific combining ability when visual selection is completed. Established research programmes have a few key lines used in commercial hybrids.

Raghuram Reddy *et al.* (1987) compared yield performance of single cross, double cross and three way cross hybrids in maize crop. Yield levels of single cross maize hybrids were more followed by three way and double cross hybrids. Jha and Khehra (1992) in their study on evaluation of maize inbred lines derived from two heterotic populations by using factorial mating analysis with eighty crosses of maize produced by crossing five females with sixteen pollen parents in two different locations for combining ability noticed that specific combining ability(sca) and sca x environmental components were of higher magnitude than general combining ability (gca) and gca x environmental components for grain yield indicating greater contribution of nonadditive gene action and its pronounced interactions with the environments. Hallauer *et al.* (1994) evaluated B97 and B98 inbred lines by hybrid performance. As they found both B97 and B98 were good inbred lines, they concluded that both can be used as either male or female in the production of hybrid seed.

Venkatesh *et al.* (2001) conducted early generation identification and utilization of potential inbred lines in modified single cross hybrids of maize and suggested that the essential pre-requisite for commercial production of single cross maize hybrids is the development of vigorous high yielding inbred parents. Menkir *et al.* (2004) reported that the classification of maize inbred lines into heterotic groups is an important undertaking in hybrid breeding. Thirty-eight tropical mid-altitude maize inbred lines were crossed to two inbred line testers representing the flint and dent heterotic pattern, respectively. The resulting testcrosses were evaluated in a trial at three locations for 2 years. Significant general combining ability (GCA) and specific combining ability (SCA) effects for grain yield were detected among the inbred lines. The tester inbred lines classified 23 of the 38 tested inbred lines into two heterotic groups based on SCA effects and testcross mean grain yields. Diversity analysis of the 40 maize inbred lines using AFLP and SSR markers found high levels of genetic diversity among these lines and subdivided them into two main groups with subdivision into sub-groups consistent with breeding history, origin and parentage of the lines.

Jyoti Kumari *et al.* (2007) evaluated six sweet corn inbreds, three each of sugary (P1, P2 and P3) and shrunken2 (P4, P5 and P6) types derived from different source populations were crossed in half diallel mating design. The mean sums of square due to G x E interaction were highly significant for all the traits except number of kernel rows and 100-grain weight, which implied the importance of carrying out trials in different environments. Significance of both GCA and SCA variance for most of the characters implied that both additive as well as non-additive components are important. The estimates of GCA effect indicated inbred P5 as the most promising parent since it was observed as a good general combiner for plant height, kernel rows, 100-grain weight, yield per plant, whereas P1 and P3 reflected significant GCA effect for early maturity and plant height, respectively. The SCA effect revealed P2 x P6 as the best specific combiner for grain yield per plant, followed by P2 x P5 and P3 x P4.

Kadubiec and Kuriata (2007) reported that eight parental lines and the 28 hybrids obtained by crossing the parents in a diallel crossing design were investigated for relationship of some traits in Poland during 2001 and 2002. Six traits were evaluated: length and diameter of ear, ear row number, grain yield/ear, plant height and ear height. All traits except grain row number were highly and significantly correlated with grain yield in both years. Direct effects of ear length and diameter on grain yield were observed in both years; as well as ear height in 2001; and grain row per ear in 2002.

Joyti Kumari *et al.* (2008) reported that the inbred lines differed significantly for their flowering parameters, green ear weight, yield, total soluble solids and biochemical traits. Parents DMB 325, DMB 326 and SCI 308 were good general combiners for early maturity, whereas DMB 322 combined well for yield and sugar content. Testers SCI 308 and SCI 302 were good combiners for early maturity and total sugar, respectively. Among the crosses, 13MB321 x SCI 303, DMB 326 x SCI 303 and DMB 327 x SCI 303 were best specific combiners for early maturity, field emergence and fresh ear weight while hybrid DMB 327 x SCI 303 had better specific combining ability for grain yield and sugar content, the latter being heterotic over the standard controls.

2.2 Heterosis

Heterosis of varying magnitude has been observed in almost all the crop plants. Any of a multitude of genetic phenomena known to influence qualitative or quantitative characters is expected to influence heterosis but over the years that dispersion of completely or incompletely dominant genes and over-dominance along with some contribution of non-allelic interactions have been considered to be the main causes of heterosis. Heterosis breeding has received more attention than other branches of plant breeding in several crop plants and maize is one such cross fertilized crop in which has an array of hybrids have been realized over decades. Heterosis is the deviation of F1 from the reference for the particular character.

Shull (1908) coined the term heterosis to provide a term to describe the phenomenon but it did not include a description of genetic mechanism involved in its expression. Bruce (1910) and Keeble and Pellow (1910) put-forth the support for dominance hypothesis, which suggested that increase in vigour after crossing resulted from the combination of various dominant alleles by each parent. Shull (1911), East and Hayes (1912) objected the dominance theory and proposed overdominance hypothesis indicating heterosis as the result of heterozygosis. Ashby (1930 and 1932) suggested that heterosis resulted from the maintenance of the initial advantage in embryo size and not from an acceleration of metabolic process. East (1936) concluded that seed size or the size of any part of the seed cannot be the cause of heterosis. Hull (1945, 1946 and 1948) reported the evidence of overdominance in the expression of heterosis.

The degree of geographical separation and the degree of ancestral relationship can be used as an indication of genetic diversity. The greater genetic diversity of the parents is associated with greater heterosis in the F1 (Moll *et al.*, 1962, Paternani and Lonnquist, 1964; Wellhausen, 1965; Heidrich Sobrinho and Cordeiro, 1975; Vasal *et al.*, 1992). Moll *et al.* (1967) reported that heterosis increased with increased divergence within certain limits and extremely divergent crosses in maize resulted in decrease in heterosis. Griffing and Zsiros (1971) viewed heterosis as not entirely the result of genetic stimuli but rather as a result of the interaction between genetic and environmental stimuli and implicated that the environment was a significant factor in the manifestation of heterosis. Karvencheko *et al.* (1971) reported heterosis for ear length, plant height, 100-grain weight, number of kernel rows and yield. Annenkova (1973) stated that selecting suitable pollen parents with 21.8 to 41.2 per cent higher yield than standard check could produce hybrids with superior heterotic vigour.

Dornescu (1973) noticed varying degrees of heterosis in single cross hybrids of maize. Grain weight per ear showed significant heterosis and was directly correlated with ear length. Mukherjee *et al.* (1974) obtained significant heterotic effect for ear circumference and grain rows per ear. Appadurai and Nagarajan (1975) observed increased yield in 20 combinations exceeding 100 per cent over their respective parents, 33 showed heterosis for plant height, 44 for earliness, 18 for grain rows per ear, 40 for kernel number per row and 45 for grain weight per ear. Dhillon and Singh (1976) obtained heterosis for grain yield over mid parental and better parental values by 31 and 13 hybrids, respectively. Mabo (1977) noticed encouraging results by selecting parents with a large number of grain rows per cob, since the degrees of heterosis for the number of grains per ear, number of grains per row, plant height and grain yield depended on the number of grain rows per ear in the parents. Petrenko (1980) observed high positive heterosis for yield and yield components *viz.,* plant height, ear height and length of growth period.

Debnath (1984) obtained heterosis over mid parental value and better parent for grain yield components in 36 F1 hybrids from a diallel cross among nine elite diverse inbreds. The heterosis for grain yield ranged from 21.07 to 123.58 per cent over the mid parental value and from –2.96 to 95.07 per cent over the better parent. Heterosis was high for grains per row and ear length. Mukherjee and Saha (1984) observed positive heterosis for grains per ear in seven crosses, ear length in ten crosses and 100-grain weight in eight cross combinations.

According to Prasad and Singh (1986), the magnitude of heterosis for grain yield per plant and six of its components were greater when the parents were moderately diverse than when they were highly diverse. Shakoor (1988) observed positive heterosis for number of leaves (13. 4% to 20.0%) and leaf area per plant (-0.01 to 54.8) over better parent. Muthiah (1989) obtained significant positive heterosis for grain yield per plant and other 15 yield related characters in several cross combinations from 9 × 9 diallel analysis.

Masikevich *et al.* (1989) presented evidence that the increased yield of heterotic hybrids is the result of competitive interaction between photorespiration and photosynthesis. They have shown that heterotic organisms have a more economical utilization of energy and nutrient resources than non-heterotic ones and greater autonomy of the protein synthesizing system of the chloroplasts in relation to the ribonuclease function.

Malhi *et al.* (1993) in their study of relative performance of the single crosses and double crosses observed that the single cross hybrids had a significantly higher ranking than the double cross hybrids for yield on average over all crosses and over the five best crosses. Comparison of yield performance indicated that the single cross hybrids were more stable than the double cross hybrids. Bhatnagar *et al.* (1993) observed high heterotic effects for early silking and grain yield per plant in early maize inbred lines. High heterotic effects for grain yield per plant and time to silk was reported by Vasal *et al.* (1993) based on the combining ability analysis of maize germplasm lines. Gupta *et al.* (1994) studied 23 double cross hybrids and reported that 16 out of 23 double cross hybrids showed high degree of heterosis for grain yield than the best standard variety "Shweta".

Abdul (1995) noticed heterotic effects in plant height and leaf area per plant. Kumar (1995) observed high degree of heterosis for grain yield per plant and earliness in eight hybrids. Lamkey (1995) indicated that hybrids obtained from the crosses between 24 high yielding and 24 low yielding inbred lines differed significantly for group means and heterosis for yield and days to silking. Nagda *et al.* (1995) obtained significant positive heterosis for grain yield per plant over the best check in 15 crosses and significant relative heterosis for days to silking, plant height and ear height in 14 hybrid combinations.

Ling *et al.* (1996) noticed that mean heterotic effects were highest for grain yield per plant followed by grain weight and ear thickness. Saha and Mukherjee (1996) observed significant positive heterosis for grains per ear and the crosses with highest heterosis for 100-grain weight and grain yield per plant and negative heterosis for percentage grain conversion. Verma and Singh (1996) reported that dominance × dominance gene interactions were important for improving heterosis for yield. Yurankova *et al.* (1996) obtained considerable instability in heterosis for ear width, ear length and number of grains per row. Heterosis was slight or absent for number of rows per ear. Geetha (1997) obtained positive heterosis over mid parent in 24 hybrids and significant standard heterosis in 19 hybrids. Nagesh Kumar *et al.* (1999) observed heterosis for grain yield that ranged from 26.31 to 37.30 per cent over better parent.

Stojokovic *et al.* (1999) reported that partial or complete dominance of dominant alleles with additive effects were the main contributers to heterosis in maize. Over dominance may exist at some loci but of minor importance. Sain Dass and Pawan Arora (1999) reported that negative heterosis will be considered as desirable for the phenological traits as it contributed favourable genes for earliness. Netaji *et al.* (2000) obtained significant and positive heterosis and heterobeltiosis for grain and moreover the expression of heterobeltiosis was most evident for grain yield per plot followed by test weight, ear length, plant height and number of grain rows per ear. Rosa *et al.* (2000) noticed the highest values of heterosis over the mid-parental value in the hybrid PP-9539 × AN-453 (11.35%) and PP-9603 × PP-9539 (11.13%). Geetha (2001) obtained maximum heterosis for grain yield per plant, ear weight and number of grains per ear. They also reported that significant positive heterosis in grain yield which was associated with the heterosis for plant height, number of grains per row, 100grain weight and number of rows per ear.

Han Li Jun *et al.* (2001) made crosses using North Carolina Design II. The results showed that all the F1 hybrids exhibited positive heterosis in some degrees and the highest heterosis was in crosses in which MO-17 was the male parent. Kara (2001) observed positive heterosis for all characters studied except for days to tasseling with the average hybrid yield being 79.89 per cent above that of the parents. Nigussie *et al.* (2001) reported that the crossing maize (Zea mays L.) genotypes obtained from different sources could result in better utilization of hybrid vigour. This study was conducted to determine the heterosis and combining ability of eight elite maize genotypes. The eight parents were selected based on per se and top-cross performance. Mid-parent heterosis occurred in varying degrees for the different traits. It was in the range of -11.6 to 21.9 per cent for grain yield.

Shahwani *et al.* (2001) noticed positive and significant heterosis in 17 hybrids, while 11 hybrids showed heterobeltiosis for ears per plant. Vidal Martinez *et al.* (2001) observed negative heterotic values in pollen yield components and reported heterotic values upto 300 per cent for pollen yield in Corn belt genotypes and upto 200 per cent for grain yield in exotic genotypes. Bassey (2002) Field studies were conducted to evaluate the heterosis and combining ability of two maize cultivars, FARZ 32 (yellow, YE) and FARZ 11 (white, WT), for crop yield and yield components. The highest mid-parent heterosis of 28.15% was observed between the F1 hybrids of Y[female] x W[male] for fresh weight of the plant, while the lowest of 3.45% was exhibited by the F1 hybrids of Y[female] x W[male] for dry weight of the maize ears. Highest mid-parent heterosis of 40.17% was exhibited by the F1 hybrids of W[female] x Y[male] for fresh weight of the plant while the lowest was by the F1 hybrids of W[female] x Y[male] for number of grains/ear.

Jha *et al.* (2002) reported the heterosis and gene action for number of days to 50% silking, plant height, basal stem girth, number of leaves per plant, leaf:stem ratio, green fodder yield and dry matter yield were studied using 30 crosses and 12 parental genotypes. Standard heterosis was up to 23.42% in APFM-22 x African Tall for green fodder yield, and up to 20.94% in GBM-84-2 x African Tall for dry matter yield. This heterosis can be exploited for the improvement of green fodder yield in maize. Thus, it is suggested that reciprocal recurrent selection may be adopted for the improvement of heterotic populations. Saleh *et al.* (2002) reported high estimates of heterosis for grain yield, ear weight, grain weight per ear, moderate estimates for plant and ear height, shelling percentage, ear circumference, number of kernel rows per ear, number of kernels per ear row and grain weight.

Singh *et al.* (2002) reported that the eight diverse inbreds were crossed in a half diallel to estimate heterosis and combining ability. Based on the *per se* performance, GCA effect and heterosis, P1 x P7 was the best hybrid, yielding 14.30% more grain yield per plant followed by P4 x P7 (13.07%) over the superior control: CM-400 x CM-300. Crosses between high x high and high x low GCA parents exhibited greater heterosis. Heterosis for yield was generally accompanied by heterosis for yield components. Ashish *et al.* (2003) reported that eighty single crosses along with parental lines were evaluated in three environments. All crosses showed high relative heterosis and SCA effects for grain yield along with negative relative heterosis for days to 50% silking, which is desirable for developing early maturing single cross hybrids.

Betran *et al.* (2003) conducted experiment on genetic diversity and heterosis in tropical maize under stress environment. They observed that SCA had the strongest correlation with genetic diversity. Environment significantly affected the correlation between F1, SCA, MPH and HPH, with lower values of genetic distance revealed in most stress condition. Cruz Lazaro *et al.* (2003) observed positive heterosis for both mid and high parent. Kabdal *et al.* (2003) in their studies on combining ability and heterosis analysis for grain yield and its components in maize by using 7 inbred lines derived from half-diallel mating, along with 4 control cultivars were determined in a field experiment conducted in Pantnagar, during the *kharif* season of 1999. The general combining ability for all the characters examined was higher than the specific combining ability except for ear height.

Srivastava *et al.* (2003) studied heterosis and combining ability for yield and maturity by using exotic and indigenous inbred lines of maize. Eighty single crosses along with parental lines were evaluated in three environments *viz.*, Uttaranchal, Uttarpradesh and Punjab, during *kharif* 2000. The mean square due to interaction of lines and lines x testers with environments were significant for all characters, while testers with environments was significant for days to 50 per cent silking. Li-Jizhu (2004) reported highest heterosis for ear grain weight and lowest for ear row number. All characters studied were controlled by additive gene action. Ear length had significant additive and dominance effects, whereas, ear row number and ear grain weight had dominant and epistatic effects, respectively.

2.3 Combining ability and gene action

In relation to single cross of corn, Sprague and Tatum (1942) formulated the concept of combining abilities. General combining ability is the average performance of a strain in a series of cross combinations, estimated from the performance of F1s from the crosses, whereas specific combining ability is used to designate those cases in which certain combinations do relatively better or worse than would be expected on the basis of average performance of lines involved. Griffing (1956) has shown relationship between various heritable variance components and GCA and SCA variances. GCA variance is due to additive variance and additive × additive interaction variance while, SCA variance is due to dominance variance, additive × additive variance, additive × dominance variance and dominance × dominance variance components. Estimates of the variances due to GCA and SCA provide an appropriate diagnosis of the predominant role of additive or non-additive variances of gene.

Ratio of additive to nonadditive gene action is to be considered in order to decide the predominance of the kind of genetic variation for a given character. The ratio of additive to nonadditive gene action is more than unity it indicates the major role of additive variance in controlling the expression of a character, whereas, less than unity indicates the importance of non-additive variance (Gardner, 1963). Tandon *et al.* (1970) opined that the combining ability analysis was better than graphical analysis in predicting the prepotency of cultures especially in the later generations, when the expression of dominance effect is reduced. According to Dhillon and Singh (1976), general combining ability was more important than specific combining ability for the inheritance of days to 50 per cent silking, grain moisture, plant height, ear height, ear length, ear circumference and kernel row number but not for grain yield.

Martin and Hallauer (1976) studied diallel analysis for ear length, ear circumference, 100-grain weight, number of grain rows and yield and concluded that epistasis was more frequent for all characters except for 100-grain weight. Epistasis was most common for ear circumference and number of grain rows and least common for yield. Bhalla and Khehra (1977) reported significant general combining ability for yield per plant, ear length and plant height. Ramamurthy (1980) reported the predominance of additive gene effects for plant height, 100-grain weight, while non-additive effects were important for ear height and grain yield per plant. Murthy *et al.* (1981) observed predominance of additive gene action for days to silking and non-additive gene action for grain yield per plant. Ali and Topara (1986) noticed that the additive gene action was more important than non-additive gene action for days to silking and plant height, whereas non-additive gene action was more important for ear circumference, number of grain rows per ear, grains per ear and grain yield.

Singh *et al.* (1983) in their study on combining ability in maize noticed that additive genetic variance was relatively more important for days to 75% silk and plant height but yield per plant was controlled by non additive genetic variance. Significant maternal effects were reported by Melchinger *et al.* (1986) for yield and plant height. Diallel analysis revealed that epistatic variance for yield was significant and negative in 11 out of 15 crosses studied. Pavilikova and Rood (1987) indicated that dominant and over dominant effect was responsible for increased leaf area in maize. The ratio of *gca/sca* mean squares showed that gca effects were more important than *sca* effects. Muthiah (1989) reported that the proportion of GCA variance was higher than the SCA variance showing preponderance of additive genetic effects for all the characters studied.

Prasad *et al.* (1988) studied combining ability analysis in an 8 x 8 maize diallel for days to silk, plant height, cob placement, kernel rows per cob, kernels per row, cob length, cob girth, test weight, grain yield per plant and stover yield per plant by using different inbreds in the crossing program such as CM104, CM105, CM110, CM111, CM300, CM400, CM500 and inbred NLD composite reported mean squares due to gca,sca and reciprocals were highly significant for all the ten characters and the general predictability ratio indicated that the progeny performance was based on both gca and sca. According to Debnath and Sarkar (1990), non-additive gene action was preponderant in the inheritance of grain yield, ear circumference, whereas equal importances of both additive and non additive effects were observed for ear length, kernel rows per ear and kernels per row. Zargar and Singh (1990) suggested that additive components of variance with dominance played a major role in the inheritance of grain yield, plant height, ear height, ear length, kernel rows per ear and 100 kernel weight exhibited importance of variance with dominance in a partial to negligible range.

Paul *et al.* (1991) reported that pratap was the best general combiner and E< sub>1</ sub> x E< sub>2</ sub> had the highest SCA effect for yield, followed by E< sub>2</ sub> x Ageti 76. Parents with high GCA did not always produce hybrids with high estimates of SCA. Quadri *et al.* (1993)in their study on combining ability under two population sizes for ear traits in maize observed that gca and sca effects were highly significant for the ear character, ear height, ear girth, cob girth and grain rows. Predominance of additive genetic variation was observed for all the ear character and identified composite Rutherford was the best general combiner for all the ear character. Population improvement programme by selecting the plant with more ear length, ear girth and number of grain rows per ear was suggested to make yield improvement.

Alika (1994) observed highly significant variation due to gca for ear length, ear circumference, ear weight and 100-kernel weight and sca for ear circumference. Satyanarayana (1995) recorded low genotypic coefficient of variance estimates combined with low to medium heritability and low genetic advances for grain yield. In case of other agronomic characters, genotypic coefficient of variance estimated was high combined with high heritability and genetic advance indicating the inheritance of additive gene action controlling these traits. According to Packiaraj (1995), GCA variance was greater in magnitude than SCA for shelling percentage, number of leaves, leaf breadth, 100-grain weight, days to 50 per cent silking, number of grains per row and plant height. SCA variance was high for ear weight, grain weight per plant and number of grain rows per ear indicating that dominance and epistatic played a major role in the expression of these traits.

Dass *et al.* (1997) reported that non-additive gene action played major role in the inheritance of grain yield and majority of ear traits. But, Geetha (1997) observed that additive gene effects controlled the inheritance of grain yield per plant and also added that proportion of GCA variance was higher than the SCA variance having preponderance of additive genetic effects for characters such as plant height, number of grain rows per cob, number of grains per row, ear weight, days to 50 per cent silking, 100-grain weight and starch content.

According to Altinbos and Tosum (1998) GCA and SCA variances for grain yield per plant and other yield components indicated that screening the parental lines and crosses based on combining ability effects for 100-grain weight and ear length should be effective. Dutu (1998) observed that plant height was controlled by additive and nonadditive gene actions and cytoplasmic inheritance. Whereas, number of leaves per plant was controlled by additive gene only. Joshi *et al.* (1998) revealed that there was preponderance of non-additive gene action in the expression of yield per plant, protein content and starch content, while for oil content and 100-grain weight there was preponderance of additive gene action. Lou Xiang *et al.* (1998) concluded that most plant and ear characters were improved with additive and dominance effects of the female parents. According to Singh and Singh (1998), GCA variance was more important for ear length, number or kernel rows per ear, but SCA variance was important for other characters like grain yield per plot, ear circumference, number of kernels per ear row, 100-kernel weight, days to 50 per cent silking, plant height and ear height.

Mikhailov and Chernov (1999) reported that partial dominance of the positive allele is the main type of allelic interaction in the loci controlling kernel row number. Paul and Debnath (1999) obtained significant gca and sca effects for all characters studied *viz.,* days to silking, plant height and ear height. Combining ability analysis indicated that additive gene action was more important than non-additive gene action and the best general and specific combiners were selected. Talleei and Kochaksaraei (1999) observed significant gca effects for plant height, ear height, kernel length and yield per plant. Yu Zhongliang *et al.* (1999) concluded that an endosperm genetic effect was controlled by most of the traits, although maternal effects were predominant and utilization of maternal heterosis was an effective way of improving traits. Choudhary *et al.* (2000) estimated the combining ability of early generation inbred lines derived from two maize populations aimed at forming a heterotic group Fen 81 line were derived from two maize populations namely jogia local and DH 8644.showing that better performing crosses usually had at least one parent with high general combining ability but for ear length inter population crosses were usually superior to intrapopulation crosses.

Gupta and Nagda (2000) observed variances due to variety heterosis and its components were significant for all the characters studied. Kadlubiec *et al.* (2000) obtained higher GCA values than those of SCA for majority of traits suggesting the importance of additive gene action. Non-additive gene action effects were responsible for the inheritance of lodging resistance only. Rameeh *et al.* (2000) observed greater ratios of GCA to SCA mean squares for all traits, except for number of seed rows per ear, indicating importance of non-additive gene effects in their genetic control. Rosa *et al.* (2000) obtained highest SCA values in 13 × 13 diallel crosses *viz.,* AS-910 × AS-4450 and PP-9538 × AS-948. Singh *et al.* (2000) the results revealed that general combining ability (GCA) variance was lower under both rainfed and irrigated conditions for all the characters except for cob width. When compared between rainfed and irrigated conditions, GCA variance and specific combining ability (SCA) variance were higher in irrigated conditions. The proportion of SCA variance to GCA variance was higher for grain yield and cob length under both the situations.

Suneetha *et al.* (2000) noticed significant variances for GCA and SCA for days to 50 per cent tasseling, plant height and neutral detergent fiber content. Zelleke (2000) had derived an information from data on grain yield, plant height, ear length, days to maturity and 1000-grain weight from a diallel mating that both gca and sca effects were significant for all traits. Geetha and Jayaraman (2000b) reported that additive and dominance components were significant for plant height, number of kernel rows per cob, number of kernels per row, ear weight, 100-grain weight and grain yield. Desai and Singh (2001) reported significant difference in gca and sca effects for the traits *viz.,* days to 50 per cent tasselling, days to 50 per cent silking, anthesis, silking interval, plant height, ear height, number of leaves per plant. Kalla *et al.* (2001) reported that both additive and non-additive gene actions were significant for 1000-grain weight, grains per ear, ear girth and ear length. The non-additive gene action was predominant for ear length and 1000-grain weight, and significant for grain yield per plant. The additive (D) component was significant for grain yield per plant, grains per ear and 1000-grain weight.

Kara (2001) observed significant gca effects for all the traits and significant sca effects for ear circumference, ear height and grain yield per unit area. Konak *et al.* (2001) obtained non-additive gene effects for ear length and number of kernel rows on ear and additive gene effect for yield, 1000-kernel weight, plant height, ear height and days to silking.

Mandal *et al.* (2001) noticed significant GCA and SCA variances for most of the traits studied. Mahto ad Ganguly (2001) observed that both additive and non-additive genetic components for 100-grain weight and shelling percentage in CML 85 and CML 79. The crosses showed positive and highly significant specific combining ability effect for grain yield.

Shieh-Guang Jauh and Thseng-FuSheng (2001) they suggests that early testing was effective for predicting the combining abilities expressed at later inbreeding generations. In addition, the additive effects of inbred lines may be a main contributor to the relationships between the S_2 to S_5 generation hybrids for ear dry weight and grain dry weight. Vidal Martinez *et al.* (2001) obtained better *per se* combining ability for pollen yield of Corn Belt genotypes and good combining ability for grain yield and their components for exotic genotypes. Dominance gene effects were the most important contributors to the inheritance of pollen yield, grain yield and their components.

Vacaro *et al.* (2002) reported that mean sum of square for gca effects was greater than that for sca effects for the traits like plant height, point of insertion of the first ear, number of ears per plant, number of grains per ear, root and stalk lodging and grain yield indicating the predominance of additive effects. Kanta *et al.* (2002) observed preponderance of additive gene effects for all traits. Alamnie *et al.* (2003) reported that a high magnitude of specific combining ability (sca) than general combining ability (gca) for all the characters indicate the predominance of non-additive gene action. The variance components of gca and sca were significant indicating the role of both additive and non-additive gene actions in the inheritance of the characteristics.

Dodiya and Joshi (2003) conducted line x tester analysis by using 20 lines and 3 testers in maize (*Zea mays*) along with their F1 hybrids was carried out in three environments to asses combining ability and heterosis with respect to quality and yield attributes and they observed that combining ability analysis showed the predominant role of non-additive type of genetic component in the inheritance of all the characters. Wu-Guang Cheng *et al.* (2003) reported that the kernel weight percentage, growth period, plant height, rows/cob, cob length, seed-bearing cob length, kernels/row and cob position should be selected during early generations of maize breeding, while the other 4 traits should be selected in later generations.

Al-Ahmad.S.A *et al.* (2004) reported that the general and specific combining abilities for grain yield, ear diameter and silking date were higher during the late than the normal planting. Genetic variances for the traits were higher during the late planting. El-Moula *et al.* (2004) indicated that magnitude of delta 2-GCA was greater for days to 50 per cent silking, plant and ear heights, while delta 2SCA was greater for number of ears per 100 plant and grain yield. Interaction of delta 2SCA × L was higher than that of delta 2GCA × L for all traits indicating that the non-additive type of gene action was more affected by environmental conditions than the additive type. Hossain *et al.* (2004) conducted the combining ability analysis in flood tolerant maize inbred lines and their hybrid under waterlogged situation and the experimental results showed that combining ability study revealed that none of the parents had significant desirable effects of gca for all the characters. Malik *et al.* (2004) reported that temperate material gave high gca effects for striking characters contributing towards high grain yield i.e., plant and ear height, leaf area, ears per plant, ear weight and kernels per row. Surya Prakash and Ganguli (2004) revealed that gene action appeared to be non-additive for all traits except for number of days to 50 per cent tasseling, ear height and number of kernel rows per ear, which are characterized by additive gene action.

Katna *et al.* (2005) in their study of combining ability for yield and its related traits in maize involving 12x12 half diallel set and three checks at two climatically diverse locations, noticed that both general and specific combining ability effects were significant for all the traits at both the locations. Vafias and Ipsilandis (2005) observed that rapid lines developed from combining half sib/S1 evaluation may ensure high and stable crossing performances, based on additive gene action. Stability and uniformity of performance of three way crosses was due to proper breeding incorporated in single cross hybrid and to high stable inbred line performance. Welcker *et al.* (2005) reported that heterosis and combining ability for maize adaptation to tropical acid soils in five different environments and observed significant genotype x soil condition interactions grain yield. Mid parent heterosis for yield was significantly higher in acid soils (32%) than non acid soils (20%) and suggested that the development of variety crosses between acid soil-tolerant populations could be used to increase maize yields in acid soil cropping pattern

Abelardo *et al.* (2006) estimated that the general combining ability and specific combining ability help plant breeder to devise breeding and selection strategies. The objectives of their study was to apply two mode principle component analysis (PCA) to environment-centered and normalized female(F) or male(M) x environment (E) and these interactions study were able to identify the best tester for either broader specific adaptation. Amit Dadheech *et al.* (2007) reported that the ratio of non additive/additive gene effect revealed that there was preponderance of non additive gene action in the expression of all the traits under study. Inbred lines L9 and L10 were good general combiner for all the three quality traits. While inbred line L9 was also good general combiner for grain yield, oil content, starch content and protein content. Single cross L15 x T1 had positive significant sca effects for oil content along with starch content with highest estimate of heterobeltiosis for oil content.

Jumbo *et al.* (2008) reported that the general combining ability (GCA) effects were on average larger than specific combining ability (SCA) effects. Maternal effects (ME) and reciprocal effects (RE) were not significant for all traits, except for ear height. Kumar (2008) reported that the combining ability for 9 traits was studied from 36 diallel hybrids and 9 inbreds of maize. MG 14, MG 2 and MG 10 were superior parents as they recorded highly significant general combining ability effects for most of the economic characters. Hybrids MG 7/ML 47 and MG-35/ML 47 were the most suitable for the exploitation of heterosis, followed by hybrids MG 7/ML 47, MG 2/ML 47 and MG 37/CO 1.

2.4 Relationship between heterosis and combining ability

The information on heterosis and combining ability considered together will be more meaningful. If the heterotic hybrids involve both the parents with high general combining ability effects, then it implies that the parental contribution to heterosis is mainly through additive gene action.

Johnson and Hayes (1940) found that low × low crosses yielded less than low × high or high × high, although the F1 crosses between low × high yielded as well, on the average, as F1 crosses between high × high. Hull (1952) believed that while the mean of the high × high combination may be best, the highest specific combination is more likely to occur in high x low crosses. Leng (1954) reported that if over dominance is present, the highest degree of heterosis should be found in high × low crosses.

Tarutina *et al.* (1980) reported that heterosis was observed for many characters under different environmental conditions. As a rule, hybrid with the highest percentage of heterosis had a line with high gca as one of its parents. Khotylera *et al.* (1986) in a study of general and specific combining ability for six yield components in F1-F2 hybrids from a diallel cross of seven lines and in the backcross to each parent reported that high percentage of heterosis was generally found in those hybrids in which at least one of the parents had high gca and specific combining ability also played major role in determining heterosis. Vaidya (1986) reported that the crosses showing heterosis over check for yield and yield components had at least one good general combiner in their parentage.

Giridharan *et al.* (1996) in their study on gene action and combining ability in grain yield, found that yield was controlled by additive and non-additive gene action in diallel crosses and dominant gene action in triallel and quadriallel crosses, suggesting that grain yield could be improved by heterosis breeding. Rana and Vinod Kumar (2001) reported that the non-additive gene action was important for grain yield and its components, while additive gene effects were important for phenological traits. San-Vicente *et al.* (2001) reported that the combined analysis of variance detected highly significant differences among genotypes, parents and crosses for all traits. The test for average heterosis, parents versus crosses, was significant for grain yield and time to silk. General combining ability (GCA) was significant or highly significant for all traits, whereas specific combining ability (SCA) was highly significant for grain yield and time to silk.

Bassey (2002) the analysis of variance showed that the parental plants were significantly different at P<0.01. The highest mid-parent heterosis of 28.15% was observed between the F1 hybrids of Y[female] x W[male] for fresh weight of the plant, while the lowest of 3.45% was exhibited by the F1 hybrids of Y[female] x W[male] for dry weight of the maize ears. Highest mid-parent heterosis of 40.17% was exhibited by the F1 hybrids of W[female] x Y[male] for fresh weight of the plant while the lowest was by the F1 hybrids of W[female] x Y[male] for number of grains/ear. Singh *et al.* (2002) reported that based on the per se performance, GCA effect and heterosis, P1 x P7 was the best hybrid, yielding 14.30% more grain yield per plant followed by P4 x P7 (13.07%) over the superior control: CM-400 x CM-300. Crosses between high x high and high x low GCA parents exhibited greater heterosis. Heterosis for yield was generally accompanied by heterosis for yield components.

Dodiya and Joshi (2003) reported that the combining ability analysis showed the predominant role of non-additive type of genetic component in the inheritance of all characters. Single cross Pop-30-25-1-1-1 x X1 W-1076-1 had positive significant specific combining ability effects all characters except for starch content, with the highest estimates of economic heterosis for oil content. Yousif *et al.* (2003) reported that highly significant variation was observed among genotypes (parents and their crosses) and in genotype x environment interaction. These results indicated significant heterosis for all traits except leaf area, and the presence of partial-, complete and overdominance gene effects. Maximum heterosis was recorded for grain yield.

Abdel Hady *et al.* (2004) reported that highly significant heterosis relative to better parent and mid parents were found for callus growth in vitro and also for grain yield in the field. There were highly significant differences due to general and specific combining ability for callus growth and also for grain yield. Abdolhamid *et al.* (2004) reported that the additive gene effects were more important than non additive gene effects for all traits. General combining ability effects were significant for most of the parents and all the traits. Specific combining ability effects were significant in a few crosses for all traits. Yield and plant height were significant in more than 50% of the crosses. High heterosis was observed in more than 50% of the crosses for all studied characteristics. The highest and lowest amounts of heterosis were observed for grain yield and number of ears per row, respectively.

Katna *et al.* (2005) reported that both the general and specific combining ability effects were significant for all traits at both locations. Preponderance of additive gene effects was important in the expression of all the traits studied. Amit-Dadheech and Joshi (2007) reported that the ratio of non additive/additive gene effect revealed that there was preponderance of non additive gene action in the expression of all the traits under study. Single cross L15 x T1 had positive significant sca effects for oil content along with starch content with highest estimate of heterobeltiosis for oil content.

The review of literature pertaining to combining ability and heterosis in respect of 9 quantitative characters *viz.,* Days to 50 per cent tasseling, Days to 50 per cent silking, Plant height, Ear length, Ear circumference, 100-grain weight, Grain yield per plant, Grain yield per hectare and Fodder yield per plot have been presented Tables 1 and 2.

2.5 Association between yield and its components

According to Appadurai and Nagarajan (1975) grain weight per ear and grain numbers per row had little effect on yield, while ear length and ear circumference had positive correlation with yield. Kim (1975) reported that 1000grain weight was negatively correlated with days to silking and days to tasseling. Probecky (1976) that yield depend primarily on the number of grains per plant, which in turn depended mainly on the number of grains in the rows.

Sharma *et al.* (1982) reported that grain yield was positively correlated with grains per ear, 100 grain weight, plant height and ear height. El-Nagouly *et al.* (1983) concluded that phenotypic and genotypic correlation between yield and days to 50 percent silking and ear height was positive and highly significant. Path analysis showed that yield was directly influenced by ear height and indirectly affected by days to 50 per cent silking via ear height. Saha and Mukherjee (1985) observed that grain yield per plant was significantly correlated with ovules per ear, grains per ear and 100 grain weight. Malhotra and Khehra (1986) recorded positive correlation between grain yield and yield components like ear length, ear circumference, number of rows per ear, 1000- grain weight, shelling percentage, days to silking, ear height and plant height.

Tyagi *et al.* (1988) opined that grain yield was influenced more by ear weight, ear length, plant height, kernels per row and 100 grain weight. They also reported that 50 per cent pollen shedding and silking had a direct correlation with yield and so, early maturing genotypes had relatively low yield. Mahajan *et al.* (1990) concluded that grain yield was positively correlated with ear length, number of kernels per row and plant height. Singh *et al.* (1991) noted that grain yield per plant had significant positive correlation with plant height and ear height in F1 and F2 generations under alkaline soil and with leaf area in both the generations under normal soil. Debnath and Khan (1991) revealed that days to silking, plant height, number of kernels per row and 1000-grain weight had strong positive contributions to grain yield.

Boraneog and Duara (1993) observed that plant height and ear height were found to be significant and positively correlated with yield. Saha and Mukherjee (1993) reported positive significant correlations between grain yield per plant with 100-grain weight, ear length, ear circumference, number of grain rows per ear and number of grains per row. The ear circumference and number of grains per row had higher direct and indirect effects on grain yield. Krishnan and Natarajan (1995) obtained high positive association between grain yield on the one hand and plant height, ear length, ear weight, number of kernels per row, dry matter production and harvest index on the other. Path coefficient analysis revealed that selection on any trait in maize will influence the grain yield only through dry matter production.

Table 1. Characterwise review of literature pertaining to combining ability

Sl.No	Character	Additive (GCA)	Non-additive (SCA)	Additive and non-additive
1	Days to 50% tasseling	Hassaballa *et al.* (1980), Sanghi (1983), Mathur and Bhatnagar (1995), Paul *et al.* (1999), Nigussie and Zelleke (2001), Kumar (2008)	Lee (1983) and Guo *et al.* (1986) Jayakumar and Sundaram (2007)	Suneetha *et al.* (2000), Desai and Singh (2001), Arun kumar (2001), Singh *et al.* (1998)
2	Days to 50% silking	Singh *et al.* (1983), Mahajan *et al.* (1991),Vasal *et al.*(1992), El-Hosary *et al.*(1994b), Altinbos (1995), Mathur *et al.*(1998), Paul and Debnath (1999), Talleei and Kochak Saraei (1999), Nigussie and Zelleke (2001), Ashish and Singh (2002), Kumar (2008)	Paul and Duara (1991), Sedhom (1994), Dehghanapour *et al.* (1997), Suneetha *et al.* (2000), Jayakumar and Sundaram (2007)	Hassaballa *et al.* (1980), Lee *et al* (1986), Singh *et al.* (1998), Desai and Singh (2001), Arun kumar (2001),
3	Plant height	Singh *et al.* (1983), Shahi and Singh (1986), Crossa *et al.* (1987,1990), Vasal *et al.*(1992), Zheng-Zuping *et al.* (1995), Konak *et al.* (1999), Nigussie and Zelleke (2001),Wu-Guang Cheng *et al.* (2003), Kumar (2008)	Guo *et al.* (1986), Herbert and Gallis (1986), Pal *et al.* (1986), El-Hosary *et al.* (1994a), Rana and Vinod (2001), Jayakumar and Sundaram (2007)	Sharma *et al.* (1982), Debnath and Sarkar (1987), Kumar *et al.* (1998), Singh *et al.* (1998), Suneetha *et al.* (2000), Desai and Singh (2001), Arun kumar (2001), Katna *et al.* (2005)
4	Ear length	Mohamoud *et al.* (1990), El-Hosary *et al.* (1994b), Mathur and Bhatnagar (1995) Mathur *et al.* (1998), Ashish and Singh (2002), Yu-HaiQiu *et al.* (2003), Wu-GuangCheng *et al.* (2003) Kumar (2008)	Ali and Topera (1986), Mohammed (1993), Pal and Prodhan (1994), Sedhom (1994),Sinobas and Monteagudo (1994) , Khristova *et al.* (1995), Konak *et al.* (1999), Suneetha *et al.* (2000), Rana and Vinod (2001), Jayakumar and Sundaram (2007)	Singh *et al.* (1983), Shen and Lai (1987), Turgut *et al.* (1995), Kumar *et al.* (1998), Singh *et al.* (1998), Kalla *et al.* (2001), Arun kumar (2001), Katna *et al.* (2005),Li-Jizhu *et al.* (2004),

Table 1. Contd….

Sl.No	Character	Additive (GCA)	Non-additive (SCA)	Additive and non-additive
5	Ear circumference	Sanghi *et al.* (1982), Quadri *et al.,*(1993), Pal and Prodhan (1994), Mathur and Bhatnagar (1995), Mathur *et al.* (1998), Kumar (2008)	Pal *et al.* (1986), Mohammed (1993), El-Hosary *et al.* (1994a), Sinobas and Monteagudo (1994), Kumar *et al.* (1998), Suneetha *et al.* (2000), Rana and Vinod 2001), Yu- HaiQiu *et al.* (2003), Jayakumar and Sundaram (2007)	Sharma *et al.* (1982), Turgut *et al.*(1995), Kalla *et al.* (2001), Arun kumar (2001), Wu-GuangCheng *et al.,*(2003), Katna *et al.* (2005)
6	Number of kernel rows per cob	Mathur *et al.* (1995), Petrovic (1998)	Pal and Prodhan (1994), Dehghanapour *et al.* (1997), Kumar *et al.* (1998), Li-Jizhu *et al* (2004)	
7	Number of kernels per row	Mathur *et al.* (1998)	Dehghanapour *et al.* (1997)	Kumar *et al.* (1998)
8	100-grain weight	Shahi and Singh (1985), Pal and Prodhan (1994), Mathur and Bhatnagar (1995), Turgut *et al.*(1995), Rastogi (1997), Joshi *et al.* (1998)	Kimani (1984), Mohammed (1993), Dehghanapour *et al.*(1997), Petrovic (1998), Suneetha *et al.* (2000), Yu-HaiQiu *et al.* (2003),	Pal *et al.* (1986), Arun kumar (2001), Wu-GuangCheng *et al.* (2003) , Katna *et al.* (2005)
9	Shelling per cent	Mathur *et al.* (1998)		
10	Gain yield per plant	Murthy *et al.*(1981), Sanghi *et al.* (1982), Mohammed (1993), Mathur *et al.* (1998), Yu-HaiQiu *et al.* (2003), Kumar (2008)	El-Hosary *et al.* (1994), Mathur and Bhatnagar (1995), Joshi *et al.*(1998), Konak *et al.* (1999), Suneetha *et al.* (2000), Jayakumar and Sundaram (2007)	Yang (1982), Kumar *et al.* (1999), Arun kumar (2001),
11	Grain yield per ha	Singh *et al.* (1983), Vasal *et al.* (1992), Rastogi (1997), Nigussie and Zelleke (2001),	Singh *et al.* (1983), Guo *et al.* (1986), Crossa *et al.*(1990), Paul and Duara (1991), Mustyaysa *et al.*(1991), Mohammed (1993), Damborsky *et al.* (1994),Satyanarayana (1994), Sedhom (1994), Zheng-Zuping *et al.* (1995),Rana and Vinod (2001)	Zambezi *et al.* (1986), Sain Dass *et al.* (1992), Pal and Prodhan (1994), Turgut *et al.* (1995), Arun kumar (2001), Desai and Singh (2001), Mahto and Ganguly (2001), Ashish and Singh (2002), Turgut and Duman (2004)
12	Fodder yield per plot		Suneetha *et al.* (2000)	Arun kumar (2001), Nirala and Jha (2001), Jha *et al.* (2002)

Table 2. Charecterwise review of literature pertaining to heterosis

Sl.No.	Characters	Heterosis	References
1	Days to 50 per cent tasseling	• Significant average heterosis	Gomes-e-Gamma *et al.* (1993), Turgut *et al.* (1995), Perez-Velasquez *et al.* (1995)
2	Days to 50 per cent silking	• Low heterosis	Beck *et al.* (1990)
		• Mid parent heterosis ranges from -3.55 to 11.42	Akthar and Singh (1981)
		• Heterotic effect	Perez-Velasquez *et al.* (1995), Setiyono and Subandi (1996)
		• Heterobeltiosis	Vasal *et al.* (1992), Satyanarayana *et al.* (1994), Altinbos (1995), Konak *et al.* (1999)
3	Plant height	• Low heterosis	Beck *et al.* (1990), Vasal *et al.* (1992), Reddy and Agarwal (1992),
		• Average and non-significant heterosis	Gomes-e-Gamma *et al.* (1993)
		• Positive heterobeltiosis	Ganguli *et al.* (1989), Konak *et al.* (1999)
4	Ear length	• Positive heterobeltiosis and mid parent heterosis	Debnath (1987), Konak *et al.* (1999)
		• highest heterosis over the mid-parent	Kabdal *et al.* (2003)
		• Heterobeltiosis ranged from -5.9 to 19.9	Verma and Singh (1980)
5	Ear circumference	• Heterotic effect	Turgut *et al.* (1995)
		• Low mid parent heterosis	Debnath (1987)
		• Heterobeltiosis	Konak *et al.* (1999)
6	Number of kernel rows per cob	• Significant heterotic effects	Mukherjee *et al.,*(1974), Verma and Singh (1980)
		• Magnitude of heterosis	Appaduri and Nagarajan (1975)
		• Non-significant positive heterosis	Genova (1984)
		• Maximum heterosis of 6.28 per cent over better parent and 8.94 per cent over check variety.	Rao *et al.,*(1996)
7	Number of kernels per row	• Marked heterosis	Debnath (1984), Presolska and Kamara (1991)
		• Maximum of 11.07 per cent and 18.24 per cent heterosis over better parent and over check variety.	Rao *et al.,*(1996)
		• Heterotic effect	Salillari and Hoxha (1998)

Table 2. Contd…..

Sl.No.	Characters	Heterosis	References
8	100-grain weight	• Significant heterosis over mid parent ranges from - 4.37% to 30.69%	Mukherjee and Shah (1984)
		• Heterotic effect	Turgut *et al.* (1995), Salillari and Hoxha (1998), Petrovic (1998)
		• Heterobeltiosis	Konak *et al.* (1999)
9	Shelling percentage	• Moderate heterosis	Saleh *et al.,*(2002)
10	Grain yield per plant	• Significant epistatic effect	Li-Jizhu *et al.* (2004)
		• Heterosis ranges from 1.3 to 98.6 per cent over mid parent	Verma and Singh (1980)
		• Heterosis ranges from -35.3 to 251.8 per cent over better parent	Murthy *et al.* (1981
		• Mid parent heterosis	Mufti and Rao (1995)
11	Grain yield per ha	• Heterosis ranges from 1.3 to 98.6 per cent over better parent	Verma and Singh (1980)
		• Heterosis ranges from 21.07 to 123, 68 per cent and 2.69 to 95.07 per cent over mid parent and better parent respectively	Debnath (1984)
		• Positive heterosis over better parent	Ganguli *et al.* (1989)
		• Heterosis over control	Mejiya and Lambert (1992)
		• Highest heterosis over the mid-parent	Kabdal *et al.* (2003), Vasal *et al.* (1992)
		• Heterobeltiosis	Konak *et al.* (1999)
		• Mid-parent heterosis ranges from – 11.6 to 21.9 per cent	Nigussie and Zelleke (2001)
		• Average heterosis of 8.4 per cent for top crosses	Gomes-e-Gamma (1993)
		• Heterotic effect	Turgut *et al.* (1995), Perez-Velasquez *etal.* (1995)
		• Heterosis value varied between 19.5 to 125.4 per cent	Turgut and Duman (2004)
		• 55 per cent mid parent heterosis for variety crosses and 105 per cent for inbred crosses	Satyanarayana *et al.* (1994), Perez-Velasquez *et al.* (1995), Larish and Brewbaker (1999)
		• Mid-parent heterosis was higher in acid soils (32%) than in nonacid soils (20%)	Welcker *et al.* (2005)
12	Fodder yield per plot	• Standard heterosis was up to 23.42 per cent	Jha *et al.* (2002)
		• Highest mid-parent heterosis was 28.15 per cent between F1hybrids of Yellow x White and 40.17 per cent between F1 hybrids of White x Yellow.	Bassey (2002)

Packiaraj (1995) observed direct positive correlation between grain yield and number of grains per row. Rahman *et al.* (1995) reported that grain yield was significantly and positively correlated with plant height, ear height, number of grains per ear and 1000-grain weight. Path analysis revealed that ear height, plant height and 1000-grain weight were the main contributors for grain yield.

The studies conducted by Sree Kumar and Suma Bai (1995) revealed that plant population recorded high coefficient of variation, heritability and genetic advance for plant height indicating that selection based on these characters will result in improving fodder yield. Highest genotypic correlation was observed between plant population and dry fodder yield. According to Satyanarayana (1996) grain yield was positively correlated with kernel rows per ear, ear length, ear circumference and 100-grain weight. Guirong *et al.* (1997) obtained direct correlation between yield and 1000-grain weight, rows per ear, ear circumference and kernels per row. According to Kumar and Kumar (1997) values of genotypic correlation were slightly higher than the corresponding phenotypic values. Significant positive correlation was recorded for plant height, days to 50 per cent silking, ear length and ear height with yield per plant.

Annapurna *et al.* (1998) showed that seed yield was positively and significantly correlated with plant height, ear circumference, number of seeds per row, number of seed rows per ear, number of seeds per ear and test weight exercised maximum direct influence on yield. Dutu (1998) reported correlations using the date of flowering, plant height and the number of leaves as indirect selection criteria may results in a positive correlated response in earliness, yielding potential and superior stalk quality. Khakim *et al.* (1998) noticed that grain yield was positively correlated with plant and ear insertion height, leaf area, ear number, ear length, row number, grain number per row and per cob, grain weight per cob, ear weight and 1000-grain weight. Manivannan (1998) reported that ear circumference; number of kernels per row, 1000-grain weight, kernels per row and ear length had significant and positive correlation with grain yield. High and positive direct effects were observed for kernel rows and 1000-grain weight.

Alok Kumar *et al.* (1999) revealed that the number of grains per row, number of rows per ear, ear circumference, ear length, days to 50 per cent flowering and days to 50 per cent maturity had direct effect on grain yield. Dutu (1999) indicated that at the phenotypic and additive genetic level, growth period was strongly correlated with plant height and leaf number. Firoza Khatun *et al.* (1999) reported that grain yield per plant was positively and significantly correlated with 1000-grain weight, number of kernels per ear, ear circumference and ear height. Path analysis showed that 1000-grain weight, number of kernels per ear and number of ears per plant was more important components for determining grain yield.

Gautam *et al.* (1999) suggested that maximum correlation of grain yield was obtained with number of kernels per row followed by leaf area, plant height, tassel length and ear length. Path analysis revealed that the number of kernels per row, plant height, ear width, leaf area and 1000-grain weight had positive direct effect on grain yield. Mani *et al.* (1999) reported that grain yield per plant highly significant positive correlations with all the attributes and were highest with ear weight per plant. Path analysis also suggested that ear weight per plant followed by grains per row were the best direct contributors to grain yield per plant. Mohammad Basheruddin *et al.* (1999) showed that correlation coefficients had positively and highly significant influence of plant height, number of leaves, leaf area per plant, stem girth, crude protein and ear height on forage production.

Nawar *et al.* (1999) observed that additive components were significant for row number. Highly significant positive correlation coefficients were detected among yield per plant, components of ear and plant height. Number of kernels per row imparted positive direct effect towards grain yield followed by plant height. Rather *et al.* (1999) observed that days to 50 per cent silking was positively correlated with ear height and grain yield. Kumar and Kumar (2000) suggested that selection based on plant height with greater ear weight, number of seed rows per ear and number of seeds per ear was desirable for grain yield. Netaji *et al.* (2000) reported that yield per plot was significantly and positively correlated with all the characters except days to 50 per cent tasselling, silking and dry husk. Maximum variability was observed for plant height followed by ear height and test weight. Umakanth *et al.* (2000)

observed that yield per plot was positively correlated with plant height, 1000 grain weight and kernels per ear. But, days to 50 per cent silking had negative correlation with yield.

Vaezi *et al.* (2000) noticed that grain yield was significantly and positively correlated to ear weight, ear circumference, kernels weight and number of kernels per row. Path analysis for grain yield showed that kernel weight and kernel depth had the highest positive effect on grain yield. Geetha and Jayaraman (2000a) studied the effects of different quantitative traits on grain yield in 90 hybrids and suggested that the number of grains per row exerted maximum direct effect on grain yield. Kara (2001) reported that the average heterosis was significant for all characteristics studied and was positive, except for days to tasselling, with the average hybrid yield being 79.89% above that of the parents. In view of the general combining ability (GCA) effects of the parents, the parental lines YUZ P709 and FR 64A were identified as the best overall parent combiners for grain yield and yield components. With respect to ear height and grain yield per unit area, SCA effects were more pronounced when compared to GCA effects, indicating the predominance of non-additive gene action in the inheritance of these traits.

Pradeep Kumar and Satyanarayana (2001) concluded that grain yield was positively associated with plant height, ear height, ear length, ear circumference, number of seed rows per ear and test weight. Sujiprihati *et al.* (2001) reported that the significant GCA and SCA effects observed reflected the importance of both additive and non-additive gene actions for yield and related characters in the hybrids. However, the SCA variances for all the characters studied were much higher than their respective GCA variances. Swarnalatha Devi and Shaik Mohmmed (2001) indicated that the plant height, days to 75 per cent silking and maturity, ear length, number of seeds per row and 100 grain weight positively influenced the yield directly and also indirectly through several yield components. Umakanth and Khan (2001) observed that grain yield per plot showed significant and positive correlations with ear circumference, ear length, plant height and 100 seed weight. Path anaysis revealed that plant height followed by number of seeds per row, 100 seed weight, ear length and ear circumference showed maximum positive direct genotypic effects as well as indirect contribution through other characters on grain yield.

Dodiya and Joshi (2002) reported that the mean squares due to the interaction of lines, testers and line x tester with the environment were significant for all characters except for days to 50% brown husk and 100-grain weight. Among the crosses, L18 x T3 and L9 x T3 exhibited desired sca and gca effects, high per se performance and involved good x good parent combination. Guang-Cheng *et al.* (2002) noticed that grain yield per plot had significant positive correlation with 100-kernel weight. Path analysis indicated that the relative importance of cob length followed by cob diameter, kernel percentage, 1000 kernel weight, kernels per row, kernel rows per cob and cob length in promotion of growth yield per plant. Katna *et al.* (2002) reported that both the general and specific combining ability effects were significant for all the traits. Preponderance of additive gene effects was observed in the expression of all the traits studied.

Venugopal *et al.* (2003) indicated that plant height, ear height, ear length, ear girth, 100-seed weight and number of seeds per row were positively associated with grain yield. Path coefficient analysis revealed that number of seeds per row followed by 100 seed weight, days to 50 per cent tasseling, ear girth and plant height contributed directly towards grain yield per plant. Although, the character number of seed rows per ear had a direct positive contribution towards grain yield, it had indirect negative influence through ear length, 100-seed weight and number of seeds per row. Singh *et al.* (2003) reported that ear length had the maximum direct effect on grain yield followed by 500 kernel weight and ear length at both phenotypic and genotypic levels. Number of leaves per plant, leaf: stem ratio and girth of basal internodes also had high positive direct effect on grain yield per plant both at phenotypic and genotypic levels.

Arun Kumar and Singh (2004) reported that days to 50 per cent silking and cob length had maximum positive direct effect on grain yield at genotypic and phenotypic levels, respectively. Path analysis revealed that six characters had positive contribution to grain yield via larger number of characters both at genotypic and phenotypic levels. Bao *et al.* (2004) revealed that grain yield was mainly influenced by ear length followed by number of kernels per row, ear width, number of rows per ear, growth period and 100-seed weight. Singh *et al.* (2004) reported that in general *per se,* the performance of crosses is closely related with SCA the effects for grain yield. Srivas and Singh (2004) reported that path coefficient analysis revealed that characters such as plant height, days to 50% silking, stem girth, leaf length, leaf width and number of leaves per plant had positive direct effect on dry fodder yield at phenotypic levels

El-Shouny *et al.* (2005) evaluated under two planting dates to estimate phenotypic correlations and showed that grain yield per plant correlated positively and significantly with ear diameter, ear length, number of kernels per row, 100 kernel weight, number of rows per ear, ear height, plant height and day to silking under normal planting date and with number of kernels per row, ear diameter, 100-kernel weight, ear length, number of rows per ear, ear height under late planting date. Path coefficient analysis indicated that ear diameter, ear length and number of kernels per row under normal planting date and number of kernels per row, ear diameter, 100- kernel weight and ear length under late planting date. Patel et al., (2005) reported that path coefficient revealed that the dry matter yield per plant, number of leaves per plant, days to 50% silking and plant height had positive direct effects on green fodder yield.

Harjinder Singh *et al.,* (2006) reported that significant positive correlations for grain yield were observed with days to 75% dry husk, plant height, ear height and number of ears. Further, significant desirable correlations were observed for days to 50 per cent silk emergence with days to 50 per cent pollen shedding tassels; ear height with plant height and ear height with number of ears. Kumar et al., (2006) reported that the grain yield had positive and significant correlation with ear length, ear height, kernel rows per ear and 100-seed weight both at genotypic and phenotypic levels. Path analysis revealed that days to 50% tasselling, anthesis silking interval (ASI), ear height and 100-seed weight had highest direct effect on grain yield. The days to 50% silking exhibited negative direct effect on grain yield, however, influenced the yield indirectly through days to 50% tasselling. Neha-Singhal *et al.,* (2006) Reported that all characters except days to 50% tasselling and silking showed significant positive correlations with grain yield. Path-coefficient analysis revealed that 100-kernel weight had highest direct effect towards grain yield followed by plant and ear heights.

Abirami *et al.,* (2007) reported that path analysis showed that the weight of the cob contributed to the maximum direct effect to grain yield. It implied that selection for weight of the cob will be highly effective for the improvement of grain yield. Amit-Dadheech and Joshi (2007) reported that the in general parental inbreds possessed high per se performance for quality traits along with grain yield per plant and 100 grain weight. Jayakumar and Sundaram (2007) reported that the specific combining ability (sca) variances were higher than the general combining ability variances for all the characters. UMI 154 x UMI 246 and UMI 82 x UMI 208 were the superior hybrids based on per se performance, sca effects, and standard heterosis.

Sofi and Rather (2007) reported that the genotypic correlation coefficient revealed that ear diameter, 100-seed weight, ear length, number of kernel rows per ear, and number of kernel per row showed the greatest correlation with grain yield. Path analysis indicated that 100-seed weight had the greatest direct effect on grain yield, followed by number of kernels per row, number of kernel rows per ear, ear length and ear diameter. Shakoor et al., (2007) reported that plant height, followed by ear height, days to 50% tasseling and days to 50% silking, had strong genotypic and phenotypic associations with each other and significantly positive genotypic correlation with grain yield. Plant height, followed by days to 50% tasseling, also exerted positive direct effect on grain yield.

Brar *et al.* (2008) reported that studies conducted on 15 single cross hybrids (F1) of maize over two locations revealed that plant height, ear height, ear length, ear girth and number of ears per plot, had significant positive genotypic and phenotypic correlations with yield per plot. Highest direct effects (in descending order) with yield per plot were exhibited by ear girth, ear length, number of ears per plot, ear height and days to 50% pollen shedding

3. MATERIAL AND METHODS

The present investigation was carried out at Main Agricultural Research Station (MARS), Agricultural College, Dharwad and All India Co-ordinated Maize Improvement Project (AICMIP), Agricultural Research station (ARS), Arabhavi (University of Agricultural Sciences, Dharwad). Base population was raised and crossing programme was conducted at Main Agricultural Research Station (MARS), Agricultural College, Dharwad, during *kharif* 2008. The evaluation of parents and F_1s was conducted at All India Co-ordinated Maize Improvement Project (AICMIP), Agricultural Research station (ARS), Arabhavi, during *rabi/*summer 2009.

3.1 Geographical location and weather conditions

3.1.1 Dharwad

Geographically, Dharwad is situated at 15°26'N latitude and 70°26'E longitude and at an altitude of 678 m above mean sea level. The average annual rainfall is about 770.95 mm, which was distributed evenly during the cropping period. The monthly maximum and minimum temperatures during hot months (March-April) was 27.20°C to 37.10°C and during cold months (December-January) was 13.14°C to 21.45°C respectively.

3.1.2 Arabhavi

All India Co-ordinated Maize Improvement Project (AICMIP), Agricultural Research station (ARS), Arabhavi is located in Northern dry zone (Zone III) of Karnataka. Geographically it lies at 16°12' N latitude and 74°57' E longitude with an altitude of 640 m above sea level. The soils are sandy loam type with pH of 7.2. Source of irrigation water is from Ghataprabha Left Bank Canal [GLBC], which flows from first week of July to end of February month (8 months) and from March to June (4 months) open wells are the source of irrigation. Crop was raised under irrigated situation. The average rainfall of the Agricultural Research station, Arabhavi is 546 mm. The monthly maximum and minimum temperatures during hot months (March-April) was 18.67°C to 37.2°C and during cold months (December-January) was 12.5°C to 31.2°C respectively.

3.2 Experimental material

Twenty nine best promising inbred lines were selected from nation yellow pool based on their performance in their S4 generation and these selected 29 inbred lines were crossed with three different testers *viz.,* Prabha, KDMI-10 and CI-5 during *kharif* season 2008 and generated 87 single cross hybrids which were evaluated during *rabi/*summer 2009 along with five commercial checks *viz.,* DMH-2, EH-434042 (Arjun), 900M, Bio-9681 and Pinnacle for their performance.

3.3 Hybridization programme

The crossing programme was laid out at Main Agricultural Research Station (MARS), Agricultural Collage, Dharwad. The sowing was taken up in plot no D 66 on 2nd July 2008 with a spacing of 75 x 20 cm. Fertilizer *viz.*, Urea-2.7 Kg , DAP-9 Kg and MOP- 3.6 Kg was applied at the time of sowing and staggered sowing was done on 8^{th} July 2008 with ten rows of each male parent. The crossing programme was started on 28^{th} August 2008 and it includes silk cutting, bagging and pollination.

3.3.1 Silk cutting

Three to four days before the pollination, silks were cut back on shoot to achieve uniform silk emergence. Then, shoots were bagged with silk bags which pinched securely between shoot and stalk to hold it in place.

Plate.1. General view of the experimental plot

3.3.2 Bagging

Bagging was done a day before the pollination according to tassel bag method. Tassel bag method involves the covering the tassel with bag made of heavy craft paper with water proof glue. The bag was placed over the tassel and fastened with a paper clip. Pollens were collected 24 hours after bagging the tassel and care had been taken to prevent contamination and to avoid spilling the pollen.

3.3.3 Pollination

Pollens were applied to the silk in such a way that, silk bag is removed without touching or exposing the silks. Bottom of the tassel bag is flipped upwards, causing the pollen to fall upon the silk. The tassel bag is pulled down over the shoot and fastened with stapler or paper clip.

3.4 Field plot technique used

The main experiment was laid out at All India Co-ordinated Maize Improvement Project (AICMIP), Agricultural Research station (ARS), Arabhavi during *rabi/*summer 2009. The summary of experimental lay out is given below. The experiment comprising of 124 entries (87 hybrids, 29 female lines, 3 males and 5 checks) was sown on 19th January 2009 in randomized complete block design with two replications, each entry was raised in two rows with a row length of 4 m. The spacing maintained was 75 cm between the rows and 20 cm between the plants. The hybrids and parents were randomized separately but grown in contiguous plots. The recommended packages of practices were followed to raise a good crop.

3.5 Materials used

3.5.1 For line × tester analysis

Sl.No	Lines(Females)	Sl.No	Lines(Females)
1	YP⊗4 #07-1	16	YP⊗4 #07-16
2	YP⊗4 #07-2	17	YP⊗4 #07-17
3	YP⊗4 #07-3	18	YP⊗4 #07-18
4	YP⊗4 #07-4	19	YP⊗4 #07-19
5	YP⊗4 #07-5	20	YP⊗4 #07-20
6	YP⊗4 #07-6	21	YP⊗4 #07-21
7	YP⊗4 #07-7	22	YP⊗4 #07-22
8	YP⊗4 #07-8	23	YP⊗4 #07-23
9	YP⊗4 #07-9	24	YP⊗4 #07-24
10	YP⊗4 #07-10	25	YP⊗4 #07-25

11	YP⊗4 #07-11	26	YP⊗4 #07-26
12	YP⊗4 #07-12	27	YP⊗4 #07-27
13	YP⊗4 #07-13	28	YP⊗4 #07-28
14	YP⊗4 #07-14	29	YP⊗4 #07-29
15	YP⊗4 #07-15		
Testers(Males)			
1	Prabha [Composite]		
2	KDMI-10 [Q604 (line from X_2 heterotic pool]		
3	CI-5 [POP28-C6-HS-b-#-#-#-#]		
Experimental Hybrids			
Sl.No	Line x Tester =Hybrid	Sl.No	Line x Tester =Hybrid
1	YP⊗4 #07-1 x Prabha	48	YP⊗4 #07-16 x CI-5
2	YP⊗4 #07-1 x KDMI -10	49	YP⊗4 #07-17 x Prabha
3	YP⊗4 #07-1 x CI-5	50	YP⊗4 #07-17 x KDMI -10
4	YP⊗4 #07-2 x Prabha	51	YP⊗4 #07-17 x CI-5
5	YP⊗4 #07-2 x KDMI -10	52	YP⊗4 #07-18 x Prabha
6	YP⊗4 #07-2 x CI-5	53	YP⊗4 #07-18 x KDMI -10
7	YP⊗4 #07-3 x Prabha	54	YP⊗4 #07-18 x CI-5
8	YP⊗4 #07-3 x KDMI -10	55	YP⊗4 #07-19 x Prabha
9	YP⊗4 #07-3 x CI-5	56	YP⊗4 #07-19 x KDMI -10
10	YP⊗4 #07-4 x Prabha	57	YP⊗4 #07-19 x CI-5
11	YP⊗4 #07-4 x KDMI -10	58	YP⊗4 #07-20 x Prabha
12	YP⊗4 #07-4 x CI-5	59	YP⊗4 #07-20 x KDMI -10
13	YP⊗4 #07-5 x Prabha	60	YP⊗4 #07-20 x CI-5
14	YP⊗4 #07-5 x KDMI -10	61	YP⊗4 #07-21 x Prabha

15	YP⊗4 #07-5 x CI-5	62	YP⊗4 #07-21 x KDMI -10
16	YP⊗4 #07-6 x Prabha	63	YP⊗4 #07-21 x CI-5
17	YP⊗4 #07-6 x KDMI -10	64	YP⊗4 #07-22 x Prabha
18	YP⊗4 #07-6 x CI-5	65	YP⊗4 #07-22 x KDMI -10
19	YP⊗4 #07-7 x Prabha	66	YP⊗4 #07-22 x CI-5
20	YP⊗4 #07-7 x KDMI -10	67	YP⊗4 #07-23 x Prabha
21	YP⊗4 #07-7 x CI-5	68	YP⊗4 #07-23 x KDMI -10
22	YP⊗4 #07-8 x Prabha	69	YP⊗4 #07-23 x CI-5
23	YP⊗4 #07-8 x KDMI -10	70	YP⊗4 #07-24 x Prabha
24	YP⊗4 #07-8 x CI-5	71	YP⊗4 #07-24 x KDMI -10
25	YP⊗4 #07-9 x Prabha	72	YP⊗4 #07-24 x CI-5
26	YP⊗4 #07-9 x KDMI -10	73	YP⊗4 #07-25 x Prabha
27	YP⊗4 #07-9 x CI-5	74	YP⊗4 #07-25 x KDMI -10
28	YP⊗4 #07-10 x Prabha	75	YP⊗4 #07-25 x CI-5
29	YP⊗4 #07-10 x KDMI -10	76	YP⊗4 #07-26 x Prabha
30	YP⊗4 #07-10 x CI-5	77	YP⊗4 #07-26 x KDMI -10
31	YP⊗4 #07-11 x Prabha	78	YP⊗4 #07-26 x CI-5
32	YP⊗4 #07-11 x KDMI -10	79	YP⊗4 #07-27 x Prabha
33	YP⊗4 #07-11 x CI-5	80	YP⊗4 #07-27 x KDMI -10
34	YP⊗4 #07-12 x Prabha	81	YP⊗4 #07-27 x CI-5
35	YP⊗4 #07-12 x KDMI -10	82	YP⊗4 #07-28 x Prabha
36	YP⊗4 #07-12 x CI-5	83	YP⊗4 #07-28 x KDMI -10
37	YP⊗4 #07-13 x Prabha	84	YP⊗4 #07-28 x CI-5

38	YP⊗4 #07-13 x KDMI -10	85	YP⊗4 #07-29 x Prabha
39	YP⊗4 #07-13 x CI-5	86	YP⊗4 #07-29 x KDMI -10
40	YP⊗4 #07-14 x Prabha	87	YP⊗4 #07-29 x CI-5
41	YP⊗4 #07-14 x KDMI -10		
42	YP⊗4 #07-14 x CI-5		Commercial Checks
43	YP⊗4 #07-15 x Prabha	1	DMH-2
44	YP⊗4 #07-15 x KDMI -10	2	EH-434042 (Arjun)
45	YP⊗4 #07-15 x CI-5	3	900M
46	YP⊗4 #07-16 x Prabha	4	Bio9681
47	YP⊗4 #07-16 x KDMI-10	5	Pinnacle

3.6 Recording of observations

Observations on 12 different quantitative characters were recorded on five competitive randomly selected plants. The average was taken as the mean of the treatment. The way in which observations were recorded is described below.

3.6.1 Days to 50 per cent tasseling

The number of days taken from the date of sowing to the day on which 50 per cent of plants in a treatment showed full tassel emergence was recorded as days to 50 per cent tasseling.

3.6.2 Days to 50 per cent silking

The number of days taken from the date of sowing to the day on which 50 per cent of the plants in a treatment showed complete silk emergence was recorded as days to 50 per cent of silking.

3.6.3 Plant height (cm)

Height of the plant from ground level upto the base of fully opened flag leaf was recorded in centimetres as plant height when plants were matured.

3.6.4 Ear length (cm)

Cob length was measured from bottom to the top of the cob and recorded in centimetres.

3.6.5 Ear circumference (cm)

Ear circumference was measured and recorded in centimetres as the thickness of the ear *i.e.,* at the middle of the cob.

3.6.6 Number of kernel rows per cob

The number of kernel rows per cob was counted and recorded.

3.6.7 Number of kernels per row

Number of kernels in each kernel row was counted and average was recorded as number of kernels per row.

3.6.8 100-grain weight (g)

Weight of 100 grain drawn from a random sun dried sample from each plot was recorded in grams at 15 per cent moisture content.

3.6.9 Shelling percentage

Average pith weight and average grain weight of the randomly selected plants per plot were used to compute the shelling percentage by using the following formula.

$$\text{Shelling percentage} = \frac{\text{Grain weight}}{\text{Total weight (Grain weight + pith weight)}} \times 100$$

3.6.10 Grain yield per plant (g)

Grain yield per plant expressed in gram was recorded by weighing the grains obtained after shelling of cobs from individual plant.

3.6.11 Grain yield per hectare (q/ha)

At physiological maturity, the cobs were dehusked and harvested in each plot. The harvested cobs are air dried, shelled, cleaned and weighed. Grain yield per ha was calculated by using the formula given below and expressed in quintals per ha.

$$\text{Grain yield per ha (q/ha)} = \frac{\text{Fresh ear weight} \times (100 - \text{AVM}) \times 10 \times K}{\text{Stand harvest} \times 100}$$

$$K = \frac{10{,}000 \times 0.9412 \times (100 - \text{AVM})}{100 \times \text{Plot area}}$$

Where,

AVM = Average moisture content

3.6.12 Fodder yield per plot (t/ha)

Fodder yield per plot was recorded (Kg/plot) and converted and expressed in tonnes per hectare.

3.7 Statistical analysis

Mean values of the plants selected at random in each treatment and replication were subjected to statistical analysis. The following statistical methods were adapted.

3.7.1 Analysis of variance for parents and hybrids (ANOVA)

Mean values of the 12 quantitative characters recorded for the hybrids and parents were subjected for statistical analysis and variances due to different sources were estimated. The method of Panse and Sukhatme (1961) was followed for analysis of variance.

ANOVA for parents and hybrids

Sl. No.	Sources of variation	Degrees of freedom	Mean sum of squares	Variance ratio
1.	Replication	(r-1)	Mr	Mr/Me
2.	Treatments	(t-1)	Mt	Mt/Me
a.	Parents	(f + m-1)	Mp	Mp/Me
i.	Females	(f-1)	Mf	Mf/Me
ii.	Males	(m-1)	Mm	Mm/Me
iii.	Females Vs Males	1	Mf Vs Mm	Mf Vs Mm/Me
b.	Hybrids	(fm-1)	Mh	Mh/Me
c.	Parents Vs Hybrids	1	Mp Vs Mh	Mp Vs Mh/M
3.	Error	(t-1) (r-1)	Me	-
4.	Total	(mfr-1)	-	-

Where,

r = Number of replications

t = Number of treatments

f = Number of females (lines)

m = Number of males (testers)

p = Parents

h = Hybrids

e = Error

M = Mean sum of squares

3.7.2 Combining ability analysis

3.7.2.1 Analysis of variance

The mean of each character for each entry were subjected to line × tester analysis and the variance of general combining ability of different cross combinations were estimated by the procedure developed by Kempthorne (1957). The form of analysis is given in the table below.

Sources of variation	Degrees of freedom	Mean sum of squares	Expected mean sum of squares
Replication	(r-1)		
Hybrids	(fm-1)		
Females	(f-1)	M1	σe^2 + r[COV (FS) – 2 COV (HS)] + [mr COV (HS)]
Males	(m-1)	M2	σe^2 + r[COV (FS) – 2 COV (HS)] + [fr COV (HS)]
Females × Males	(f-1) (m-1)	M3	σe^2+ r[COV (FS) – 2 COV (HS)]
Error	(r-1) (fm-1)	M4	σe^2

Where,

r = Number of replications

f = Number of females (lines)

m = Number of males (testers)

COV (FS) = Covariance of full sibs

COV (HS) = Covariance of half sibs

M1 = Mean sum of squares due to females (lines)

M2 = Mean sum of squares due to males (testers)

M3 = Mean sum of squares due to females × males

M4 = Mean sum of squares due to error

3.7.2.2 Estimation of variance components

From the expectation of mean squares, the covariance between half sibs (COV HS) and covariance between full sibs (COV FS) were estimated as detailed below.

$$\text{COV HS} = \frac{M_1 + M_2 - 2\,M_3}{r\,(f + m)}$$

$$\text{COV FS} = \frac{[(M1 + M2 + M3 - 3M4) + 2r\ \text{COVS HS} - r\,(f + m)\ \text{COV HS}]}{3r}$$

The estimates of COV HS and COV FS were used to estimate the variance due to general combining ability (GCA) and variance due to specific combining ability (SCA) as below.

$\sigma^2 GCA = COV\ HS$

$\sigma^2 SCA = COV\ FS - 2COV\ HS$

The estimates of variance component due to females, males and hybrids were obtained as shown below.

$$\sigma^2 f = COV\ HS\ (lines) = \frac{M_1 - M_3}{rm}$$

$$\sigma^2 m = COV\ HS\ (testers) = \frac{M_2 - M_3}{rf}$$

$$\text{Covariance (HS) average} = \frac{M_1 + M_2 - 2M_3}{r\ (f + m)}$$

$$\sigma^2 mf = \sigma^2 SCA = \frac{M_3 - M_4}{r}$$

After estimating the GCA and SCA variances as mentioned above, the GCA/SCA ratio was computed to predict the type of gene action involved.

3.7.2.3 Proportional contribution of lines, testers and line × tester

$$\text{a. Contribution of lines (\%)} = \frac{SS\ (f)}{SS\ (c)} \times 100$$

$$\text{b. Contribution of testers (\%)} = \frac{SS\ (m)}{SS\ (c)} \times 100$$

$$\text{c. Contribution of lines} \times \text{testers} = \frac{SS\ (f \times m)}{SS\ (c)} \times 100$$

Where,

SS (c) = Sum of squares due to crosses

SS (f) = Sum of squares due to lines

SS (m) = Sum of squares due to testers

SS (f × m) = Sum of squares due to crosses

3.7.2.4 Estimation of combining ability effects

The models used to estimate gca and sca effect of ijk observations was as follows.

$Xij = \mu + gi + gj + sij + eijk$

Where,

μ = population

gi = gca effects of the ith female parent

gj = gca effects of the jth female parent

sij = sca effects of the ijth cross combination

i = number of female parents involved

j = number of male parents involved

k = number of replications

eijk = error associated with the observation Xijk

The individual effects were estimated as follows.

3.7.2.4.1 General combining ability (gca) effects

$$\text{a) Lines (gi)} = \frac{X_{i\ldots}}{mr} - \frac{X\ldots}{mfr}$$

Where,

Xi… = total of i^{th} female parent over all male (m) parents and replications (r).

X... = total of all the hybrids over all male parents (m), female parents (f) and replications (r).

$$\text{b) Testers } (g_j) = \frac{X_{j\ldots}}{fr} - \frac{X\ldots}{mfr}$$

Where,

Xj… = total of the j^{th} male parent over all female parents (f) and replication (r).

3.7.2.4.2 Specific combining ability (sca) effects

$$Xij = \frac{X_{ij}}{r} - \frac{X_i}{mr} - \frac{X_j}{fr} + \frac{X}{mfr}$$

Where,

Xij = ji^{th} combination total over all replications (r).

3.7.2.4.3 Standard error for combining ability effects

The standard error (SE) pertaining to gca effects of males and females and sca effects of different combinations were calculated as under.

a) SE for gca effects of lines

$$\text{SE gi} = (M_4/\ rm)^{1/2}$$

b) SE for gca effects of testers

$$\text{SE gj} = (M_4\ /\ rf)^{1/2}$$

c) SE for sca effects

$$\text{SE gij} = (M_4\ /\ r)^{1/2}$$

3.7.2.4.4 Critical difference (CD)

The critical difference values in each case were computed by multiplying their corresponding SE values with Table‘t’ value at error degrees of freedom at 5 and 1 per cent level of significance.

3.7.3 Estimation of heterosis

Heterosis expressed as per cent increase or decrease of F1 hybrid over mid-parent (average or relative heterosis), better parent (heterobeltiosis) and the best commercial check (standard heterosis) were computed for each character using the following formulae (Turner, 1953 and Hayes *et al.,* 1955). Out of three checks, the mean performance of the best check in a given character was considered to work out the standard heterosis.

a. Heterosis over mid parent (relative heterosis) = $\dfrac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$

b. Heterosis over better parent (heterobeltiosis) = $\dfrac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$

c. Heterosis over check (standard heterosis) = $\dfrac{\overline{F_1} - \overline{CC}}{\overline{CC}} \times 100$

Where,

$\overline{F1}$ = Mean performance of F1

$\overline{MP}$ = Mean mid-parental value = $(\overline{P1} + \overline{P2})/2$

P1 = Mean performance of parent one

P2 = Mean performance of parent two

$\overline{BP}$ = Performance of better parent

$\overline{CC}$ = Performance of the best commercial check

The differences in the magnitude of heterosis were tested following the procedure given by Panse and Sukhatme (1961).

a. Critical difference for mid-parent heterosis = $(3Me/2r)^{1/2} \times t$

b. Critical difference for better parent heterosis = $(2Me/2r)^{1/2} \times t$

c. Critical difference for commercial check = $(2Me/2r)^{1/2} \times t$

Where,

r = Number of replications

Me = Error mean sum of square from analysis of variance table

T = Table value of ‘t’ test at error degrees of freedom corresponding to 5% or 1% level of significance.

3.7.4 Association analysis between yield and its components

3.7.4.1 Genotypic and phenotypic correlation coefficients

Genotypic and phenotypic correlation coefficients were worked out as per the methods suggested by Johnson *et al.* (1955) to find out the relationship between yield, starch, oil and their contributing characters. Analysis of covariance was done similar to that of analysis of variance taking two characters at a time. The genotypic and phenotypic co-variances were derived as detailed for genotypic variance. The genotypic and phenotypic variance and co-variance components were utilized to calculate genotypic and phenotypic correlation coefficients (r) by applying the formula.

$$r = \sqrt{\frac{COV.g.1.2}{(\sigma^2 g_1) \times (\sigma^2 g_2)}} \quad \text{and} \quad \sqrt{\frac{COV.p.1.2}{(\sigma 2p1) \times (\sigma 2p2)}}$$

Where,

Cov.g. 1.2 - Genotypic covariance between two traits (1 and 2)

Cov.p. 1.2 - Phenotypic covariance between two traits (1 and 2)

σ2g1 - Genotypic covariance for first trait

σ2p1 - Phenotypic covariance for first trait

σ2g2 - Genotypic covariance for second trait

σ2p2 - Phenotypic covariance for second trait

Referring to correlation table of Snedecor and Cochran (1967), the significance of correlation coefficient was tested.

3.7.4.2 Path coefficient analysis

In all the segregating populations path coefficient analysis was carried out using the simple correlation coefficient to know the direct and indirect effects of the yield components on yield as suggested by Wright (1921) and illustrated by Dewey and Lu (1959). Standard path coefficient which are the standard partial regression coefficient were obtained by solving the following set of 'P' simultaneous equation through the use of "DOOLITTLE TECHNIQUE" as described by Goulden (1959).

$$P_{01} + P_{01}r_{12} + \ldots\ldots + P_{0p}r_{1p} = r_{01}$$

$$P_{01}r_{12} + P_{02} + \ldots\ldots + P_{0p}r_{2p} = r_{02}$$

$$P_{01}R_{1p} + P_{02}\, r_{2p} + \ldots\ldots + P_{0p} = r_{0p}$$

Where,

P_{01}, P_{02},……………..P_{0p} = Direct path coefficient of variables. 1, 2,…….P on the independent variables 0.

r_{12}, r_{13} ………….r_{ip} …………$r_{p(P-1)}$ = Possible correlation coefficient between independent variables.

r_{01}, r_{02}……….r_{0p} = The correlation between dependent and independent variables.

The direct effect of i^{th} variable worked out as (Poj x rij). From the simultaneous equation, it is clear that the correlation coefficient is the sum of direct and indirect effects on dependent character. Residual effect (P^2ox) was calculated as under.

$$P^2ox = 1 - (P_{20}1 + 2P_{01}P_{02}r_{12} + 2\ P_{01}P_{03}r_{13} \ldots\ldots\ldots\ldots\ldots\ldots\ldots.2_{P02}P_{03}r_{23} + \ldots\ldots\ldots+P_{20}p.$$

The direct and indirect effects were suggested by Lenka and Mishra (1973);

>1	- Very high
0.3 – 0.9	- High
0.2 – 0.29	- Moderate
0.1 – 0.19	- Low
<0.1	- Negligible

4. EXPERIMENTAL RESULTS

A line x tester experiment consisting of 29 lines and 3 testers and their 87 F_1 hybrids, were evaluated along with the five commercial checks during *rabi* 2008-09 at All India Co-ordinate Maize improvement Project (AICIMP), Agricultural Research station (ARS), Arabhavi, University of Agricultural Sciences, Dharwad. The results of the studies on 12 characters *viz.,* days to 50 per cent tasseling, days to 50 per cent silking, plant height (cm), ear length (cm), ear circumference (cm), number of kernel rows per ear, number of kernels per row, 100-grain weight (g), shelling percentage, grain yield per plant (g), fodder yield (t/ha) and grain yield (q/ha) are presented under the following headings.

- 4.1 Analysis of variance (ANOVA)
- 4.2 Mean sum of squares for parents and hybrids
- 4.3 Proportional contribution of lines, testers and their interaction to total hybrid variance
- 4.4 *Per se* performances of lines, testers, single cross hybrids and checks
- 4.5 Variance of combining ability
- 4.6 General combining ability effects
- 4.7 Specific combining ability effects
- 4.8 Heterosis over mid parent, better parent and checks
- 4.9 Inter character correlation
- 4.10 Path coefficient analysis

4.1 Analysis of variance

The analysis of variance for all entries including parents, hybrids and checks for nine characters are presented in Table 3. The treatment variance were highly significant for days to 50 per cent tasseling, days to 50 per cent silking, number of kernel rows per ear, number of kernels per row, 100-grain weight, shelling percentage and fodder yield per hectare, but non significant for the characters *viz.,* plant height, ear length, ear circumference, grain yield per plant and grain yield per hectare.

4.2 Mean sum of squares for parents and hybrids

Mean sum of squares for nine quantitative traits of parents and hybrids are presented in Table 4. The mean sum of squares for parents and females were highly significant for all the traits. Highly significant mean sum of squares were observed in males for five characters *viz.,* number of kernels per row, 100-grain weight, grain yield per plant, fodder yield per hectare and grain yield per hectare. The mean sum squares for female versus male were significant for days to 50 per cent tasseling whereas highly significant for all traits except ear length, ear circumference, shelling percentage and fodder yield per hectare.

The mean sum of squares for hybrids were highly significant for days to 50 per cent tasseling, days to 50 per cent silking, number of kernel rows per ear, number of kernels per row, 100-grain weight, shelling percentage and fodder yield per hectare. The parents versus hybrids mean sum of squares were highly significant for all traits *viz.,* days to 50 per cent tasseling, days to 50 per cent silking, plant height, ear length. ear circumference, number of kernel rows per ear, number of kernels per row, 100-grain weight, shelling percentage, grain yield per plant, fodder yield per hectare and grain yield per hectare.

4.3 Proportional contribution of lines, testers and their interaction to total hybrid variance

The proportional contribution of lines, testers and their interaction to total hybrid variance for nine characters were presented in Table 5. In this study it was clear that contribution towards total hybrid variance was found to be higher from females than males for all characters under study. The contribution of the female x male interaction for the total variance was higher than that of males for all characters. On the other hand, the contribution

Table 3: Analysis of variance of all entries for 12 characters

Sl.No	Sources of variation	Replication	Treatments	Error
1.	Degrees of freedom	1	91	91
2.	Days to 50% tasseling	35.66	4.00**	1.44
3.	Days to 50 % silking	68.17	6.00**	2.55
4.	Plant height (cm)	2035.57	277.45	215.54
5.	Ear length (cm)	58.33	3.61	3.93
6.	Ear circumference (cm)	4.78	0.82	1.03
7.	No. of kernel rows per ear	2.96	0.59*	0.37
8.	No. of kernels per row	14.68	15.56**	2.59
9.	100 grain weight (g)	0.92	41.42**	2.00
10.	Shelling (%)	3.72	6.59**	2.09
11.	Grain yield per plant (g)	13.36	88.91	91.50
12.	Fodder yield (t/ha)	2.63	5.46**	0.18
13.	Grain yield (q/ha)	3.86	38.95	39.24

* Significant at 5% level

** Significant at 1% level

Table 4: Mean sum of squares for parents and hybrids in respect of 12 characters in maize

Sources of variation	Degrees of freedom	Days to 50% tasseling	Days to 50% silking	Plant height (cm)	Ear length (cm)	Ear circumference (cm)	Number of kernel rows per ear
Replication	1	57.52	94.54	1610.96	38.88	0.48	5.69
Parents	31	5.98**	4.87**	412.71**	5.29*	1.52**	0.87**
Females (Lines)	28	6.51**	5.15**	437.01**	5.51*	1.62**	0.76**
Males (Testers)	2	0.50	0.67	18.67	4.67	0.69	0.17
Females Vs Males	1	1.98*	5.38**	520.50**	0.27	0.29	5.28**
Hybrids	86	2.68**	4.87**	245.35	3.51	0.84	0.57**
Parents Vs Hybrids	1	156.12**	86.23**	8169.72**	78.26**	56.75**	4.80**
Error	118	1.38	2.25	210.05	3.67	0.94	0.37

Contd…..

Sources of variation	Degrees of freedom	No of kernels per row	100-grain weight (g)	Shelling (%)	Grain yield per plant (g)	Fodder yield (t/ha)	Grain yield (q/ha)
Replication	1	67.77	0.04	5.97	64.57	2.07	12.50
Parents	31	32.01**	59.77**	11.91**	165.29**	5.11**	69.48**
Females (Lines)	28	29.23**	61.45**	13.01**	140.81**	5.60**	60.71**
Males (Testers)	2	12.33**	41.17**	2.43	443.89**	0.71**	169.75**
Females Vs Males	1	149.31**	50.26**	0.01	293.58**	0.08	114.33**
Hybrids	86	16.66**	42.51**	6.43**	84.48	5.16**	38.07
Parents Vs Hybrids	1	1550.76**	1066.18**	94.51**	110834.70**	195.50**	11577.87**
Error	118	2.53	2.25	3.41	85.39	0.19	36.08

* Significant at 5% ** Significant at 1%

Table 5: Proportional contribution of lines, testers and their interaction to total hybrid variance

Sl.No	Characters	Contribution of females (%)	Contribution of males (%)	Contribution of females x males (%)
1	Days to 50% tasseling	68.44	2.28	29.28
2	Days to 50% silking	62.33	1.98	35.69
3	Plant height (cm)	58.84	7.36	33.80
4	Ear length (cm)	48.15	1.59	50.26
5	Ear circumference (cm)	51.93	1.11	46.96
6	No. of kernel rows per ear	45.4	0.63	53.97
7	No. of kernel per row	43.8	0.61	55.59
8	100-grain weight (g)	50.07	2.93	47.00
9	Shelling percentage	44.83	0.53	54.64
10	Grain yield per plant (g)	39.87	0.14	59.98
11	Fodder yield (t/ha)	51.18	2.75	46.08
12	Grain yield (q/ha)	43.24	0.37	56.39

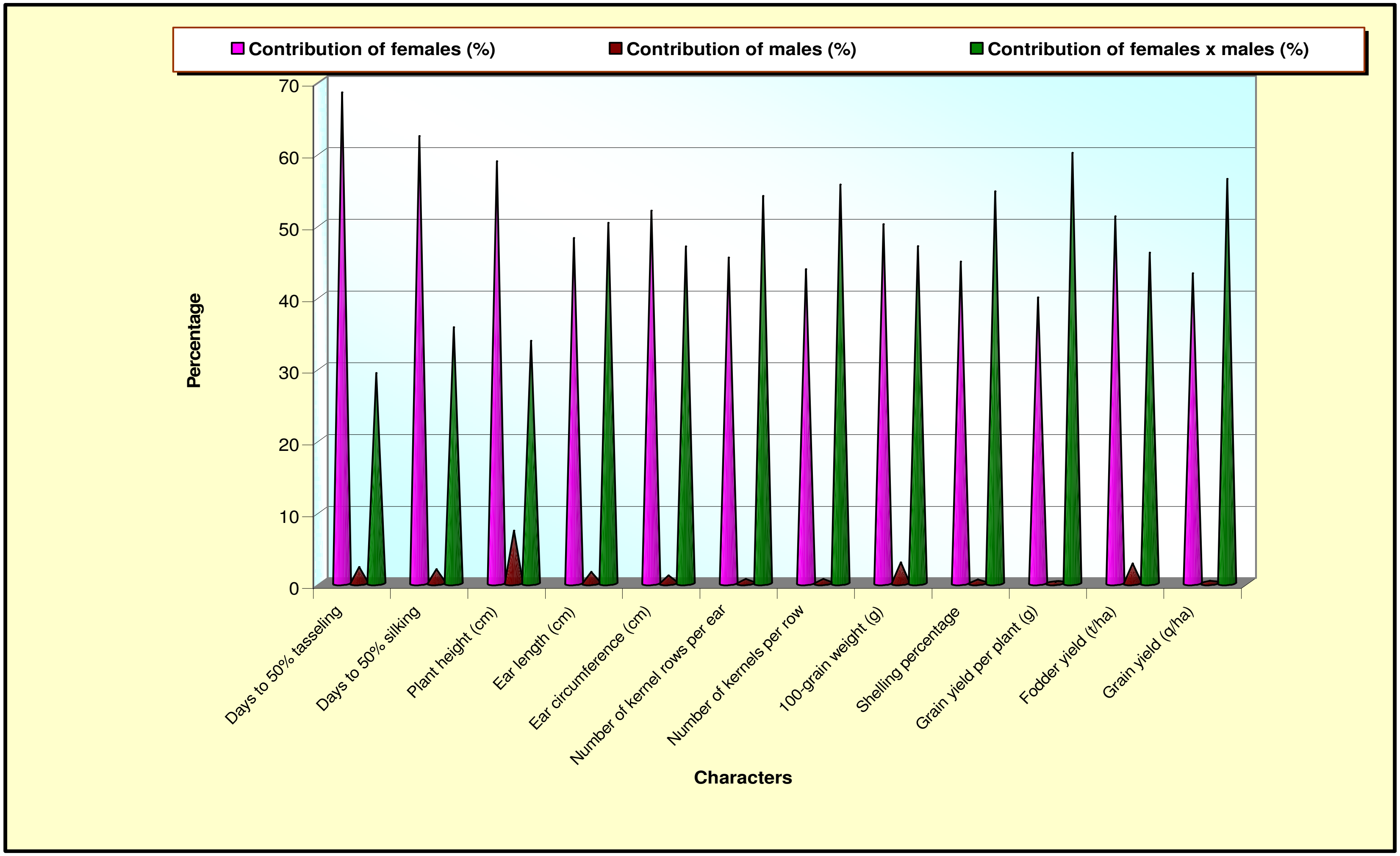

Fig.2. Proportional contribution of lines, testers and their interaction to total hybrids varience

of the female x male interaction was higher than that of females for ear length, number of kernel rows per ear, number of kernels per row, shelling percentage, grain yield per plant and grain yield per hectare, but the contribution of the female x male interaction was lower than that of females for days to 50 per cent tasseling, days to 50 per cent silking, plant height, ear circumference, 100-grain weight and fodder yield per hectare (Fig 2).

4.4 *Per se* performance of lines, testers, hybrids and checks

Per se performance of lines, testers, hybrids and checks are given in Table 6.

4.4.1 Days to 50 per cent tasseling

The mean varied from 62.5 (YP⊗4#07-27) to 70 days (YP⊗4#07-6, YP⊗4#07-7 and YP⊗4#07-23) in females, 67 (CI-5) to 68 days (Prabha) in males, 62 (YP⊗4#07-13 x CI-5) to 67.5 (YP⊗4#07-17 x Prabha and YP⊗4#07-19 x KDMI-10) in hybrids and 66.5 (DMH-2 and EH-434042 (Arjun)) to 70 days (900M and Pinnacle) in checks. Lines (YP⊗4#07-27, YP⊗4#07-2, YP⊗4#07-9, YP⊗4#07-19, YP⊗4#07-8, YP⊗4#07-11, YP⊗4#07-16, YP⊗4#07-26, YP⊗4#07-12, YP⊗4#07-14, YP⊗4#07-15, YP⊗4#07-18 and YP⊗4#07-28) required shortest period to tassel and testers do not show earliness in developing tassel. Among crosses, 74 hybrids exhibited early tasseling as compared to the check hybrid DMH-2 and EH434042 (EH-434042 (Arjun)), while all hybrids exhibited early tasseling as compared to the check hybrids 900M and Pinnacle.

4.4.2 Days to 50 per cent silking

The trait days to 50 per cent silking ranged from 66 days (YP⊗4#07-27) to 72.5 days (YP⊗4#07-23) in female, 70days (CI-5) to 71 days (Prabha and KDMI-10) in males, 64.5 days (YP⊗4#07-13 x CI-5) to 74 days (YP⊗4#07-6 x Prabha) in hybrids and 69.5 days (EH-434042 (Arjun)) to 73 days (900M, Bio-9681 Pinnacle) in checks. Lines (YP⊗4#07-27, YP⊗4#07-12, YP⊗4#07-8, YP⊗4#07-11, YP⊗4#07-19, YP⊗4#07-26, YP⊗4#07-2, YP⊗4#07-9, YP⊗4#07-14, YP⊗4#07-1, YP⊗4#07-16, YP⊗4#07-18 and YP⊗4#07-28) required short periods in developing silks and testers do not show earliness in developing silks when compared to checks. Among crosses, 60 hybrids exhibited early silking as compared to the check hybrid EH-434042 (Arjun) and all hybrids exhibited early silking as compares to check hybrid Pinnacle, Bio-9681 and 900-M.

4.4.3 Plant height (cm)

The range for plant height was from 98 (YP⊗4#07-29) to 159.9 cm (YP⊗4#07-19) in females. 121 (Prabha) to 127 cm (KDMI-10) in males, 116 cm (YP⊗4#07-6 x CI-5) to 172 cm (YP⊗4#07-18 x Prabha and YP⊗4#07-9 x KDMI-10) in hybrids and 115.5 days (Pinnacle) to 134.5 cm (EH-434042 (Arjun)) in checks. Twenty five lines exhibited higher plant height than Pinnacle and 13 lines exhibited higher plant height than EH-434042 (Arjun) and all the testers exhibited higher plant height than Pinnacle, while none of the testers exhibited higher plant height than EH-434042 (Arjun). Among the crosses, seventy five exhibited higher plant height than Pinnacle and eleven crosses exhibited higher plant height than EH-434042 (Arjun) while YP⊗4#07-13 x KDMI-10 exhibited similar plant height to that of EH-434042 (Arjun).

4.4.4 Ear length (cm)

The range of ear length was from 12.1 cm (YP⊗4#07-8) to 17.7 (YP⊗4#07-23) in females, 13.4 cm (CI-5) to 16.5 cm (KDMI-10) in males, 12.3 cm (YP⊗4#07-5 x KDMI-10) to 19.4 m (YP⊗4#07-3 x KDMI-10 and YP⊗4#07-18 x Prabha) in hybrids and 13.3 cm (DMH-2) to 15.8 cm (900M) in checks. Twenty five lines were longer than checks DMN-2 and nine

Table 6. *Per se* performance of lines, testers, single cross experimental hybrids and checks in maize

Sl.No	Entries	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
	Lines (Females)												
1	YP ⊗ 4 #07-1	67.0	69.0	133.5	17.1	13.7	13.0	33.7	32.0	83.9	80.64	3.9	43.89
2	YP ⊗ 4 #07-2	64.5	68.0	137.5	16.4	13.4	12.6	30.0	22.0	84.9	77.94	5.6	40.50
3	YP ⊗ 4 #07-3	67.0	70.5	133.5	13.8	12.2	12.1	26.0	22.0	79.1	64.22	3.1	33.67
4	YP ⊗ 4 #07-4	67.0	69.5	140.0	17.1	13.8	12.8	31.9	29.5	82.9	79.97	4.7	42.98
5	YP ⊗ 4 #07-5	67.0	71.0	127.0	14.7	12.7	11.9	24.6	26.5	73.8	65.69	2.5	33.12
6	YP ⊗ 4 #07-6	70.0	72.5	134.0	13.7	11.9	12.1	26.7	26.0	76.9	70.05	4.6	36.04
7	YP ⊗ 4 #07-7	70.0	72.0	129.0	13.7	11.6	13.0	32.9	19.0	83.2	81.42	2.3	43.80
8	YP ⊗ 4 #07-8	65.5	68.0	122.5	12.1	13.0	11.4	22.7	24.0	80.9	58.69	3.9	28.61
9	YP ⊗ 4 #07-9	65.0	68.5	125.0	14.4	12.8	12.1	26.3	19.5	82.9	67.11	3.1	33.83
10	YP ⊗ 4 #07-10	69.0	71.5	110.5	13.0	12.0	11.7	24.5	20.5	81.2	62.88	1.7	32.23
11	YP ⊗ 4 #07-11	65.5	68.0	131.5	14.3	13.5	11.7	24.1	23.5	81.1	61.73	2.9	31.99
12	YP ⊗ 4 #07-12	66.0	67.5	158.0	17.0	14.4	13.9	34.9	30.0	81.5	87.99	5.2	48.28
13	YP ⊗ 4 #07-13	69.0	71.0	131.5	14.7	13.1	12.9	32.7	32.0	83.2	79.87	5.2	43.25
14	YP ⊗ 4 #07-14	66.0	68.5	153.0	14.3	12.2	12.1	26.6	27.5	80.9	68.55	5.4	35.01
15	YP ⊗ 4 #07-15	66.0	70.0	138.5	14.1	12.2	11.4	22.8	25.0	77.1	60.03	2.4	29.27
16	YP ⊗ 4 #07-16	65.5	69.0	113.5	12.3	11.6	11.2	21.2	26.0	79.9	57.77	1.7	27.44
17	YP ⊗ 4 #07-17	67.5	69.5	142.0	15.9	13.7	12.2	27.7	32.0	83.5	73.31	4.0	38.87
18	YP ⊗ 4 #07-18	66.0	69.0	116.5	13.8	11.1	12.6	30.5	20.0	81.9	77.63	1.6	41.38
19	YP ⊗ 4 #07-19	65.0	68.0	159.9	16.2	13.7	12.0	24.8	34.0	80.1	66.90	7.2	33.15
20	YP ⊗ 4 #07-20	68.0	71.0	143.5	13.8	12.7	12.2	28.4	33.5	84.4	74.81	4.2	38.94
21	YP ⊗ 4 #07-21	68.0	70.5	153.0	14.7	13.7	11.6	23.6	37.5	80.6	63.16	8.6	30.41
22	YP ⊗ 4 #07-22	68.5	71.0	142.5	17.6	13.8	12.6	30.6	34.5	82.8	78.59	5.4	41.89
23	YP ⊗ 4 #07-23	70.0	72.5	154.0	17.7	14.5	13.2	34.3	29.0	84.4	83.27	6.4	43.95

24	YP ⊗ 4 #07-24	68.5	70.5	133.0	13.5	12.9	12.7	27.3	18.5	79.6	73.28	2.8	38.86
25	YP ⊗ 4 #07-25	68.0	70.5	147.5	13.7	12.8	11.6	24.1	30.5	80.5	60.51	4.7	31.08
26	YP ⊗ 4 #07-26	65.5	68.0	136.0	17.1	13.5	11.8	24.5	30.5	80.8	62.42	4.7	32.28
27	YP ⊗ 4 #07-27	62.5	66.0	130.5	15.6	13.1	12.6	29.7	30.5	80.9	75.33	4.0	39.68
28	YP ⊗ 4 #07-28	66.0	69.0	114.5	12.3	11.4	12.1	26.7	19.5	84.7	69.26	3.1	35.69
29	YP ⊗ 4 #07-29	66.5	70.5	98.0	14.0	12.5	12.1	26.4	19.5	78.6	66.40	3.0	34.26
	Testers (Males)												
30	Prabha	68.0	71.0	121.0	15.1	12.9	12.9	30.8	19.5	80.2	76.67	3.8	40.39
31	KDMI-10	67.5	71.0	127.0	16.5	13.8	13.4	35.6	28.5	82.4	93.54	4.9	50.92
32	CI-5	67.0	70.0	125.0	13.4	12.7	13.4	32.1	23.0	81.2	63.84	3.9	32.56
	Experimental hybrids												
33	YP ⊗ 4 #07-1 x Prabha	66.0	70.0	167.0	16.3	15.3	13.2	36.4	35.0	79.9	123.15	8.1	55.89
34	YP ⊗ 4 #07-1 x KDMI-10	64.5	69.0	168.0	16.1	15.3	13.1	36.2	35.5	82.7	125.44	6.3	55.63
35	YP ⊗ 4 #07-1 x CI-5	64.5	69.0	141.0	16.7	14.9	12.9	35.1	35.5	80.1	123.18	5.4	54.60
36	YP ⊗ 4 #07-2 x Prabha	62.5	66.5	159.0	16.2	13.6	12.4	32.6	38.0	81.9	116.71	7.2	50.66
37	YP ⊗ 4 #07-2 x KDMI-10	62.5	66.5	145.0	17.0	14.2	12.8	35.0	28.5	82.8	123.11	5.5	54.41
38	YP ⊗ 4 #07-2 x CI-5	63.0	66.0	150.5	17.1	13.7	12.6	33.6	36.5	82.7	119.03	4.1	51.69
39	YP ⊗ 4 #07-3 x Prabha	64.5	67.5	145.5	16.6	13.6	12.6	33.9	27.0	83.9	120.11	5.5	52.47
40	YP ⊗ 4 #07-3 x KDMI-10	65.5	70.0	154.5	19.4	14.7	13.5	37.6	41.0	84.9	132.88	7.3	60.55
41	YP ⊗ 4 #07-3 x CI-5	64.5	68.0	154.5	16.9	14.1	12.8	34.8	37.0	81.0	120.65	5.4	53.36
42	YP ⊗ 4 #07-4 x Prabha	64.0	68.0	151.5	17.3	15.0	13.8	40.0	35.5	85.8	133.18	7.1	61.54
43	YP ⊗ 4 #07-4 x KDMI-10	62.5	66.0	142.0	17.7	14.7	12.8	34.7	36.5	82.3	121.87	4.9	53.25
44	YP ⊗ 4 #07-4 x CI-5	64.0	67.5	132.5	15.0	13.4	12.3	32.0	29.0	80.7	115.80	5.9	49.76
45	YP ⊗ 4 #07-5 x Prabha	65.5	70.0	143.5	15.2	13.8	12.2	31.7	29.5	86.2	114.97	5.4	49.43
46	YP ⊗ 4 #07-5 x KDMI-10	65.5	70.0	128.5	12.3	12.8	12	31.2	28.5	81.4	112.98	3.1	48.32
47	YP ⊗ 4 #07-5 x CI-5	65.0	69.0	122.5	15.4	13.4	12.2	31.6	26.5	82.9	116.66	3.3	49.17

48	YP ⊗ 4 #07-6 x Prabha	65.5	74.0	136.5	16.3	13.8	12.6	33.8	28.5	84.2	117.97	4.8	51.69
49	YP ⊗ 4 #07-6 x KDMI-10	64.5	67.5	127.5	14.0	12.9	11.4	27.6	30.5	79.8	109.07	5.4	43.49
50	YP ⊗ 4 #07-6 x CI-5	62.5	66.5	116.0	13.5	12.1	11.8	28.1	19.5	79.0	113.14	3.1	46.39
	Experimental hybrids												
51	YP ⊗ 4 #07-7 x Prabha	64.5	68.5	144.0	14.8	13.9	12	30.8	31.0	80.9	114.94	5.8	48.18
52	YP ⊗ 4 #07-7 x KDMI-10	66.0	69.5	133.5	15.2	13.2	12.3	32.0	25.0	80.6	115.60	4.0	50.35
53	YP ⊗ 4 #07-7 x CI-5	65.5	68.5	140.5	14.0	13.5	12.1	31.2	26.0	83.1	113.87	5.6	48.55
54	YP ⊗ 4 #07-8 x Prabha	66.5	69.5	148.5	18.0	13.8	13.5	37.8	23.0	85.2	131.61	8.1	61.07
55	YP ⊗ 4 #07-8 x KDMI-10	65.5	69.5	137.0	16.2	13.9	12.8	34.4	25.5	82.9	121.19	9.1	53.13
56	YP ⊗ 4 #07-8 x CI-5	65.0	68.5	143.5	18.5	14.5	12.8	34.9	31.5	83.7	120.31	5.5	53.54
57	YP ⊗ 4 #07-9 x Prabha	65.0	68.0	146.5	16.2	13.4	12.2	31.8	27.0	83.6	115.36	8.1	49.47
58	YP ⊗ 4 #07-9 x KDMI-10	65.5	69.0	172.0	18.5	15.1	13.3	37.1	31.0	83.9	126.64	9.8	57.76
59	YP ⊗ 4 #07-9 x CI-5	66.5	70.5	154.5	16.4	13.7	12.6	33.9	31.0	82.8	118.65	5.5	52.44
60	YP ⊗ 4 #07-10 x Prabha	66.0	70.0	145.5	15.8	14.2	13.0	36.1	27.5	80.4	124.34	6.4	55.56
61	YP ⊗ 4 #07-10 x KDMI-10	65.5	69.0	151.5	16.0	14.6	12.8	34.7	31.0	81.1	120.69	8.1	53.29
62	YP ⊗ 4 #07-10 x CI-5	64.5	68.0	144.5	14.3	14.3	12.1	31.3	34.0	82.8	112.83	9.9	48.55
63	YP ⊗ 4 #07-11 x Prabha	64.5	67.0	133.0	15.7	13.2	12.2	31.7	31.0	82.9	114.10	3.3	49.39
64	YP ⊗ 4 #07-11 x KDMI-10	64.5	66.5	123.5	14.8	12.6	12.3	32.0	28.0	80.7	112.47	4.2	49.74
65	YP ⊗ 4 #07-11 x CI-5	64.0	67.0	132.5	14.9	13.1	12.0	30.1	27.5	82.7	112.71	5.0	47.82
66	YP ⊗ 4 #07-12 x Prabha	65.5	67.0	156.0	16.6	14.8	13.3	37.1	24.0	80.3	127.82	7.0	57.75
67	YP ⊗ 4 #07-12 x KDMI-10	65.0	68.5	141.0	15.2	13.7	12.3	32.0	30.0	81.9	112.98	6.2	49.61
68	YP ⊗ 4 #07-12 x CI-5	65.0	67.0	135.5	15.2	13.3	11.9	29.6	31.5	81.3	110.46	4.2	47.42
69	YP ⊗ 4 #07-13 x Prabha	65.0	67.5	127.5	15.1	13.6	13.0	35.9	34.0	83.1	122.46	6.4	55.30

70	YP ⊗ 4 #07-13 x KDMI-10	65.0	68.0	134.5	16.0	14.1	13.0	36.1	33.0	82.4	123.14	8.9	55.34
71	YP ⊗ 4 #07-13 x CI-5	62.0	64.5	139.5	17.4	14.4	13.0	35.6	34.5	82.5	122.08	6.5	55.09
72	YP ⊗ 4 #07-14 x Prabha	67.0	70.0	154.0	15.9	14.5	12.6	33.8	39.0	82.8	117.89	6.4	52.10
73	YP ⊗ 4 #07-14 x KDMI-10	65.5	69.5	145.0	17.0	13.6	12.0	29.8	29.5	82.3	112.80	7.2	47.70
74	YP ⊗ 4 #07-14 x CI-5	66.0	69.5	154.0	16.0	14.4	12.7	33.9	28.5	82.0	119.98	6.4	52.64
75	YP ⊗ 4 #07-15 x Prabha	64.0	67.0	162.0	14.6	13.1	11.3	24.8	19.0	82.7	107.11	9.7	43.07
76	YP ⊗ 4 #07-15 x KDMI-10	65.5	69.0	153.0	16.2	14.6	12.8	34.8	36.0	82.8	121.51	5.5	53.37
	Experimental hybrids												
77	YP ⊗ 4 #07-15 x CI-5	66.0	70.0	141.5	16.7	14.3	12.8	35.0	35.0	83.5	121.91	5.5	54.36
78	YP ⊗ 4 #07-16 x Prabha	65.5	70.5	157.5	17.9	15.0	12.7	34.1	29.0	80.4	119.04	7.2	53.01
79	YP ⊗ 4 #07-16 x KDMI-10	66.5	70.5	152.0	18.2	14.0	12.5	33.3	34.0	83.4	118.09	6.3	51.42
80	YP ⊗ 4 #07-16 x CI-5	65.5	68.0	148.5	17.1	14.5	12.5	33.3	37.5	83.1	117.27	5.4	51.51
81	YP ⊗ 4 #07-17 x Prabha	67.5	71.0	135.5	18.1	13.8	12.5	32.7	22.0	83.4	116.94	5.4	50.95
82	YP ⊗ 4 #07-17 x KDMI-10	66.0	69.0	153.5	14.6	13.2	12.0	30.7	26.0	82.8	113.22	5.5	48.09
83	YP ⊗ 4 #07-17 x CI-5	66.0	69.0	156.0	17.3	14.1	12.9	35.1	28.5	86.1	122.98	8.1	54.62
84	YP ⊗ 4 #07-18 x Prabha	67.0	70.5	172.0	19.4	14.3	13.0	35.3	32.5	80.4	122.14	9.2	55.08
85	YP ⊗ 4 #07-18 x KDMI-10	66.5	70.0	152.0	16.7	14.5	12.5	33.1	31.0	81.5	118.12	8.1	51.24
86	YP ⊗ 4 #07-18 x CI-5	66.0	70.0	141.0	15.6	14.3	12.5	33.0	32.5	80.7	116.84	7.5	51.23
87	YP ⊗ 4 #07-19 x Prabha	67.0	70.0	170.0	16.1	13.7	12.6	33.3	28.0	84.3	118.29	7.1	51.60
88	YP ⊗ 4 #07-19 x KDMI-10	67.5	71.0	164.5	16.0	13.8	12.1	31.4	27.0	83.2	113.22	8.7	48.75
89	YP ⊗ 4 #07-19 x CI-5	66.0	69.5	145.0	13.8	13.6	12.0	29.7	36.5	82.7	115.27	5.5	47.55
90	YP ⊗ 4 #07-20 x Prabha	65.5	68.5	143.5	15.1	13.8	12.8	34.6	25.5	83.6	118.32	6.4	53.20

91	YP ⊗ 4 #07-20 x KDMI-10	64.5	68.5	142.0	15.0	14.0	13.2	36.7	33.5	83.3	126.31	4.0	55.93
92	YP ⊗ 4 #07-20 x CI-5	65.5	69.5	134.0	15.1	12.9	14.1	40.9	33.5	87.4	141.64	3.9	67.29
93	YP ⊗ 4 #07-21 x Prabha	67.0	70.0	136.0	15.9	14.5	13.2	36.7	34.5	81.6	125.69	5.3	56.79
94	YP ⊗ 4 #07-21 x KDMI-10	65.5	67.5	154.0	16.0	13.9	11.9	28.3	34.5	81.2	112.00	5.2	47.36
95	YP ⊗ 4 #07-21 x CI-5	66.0	69.0	147.5	16.5	14.1	12.7	34.0	38.0	82.5	119.49	7.0	52.73
96	YP ⊗ 4 #07-22 x Prabha	65.0	68.5	140.0	15.7	13.0	12.2	31.5	30.5	77.1	114.24	4.8	48.75
97	YP ⊗ 4 #07-22 x KDMI-10	64.5	69.0	151.5	16.3	14.9	12.4	32.4	31.5	82.0	116.24	8.1	50.48
98	YP ⊗ 4 #07-22 x CI-5	65.0	69.0	135.0	15.8	13.5	12.7	33.9	28.5	83.7	118.46	6.4	52.60
99	YP ⊗ 4 #07-23 x Prabha	66.5	70.0	146.0	15.0	13.8	11.6	27.9	29.0	81.7	107.94	7.5	45.29
100	YP ⊗ 4 #07-23 x KDMI-10	65.5	69.0	156.0	17.0	14.6	13.4	37.4	26.5	84.5	129.26	6.8	59.51
101	YP ⊗ 4 #07-23 x CI-5	65.5	68.5	148.0	14.4	13.8	12.2	31.5	25.0	82.8	115.61	7.0	49.09
102	YP ⊗ 4 #07-24 x Prabha	65.0	67.0	148.0	18.1	14.3	13.6	39.3	30.0	85.5	134.13	4.2	61.35
	Experimental hybrids												
103	YP ⊗ 4 #07-24 x KDMI-10	64.0	66.0	146.5	15.7	13.4	12.4	32.6	29.5	83.7	115.16	5.2	50.66
104	YP ⊗ 4 #07-24 x CI-5	64.5	66.5	146.0	16.2	14.0	12.6	33.3	34.0	81.8	119.49	7.3	51.66
105	YP ⊗ 4 #07-25 x Prabha	64.5	66.5	149.0	14.8	13.8	13.0	35.2	31.0	85.3	122.53	4.8	55.02
106	YP ⊗ 4 #07-25 x KDMI-10	65.0	66.5	152.0	15.9	14.4	13.0	36.2	39.5	83.5	122.56	5.5	55.59
107	YP ⊗ 4 #07-25 x CI-5	64.5	66.5	144.0	17.3	14.7	13.3	37.2	34.0	84.0	129.14	8.1	59.42
108	YP ⊗ 4 #07-26 x Prabha	65.0	67.0	154.0	17.5	15.2	13.1	36.2	36.5	82.1	124.70	5.5	55.70
109	YP ⊗ 4 #07-26 x KDMI-10	64.0	66.0	157.0	18.1	15.2	13.4	37.5	38.5	84.7	133.79	4.8	60.52
110	YP ⊗ 4 #07-26 x CI-5	63.5	66.0	138.0	15.6	14.0	12.1	31.2	34.0	84.1	112.67	4.2	48.44
111	YP ⊗ 4 #07-27 x Prabha	64.0	66.5	153.0	17.0	14.5	13.2	36.8	31.0	80.8	125.87	4.0	57.66

112	YP ⊗ 4 #07-27 x KDMI-10	63.0	66.5	147.0	14.7	14.2	12.8	35.0	32.0	78.7	121.19	6.4	54.13
113	YP ⊗ 4 #07-27 x CI-5	65.5	68.0	135.0	14.1	13.9	13.4	37.3	35.0	84.2	129.14	4.8	59.42
114	YP ⊗ 4 #07-28 x Prabha	64.5	67.5	140.5	15.8	13.7	12.8	34.4	39.5	84.7	119.53	4.7	53.02
115	YP ⊗ 4 #07-28 x KDMI-10	64.5	67.5	145.5	15.6	14.0	13.4	37.4	34.5	84.5	129.25	5.0	59.50
116	YP ⊗ 4 #07-28 x CI-5	65.5	68.0	145.5	16.0	14.6	13.2	36.8	35.5	85.0	128.66	4.8	57.60
117	YP ⊗ 4 #07-29 x Prabha	65.5	67.5	160.5	15.7	14.1	12.5	32.6	25.0	84.8	115.17	7.5	50.90
118	YP ⊗ 4 #07-29 x KDMI-10	67.0	69.5	157.0	15.3	13.3	12.9	35.2	28.0	83.6	124.64	7.3	54.78
119	YP ⊗ 4 #07-29 x CI-5	66.5	69.0	159.0	18.2	14.0	12.9	35.1	29.5	83.0	122.87	5.2	54.61
	Commercial Hybrids												
120	DMH-2	66.5	70.0	121.5	13.3	13.5	12.1	31.3	32.5	79.2	104.38	4.6	44.31
121	EH-434042 (Arjun)	66.5	69.5	134.5	15.5	14.2	12.2	31.7	34.5	82.9	127.86	4.0	58.04
122	900M	70.0	73.0	131.5	15.8	14.0	12.3	32.0	27.0	80.7	119.62	4.7	51.50
123	Bio9681	69.5	73.0	131.0	14.1	13.2	12.0	30.1	29.0	82.7	125.59	3.0	55.10
124	Pinnacle	70.0	73.0	115.5	14.9	13.5	13.3	37.1	26.5	84.3	128.72	3.0	58.21
	Mean (lines)	66.9	69.7	134.12	14.76	12.85	12.2	27.6	26.71	81.24	70.67	4.05	36.70
	Mean(testers)	67.5	70.7	124.33	14.98	13.08	13.2	32.8	23.67	81.26	78.02	4.17	41.29
	Mean (single cross hybrids)	65.1	68.4	146.41	16.07	13.98	12.66	33.8	31.2	82.7	120.03	6.1	52.86
	Mean (checks)	68.5	71.7	126.80	14.71	13.7	12.4	32.44	29.9	81.9	121.23	3.9	53.43
	Grand mean	65.6	68.8	142.86	15.73	13.68	12.57	32.29	29.91	82.28	106.94	5.55	48.63
	SEm±	1.18	1.50	14.49	1.92	0.97	0.60	1.58	1.50	1.84	9.24	0.44	6.01
	CD at 5%	2.30	2.94	28.41	3.75	1.90	1.19	3.11	2.94	3.62	18.11	0.86	11.77
	CD at 1%	3.03	3.87	37.39	4.94	2.50	1.56	4.09	3.87	4.76	23.84	1.14	15.50
	CV (%)	1.79	2.18	10.14	12.18	7.09	4.83	4.92	5.01	2.24	8.64	7.94	12.35

X1 - Days to 50% tasseling	X5 - Ear circumference (cm)	X9 – Shelling percentage (%)
X2 - Days to 50% silking	X6 – Number of kernel rows per cob	X10 – Grain yield per plant (g)
X3 - Plant height (cm)	X7 – Number of kernels per row	X11 – Fodder yield (t/ha)
X4- Ear length (cm)	X8- 100-grain weight (g)	X12-Grain yield (q/ha)

lines were longer than check 900M. In testers CI-5 (13.4) was longer than DMH-2 (13.3) while KDMI-10 has longer ear length than 900M (15.8). Among crosses, 86 crosses exhibited higher ear length than DMH-2 and 51 crosses exhibited higher ear length than 900M, while three crosses (YP⊗4#07-10 x Prabha, YP⊗4#07-22 x CI-5 and YP⊗4#07-28 x Prabha) have similar ear length to that of checks 900M.

4.4.5 Ear circumference (cm)

The ear circumference ranged from 11.1 cm (YP⊗4#07-18) to 14.5 cm (YP⊗4#07-23) in females, 12.7 cm (CI-5) to 13.8 cm (KDMI-10) in males, 12.1 cm (YP⊗4#07-6x CI-5) to 15.3 cm (YP⊗4#07-1 x Prabha and YP⊗4#07-1 x KDMI-10) in hybrids and 13.2 cm (Bio-9681) to 14.2 cm (EH-434042 (Arjun)) in checks. Eleven lines exhibited higher ear circumferences than Bio-9681 and two lines exhibited higher ear circumference than EH-434042 (Arjun). In testers only KDMI-10 exhibited higher ear circumference than Bio-9681. Among crosses, 76 crosses exhibited higher ear circumference than Bio-9681 and 28 crosses exhibited higher ear circumference than EH-434042 (Arjun), while three crosses (YP⊗4#07-2 x KDMI-10, YP⊗4#07-10 x Prabha and YP⊗4#07-27 x KDMI-10) exhibited similar ear circumference to that of check EH-434042 (Arjun).

4.4.6 Number of kernel rows per ear

The Number of kernel rows per ear ranged from 11.2 (YP⊗4#07-16) to 13.9 (YP⊗4#07-12) in females, 12.9 (Prabha) to 13.4 (KDMI-10, CI-5) in males, 11.3 (YP⊗4#07-15 x Prabha) to 14.1 (YP⊗4#07-20 x CI-5) in hybrids and 12 (Bio-9681) to 13.3 (Pinnacle) in checks. Out of 29 lines, 13 lines exhibited higher kernel rows per ear than DMH-2 and line YP⊗4#07-12 (13.9) showed higher kernel rows per ear than Pinnacle. In testers, KDMI-10 and CI-5 showed higher kernel rows per ear than Pinnacle but all of them showed higher kernel rows per ear than DMH-2. Among crosses, 71 exhibited higher kernel rows per ear than DMH-2 and only two crosses *viz.,* YP⊗4#07-4 x Prabha (13.8) and YP⊗4#07-20 x CI-5 (14.1) showed higher kernel rows per ear than Pinnacle.

4.4.7 Number of kernels per row

The number of kernels per row ranged from 21.2 (YP⊗4#07-16) to 34.9 (YP⊗4#07-12) in females, 30.8 (Prabha) to 35.6 (KDMI-10) in males, 24.8 (YP⊗4#07-15 x Prabha) to 40.9 (YP⊗4#07-20 x CI-5) in crosses and 31.3 (DMH-2) to 37.1 (Pinnacle) in checks. Among lines, 6 exhibited higher kernels per row than DMH-2 and none of the lines exhibited higher kernels per row than Pinnacle. In case of testers all three showed higher kernels per row than DMH-2 but none of the testers showed higher kernels per row than Pinnacle. Among crosses, 73 exhibited higher kernels per row than DMH-2 and six crosses showed higher kernels per row than Pinnacle.

4.4.8 100-grain weight (g)

The mean ranged from 18.5 (YP⊗4#07-24) to 37.5g (YP⊗4#07-21) in females, 19.5g (Prabha) to 28.5g (KDMI-10) in males, 19g (YP⊗4#07-15 x Prabha) to 41g (YP⊗4#07-3 x KDMI-10) in hybrids and 26.5g (Pinnacle) to 34.5g (EH-434042 (Arjun)) in checks. Fourteen lines exhibited higher 100-grain weight than Pinnacle, while YP⊗4#07-21 exhibited higher 100-grain weight than EH-434042 (Arjun). Tester KDMI-10 (28.5g) showed more 100-grain weight than Pinnacle. Among crosses, 72 crosses showed more 100-grain weight than Pinnacle, while 4 crosses (YP⊗4#07-13 x CI-5, YP⊗4#07-21 x Prabha, YP⊗4#07-21 x KDMI-10 and YP⊗4#07-28 x KDMI-10) were on par with EH-434042 (Arjun) and 21 crosses exhibited higher 100-grain weight than EH-434042 (Arjun).

4.4.9 Shelling (%)

The mean ranged from 73.8 per cent (YP⊗4#07-5) to 84.9 per cent (YP⊗4#07-2) in females, 80.2 per cent (Prabha) to 82.4 per cent (KDMI-10) in males, 77 per cent (YP⊗4#07-22 x Prabha) to 87.4 per cent (YP⊗4#07-20 x CI-5) in crosses and 79.2 per cent (DMH-2) to 84.3 per cent (Pinnacle) in checks. Among lines, 24 exhibited higher shelling percentage than DMH-2, while four lines *viz.,* YP⊗4#07-2 (85 per cent), YP⊗4#07-28 (84.7 per cent), YP⊗4#07-23 (84.3 per cent) and YP⊗4#07-20 (84.3 per cent) showed higher shelling per cent than Pinnacle. Among crosses, 84 exhibited higher shelling percentage than DMH-2, while 13 exhibited higher shelling percentage than Pinnacle and two crosses namely YP⊗4#07-27 x CI-5 and YP⊗4#07-6 x Prabha were on par with Pinnacle for shelling per cent. Among testers all three showed higher shelling per cent than DMH-2.

4.4.10 Grain yield per plant (g)

The grain yield per plant ranged from 57.7g (YP⊗4#07-16) to 87.9g (YP⊗4#07-12) in females, 63.84g (CI-5) to 93.54g (KDMI-10) in males, 107.11g (YP⊗4#07-15 x Prabha) to 141.64g (YP⊗4#07-20 x CI-5) in hybrids and 104.38g (DMH-2) to 128.72g (Pinnacle) in checks. Both lines and testers did not show higher grain yield per plant compared to checks. Among the crosses, all the hybrid combinations showed higher grain yield per plant than DMH-2 and 10 crosses *viz.,* YP⊗4#07-25 x CI-5, YP⊗4#07-27 x CI-5, YP⊗4#07-28 x KDMI-10, YP⊗4#07-23 x KDMI-10, YP⊗4#07-8 x Prabha, YP⊗4#07-3 x KDMI-10, YP⊗4#07-4 x Prabha, YP⊗4#07-26 x KDMI-10, YP⊗4#07-24 x Prabha and YP⊗4#07-20 x CI-5 showed higher grain yield per plant than standard check, Pinnacle.

4.4.11 Fodder yield per hectare (t/ha)

The fodder yield per hectare ranged from 1.6 t/ha (YP⊗4#07-18) to 8.6 t/ha (YP⊗4#07-21) in females, 3.8 t/ha (Prabha) to 4.9 t/ha (KDMI-10) in males, 3.1 t/ha (YP⊗4#07-5 x KDMI-10) to 9.9 t/ha (YP⊗4#07-10 x CI-5) hybrids and 3 t/ha (Bio-9681) to 4.7 t/ha (900M) in checks. Twenty lines *viz.,* YP⊗4#07-3, YP⊗4#07-9, YP⊗4#07-28 (3.1 t/ha), YP⊗4#07-1, YP⊗4#07-8 (3.9 t/ha), YP⊗4#07-27, YP⊗4#07-17 (4 t/ha), YP⊗4#07-20 (4.2 t/ha), YP⊗4#07-6 (4.6 t/ha), YP⊗4#07-4, YP⊗4#07-25, YP⊗4#07-26 (4.7 t/ha), YP⊗4#07-12, YP⊗4#07-13 (5.2 t/ha), YP⊗4#07-14, YP⊗4#07-22 (5.4 t/ha), YP⊗4#07-2 (5.6 t/ha), YP⊗4#07-23 (6.4 t/ha), YP⊗4#07-19 (7.2 t/ha) and YP⊗4#07-21 (8.6 t/ha) showed higher fodder yield per hectare than checks Bio-9681 and Pinnacle, eight lines *viz.,* YP⊗4#07-12, YP⊗4#07-13 (5.2 t/ha), YP⊗4#07-14, YP⊗4#07-22 (5.4 t/ha) YP⊗4#07-2 (5.6 t/ha), YP⊗4#07-23 (6.4 t/ha), YP⊗4#07-19 (7.2 t/ha) and YP⊗4#07-21 (8.6 t/ha) showed higher yield per hectare than check 900M. In testers, Prabha (3.8 t/ha) and CI-5 (3.9 t/ha) showed higher fodder yield per hectare than Bio-9681, Pinnacle (3.0 t/ha) and KDMI-10 (4.9 t/ha) showed higher fodder yield per hectare over 900M (4.7 t/ha). Among the crosses, all the crosses showed high fodder yield per hectare over Bio-9681 and Pinnacle and 63 crosses showed high fodder yield per hectare over 900M the highest among checks.

4.4.12 Grain yield per hectare (q/ha)

The grain yield per hectare ranged from 27.44 q/ha (YP⊗4#07-16) to 48.28 q/ha (YP⊗4#07-12) in females, 32.56 q/ha (CI-5) to 50.92 q/ha (KDMI-10) in males , 43.07 q/ha (YP⊗4#07-15 x Prabha) to 67.29 q/ha (YP⊗4#07-20 x CI-5) in hybrids and 44.31 q/ha (DMH-2) to 58.21q/ha (Pinnacle) in checks. Among lines, YP⊗4#07-12 (48.28 t/ha) showed higher grain yield per hectare over DMH-2 and in males KDMI-10 (50.92 t/ha) showed higher grain yield per hectare over DMH-2, while none of the lines and testers had over yielded the standard check , Pinnacle. Among crosses, 85 crosses showed higher grain yield per hectare over check DMH-2 and 10 crosses *viz.,* YP⊗4#07-25 x CI-5, YP⊗4#07-27 x CI-5 (59.42), YP⊗4#0707-28 x KDMI-10 (59.5q/ha), YP⊗4#07-23 x KDMI-10 (59.51 t/ha), YP⊗4#07-26 x KDMI-10 (60.52q/ha), YP⊗4#07-3 x KDMI-10 (60.55q/ha), YP⊗4#07-8 x Prabha (61.07 q/ha), YP⊗4#07-24 x Prabha (61.35 q/ha), YP⊗4#07-4 x Prabha (61.54 q/ha) and YP⊗4#07-20 x CI-5 (67.29 q/ha) showed higher grain yield per hectare over standard check, Pinnacle.

4.5 Anova for combining ability

4.5.1 Variance due to females, males and female x male interaction

Variance due to females, males and female x male interaction in respect to 12 quantitative traits are presented in Table 7. The variance due to female was highly significant for all traits except for number of kernel rows per ear and grain yield per plant. Variance due to male were highly significant for days to 50 per cent tasseling, days to 50 per cent silking, plant height, 100-grain weight, fodder and grain yield per hectare. The female x male interaction variance was highly significant for number of kernels per row, 100-grain weight, shelling per cent and fodder yield per hectare.

4.5.2 Estimates of gene actions

The variances (σ^2GCA, σ^2 SCA, σ^2A and σ^2D) and ratios (σ^2GCA/ σ^2 SCA, σ^2A/σ^2D) are presented in Table 8. The analysis of variance revealed highest magnitude of SCA than GCA for all characters and the ratio of GCA to the SCA variance for these traits was less than unity. The analysis of variance revealed highest magnitude of dominance than additive for all characters. The ratio of additive to dominance was lesser than unity for all character. It was observed from the data (Table 8) that all the traits had higher magnitude of SCA variance than GCA variance.

4.6 General combining ability effects

The gca effects of 29 female parents (lines) and 3 male (testers) parents for different traits are given in Table 9.

4.6.1 Days to 50 per cent tasseling

The gca effects for days to 50 per cent tasseling ranged from -2.46 to 1.71. Out of 29 lines, as many as 13 lines exhibited negative gca effects where as remaining 16 lines had positive gca effects. Lines YP⊗4#07-2 (-2.46), YP⊗4#07-4 (-1.63), YP⊗4#07-13 (-1.13), YP⊗4#07-6, YP⊗4#07-26, YP⊗4#07-27 (-0.96) were top 6 parents exhibited significantly high gca effects in the negative direction. On the other hand, YP⊗4#07-19 (1.71), YP⊗4#07-18 (1.37), YP⊗4#07-29 (1.21) YP⊗4#07-21(1.04), YP⊗4#07-14 (1.04) were six top parents exhibited significantly high gca effects in the positive direction. Two testers, CI-5 (-0.18) and KDMI-10 (-0.06) showed gca effects in negative direction and Prabha (0.24) showed gca effects in positive direction. None of them had significant gca effects.

4.6.2 Days to 50 per cent silking

The gca effects for days to 50 per cent silking ranged from -2.07 to 1.76. Out of 29 lines, as many as 10 lines exhibited negative gca effects, whereas remaining 19 lines exhibited positive gca effect. Lines YP⊗4#07-2 (-20.7), YP⊗4#07-26 (-2.07), YP⊗4#07-24 (-1.91), YP⊗4#07-25 9 (-1.91), YP⊗4#07-13 (-1.74), YP⊗4#07-11 (-1.57), YP⊗4#07-27 (-

Table 7: Mean sum of squares of females, males and female x male interactions in respect of 12 characters of maize

Sl.No	Sources of variation	Replication	Females (Lines)	Males (Testers)	Female Vs Males	Error
1.	Degrees of freedom	1	28	2	56	86
2.	Days to 50% tasseling	40.55	5.63**	2.63**	1.20	1.40
3.	Days to 50% silking	76.01	9.32**	4.15**	2.67	2.55
4.	Plant height (cm)	2124.51	443.38**	776.60**	127.37	226.25
5.	Ear length (cm)	45.42	5.19**	2.40	2.71	3.85
6.	Ear circumference (cm)	3.52	1.35**	0.40	0.61	0.99
7.	Number of kernel rows per ear	3.71	0.80	0.16	0.47	0.42
8.	Number of kernels per row	53.85	22.42*	4.36	14.22**	2.96
9.	100-grain weight (g)	0.04	65.38**	53.59**	30.69**	1.92
10.	Grain yield per plant (g)	76.27	103.46	5.24	77.82	83.73
11.	Shelling percentage (%)	3.01	8.86*	1.46	5.40**	2.49
12.	Fodder yield (t/ha)	2.73	8.12**	6.10**	3.66**	0.18
13.	Grain yield (q/ha)	26.36	50.55*	6.12	32.97	35.30

* Significant at 5%

** Significant at 1%

Table 8: Estimates of variance components as reference to the prevailing gene action in maize for 12 characters

Sl.No	Characters	σ^2GCA	σ^2SCA	σ^2GCA/σ^2SCA	σ^2A	σ^2D	σ^2A/σ^2D
1.	Days to 50% tasseling	0.01	-0.10	-0.15	0.06	-0.39	-0.15
2.	Days to 50% silking	0.02	0.06	0.39	0.09	0.23	0.39
3.	Plant height (cm)	1.19	-49.44	-0.02	4.76	-197.77	-0.02
4.	Ear length (cm)	0.01	-0.57	-0.01	0.03	-2.28	-0.01
5.	Ear circumference (cm)	0.00	-0.19	-0.01	0.01	-0.76	-0.01
6.	Number of kernel rows per ear	0.00	0.03	0.03	0.00	0.11	0.036
7.	Number of kernels per row	0.02	5.63	0.004	0.10	22.54	0.004
8.	100-grain weight (g)	0.12	14.38	0.01	0.48	57.54	0.01
9.	Shelling percentage (%)	0.01	1.46	0.01	0.04	5.82	0.01
10.	Grain yield per plant (g)	0.07	-2.95	-0.02	0.27	-11.82	-0.02
11.	Fodder yield (t/ha)	0.02	1.74	0.01	0.06	6.95	0.01
12.	Grain yield (q/ha)	0.05	-1.17	-0.04	0.21	-4.67	-0.04

Table 9: General combining ability (gca) effects of parents in respect of 12 characters

Sl.No	Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
	Females (Lines)												
1	YP ⊗ 4 #07-1	-0.13	0.93	12.25*	0.28	1.17**	0.41	2.06**	4.14**	-1.8**	3.9	0.48**	2.51
2	YP ⊗ 4 #07-2	-2.46**	-2.07**	5.09	0.68	-0.18	-0.06	-0.11	3.14**	-0.25	-0.41	-0.54**	-0.61
3	YP ⊗ 4 #07-3	-0.29	0.09	5.09	1.56	0.16	0.31	1.59*	3.8**	0.59	4.51	-0.07	2.6
4	YP ⊗ 4 #07-4	-1.63**	-1.24	-4.41	0.54	0.39	0.31	1.73*	2.47**	0.25	3.59	-0.14	1.98
5	YP ⊗ 4 #07-5	0.21	1.26	-14.91*	-1.81*	-0.66	-0.53*	-2.34**	-3.03**	0.79	-5.16	-2.19**	-3.89
6	YP ⊗ 4 #07-6	-0.96*	0.93	-19.75**	-1.51	-1.06*	-0.73**	-4.01**	-5.03**	-1.7**	-6.63	-1.7**	-5.67*
7	YP ⊗ 4 #07-7	0.21	0.43	-7.08	-1.42	-0.46	-0.53*	-2.51**	-3.86**	-1.18	-5.22	-0.99**	-3.84
8	YP ⊗ 4 #07-8	0.54	0.76	-3.41	1.48	0.08	0.37	1.86**	-4.53**	1.24	4.34	1.43**	3.05
9	YP ⊗ 4 #07-9	0.54	0.76	11.25	0.96	0.06	0.04	0.43	-1.53**	0.72	0.19	1.68**	0.36
10	YP ⊗ 4 #07-10	0.21	0.59	0.75	-0.72	0.37	-0.03	0.19	-0.36	-1.23	-0.74	2.01**	-0.4
11	YP ⊗ 4 #07-11	-0.79	-1.57*	-16.75**	-0.96	-1.04*	-0.49	-2.57**	-2.36**	-0.6	-6.94	-1.94**	-3.87
12	YP ⊗ 4 #07-12	0.04	-0.91	-2.25	-0.44	-0.06	-0.16	-0.94	-2.7**	-1.53*	-2.94	-0.32	-1.27
13	YP ⊗ 4 #07-13	-1.13*	-1.74**	-12.58*	0.08	0.02	0.34	2.03**	2.64**	-0.01	2.53	1.2**	2.38
14	YP ⊗ 4 #07-14	1.04*	1.26	4.59	0.19	0.2	-0.23	-1.34	1.14*	-0.33	-3.14	0.58**	-2.04
15	YP ⊗ 4 #07-15	0.04	0.26	5.75	-0.29	-0.01	-0.36	-2.31**	-1.2*	0.34	-3.18	0.78**	-2.59
16	YP ⊗ 4 #07-16	0.71	1.26	6.25	1.64*	0.49	-0.09	-0.27	2.3**	-0.41	-1.89	0.21	-0.88
17	YP ⊗ 4 #07-17	1.37**	1.26	1.92	0.58	-0.28	-0.19	-1.01	-5.7**	1.44*	-2.31	0.23	-1.64
18	YP ⊗ 4 #07-18	1.37**	1.76**	8.59	1.14	0.34	0.01	-0.04	0.8	-1.81**	-1	2.16**	-0.34
19	YP ⊗ 4 #07-19	1.71**	1.76**	13.42*	-0.79	-0.29	-0.43	-2.37**	-0.7	0.72	-4.43	1**	-3.56
20	YP ⊗ 4 #07-20	0.04	0.43	-6.58	-1.01	-0.43	0.71**	3.56**	-0.36	2.09**	8.73*	-1.32**	5.95*
21	YP ⊗ 4 #07-21	1.04*	0.43	-0.58	0.03	0.16	-0.06	-0.84	4.47**	-0.91	-0.97	-0.27	-0.57
22	YP ⊗ 4 #07-22	-0.29	0.43	-4.25	-0.19	-0.19	-0.23	-1.24	-1.03	-1.78**	-3.72	0.33	-2.25
23	YP ⊗ 4 #07-23	0.71	0.76	3.59	-0.64	0.09	-0.26	-1.57*	-4.36**	0.3	-2.42	0.98**	-1.57
24	YP ⊗ 4 #07-24	-0.63	-1.91**	0.42	0.58	-0.11	0.21	1.23	-0.03	0.95	2.9	-0.55**	1.7

Contd…

Sl.No	Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
	Female (Lines)												
25	YP ⊗ 4 #07-25	-0.46	-1.91**	1.92	-0.09	0.31	0.44	2.36**	3.64**	1.55*	4.71	0	3.82
26	YP ⊗ 4 #07-26	-0.96*	-2.07**	3.25	0.96	0.82*	0.21	1.13	5.14**	0.94	3.69	-1.25**	2.02
27	YP ⊗ 4 #07-27	-0.96*	-1.41*	-1.41	-0.84	0.21	0.47	2.53**	1.47*	-1.48*	5.37	-1.04**	4.21
28	YP ⊗ 4 #07-28	-0.29	-0.74	-2.58	-0.29	0.07	0.47	2.36**	5.3**	2.04**	5.79	-1.29**	3.85
29	YP ⊗ 4 #07-29	1.21*	0.26	12.42*	0.29	-0.21	0.11	0.46	-3.7**	1.12	0.86	0.53**	0.57
	Males (Testers)												
30	Prabha	0.24	0.26	2.74	0.2	0.04	0.05	0.26	-1.09**	0.05	0.19	0.2**	0.31
31	KDMI-10	-0.06	0.01	1.41	0	0.06	0	0.03	0.37*	-0.18	0.16	0.17**	0.03
32	CI-5	-0.18	-0.27	-4.16*	-0.2	-0.1	-0.05	-0.29	0.72**	0.13	-0.35	-0.37**	-0.34
	CD at 5% female	1.35	1.83	17.19	2.24	1.14	0.742	1.96	1.58	1.80	10.46	0.49	6.79
	CD at 1% female	1.80	2.43	22.84	2.98	1.51	0.98	2.61	2.10	2.39	13.89	0.65	9.02
	S.Em±	0.68	0.92	8.68	1.13	0.57	0.37	0.99	0.80	0.91	5.28	0.25	3.43
	CD at 5% male	0.44	0.59	5.53	0.72	0.37	0.23	0.63	0.51	0.58	3.36	0.16	2.18
	CD at 1% male	0.58	0.78	7.35	0.96	0.49	0.31	0.83	0.68	0.77	4.47	0.21	2.90
	S.Em±	0.22	0.30	2.79	0.36	0.18	0.12	0.31	0.26	0.29	1.70	0.08	1.10

*-Significant At 5% Level **-Significant at 1% level

X1 - Days to 50% tasseling
X2 - Days to 50% silking
X3 - Plant height (cm)
X4- Ear length (cm)
X5 - Ear circumference (cm)
X6 – Number of kernel rows per cob
X7 – Number of kernels per row
X8- 100-grain weight (g)
X9 – Shelling percentage (%)
X10 – Grain yield per plant (g)
X11 – Fodder yield (t/ha)
X12-Grain yield (q/ha)

1.41) where seven top female parents exhibited significantly high gca effects in the negative direction. On the other hand, YP⊗4#07-19 and YP⊗4#07-18 (1.76) were two top female parents exhibited significantly high gca effects in the positive direction. However, out of three testers, CI-5 (-0.27) showed negative gca effects and two testers Prabha (0.26) and KDMI-10 (0.01) showed positive gca effects. None of them had significant gca effects.

4.6.3 Plant height

The gca effects for plant height ranged from -19.75 to 13.42. Out of 29 lines, as many as 13 lines showed negative gca effects whereas 16 lines showed positive gca effects. Lines YP⊗4#07-6 (-19.75), YP⊗4#07-11 (-16.75), YP⊗4#07-5 (-14.91), YP⊗4#07-13 (-12.59) were four top female parents exhibited significantly high gca effects in the negative direction. On the other hand, YP⊗4#07-19 (13.42), YP⊗4#07-29 (12.42), YP⊗4#07-1 (12.25) were three top female parents exhibited significantly high gca effects in the positive direction. Out of 3 testers, CI-5 (-4.16) showed significantly high gca effects in the negative direction and two testers Prabha (2.74) and KDMI-10 (1.41) showed gca effects in the positive direction but none of them had shown significant levels.

4.6.4 Ear length

The gca for ear length ranged from -1.81 to 1.64. Two female parents showed significant gca effects of which YP⊗4#07-5 and YP⊗4#07-16 had negative and positive direction respectively. The testers, CI-5 (-0.2) manifested negative gca effects and Prabha (0.2) showed positive gca effects whereas gca effects of KDMI-10 was nil.

4.6.5 Ear circumference

The gca effects for ear circumference ranged from -1.06 to 1.17. Four parents showed significantly gca effects of which YP⊗4#07-6 (1.06), YP⊗4#07-11 (-1.04) was in the negative direction and YP⊗4#07-1 (1.17) and YP⊗4#07-26 (0.82) was in the positive direction. The tester, CI-5 (-0.1) manifested negative gca effect and KDMI-10 (0.06) and Prabha (0.04) showed gca effects in positive direction. None of them had expressed significant gca effects.

4.6.6 Number of kernel rows per ear

The gca effects for number of kernel rows per ear ranged from -0.73 to 0.71. Out of 29 lines, only four lines showed significant gca effects. YP⊗4#07-20 and YP⊗4#07-6, YP⊗4#07-5, YP⊗4#07-7 was in positive and negative direction respectively. The testers, CI-5 (-0.05) manifested negative gca effects and KDMI-10 (0) and Prabha (0.05) showed gca effects in positive direction. None of them had expressed significant gca effects.

4.6.7 Number of kernels per row

The gca effects for number of kernels per row ranged from -4.01 to 3.56. Out of 29 lines, 16 showed significant gca effects of which nine were in positive direction and seven were in negative direction. Among testers, CI-5 (-0.29) manifested negative gca effects and KDMI-10 (0.03) and Prabha (0.26) showed gca effects in positive direction. None of them had expressed significant gca effects.

4.6.8 100-grain weight

The gca effects for 100-grain weight ranged from -5.7 to 5.3. Out of 29 lines, as many as 16 lines exhibited negative gca effect whereas remaining 13 lines has positive gca effect. Lines YP⊗4#07-17 (-5.7), YP⊗4#07-6 (-5.03), YP⊗4#07-8 (-4.53), YP⊗4#07-23 (-4.36), YP⊗4#07-7 (-3.86), YP⊗4#07-29 (-3.7), YP⊗4#07-5 (-3.03), YP⊗4#07-12 9-2.7), YP⊗4#07-11 (-2.36), YP⊗4#07-9 (-1.53), YP⊗4#07-15 (-1.2) were 11 top female parents exhibited significantly high gca effects in the negative direction and lines YP⊗4#07-28 (5.3), YP⊗4#07-26 (5.14), YP⊗4#07-21 (4.47), YP⊗4#07-1 (4.14) YP⊗4#07-3 (3.8), YP⊗4#07-25 (3.64), YP⊗4#07-2 (3.14), YP⊗4#07-13 (2.64), YP⊗4#07-4 (2.47), YP⊗4#07-16 (2.3), YP⊗4#07-27 (1.47) and YP⊗4#07-14 (1.4) were 12 top female parents exhibited significantly high gca effects in the positive direction. However, out of three testers, Prabha (-1.09) showed significantly high gca effects in negative direction and CI-5 (0.72) and KDMI-10 (0.37) showed significantly high gca effects in positive direction.

4.6.9 Shelling percentage (%)

The gca effects for shelling per cent ranged from -1.81 to 2.09. Out of 29 lines, YP⊗4#07-17, YP⊗4#07-20, YP⊗4#07-25 and YP⊗4#07-28 were top four females exhibited significantly high gca effects in positive direction and YP⊗4#07-1, YP⊗4#07-6, YP⊗4#07-12, YP⊗4#07-18, YP⊗4#07-22, YP⊗4#07-27 were top six females exhibited significantly high gca effects in negative direction. However, out of three testers, KDMI-10 (-0.18) showed significantly high gca effects in negative direction and CI-5(0.13) and Prabha (0.05) showed significantly high gca effects in positive direction.

4.6.10 Grain yield per plant

The gca effects of grain yield per plant ranged from -6.94 to 8.73. Only one line YP⊗4#07-20 (8.73) showed significantly high gca effect in positive direction and none of the lines showed significantly high gca effect in the negative direction. However, out of three testers, CI-5 (-0.35) showed gca effects in negative direction and Prabha (0.19) and KDMI-10 (0.16) showed gca effects in positive direction. None of them had significant gca effects.

4.6.11 Fodder yield per hectare

The gca effects for fodder yield ranged from -2.19 to 2.16. Out of 29 lines, as many as 14 lines exhibited negative gca effects and 15 lines exhibited positive gca effect. Lines YP⊗4#07-5 (-2.19), YP⊗4#07-11(-1.94), YP⊗4#07-6 (-1.7), YP⊗4#07-20 (-1.32), YP⊗4#07-28 (-1.29), YP⊗4#07-26 (-1.25), YP⊗4#07-27 (-1.04), YP⊗4#07-7 (-0.99) YP⊗4#07-24 (-0.55) and YP⊗4#07-2(-0.54) were top 10 female lines exhibited significantly high gca effects in negative direction and lines YP⊗4#07-18 (2.16), YP⊗4#07-10 (2.01), YP⊗4#07-9 (1.38), YP⊗4#07-8 (1.43), YP⊗4#07-13(1.2), YP⊗4#07-9 (1.0), YP⊗4#07-23 (0.98), YP⊗4#07-15 (0.78), YP⊗4#07-23 (0.98), YP⊗4#07-15 (0.78), YP⊗4#07-14 (0.58), YP⊗4#07-29 (0.53) and YP⊗4#07-1 (0.48) were 13 top female lines exhibited significantly high gca effects in positive direction. However, out of three testers, KDMI-10 (-0.37) exhibited significantly high gca effects in negative direction, while Prabha (0.2) and CI-5 (0.17) exhibited significantly high gca effects in positive direction.

4.6.12 Grain yield per hectare

The gca effects for grain yield per hectare ranged from -5.67 to 5.95. Two female parents showed significantly gca effects, of which only one line was in positive direction (YP⊗4#07-20) and another was in negative direction (YP⊗4#07-6). However, out of three testers, CI-5 (-0.34) showed gca effects in negative direction, while Prabha (0.31) and KDMI-10 (0.03) showed gca effects in positive direction, but none of them had gca effects at significant level.

4.7 Specific combining ability effect

The specific combining ability effects of 87 crosses are given in Table 10.

4.7.1 Days to 50 per cent tasseling

The sca effects for days to 50 per cent tasseling ranged from -1.82 (YP⊗4#07-13 x CI-5) to 1.51 (YP⊗4#07-27 x CI-5). Forty-three and 44 crosses manifested positive and negative sca effects respectively. Out of 87 crosses, the cross YP⊗4#07-13 x CI-5 (-1.82) showed significant sca effects in negative direction.

4.7.2 Days to 50 per cent silking

The sca effects for days to 50 per cent silking ranged from -2.56 (YP⊗4#07-6 x CI-5) to 4.4 (YP⊗4#07-6 x Prabha). Forty-one and 46 crosses manifested positive and negative sca effects, respectively. Out of 87 crosses, only two cross YP⊗4#07-6 x Prabha (4.4) and YP⊗4#07-6 x CI-5 (-2.56) showed significant sca effects in positive and negative direction, respectively.

4.7.3 Plant height

The sca effects for plant height ranged from -15.57 (YP⊗4#07-17 x Prabha) to 14.26 YP⊗4#07-18 x Prabha). Forty-six and 41 crosses manifested positive and negative sca effects, respectively. Out of 87 crosses, none of them showed significant sca effects.

4.7.4 Ear length

The sca effects for ear length ranged from -2.05 (YP⊗4#07-17 x KDMI-10) to 1.99 (YP⊗4#07-29 x CI-5). Forty-eight and 39 crosses showed positive and negative sca effects respectively. Out of 87 crosses, none of them showed significant sca effects.

4.7.5 Ear circumference

The sca effects for ear circumference ranged from -0.96 (YP⊗4#07-15 x Prabha) to 1.06 (YP⊗4#07-22 x KDMI-10). Forty-four and 38 crosses showed positive and negative sca effects respectively. Out of 87 crosses, none of them showed significant sca effects. However sca effects of cross YP⊗4#07-10 x CI-5 was almost nil.

4.7.6 Number of kernel rows per ear

The sca effects for number of kernel rows per ear ranged from -1.05 (YP⊗4#07-15 x Prabha) to 1(YP⊗4#07-23 x KDMI-10). Out of 87 crosses, 42 and 45 crosses showed positive and negative sca effects respectively. YP⊗4#07-15 x Prabha and YP⊗4#07-23 x KDMI-10 showed significant sca effects in negative and positive direction respectively.

4.7.7 Number of kernels per row

The sca effects for number of kernels per row ranged from -6.99 (YP⊗4#07-15 x Prabha) to 5.1 (YP⊗4#07-23 x KDMI-10). Out of 87 crosses, 44 and 43 crosses showed negative and positive sca effects respectively. Eleven and 12 crosses showed significant sca effects in negative and positive direction respectively.

Table 10: Specific combining ability (sca) effects of single cross hybrids of maize in respect of 12 characters

Sl.No	Single cross hybrids	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
1	YP ⊗ 4 #07-1 x Prabha	0.76	0.4	5.59	-0.25	0.06	0.08	0.24	0.76	-1.01	-0.96	1.32**	0.2
2	YP ⊗ 4 #07-1 x KDMI -10	-0.44	-0.34	7.92	-0.3	0.09	0.04	0.27	-0.21	1.96	1.36	-0.46	0.23
3	YP ⊗ 4 #07-1 x CI-5	-0.32	-0.06	-13.51	0.55	-0.15	-0.12	-0.51	-0.55	-0.95	-0.4	-0.86**	-0.43
4	YP ⊗ 4 #07-2 x Prabha	-0.4	-0.1	4.76	-0.75	-0.29	-0.25	-1.39	4.76**	-0.61	-3.1	1.38**	-1.9
5	YP ⊗ 4 #07-2 x KDMI -10	-0.11	0.16	-7.91	0.2	0.34	0.2	1.23	-6.21**	0.51	3.33	-0.29	2.12
6	YP ⊗ 4 #07-2 x CI-5	0.51	-0.06	3.16	0.55	-0.05	0.05	0.16	1.45	0.1	-0.24	-1.09**	-0.22
7	YP ⊗ 4 #07-3 x Prabha	-0.57	-1.26	-8.74	-1.24	-0.57	-0.42	-1.79	-6.91**	0.55	-4.62	-0.73*	-3.3
8	YP ⊗ 4 #07-3 x KDMI -10	0.72	1.49	1.59	1.77	0.51	0.54	2.13	5.63**	1.83	8.17	1.04**	5.06
9	YP ⊗ 4 #07-3 x CI-5	-0.16	-0.23	7.16	-0.53	0.06	-0.12	-0.34	1.28	-2.38*	-3.55	-0.31	-1.76
10	YP ⊗ 4 #07-4 x Prabha	0.26	0.57	6.76	0.43	0.59	0.78	4.18**	2.93**	2.79*	9.37	0.93**	6.38
11	YP ⊗ 4 #07-4 x KDMI -10	-0.94	-1.17	-1.41	1.03	0.28	-0.16	-0.9	2.46*	-0.44	-1.9	-1.29**	-1.63
12	YP ⊗ 4 #07-4 x CI-5	0.68	0.6	-5.34	-1.46	-0.87	-0.62	-3.28**	-5.39**	-2.35*	-7.47	0.36	-4.75
13	YP ⊗ 4 #07-5 x Prabha	-0.07	0.07	9.26	0.73	0.44	0.01	-0.06	2.43*	2.65*	-0.09	1.28**	0.15
14	YP ⊗ 4 #07-5 x KDMI -10	0.22	0.33	-4.41	-2.02	-0.62	-0.13	-0.33	-0.04	-1.92	-2.05	-1.04**	-0.69
15	YP ⊗ 4 #07-5 x CI-5	-0.16	-0.4	-4.84	1.29	0.18	0.12	0.39	-2.39*	-0.73	2.13	-0.24	0.54
16	YP ⊗ 4 #07-6 x Prabha	1.1	4.4**	7.09	1.48	0.84	0.61	3.71**	3.43**	3.19**	4.39	0.15	4.19
17	YP ⊗ 4 #07-6 x KDMI-10	0.39	-1.84	-0.58	-0.57	-0.12	-0.53	-2.27	3.96**	-1.04	-4.48	0.78*	-3.73
18	YP ⊗ 4 #07-6 x CI-5	-1.49	-2.56*	-6.51	-0.91	-0.72	-0.08	-1.44	-7.39**	-2.15	0.09	-0.93**	-0.46
19	YP ⊗ 4 #07-7 x Prabha	-1.07	-0.6	1.93	-0.05	0.34	-0.19	-0.79	4.76**	-0.68	-0.05	0.48	-1.15
20	YP ⊗ 4 #07-7 x KDMI-10	0.72	0.66	-7.25	0.55	-0.42	0.17	0.63	-2.71**	-0.76	0.64	-1.29**	1.29
21	YP ⊗ 4 #07-7 x CI-5	0.34	-0.06	5.32	-0.5	0.08	0.02	0.16	-2.05*	1.44	-0.59	0.81**	-0.14
22	YP ⊗ 4 #07-8 x Prabha	0.6	0.07	2.76	0.25	-0.27	0.41	1.84	-2.57*	1.25	7.06	0.32	4.85
23	YP ⊗ 4 #07-8 x KDMI-10	-0.11	0.33	-7.41	-1.35	-0.27	-0.23	-1.33	-1.54	-0.87	-3.34	1.39**	-2.82
24	YP ⊗ 4 #07-8 x CI-5	-0.49	-0.4	4.66	1.1	0.54	-0.18	-0.51	4.11**	-0.38	-3.72	-1.71**	-2.04

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Sl.No	Single cross hybrids	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
25	YP ⊗ 4 #07-9 x Prabha	-0.9	-1.43	-13.91	-1.04	-0.72	-0.55	-2.72*	-1.57	0.12	-5.04	0.12	-4.06
26	YP ⊗ 4 #07-9 x KDMI-10	-0.11	-0.17	12.92	1.47	1.01	0.6	2.8*	0.96	0.64	6.26	1.79**	4.51
27	YP ⊗ 4 #07-9 x CI-5	1.01	1.6	0.99	-0.43	-0.29	-0.05	-0.08	0.61	-0.76	-1.22	-1.91**	-0.44
28	YP ⊗ 4 #07-10 x Prabha	0.43	0.74	-4.41	0.2	-0.19	0.31	1.81	-2.24*	-1.08	4.87	-1.87**	2.79
29	YP ⊗ 4 #07-10 x KDMI-10	0.22	-0.01	2.92	0.65	0.19	0.17	0.63	-0.21	-0.16	1.24	-0.24	0.79
30	YP ⊗ 4 #07-10 x CI-5	-0.66	-0.73	1.49	-0.85	0	-0.48	-2.44*	2.45*	1.24	-6.11	2.11**	-3.58
31	YP ⊗ 4 #07-11 x Prabha	-0.07	-0.1	0.59	0.38	0.18	-0.02	0.18	3.26**	0.74	0.82	-1.07**	0.1
32	YP ⊗ 4 #07-11 x KDMI-10	0.22	-0.34	-7.58	-0.32	-0.39	0.14	0.7	-1.21	-1.19	-0.78	-0.14	0.73
33	YP ⊗ 4 #07-11 x CI-5	-0.16	0.44	6.99	-0.06	0.21	-0.12	-0.88	-2.05*	0.45	-0.04	1.21**	-0.82
34	YP ⊗ 4 #07-12 x Prabha	0.1	-0.76	9.09	0.71	0.84	0.75	3.94**	-3.41**	-0.93	10.55	1.02**	5.85
35	YP ⊗ 4 #07-12 x KDMI-10	-0.11	0.99	-4.58	-0.48	-0.27	-0.2	-0.93	1.13	0.89	-4.27	0.19	-2.02
36	YP ⊗ 4 #07-12 x CI-5	0.01	-0.23	-4.51	-0.23	-0.57	-0.55	-3.01*	2.28*	0.04	-6.29	-1.21**	-3.83
37	YP ⊗ 4 #07-13 x Prabha	0.76	0.57	-9.07	-1.3	-0.49	-0.05	-0.22	1.26	0.4	-0.29	-1.05**	-0.25
38	YP ⊗ 4 #07-13 x KDMI-10	1.06	1.33	-0.75	-0.15	0.04	0	0.2	-1.21	-0.12	0.42	1.48**	0.06
39	YP ⊗ 4 #07-13 x CI-5	-1.82*	-1.9	9.82	1.45	0.45	0.05	0.02	-0.05	-0.28	-0.13	-0.43	0.18
40	YP ⊗ 4 #07-14 x Prabha	0.6	0.07	0.26	-0.57	0.28	0.11	1.04	7.76**	0.42	0.81	-0.43	0.98
41	YP ⊗ 4 #07-14 x KDMI-10	-0.61	-0.17	-7.41	0.68	-0.6	-0.43	-2.73*	-3.21**	0.09	-4.25	0.29	-3.14
42	YP ⊗ 4 #07-14 x CI-5	0.01	0.1	7.16	-0.11	0.32	0.32	1.69	-4.55**	-0.51	3.44	0.14	2.17
43	YP ⊗ 4 #07-15 x Prabha	-1.4	-1.93	7.09	-1.44	-0.96	-1.05*	-6.99**	-9.91**	-0.35	-9.92	2.57**	-7.51
44	YP ⊗ 4 #07-15 x KDMI-10	0.39	0.33	-0.58	0.37	0.53	0.5	3.23**	5.63**	-0.02	4.51	-1.56**	3.07
45	YP ⊗ 4 #07-15 x CI-5	1.01	1.6	-6.51	1.07	0.43	0.55	3.76**	4.28**	0.37	5.41	-1.01**	4.43
46	YP ⊗ 4 #07-16 x Prabha	-0.57	0.57	2.09	-0.07	0.44	0.08	0.28	-3.41**	-1.95	0.72	0.68*	0.72
47	YP ⊗ 4 #07-16 x KDMI-10	0.72	0.83	-2.08	0.48	-0.57	-0.06	-0.3	0.13	1.28	-0.2	-0.14	-0.59
48	YP ⊗ 4 #07-16 x CI-5	-0.16	-1.4	-0.01	-0.41	0.13	-0.02	0.02	3.28**	0.67	-0.51	-0.54	-0.13

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Sl.No	Single cross hybrids	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
49	YP ⊗ 4 #07-17 x Prabha	0.76	1.07	-15.57	1.25	0.06	-0.02	-0.39	-2.41*	-0.75	-0.96	-1.13**	-0.58
50	YP ⊗ 4 #07-17 x KDMI-10	-0.44	-0.67	3.75	-2.05	-0.56	-0.46	-2.17	0.13	-1.12	-4.66	-1.01**	-3.16
51	YP ⊗ 4 #07-17 x CI-5	-0.32	-0.4	11.82	0.8	0.5	0.48	2.56*	2.28*	1.87	5.61	2.14**	3.74
52	YP ⊗ 4 #07-18 x Prabha	0.26	0.07	14.26	1.93	-0.11	0.28	1.24	1.59	-0.5	2.92	0.73*	2.26
53	YP ⊗ 4 #07-18 x KDMI-10	0.06	-0.17	-4.41	-0.52	0.08	-0.16	-0.73	-1.37	0.83	-1.07	-0.34	-1.31
54	YP ⊗ 4 #07-18 x CI-5	-0.32	0.1	-9.84	-1.41	0.03	-0.12	-0.51	-0.22	-0.33	-1.84	-0.39	-0.95
55	YP ⊗ 4 #07-19 x Prabha	-0.07	-0.43	7.43	0.61	-0.07	0.31	1.58	-1.41	0.87	2.51	-0.2	1.99
56	YP ⊗ 4 #07-19 x KDMI-10	0.72	0.83	3.25	0.72	0.06	-0.13	-0.1	-3.87**	-0.06	-2.54	1.48**	-0.58
57	YP ⊗ 4 #07-19 x CI-5	-0.66	-0.4	-10.68	-1.33	0.01	-0.18	-1.48	5.28**	-0.81	0.02	-1.28**	-1.41
58	YP ⊗ 4 #07-20 x Prabha	0.1	-0.6	0.93	-0.17	0.16	-0.62	-3.06*	-4.24**	-1.2	-10.62	1.47**	-5.91
59	YP ⊗ 4 #07-20 x KDMI-10	-0.61	-0.34	0.75	-0.07	0.39	-0.16	-0.73	2.29*	-1.32	-2.61	-0.96**	-2.9
60	YP ⊗ 4 #07-20 x CI-5	0.51	0.94	-1.68	0.24	-0.55	0.78	3.79**	1.95*	2.52*	13.23*	-0.51	8.82*
61	YP ⊗ 4 #07-21 x Prabha	0.6	0.9	-12.57	-0.45	0.28	0.55	3.44**	-0.07	-0.2	6.44	-0.73*	4.19
62	YP ⊗ 4 #07-21 x KDMI-10	-0.61	-1.34	6.75	-0.1	-0.29	-0.7	-4.73**	-1.54	-0.42	-7.22	-0.81**	-4.96
63	YP ⊗ 4 #07-21 x CI-5	0.01	0.44	5.82	0.55	0.01	0.15	1.29	1.61	0.62	0.77	1.54**	0.77
64	YP ⊗ 4 #07-22 x Prabha	-0.07	-0.6	-4.91	-0.44	-0.82	-0.29	-1.36	1.43	-3.88**	-2.26	-1.83**	-2.16
65	YP ⊗ 4 #07-22 x KDMI-10	-0.28	0.16	7.92	0.37	1.06	-0.03	-0.23	0.96	1.24	-0.23	1.49**	-0.16
66	YP ⊗ 4 #07-22 x CI-5	0.34	0.44	-3.01	0.07	-0.24	0.32	1.59	-2.39*	2.64*	2.49	0.34	2.32
67	YP ⊗ 4 #07-23 x Prabha	0.43	0.57	-6.74	-0.69	-0.31	-0.85	-4.62**	3.26**	-1.36	-9.85	0.22	-6.31
68	YP ⊗ 4 #07-23 x KDMI-10	-0.28	-0.17	4.59	1.52	0.48	1*	5.1**	-0.71	1.71	11.5	-0.51	8.18
69	YP ⊗ 4 #07-23 x CI-5	-0.16	-0.4	2.16	-0.83	-0.17	-0.15	-0.48	-2.55*	-0.35	-1.65	0.29	-1.87
70	YP ⊗ 4 #07-24 x Prabha	0.26	0.24	-1.57	1.25	0.39	0.68	3.98**	-0.07	1.79	11.02	-1.55**	6.49
71	YP ⊗ 4 #07-24 x KDMI-10	-0.44	-0.51	-1.75	-1	-0.57	-0.46	-2.5*	-2.04*	0.21	-7.92	-0.52	-3.93
72	YP ⊗ 4 #07-24 x CI-5	0.18	0.27	3.32	-0.25	0.18	-0.22	-1.48	2.11*	-2	-3.09	2.07**	-2.56

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Sl.No	Single cross hybrids	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
73	YP ⊗ 4 #07-25 x Prabha	-0.4	-0.26	-2.07	-1.44	-0.57	-0.15	-1.26	-2.74**	0.99	-2.39	-1.55**	-1.96
74	YP ⊗ 4 #07-25 x KDMI-10	0.39	-0.01	2.25	-0.08	0.06	-0.1	-0.03	4.29**	-0.59	-2.35	-0.82**	-1.12
75	YP ⊗ 4 #07-25 x CI-5	0.01	0.27	-0.18	1.52	0.51	0.25	1.29	-1.55	-0.4	4.74	2.37**	3.09
76	YP ⊗ 4 #07-26 x Prabha	0.6	0.4	1.59	0.21	0.36	0.18	0.98	1.26	-1.6	0.8	0.45	0.51
77	YP ⊗ 4 #07-26 x KDMI-10	-0.11	-0.34	5.92	1.07	0.34	0.54	2.5*	1.79	1.28	9.91	-0.17	5.6
78	YP ⊗ 4 #07-26 x CI-5	-0.49	-0.06	-7.51	-1.28	-0.7	-0.72	-3.48**	-3.05**	0.32	-10.71	-0.28	-6.11
79	YP ⊗ 4 #07-27 x Prabha	-0.4	-0.76	5.26	1.51	0.27	0.01	0.18	-0.57	-0.48	0.28	-1.27**	0.28
80	YP ⊗ 4 #07-27 x KDMI-10	-1.11	-0.51	0.59	-0.53	-0.05	-0.33	-1.4	-1.04	-2.36*	-4.37	1.21**	-2.97
81	YP ⊗ 4 #07-27 x CI-5	1.51	1.27	-5.84	-0.98	-0.22	0.32	1.22	1.61	2.84*	4.08	0.06	2.69
82	YP ⊗ 4 #07-28 x Prabha	-0.57	-0.43	-6.07	-0.19	-0.44	-0.39	-2.06	4.09**	-0.1	-6.47	-0.37	-3.99
83	YP ⊗ 4 #07-28 x KDMI-10	-0.28	-0.17	0.25	-0.18	-0.16	0.27	1.17	-2.37*	-0.07	3.28	0.01	2.76
84	YP ⊗ 4 #07-28 x CI-5	0.84	0.6	5.82	0.37	0.6	0.12	0.89	-1.72	0.17	3.19	0.36	1.23
85	YP ⊗ 4 #07-29 x Prabha	-1.07	-1.43	-1.07	-0.87	0.24	-0.32	-1.96	-1.41	0.92	-5.91	0.67*	-2.83
86	YP ⊗ 4 #07-29 x KDMI-10	0.72	0.83	-3.25	-1.12	-0.57	0.14	0.87	0.13	-0.01	3.59	0.44	1.32
87	YP ⊗ 4 #07-29 x CI-5	0.34	0.6	4.32	1.99	0.33	0.18	1.09	1.28	-0.91	2.32	-1.11**	1.52
	CD at 5%	2.34	3.16	29.78	3.89	1.97	1.28	3.40	2.74	3.12	18.12	0.84	11.76
	CD at 1%	3.11	4.20	39.56	5.16	2.61	1.71	4.52	3.64	4.14	24.07	1.12	15.63
	CV%	1.18	1.60	15.04	1.96	0.99	0.65	1.71	1.39	1.57	9.15	0.43	5.94

*****-Significant At 5% Level ******-Significant at 1% level

X1 - Days to 50% tasseling
X2 - Days to 50% silking
X3 - Plant height (cm)
X4- Ear length (cm)
X5 - Ear circumference (cm)
X6 – Number of kernel rows per cob
X7 – Number of kernels per row
X8- 100-grain weight (g)
X9 – Shelling percentage (%)
X10 – Grain yield per plant (g)
X11 – Fodder yield (t/ha)
X12-Grain yield (q/ha)

4.7.8 100-grain weight

The sca effects for 100 grain weight ranged from -9.91 (YP⊗4#07-15 x Prabha) to 7.76 (YP⊗4#07-14 x Prabha). Forty-two and 45 crosses showed positive and negative sca effects respectively. Out of 87 crosses, 48 crosses showed significant sca effects among them, 24 crosses expressed sca effects in positive and 24 crosses in negative direction respectively. The 24 crosses *viz.,* YP⊗4#07-14 x Prabha (7.76), YP⊗4#07-15 x KDMI-10 (5.63), YP⊗4#07-3 x KDMI-10 (5.63), YP⊗4#07-19 x CI-5 (5.28), YP⊗4#07-7 x Prabha (4.76), YP⊗4#07-2 x Prabha (4.76), YP⊗4#07-25 x KDMI-10 (4.29), YP⊗4#07-15 x CI-5(4.28), YP⊗4#07-8 x CI-5(4.11), YP⊗4#07-28 x Prabha (4.09), YP⊗4#07-6 x KDMI-10 (3.96), YP⊗4#07-6 x Prabha (3.43), YP⊗4#07-16 x CI-5 (3.28), YP⊗4#07-23x Prabha (3.26), YP⊗4#07-11 x Prabha (3.26), YP⊗4#07-4 x Prabha (2.93), YP⊗4#07-4 x KDMI-10 (2.46), YP⊗4#07-10 x CI-5 (2.45), YP⊗4#07-5 x Prabha (2.43), YP⊗4#077-20 x KDMI-10 (2.29), YP⊗4#07-17 x CI-5 (2.28), YP⊗4#07-12 x CI-5 (2.28), YP⊗4#07-24 x CI-5 (2.11) and YP⊗4#07-20 x CI-5 (1.95) exhibited significantly high sca effects in positive direction and top 24 crosses *viz.,* YP⊗4#07-15 x Prabha (-9.91). YP⊗4#07-6 x CI-5 (-7.39), YP⊗4#07-3 x Prabha (-6.91), YP⊗4#07-2 x KDMI-10 (-6.21), YP⊗4#07-4 x CI-5 (-5.39), YP⊗4#07-14 x CI-5 (-4.55), YP⊗4#07-20 x Prabha (-4.24), YP⊗4#07-19 x KDMI-10 (-3.87), YP⊗4#07-12 x Prabha (-3.41), YP⊗4#07-16 x Prabha (-3.41), YP⊗4#07-14 x KDMI-10 (-3.21), YP⊗4#07-26 x CI-5 (-3.05), YP⊗4#07-25 x Prabha (-2.75), YP⊗4#07-7 x KDMI-10 (-2.71), YP⊗4#07-8 x Prabha (-2.57), YP⊗4#07-23 x CI-5 (-2.55), YP⊗4#07-17 x Prabha (-2.41), YP⊗4#07-5 x CI-5 (-2.39), YP⊗4#07-22 x CI-5 (-2.39), YP⊗4#07-28 x KDMI-10 (-2.37), YP⊗4#07-10 x Prabha (-2.24), YP⊗4#07-7 x CI-5 (-2.05), YP⊗4#07-11 x CI-5 (-2.05) and YP⊗4#07-24 x KDMI-10 (-2.04) exhibited significantly higher sca effects in negative direction.

4.7.9 Shelling percentage

The sca effects for shelling per cent ranged from -3.88 (YP⊗4#07-22 x Prabha) to 3.19 (YP⊗4#07-6 x Prabha). Out of 87 crosses, 48 and 39 crosses showed negative and positive sca effects respectively. The six crosses *viz.,* YP⊗4#07-4 x Prabha, YP⊗4#07-5 x Prabha, YP⊗4#07-6 x Prabha, YP⊗4#07-22 x CI-5, YP⊗4#07-27 x CI-5 and YP⊗4#07-20 x CI-5 exhibited significantly higher sca effects in positive direction. The four crosses *viz.,* YP⊗4#07-3 x CI-5, YP⊗4#07-4 x CI-5, YP⊗4#07-22 x Prabha and YP⊗4#07-27 x KDMI-10 exhibited significantly higher sca effects in negative direction.

4.7.10 Grain yield per plant

The sca effects for grain yield per plant ranged from -10.71 (YP⊗4#07-26 x CI-5) to 13.23 (YP⊗4#07-20 x CI-5). Thirty-nine and 48 crosses showed positive and negative sca effects respectively. Out of 87 crosses, only YP⊗4#07-20x CI-5 showed significant sca effects in positive direction.

4.7.11 Fodder yield per hectare

The sca effects for fodder yield per hectare ranged from -1.91 (YP⊗4#07-9 x CI-5) to 2.57 (YP⊗4#07-15 x Prabha). Forty-one and 46 crosses showed positive and negative sca effects, respectively. Out of 87 crosses, 52 crosses showed significant sca effects and among these 20 crosses were in positive direction and the remaining 32 were in negative direction.

4.7.12 Grain yield per hectare

The sca effects of grain yield per hectare ranged from -7.51 (YP⊗4#07-15 x Prabha) to 8.82 (YP⊗4#07-20 x CI-5). Forty-one and 46 crosses showed positive and negative sca effects respectively. Out of 87 crosses, only YP⊗4#07-20 x CI-5 showed significant sca effects in positive direction.

4.8 Heterosis over mid parent, better parent and checks

The percentage of heterosis over mid parent (relative heterosis), better parent (heterobeltiosis) and over the best check (standard heterosis) is given in Table 11. DMH-2 was the earliest to develop tassel among checks, thus this was considered as best check to obtain standard heterosis. EH-434042 (Arjun) was the earliest to develop silking and had maximum plant height, ear circumference, 100-grain weight and shelling per cent among checks, thus this was considered as best check to obtain standard heterosis. 900M was the best check for ear length and fodder yield per hectare, while for number of kernel rows per ear, number of kernels per row, grain yield per plant and grain yield per hectare Pinnacle was found to be the best check, thus these were used to work out standard heterosis.

4.8.1 Days to 50 per cent tasseling

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -8.82 (YP⊗4#07-13 x CI-5) to 1.89(YP⊗4#07-19 x KDMI-10), -10.71 (YP⊗4#07-6x CI-5) to 0 (YP⊗4#07-19 x KDMI-10) and -7.46 (YP⊗4#07-13 x CI-5) to 0.75 (YP⊗4#07-19 x KDMI-10) per cent respectively. Forty-nine crosses exhibited significant negative heterosis over the mid parent, 55 crosses over better parent and 30 crosses over the standard heterosis. The highest significant standard heterosis was manifested by YP⊗4#07-13 x CI-5 (-7.46%) in negative direction and the lowest standard heterosis in positive direction by YP⊗4#07-29 x CI-5(-0.75) but was non significant. The highest positive standard heterosis was manifested by YP⊗4#07-19 x KDMI-10 and YP⊗4#07-17 x Prabha (0.75) and the lowest standard heterosis in positive direction by YP⊗4#07-14 x Prabha, YP⊗4#07-18 x Prabha, YP⊗4#07-19 x Prabha, YP⊗4#07-21 x Prabha and YP⊗4#07-29 x KDMI-10.

4.8.2 Days to 50 per cent silking

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -8.51 (YP⊗4#07-13 x CI-5) to 3.14 (YP⊗4#07-6 x Prabha), -9.15 (YP⊗4#07-13 x CI-5) to 2.07 (YP⊗4#07-6 x Prabha) and -6.52 (YP⊗4#07-13 x CI-5 to 7.25 (YP⊗4#07-6 x Prabha) per cent respectively. Twenty-five crosses exhibited significant negative heterosis over the mid parent, 38 over better parent and 6 crosses showed significant negative standard heterosis and one cross showed significant positive standard heterosis. The highest significant standard heterosis was recorded by YP⊗4#07-13 x CI-5 (-6.52%) and lowest significant standard was by YP⊗4#07-2 x CI-5, YP⊗4#07-4 x KDMI-10, YP⊗4#07-24 x KDMI-10, YP⊗4#07-26 x KDMI-10 and YP⊗4#07-26 x CI-5 (-4.35%) in negative direction. The highest positive significant standard heterosis was manifested by YP⊗4#07-6 x Prabha (7.25) and the lowest positive standard heterosis by YP⊗4#07-1 x KDMI-10, YP⊗4#07-1 x CI-5, YP⊗4#07-9 x KDMI-10, YP⊗4#07-15 x KDMI-10, YP⊗4#07-17 x KDMI-10, YP⊗4#07-17 x CI-5, YP⊗4#07-21 x CI-5, YP⊗4#07-22 x KDMI-10, YP⊗4#07-22 x CI-5, YP⊗4#07-23 x KDMI-10 and YP⊗4#07-29 x CI-5.

Table 11: Percent relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) for 12 characters in maize

Sl.No	Characters	Days to 50% tasseling			Days to 50% silking			Plant height (cm)		
	Single cross hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH
1	YP $\otimes$ 4 #07-1 x Prabha	-2.22	-2.94	-1.49	0.00	-1.41	1.45	31.24**	25.09*	25.09*
2	YP $\otimes$ 4 #07-1 x KDMI -10	-4.09**	-4.44*	-3.73*	-1.43	-2.82	0.00	28.98**	25.84*	25.84*
3	YP $\otimes$ 4 #07-1 x CI-5	-3.73*	-3.73*	-3.73*	-0.72	-1.43	0.00	9.09	5.62	5.62
4	YP $\otimes$ 4 #07-2 x Prabha	-5.66**	-8.09**	-6.72**	-4.32*	-6.34**	-3.62	23.02*	15.64	19.1
5	YP $\otimes$ 4 #07-2 x KDMI -10	-5.3**	-7.41**	-6.72**	-4.32*	-6.34**	-3.62	9.64	5.45	8.61
6	YP $\otimes$ 4 #07-2 x CI-5	-4.18**	-5.97**	-5.97**	-4.35*	-5.71**	-4.35*	14.67	9.45	12.73
7	YP $\otimes$ 4 #07-3 x Prabha	-4.44**	-5.15**	-3.73*	-4.59*	-4.93*	-2.17	14.34	8.99	8.99
8	YP $\otimes$ 4 #07-3 x KDMI -10	-2.60	-2.96	-2.24	-1.06	-1.41	1.45	18.62	15.73	15.73
9	YP $\otimes$ 4 #07-3 x CI-5	-3.73*	-3.73*	-3.73*	-3.2	-3.55	-1.45	19.54*	15.73	15.73
10	YP $\otimes$ 4 #07-4 x Prabha	-5.19**	-5.88**	-4.48*	-3.2	-4.23*	-1.45	16.09	8.21	13.48
11	YP $\otimes$ 4 #07-4 x KDMI -10	-7.06**	-7.41**	-6.72**	-6.05**	-7.04**	-4.35*	6.37	1.43	6.37
12	YP $\otimes$ 4 #07-4 x CI-5	-4.48**	-4.48*	-4.48*	-3.23	-3.57	-2.17	0	-5.36	-0.75
13	YP $\otimes$ 4 #07-5 x Prabha	-2.96*	-3.68*	-2.24	-1.41	-1.41	1.45	15.73	12.99	7.49
14	YP $\otimes$ 4 #07-5 x KDMI -10	-2.60	-2.96	-2.24	-1.41	-1.41	1.45	1.18	1.18	-3.75
15	YP $\otimes$ 4 #07-5 x CI-5	-2.99*	-2.99	-2.99	-2.13	-2.82	0	-2.78	-3.54	-8.24
16	YP $\otimes$ 4 #07-6 x Prabha	-5.07**	-6.43**	-2.24	3.14	2.07	7.25**	7.06	1.87	2.25
17	YP $\otimes$ 4 #07-6 x KDMI-10	-6.18**	-7.86**	-3.73*	-5.92**	-6.9**	-2.17	-2.3	-4.85	-4.49
18	YP $\otimes$ 4 #07-6 x CI-5	-8.76**	-10.71**	-6.72**	-6.67**	-8.28**	-3.62	-10.42	-13.43	-13.11
19	YP $\otimes$ 4 #07-7 x Prabha	-6.52**	-7.86**	-3.73*	-4.2*	-4.86*	-0.72	15.2	11.63	7.87
20	YP $\otimes$ 4 #07-7 x KDMI-10	-4.00**	-5.71**	-1.49	-2.8	-3.47	0.72	4.3	3.49	0
21	YP $\otimes$ 4 #07-7 x CI-5	-4.38**	-6.43**	-2.24	-3.52	-4.86*	-0.72	10.63	8.91	5.24
22	YP $\otimes$ 4 #07-8 x Prabha	-0.37	-2.21	-0.75	0	-2.11	0.72	21.97*	21.22	11.24
23	YP $\otimes$ 4 #07-8 x KDMI-10	-1.50	-2.96	-2.24	0	-2.11	0.72	9.82	7.87	2.62

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Sl.No	Characters	Days to 50% tasseling			Days to 50% silking			Plant height (cm)		
	Single cross hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH
24	YP ⊗ 4 #07-8 x CI-5	-1.89	-2.99	-2.99	-0.72	-2.14	-0.72	15.96	14.8	7.49
25	YP ⊗ 4 #07-9 x Prabha	-2.26	-4.41*	-2.99	-2.51	-4.23*	-1.45	19.11	17.2	9.74
26	YP ⊗ 4 #07-9 x KDMI-10	-1.13	-2.96	-2.24	-1.08	-2.82	0	36.51**	35.43**	28.84**
27	YP ⊗ 4 #07-9 x CI-5	0.76	-0.75	-0.75	1.81	0.71	2.17	23.6*	23.6*	15.73
28	YP ⊗ 4 #07-10 x Prabha	-3.65*	-4.35*	-1.49	-1.75	-2.1	1.45	25.7	20.25	8.99
29	YP ⊗ 4 #07-10 x KDMI-10	-4.03**	-5.07**	-2.24	-3.16	-3.5	0	27.58**	19.29	13.48
30	YP ⊗ 4 #07-10 x CI-5	-5.15**	-6.52**	-3.73*	-3.89*	-4.9*	-1.45	22.72*	15.6	8.24
31	YP ⊗ 4 #07-11 x Prabha	-3.37*	-5.15**	-3.73*	-3.60	-5.63**	-2.90	5.35	1.14	-0.37
32	YP ⊗ 4 #07-11 x KDMI-10	-3.01*	-4.44*	-3.73*	-4.32*	-6.34**	-3.62	-4.45	-6.08	-7.49
33	YP ⊗ 4 #07-11 x CI-5	-3.4*	-4.48*	-4.48*	-2.90	-4.29*	-2.90	3.31	0.76	-0.75
34	YP ⊗ 4 #07-12 x Prabha	-2.24	-3.68*	-2.24	-3.25	-5.63**	-2.90	11.83	-1.27	16.85
35	YP ⊗ 4 #07-12 x KDMI-10	-2.62	-3.7*	-2.99	-1.08	-3.52	-0.72	-1.05	-10.76	5.62
36	YP ⊗ 4 #07-12 x CI-5	-2.26	-2.99	-2.99	-2.55	-4.29*	-2.90	-4.24	-14.24	1.50
37	YP ⊗ 4 #07-13 x Prabha	-5.11**	-5.8**	-2.99	-4.93**	-4.93*	-2.17	0.99	-3.04	-4.49
38	YP ⊗ 4 #07-13 x KDMI-10	-4.76**	-5.8**	-2.99	-4.23*	-4.23*	-1.45	4.06	2.28	0.75
39	YP ⊗ 4 #07-13 x CI-5	-8.82**	-10.14**	-7.46**	-8.51**	-9.15**	-6.52**	8.77	6.08	4.49
40	YP ⊗ 4 #07-14 x Prabha	0.00	-1.47	0.00	0.36	-1.41	1.45	12.41	0.65	15.36
41	YP ⊗ 4 #07-14 x KDMI-10	-1.87	-2.96	-2.24	-0.36	-2.11	0.72	3.57	-5.23	8.61
42	YP ⊗ 4 #07-14 x CI-5	-0.75	-1.49	-1.49	0.36	-0.71	0.72	10.79	0.65	15.36
43	YP ⊗ 4 #07-15 x Prabha	-4.48**	-5.88**	-4.48*	-4.96**	-5.63**	-2.90	24.86*	16.97	21.35*
44	YP ⊗ 4 #07-15 x KDMI-10	-1.87	-2.96	-2.24	-2.13	-2.82	0.00	15.25	10.47	14.61
45	YP ⊗ 4 #07-15 x CI-5	-0.75	-1.49	-1.49	0.00	0.00	1.45	7.40	2.17	5.99
46	YP ⊗ 4 #07-16 x Prabha	-1.87	-3.68*	-2.24	0.71	-0.7	2.17	34.33**	30.17*	17.98

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Sl.No	Characters	Days to 50% tasseling			Days to 50% silking			Plant height (cm)		
	Single cross hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH
47	YP ⊗ 4 #07-16 x KDMI-10	0.00	-1.48	-0.75	0.71	-0.7	2.17	26.4*	19.69	13.86
48	YP ⊗ 4 #07-16 x CI-5	-1.13	-2.24	-2.24	-2.16	-2.86	-1.45	24.53*	18.8	11.24
49	YP ⊗ 4 #07-17 x Prabha	-0.37	-0.74	0.75	1.07	0.00	2.90	3.04	-4.58	1.5
50	YP ⊗ 4 #07-17 x KDMI-10	-2.22	-2.22	-1.49	-1.78	-2.82	0.00	14.13	8.1	14.98
51	YP ⊗ 4 #07-17 x CI-5	-1.86	-2.22	-1.49	-1.08	-1.43	0.00	16.85	9.86	16.85
52	YP ⊗ 4 #07-18 x Prabha	0.00	-1.47	0.00	0.71	-0.7	2.17	44.84**	42.15**	28.84**
53	YP ⊗ 4 #07-18 x KDMI-10	-0.37	-1.48	-0.75	0.00	-1.41	1.45	24.85*	19.69	13.86
54	YP ⊗ 4 #07-18 x CI-5	-0.75	-1.49	-1.49	0.72	0.00	1.45	16.77	12.8	5.62
55	YP ⊗ 4 #07-19 x Prabha	0.75	-1.47	0.00	0.72	-1.41	1.45	21.04*	6.32	27.34*
56	YP ⊗ 4 #07-19 x KDMI-10	1.89	0.00	0.75	2.16	0.00	2.9	14.67	2.88	23.22*
57	YP ⊗ 4 #07-19 x CI-5	0.00	-1.49	-1.49	0.72	-0.71	0.72	1.79	-9.32	8.61
58	YP ⊗ 4 #07-20 x Prabha	-3.68*	-3.68*	-2.24	-3.52	-3.52	-0.72	8.51	0	7.49
59	YP ⊗ 4 #07-20 x KDMI-10	-4.8**	-5.15**	-3.73*	-3.52	-3.52	-0.72	4.99	-1.05	6.37
60	YP ⊗ 4 #07-20 x CI-5	-2.96*	-3.68*	-2.24	-1.42	-2.11	0.72	-0.19	-6.62	0.37
61	YP ⊗ 4 #07-21 x Prabha	-1.47	-1.47	0.00	-1.06	-1.41	1.45	-0.73	-11.11	1.87
62	YP ⊗ 4 #07-21 x KDMI-10	-3.32*	-3.68*	-2.24	-4.59*	-4.93*	-2.17	10.00	0.65	15.36
63	YP ⊗ 4 #07-21 x CI-5	-2.22	-2.94	-1.49	-1.78	-2.13	0.00	6.12	-3.59	10.49
64	YP ⊗ 4 #07-22 x Prabha	-4.76**	-5.11**	-2.99	-3.52	-3.52	-0.72	6.26	-1.75	4.87
65	YP ⊗ 4 #07-22 x KDMI-10	-5.15**	-5.84**	-3.73*	-2.82	-2.82	0.00	12.43	6.32	13.48
66	YP ⊗ 4 #07-22 x CI-5	-4.06**	-5.11**	-2.99	-2.13	-2.82	0.00	0.93	-5.26	1.12
67	YP ⊗ 4 #07-23 x Prabha	-3.62*	-5**	-0.75	-2.44	-3.45	1.45	6.18	-5.19	9.36
68	YP ⊗ 4 #07-23 x KDMI-10	-4.73**	-6.43**	-2.24	-3.83*	-4.83*	0.00	11.03	1.3	16.85
69	YP ⊗ 4 #07-23 x CI-5	-4.38**	-6.43**	-2.24	-3.86*	-5.52**	-0.72	6.09	-3.9	10.86
70	YP ⊗ 4 #07-24 x Prabha	-4.76**	-5.11**	-2.99	-5.3**	-5.63**	-2.9	16.54	11.28	10.86
71	YP ⊗ 4 #07-24 x KDMI-10	-5.88**	-6.57**	-4.48*	-6.71**	-7.04**	-4.35*	12.69	10.15	9.74

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Sl.No	Characters	Days to 50% tasseling			Days to 50% silking			Plant height (cm)		
	Single cross hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH
72	YP ⊗ 4 #07-24 x CI-5	-4.8**	-5.84**	-3.73*	-5.34**	-5.67**	-3.62	13.18	9.77	9.36
73	YP ⊗ 4 #07-25 x Prabha	-5.15**	-5.15**	-3.73*	-6.01**	-6.34**	-3.62	10.99	1.02	11.61
74	YP ⊗ 4 #07-25 x KDMI-10	-4.06**	-4.41*	-2.99	-6.01**	-6.34**	-3.62	10.75	3.05	13.86
75	YP ⊗ 4 #07-25 x CI-5	-4.44**	-5.15**	-3.73*	-5.34**	-5.67**	-3.62	5.69	-2.37	7.87
76	YP ⊗ 4 #07-26 x Prabha	-2.62	-4.41*	-2.99	-3.6	-5.63**	-2.9	19.84*	13.24	15.36
77	YP ⊗ 4 #07-26 x KDMI-10	-3.76*	-5.19**	-4.48*	-5.04**	-7.04**	-4.35*	19.39*	15.44	17.6
78	YP ⊗ 4 #07-26 x CI-5	-4.15**	-5.22**	-5.22**	-4.35*	-5.71**	-4.35*	5.75	1.47	3.37
79	YP ⊗ 4 #07-27 x Prabha	-1.92	-5.88**	-4.48*	-2.92	-6.34**	-3.62	21.67*	17.24	14.61
80	YP ⊗ 4 #07-27 x KDMI-10	-3.08*	-6.67**	-5.97**	-2.92	-6.34**	-3.62	14.17	12.64	10.11
81	YP ⊗ 4 #07-27 x CI-5	1.16	-2.24	-2.24	0.00	-2.86	-1.45	5.68	3.45	1.12
82	YP ⊗ 4 #07-28 x Prabha	-3.73*	-5.15**	-3.73*	-3.57	-4.93*	-2.17	19.32	16.12	5.24
83	YP ⊗ 4 #07-28 x KDMI-10	-3.37*	-4.44*	-3.73*	-3.57	-4.93*	-2.17	20.5*	14.57	8.99
84	YP ⊗ 4 #07-28 x CI-5	-1.50	-2.24	-2.24	-2.16	-2.86	-1.45	21.5*	16.4	8.99
85	YP ⊗ 4 #07-29 x Prabha	-2.60	-3.68*	-2.24	-4.59*	-4.93*	-2.17	46.58**	32.64**	20.22
86	YP ⊗ 4 #07-29 x KDMI-10	0.00	-0.74	0.00	-1.77	-2.11	0.72	39.56**	23.62*	17.6
87	YP ⊗ 4 #07-29 x CI-5	-0.37	-0.75	-0.75	-1.78	-2.13	0.00	42.6**	27.2*	19.1

*****-Significant At 5% Level **-Significant at 1% level

RH = Relative heterosis HB = Heterobeltiosis SH = Standard heterosis

Sl.No	Characters	Ear length (cm)			Ear circumference (cm)			Number of kernel rows per ear		
	Single cross hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH
1	YP ⊗ 4 #07-1 x Prabha	1.24	-4.68	-4.68	15.09*	11.72	11.72	1.93	1.54	1.54
2	YP ⊗ 4 #07-1 x KDMI -10	-4.32	-6.14	-6.14	11.68	11.27	12.09	-0.76	-2.24	0.77
3	YP ⊗ 4 #07-1 x CI-5	9.51	-2.34	-2.34	13.31*	9.16	9.16	-2.27	-3.73	-0.77
4	YP ⊗ 4 #07-2 x Prabha	2.86	-1.22	-5.26	3.44	1.50	-0.73	-2.75	-3.88	-4.62
5	YP ⊗ 4 #07-2 x KDMI -10	3.2	3.04	-0.88	4.80	3.27	4.03	-1.54	-4.48	-1.54
6	YP ⊗ 4 #07-2 x CI-5	14.77	4.27	0.00	5.00	2.25	0.00	-3.08	-5.97	-3.08
7	YP ⊗ 4 #07-3 x Prabha	15.08	9.93	-2.92	8.80	5.84	-0.37	0.8	-2.33	-3.08
8	YP ⊗ 4 #07-3 x KDMI -10	28.48**	17.93	13.45	13.51*	6.91	7.69	5.88	0.75	3.85
9	YP ⊗ 4 #07-3 x CI-5	24.49*	22.91	-1.17	13.71*	11.46	3.3	0.39	-4.48	-1.54
10	YP ⊗ 4 #07-4 x Prabha	7.31	1.17	0.88	12.78*	9.09	9.89	7.39	6.98	6.15
11	YP ⊗ 4 #07-4 x KDMI -10	5.37	3.52	3.22	6.91	6.91	7.69	-2.29	-4.48	-1.54
12	YP ⊗ 4 #07-4 x CI-5	-1.81	-12.32	-12.57	1.52	-2.55	-1.83	-6.11	-8.21	-5.38
13	YP ⊗ 4 #07-5 x Prabha	2.01	0.66	-11.11	8.02	7.39	1.1	-1.61	-5.43	-6.15
14	YP ⊗ 4 #07-5 x KDMI -10	-21.35*	-25.53*	-28.36*	-3.59	-7.27	-6.59	-5.14	-10.45*	-7.69
15	YP ⊗ 4 #07-5 x CI-5	9.25	4.42	-10.23	5.72	5.51	-1.83	-3.56	-8.96*	-6.15
16	YP ⊗ 4 #07-6 x Prabha	13.04	7.62	-4.97	11.74	7.39	1.1	0.8	-2.33	-3.08
17	YP ⊗ 4 #07-6 x KDMI-10	-6.98	-14.89	-18.13	0.39	-6.55	-5.86	-10.59*	-14.93**	-12.31**
18	YP ⊗ 4 #07-6 x CI-5	-0.55	-1.47	-21.35	-1.22	-4.35	-11.36	-7.45	-11.94**	-9.23*
19	YP ⊗ 4 #07-7 x Prabha	2.78	-1.99	-13.45	13.93*	8.17	1.83	-7.34	-7.69	-7.69
20	YP ⊗ 4 #07-7 x KDMI-10	0.83	-7.6	-11.11	3.95	-4.36	-3.66	-6.82	-8.21	-5.38
21	YP ⊗ 4 #07-7 x CI-5	2.95	1.82	-18.42	11.57	6.72	-1.1	-8.33*	-9.7*	-6.92
22	YP ⊗ 4 #07-8 x Prabha	32.6**	19.21	5.26	7.00	6.38	1.32	11.11*	4.65	3.85
23	YP ⊗ 4 #07-8 x KDMI-10	13.68	-1.52	-5.26	3.55	0.73	1.47	3.23	-4.48	-1.54
24	YP ⊗ 4 #07-8 x CI-5	44.99**	37.69**	7.89	13.06*	11.54	6.23	3.23	-4.48	-1.54
25	YP ⊗ 4 #07-9 x Prabha	10.02	7.28	-5.26	4.09	3.89	-2.2	-2.4	-5.43	-6.15
26	YP ⊗ 4 #07-9 x KDMI-10	20.13	12.46	8.19	13.75*	9.82	10.62	4.31	-0.75	2.31

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Sl.No	Characters	Ear length (cm)			Ear circumference (cm)			Number of kernel rows per ear		
	Single cross hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH
27	YP ⊗ 4 #07-9 x CI-5	18.2	14.29	-4.09	7.27	6.64	0.00	-1.18	-5.97	-3.08
28	YP ⊗ 4 #07-10 x Prabha	12.1	4.3	-7.89	14.52	10.51	4.03	5.69	0.78	0
29	YP ⊗ 4 #07-10 x KDMI-10	8.66	-2.74	-6.43	13.62*	6.18	6.96	1.99	-4.48	-1.54
30	YP ⊗ 4 #07-10 x CI-5	8.33	6.72	-16.37	15.85*	12.65	4.40	-3.59	-9.7*	-6.92
31	YP ⊗ 4 #07-11 x Prabha	6.8	3.97	-8.19	0.00	-2.23	-3.66	-0.81	-5.43	-6.15
32	YP ⊗ 4 #07-11 x KDMI-10	-3.74	-10.03	-13.45	-7.35	-8.36	-7.69	-1.99	-8.21	-5.38
33	YP ⊗ 4 #07-11 x CI-5	7.22	3.85	-13.16	0.00	-2.97	-4.4	-4.38	-10.45*	-7.69
34	YP ⊗ 4 #07-12 x Prabha	3.12	-2.65	-3.22	8.82	3.14	8.42	-0.75	-4.32	2.31
35	YP ⊗ 4 #07-12 x KDMI-10	-9.42	-10.88	-11.4	-2.49	-4.53	0.37	-9.89*	-11.51**	-5.38
36	YP ⊗ 4 #07-12 x CI-5	0.00	-10.59	-11.11	-1.85	-7.67	-2.93	-12.82**	-14.39**	-8.46
37	YP ⊗ 4 #07-13 x Prabha	1.18	-0.33	-11.99	4.63	3.83	-0.73	0.78	0.78	0
38	YP ⊗ 4 #07-13 x KDMI-10	2.89	-2.74	-6.43	5.22	2.55	3.30	-1.14	-2.99	0
39	YP ⊗ 4 #07-13 x CI-5	24.06*	18.77	1.75	11.67	9.96	5.13	-1.14	-2.99	0
40	YP ⊗ 4 #07-14 x Prabha	8.16	5.3	-7.02	15.77*	12.84	6.23	0.8	-2.33	-3.08
41	YP ⊗ 4 #07-14 x KDMI-10	10.24	3.04	-0.88	5.05	-0.87	-0.15	-5.88	-10.45*	-7.69
42	YP ⊗ 4 #07-14 x CI-5	15.16	11.54	-6.73	15.9*	13.83	5.49	-0.39	-5.22	-2.31
43	YP ⊗ 4 #07-15 x Prabha	-0.34	-3.64	-14.91	4.15	1.56	-4.4	-7	-12.4**	-13.08**
44	YP ⊗ 4 #07-15 x KDMI-10	5.73	-1.82	-5.56	12.1	5.82	6.59	3.23	-4.48	-1.54
45	YP ⊗ 4 #07-15 x CI-5	21.09	18.09	-2.63	15.04*	13.04	4.76	3.23	-4.48	-1.54
46	YP ⊗ 4 #07-16 x Prabha	30.29*	18.21	4.39	22.54**	16.34*	9.52	5.39	-1.55	-2.31
47	YP ⊗ 4 #07-16 x KDMI-10	26.61*	10.64	6.43	10.28	1.45	2.2	1.63	-6.72	-3.85
48	YP ⊗ 4 #07-16 x CI-5	33.07*	27.61	0	19.83**	14.62	6.23	1.63	-6.72	-3.85
49	YP ⊗ 4 #07-17 x Prabha	16.77	13.84	5.85	3.95	0.73	1.1	-0.4	-3.1	-3.85
50	YP ⊗ 4 #07-17 x KDMI-10	-9.74	-11.25	-14.62	-3.83	-4	-3.3	-6.25	-10.45*	-7.69
51	YP ⊗ 4 #07-17 x CI-5	17.75	8.49	0.88	7.02	2.92	3.3	0.78	-3.73	-0.77

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Sl.No	Characters	Ear length (cm)			Ear circumference (cm)			Number of kernel rows per ear		
	Single cross hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH
52	YP ⊗ 4 #07-18 x Prabha	33.91**	28.15*	13.16	19.25**	10.89	4.4	1.96	0.78	0
53	YP ⊗ 4 #07-18 x KDMI-10	10.41	1.52	-2.34	16.53*	5.09	5.86	-3.85	-6.72	-3.85
54	YP ⊗ 4 #07-18 x CI-5	14.71	13.04	-8.77	20.25**	12.65	4.4	-3.85	-6.72	-3.85
55	YP ⊗ 4 #07-19 x Prabha	3.04	-0.31	-5.85	2.82	-0.36	0.00	1.2	-2.33	-3.08
56	YP ⊗ 4 #07-19 x KDMI-10	-1.84	-2.74	-6.43	0.55	0.36	1.1	-4.72	-9.7*	-6.92
57	YP ⊗ 4 #07-19 x CI-5	-6.94	-14.86	-19.59	3.23	-0.73	-0.37	-5.51	-10.45*	-7.69
58	YP ⊗ 4 #07-20 x Prabha	4.5	0	-11.7	7.63	7	0.73	1.99	-0.78	-1.54
59	YP ⊗ 4 #07-20 x KDMI-10	-0.83	-8.81	-12.28	5.86	1.82	2.56	3.13	-1.49	1.54
60	YP ⊗ 4 #07-20 x CI-5	11.03	9.42	-11.7	1.78	1.57	-5.49	10.16*	5.22	8.46
61	YP ⊗ 4 #07-21 x Prabha	6.38	4.97	-7.31	9.06	5.86	5.86	7.76	2.33	1.54
62	YP ⊗ 4 #07-21 x KDMI-10	2.73	-2.74	-6.43	1.46	1.09	1.83	-4.8	-11.19*	-8.46
63	YP ⊗ 4 #07-21 x CI-5	17.08	11.9	-3.8	6.84	2.93	2.93	1.6	-5.22	-2.31
64	YP ⊗ 4 #07-22 x Prabha	-4.28	-11.08	-8.48	-2.44	-5.8	-4.76	-4.31	-5.43	-6.15
65	YP ⊗ 4 #07-22 x KDMI-10	-4.55	-7.67	-4.97	8.17	7.97	9.16	-4.62	-7.46	-4.62
66	YP ⊗ 4 #07-22 x CI-5	1.61	-10.51	-7.89	1.7	-2.54	-1.47	-2.31	-5.22	-2.31
67	YP ⊗ 4 #07-23 x Prabha	-8.84	-15.54	-12.57	0.91	-4.83	1.1	-11.11**	-12.12**	-10.77*
68	YP ⊗ 4 #07-23 x KDMI-10	-0.73	-4.24	-0.88	3.36	0.69	6.96	0.75	0	3.08
69	YP ⊗ 4 #07-23 x CI-5	-7.4	-18.64	-15.79	1.66	-4.83	1.1	-8.27*	-8.96*	-6.15
70	YP ⊗ 4 #07-24 x Prabha	26.8*	19.87	5.85	11.28	11.28	4.76	6.25	5.43	4.62
71	YP ⊗ 4 #07-24 x KDMI-10	4.68	-4.86	-8.48	0.38	-2.91	-2.2	-4.98	-7.46	-4.62
72	YP ⊗ 4 #07-24 x CI-5	20.67	20.45	-5.26	9.41	8.56	2.2	-3.45	-5.97	-3.08
73	YP ⊗ 4 #07-25 x Prabha	2.61	-2.32	-13.74	7.21	7	0.73	6.12	0.78	0
74	YP ⊗ 4 #07-25 x KDMI-10	5.65	-3.34	-7.02	8.47	4.73	5.49	4	-2.99	0

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Sl.No	Characters	Ear length (cm)			Ear circumference (cm)			Number of kernel rows per ear		
	Single cross hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH
75	YP ⊗ 4 #07-25 x CI-5	27.91*	26.74	1.17	15.52*	14.84	7.69	6.4	-0.75	2.31
76	YP ⊗ 4 #07-26 x Prabha	8.39	2.05	2.05	15.37*	12.59	11.36	6.07	1.55	0.77
77	YP ⊗ 4 #07-26 x KDMI-10	7.9	5.85	5.85	11.56	10.55	11.36	6.35	0	3.08
78	YP ⊗ 4 #07-26 x CI-5	1.97	-9.06	-9.06	7.07	3.7	2.56	-3.97	-9.7*	-6.92
79	YP ⊗ 4 #07-27 x Prabha	10.6	9	-0.88	11.88	10.94	6.23	3.53	2.33	1.54
80	YP ⊗ 4 #07-27 x KDMI-10	-8.12	-10.64	-14.04	5.89	3.27	4.03	-1.54	-4.48	-1.54
81	YP ⊗ 4 #07-27 x CI-5	-2.94	-9.65	-17.84	7.85	6.12	1.61	3.08	0	3.08
82	YP ⊗ 4 #07-28 x Prabha	15.54	4.64	-7.6	12.58	6.23	0	2.4	-0.78	-1.54
83	YP ⊗ 4 #07-28 x KDMI-10	8.71	-5.17	-8.77	10.93	1.45	2.2	5.1	0	3.08
84	YP ⊗ 4 #07-28 x CI-5	24.37	19.03	-6.73	21**	15.02	6.59	3.53	-1.49	1.54
85	YP ⊗ 4 #07-29 x Prabha	8.09	3.97	-8.19	11.07	9.34	2.93	0	-3.1	-3.85
86	YP ⊗ 4 #07-29 x KDMI-10	0.33	-7.29	-10.82	1.15	-3.64	-2.93	1.18	-3.73	-0.77
87	YP ⊗ 4 #07-29 x CI-5	32.72**	30.11*	6.14	11.55	10.67	2.56	1.18	-3.73	-0.77

***-**Significant At 5% Level **-Significant at 1% level

RH = Relative heterosis HB = Heterobeltiosis SH = Standard heterosis

Sl.No	Characters	Number kernels per row			100 grain weight (g)			Shelling percentage (%)		
	Single cross hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH
1	YP ⊗ 4 #07-1 x Prabha	12.87**	8.01	8.01	35.92**	9.38*	9.38*	-2.62	-4.77*	-4.77*
2	YP ⊗ 4 #07-1 x KDMI -10	4.47	1.69	7.42	17.36**	10.94*	10.94*	-0.6	-1.49	-1.49
3	YP ⊗ 4 #07-1 x CI-5	6.69	4.15	4.15	29.09**	10.94*	10.94*	-3.03	-4.59*	-4.59*
4	YP ⊗ 4 #07-2 x Prabha	7.24	5.84	-3.26	83.13**	72.73**	18.75**	-0.88	-3.65	-2.44
5	YP ⊗ 4 #07-2 x KDMI -10	6.71	-1.69	3.86	12.87*	0	-10.94*	-1.11	-2.59	-1.37
6	YP ⊗ 4 #07-2 x CI-5	8.21	4.67	-0.3	62.22**	58.7**	14.06**	-0.51	-2.71	-1.49
7	YP ⊗ 4 #07-3 x Prabha	19.37**	10.06	0.59	30.12**	22.73**	-15.63**	5.27**	4.55*	-0.06
8	YP ⊗ 4 #07-3 x KDMI -10	22.08**	5.62	11.57*	62.38**	43.86**	28.13**	5.14**	3.03	1.19
9	YP ⊗ 4 #07-3 x CI-5	19.79**	8.41	3.26	64.44**	60.87**	15.63**	1.06	-0.25	-3.46
10	YP ⊗ 4 #07-4 x Prabha	27.59**	25.39**	18.69**	44.9**	20.34**	10.94*	5.15**	3.44	2.21
11	YP ⊗ 4 #07-4 x KDMI -10	2.81	-2.53	2.97	25.86**	23.73**	14.06**	-0.42	-0.72	-1.91
12	YP ⊗ 4 #07-4 x CI-5	0	-0.31	-5.04	10.48*	-1.69	-9.38*	-1.65	-2.65	-3.81
13	YP ⊗ 4 #07-5 x Prabha	14.44**	2.92	-5.93	28.26**	11.32*	-7.81	11.85**	7.42**	2.68
14	YP ⊗ 4 #07-5 x KDMI -10	3.65	-12.36**	-7.42	3.64	0	-10.94*	4.13*	-1.27	-3.04
15	YP ⊗ 4 #07-5 x CI-5	11.46*	-1.56	-6.23	7.07	0	-17.19**	6.87**	2.03	-1.25
16	YP ⊗ 4 #07-6 x Prabha	17.57**	9.74	0.3	25.27**	9.62	-10.94*	7.19**	4.99*	0.36
17	YP ⊗ 4 #07-6 x KDMI-10	-11.4*	-22.47**	-18.1**	11.93*	7.02	-4.69	0.13	-3.22	-4.95*
18	YP ⊗ 4 #07-6 x CI-5	-4.42	-12.46*	-16.62**	-20.41**	-25**	-39.06**	-0.13	-2.77	-5.9**
19	YP ⊗ 4 #07-7 x Prabha	-3.3	-6.38	-8.61	61.04**	58.97**	-3.13	-1.01	-2.77	-3.64
20	YP ⊗ 4 #07-7 x KDMI-10	-6.57	-10.11*	-5.04	5.26	-12.28*	-21.88**	-2.69	-3.13	-3.99
21	YP ⊗ 4 #07-7 x CI-5	-4	-5.17	-7.42	23.81**	13.04*	-18.75**	1.06	-0.12	-1.01
22	YP ⊗ 4 #07-8 x Prabha	41.31**	22.73**	12.17**	5.75	-4.17	-28.13**	5.74**	5.25*	1.55
23	YP ⊗ 4 #07-8 x KDMI-10	18.01**	-3.37	2.08	-2.86	-10.53*	-20.31**	1.44	0.55	-1.25
24	YP ⊗ 4 #07-8 x CI-5	27.37**	8.72	3.56	34.04**	31.25**	-1.56	3.18	3.02	-0.3
25	YP ⊗ 4 #07-9 x Prabha	11.38*	3.25	-5.64	38.46**	38.46**	-15.63**	2.48	0.84	-0.42

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Sl.No	Characters	Number kernels per row			100 grain weight (g)			Shelling percentage (%)		
	Single cross hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH
26	YP ⊗ 4 #07-9 x KDMI-10	19.87**	4.21	10.09*	29.17**	8.77	-3.13	1.48	1.21	-0.06
27	YP ⊗ 4 #07-9 x CI-5	16.1**	5.61	0.59	45.88**	34.78**	-3.13	0.88	-0.12	-1.37
28	YP ⊗ 4 #07-10 x Prabha	30.56**	17.21**	7.12	37.5**	34.15**	-14.06**	-0.34	-0.92	-4.17
29	YP ⊗ 4 #07-10 x KDMI-10	15.47**	-2.53	2.97	26.53**	8.77	-3.13	-0.83	-1.58	-3.34
30	YP ⊗ 4 #07-10 x CI-5	10.6*	-2.49	-7.12	56.32**	47.83**	6.25	2	1.97	-1.31
31	YP ⊗ 4 #07-11 x Prabha	15.48**	2.92	-5.93	44.19**	31.91**	-3.13	2.76	2.22	-1.25
32	YP ⊗ 4 #07-11 x KDMI-10	7.2	-10.11*	-5.04	7.69	-1.75	-12.5**	-1.25	-2.06	-3.81
33	YP ⊗ 4 #07-11 x CI-5	7.12	-6.23	-10.68*	18.28**	17.02**	-14.06**	1.88	1.79	-1.49
34	YP ⊗ 4 #07-12 x Prabha	12.94**	6.3	10.09*	-3.03	-20**	-25**	-0.77	-1.59	-4.35*
35	YP ⊗ 4 #07-12 x KDMI-10	-9.22*	-10.11*	-5.04	2.56	0	-6.25	-0.15	-0.67	-2.44
36	YP ⊗ 4 #07-12 x CI-5	-11.64**	-15.19**	-12.17**	18.87**	5	-1.56	-0.09	-0.31	-3.1
37	YP ⊗ 4 #07-13 x Prabha	13.07**	9.79*	6.53	32.04**	6.25	6.25	1.74	-0.06	-0.95
38	YP ⊗ 4 #07-13 x KDMI-10	5.71	1.4	7.12	9.09*	3.13	3.13	-0.51	-0.96	-1.85
39	YP ⊗ 4 #07-13 x CI-5	9.88*	8.87	5.64	25.45**	7.81	7.81	0.4	-0.78	-1.67
40	YP ⊗ 4 #07-14 x Prabha	17.77**	9.74	0.3	65.96**	41.82**	21.88**	2.76	2.29	-1.31
41	YP ⊗ 4 #07-14 x KDMI-10	-4.18	-16.29**	-11.57*	5.36	3.51	-7.81	0.7	-0.18	-1.97
42	YP ⊗ 4 #07-14 x CI-5	15.5**	5.61	0.59	12.87*	3.64	-10.94*	1.08	0.92	-2.32
43	YP ⊗ 4 #07-15 x Prabha	-7.46	-19.48**	-26.41**	-14.61*	-24**	-40.63**	5.15*	3.12	-1.43
44	YP ⊗ 4 #07-15 x KDMI-10	19.18**	-2.25	3.26	34.58**	26.32**	12.5**	3.82	0.49	-1.31
45	YP ⊗ 4 #07-15 x CI-5	27.5**	9.03	3.86	45.83**	40**	9.38*	5.5**	2.83	-0.48
46	YP ⊗ 4 #07-16 x Prabha	31.15**	10.71*	1.19	27.47**	11.54*	-9.38*	0.34	0.19	-4.23
47	YP ⊗ 4 #07-16 x KDMI-10	17.25**	-6.46	-1.19	24.77**	19.3**	6.25	2.68	1.15	-0.66
48	YP ⊗ 4 #07-16 x CI-5	24.95**	3.74	-1.19	53.06**	44.23**	17.19**	3.07	2.28	-1.01

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Sl.No	Characters	Number kernels per row			100 grain weight (g)			Shelling percentage (%)		
	Single cross hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH
49	YP ⊗ 4 #07-17 x Prabha	11.79*	6.17	-2.97	-14.56**	-31.25**	-31.25**	1.92	-0.06	-0.6
50	YP ⊗ 4 #07-17 x KDMI-10	-3	-13.76**	-8.9	-14.05**	-18.75**	-18.75**	-0.15	-0.78	-1.31
51	YP ⊗ 4 #07-17 x CI-5	17.39**	9.35	4.15	3.64	-10.94*	-10.94*	4.59*	3.18	2.62
52	YP ⊗ 4 #07-18 x Prabha	15.17**	14.61**	4.75	64.56**	62.5**	1.56	-0.77	-1.77	-4.17
53	YP ⊗ 4 #07-18 x KDMI-10	0.15	-7.02	-1.78	27.84**	8.77	-3.13	-0.76	-1.09	-2.86
54	YP ⊗ 4 #07-18 x CI-5	5.43	2.8	-2.08	51.16**	41.3**	1.56	-1.07	-1.47	-3.87
55	YP ⊗ 4 #07-19 x Prabha	19.78**	8.12	-1.19	4.67	-17.65**	-12.5**	5.21**	5.11*	0.48
56	YP ⊗ 4 #07-19 x KDMI-10	3.97	-11.8**	-6.82	-13.6**	-20.59**	-15.63**	2.37	0.91	-0.89
57	YP ⊗ 4 #07-19 x CI-5	4.39	-7.48	-11.87*	28.07**	7.35	14.06**	2.57	1.85	-1.43
58	YP ⊗ 4 #07-20 x Prabha	16.89**	12.34*	2.67	-3.77	-23.88**	-20.31**	1.61	-0.89	-0.36
59	YP ⊗ 4 #07-20 x KDMI-10	14.69**	3.09	8.9	8.06	0	4.69	-0.15	-1.3	-0.77
60	YP ⊗ 4 #07-20 x CI-5	35.21**	27.41**	21.36**	18.58**	0	4.69	5.59**	3.62	4.17
61	YP ⊗ 4 #07-21 x Prabha	34.93**	19.16**	8.9	21.05**	-8*	7.81	1.49	1.24	-2.74
62	YP ⊗ 4 #07-21 x KDMI-10	-4.39	-20.51**	-16.02**	4.55	-8*	7.81	-0.43	-1.52	-3.28
63	YP ⊗ 4 #07-21 x CI-5	22.08**	5.92	0.89	25.62**	1.33	18.75**	1.98	1.6	-1.67
64	YP ⊗ 4 #07-22 x Prabha	2.61	2.27	-6.53	12.96**	-11.59**	-4.69	-5.49**	-7**	-8.16**
65	YP ⊗ 4 #07-22 x KDMI-10	-2.11	-8.99*	-3.86	0.00	-8.7*	-1.56	-0.82	-1.09	-2.32
66	YP ⊗ 4 #07-22 x CI-5	8.13	5.61	0.59	-0.87	-17.39**	-10.94*	1.98	0.97	-0.3
67	YP ⊗ 4 #07-23 x Prabha	-14.29**	-18.66**	-17.21**	19.59**	0	-9.38*	-0.76	-3.2	-2.68
68	YP ⊗ 4 #07-23 x KDMI-10	7.01	5.06	10.98*	-7.83	-8.62	-17.19**	1.35	0.18	0.72
69	YP ⊗ 4 #07-23 x CI-5	-5.12	-8.16	-6.53	-3.85	-13.79**	-21.88**	-0.03	-1.9	-1.37
70	YP ⊗ 4 #07-24 x Prabha	35.28**	27.6**	16.62**	57.89**	53.85**	-6.25	6.95**	6.55**	1.85
71	YP ⊗ 4 #07-24 x KDMI-10	3.66	-8.43	-3.26	25.53**	3.51	-7.81	3.27	1.52	-0.3
72	YP ⊗ 4 #07-24 x CI-5	12.12**	3.74	-1.19	63.86**	47.83**	6.25	1.68	0.68	-2.56
73	YP ⊗ 4 #07-25 x Prabha	28.23**	14.29**	4.45	24**	1.64	-3.13	6.13**	5.97**	1.61

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Sl.No	Characters	Number kernels per row			100 grain weight (g)			Shelling percentage (%)		
	Single cross hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH
74	YP ⊗ 4 #07-25 x KDMI-10	21.27**	1.69	7.42	33.9**	29.51**	23.44**	2.49	1.27	-0.54
75	YP ⊗ 4 #07-25 x CI-5	32.38**	15.89**	10.39*	27.1**	11.48*	6.25	3.87	3.39	0.06
76	YP ⊗ 4 #07-26 x Prabha	30.92**	17.53**	7.42	46**	19.67**	14.06**	1.93	1.55	-2.21
77	YP ⊗ 4 #07-26 x KDMI-10	24.79**	5.34	11.28*	30.51**	26.23**	20.31**	3.8	2.79	0.95
78	YP ⊗ 4 #07-26 x CI-5	10.25*	-2.8	-7.42	27.1**	11.48*	6.25	3.77	3.51	0.18
79	YP ⊗ 4 #07-27 x Prabha	21.65**	19.48**	9.2	24**	1.64	-3.13	0.25	-0.19	-3.75
80	YP ⊗ 4 #07-27 x KDMI-10	7.2	-1.69	3.86	8.47	4.92	0	-3.67	-4.55*	-6.26**
81	YP ⊗ 4 #07-27 x CI-5	20.71**	16.2**	10.68*	30.84**	14.75**	9.38*	3.82	3.63	0.3
82	YP ⊗ 4 #07-28 x Prabha	19.65**	11.69*	2.08	102.56**	102.56**	23.44**	2.67	-0.06	0.89
83	YP ⊗ 4 #07-28 x KDMI-10	20.06**	5.06	10.98*	43.75**	21.05**	7.81	1.08	-0.3	0.66
84	YP ⊗ 4 #07-28 x CI-5	25.17**	14.64**	9.2	67.06**	54.35**	10.94*	2.47	0.35	1.31
85	YP ⊗ 4 #07-29 x Prabha	13.99**	5.84	-3.26	28.21**	28.21**	-21.88**	6.74**	5.67*	1.01
86	YP ⊗ 4 #07-29 x KDMI-10	13.55**	-1.12	4.45	16.67**	-1.75	-12.5**	3.85	1.46	-0.36
87	YP ⊗ 4 #07-29 x CI-5	20**	9.35	4.15	38.82**	28.26**	-7.81	3.88	2.22	-1.07

*****-Significant At 5% Level   **-Significant at 1% level

RH = Relative heterosis   HB = Heterobeltiosis   SH = Standard heterosis

Sl.No	Characters	Grain yield per plant (g)			Fodder yield (t/ha)			Grain yield (q/ha)		
	Single cross hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH
1	YP ⊗ 4 #07-1 x Prabha	56.57**	52.73**	52.73**	111.76**	107.69**	107.69**	32.62**	27.33*	27.33*
2	YP ⊗ 4 #07-1 x KDMI -10	44.04**	34.11**	55.57**	44**	29.9**	61.54**	17.36	9.26	26.75
3	YP ⊗ 4 #07-1 x CI-5	70.53**	52.76**	52.76**	37.18**	37.18**	37.18**	42.86**	24.41	24.41
4	YP ⊗ 4 #07-2 x Prabha	50.97**	49.75**	44.73**	52.94**	27.68**	83.33**	25.26*	25.09	15.42
5	YP ⊗ 4 #07-2 x KDMI -10	43.59**	31.61**	52.68**	4.31	-2.68	39.74**	19.03	6.85	23.96
6	YP ⊗ 4 #07-2 x CI-5	67.93**	52.74**	47.62**	-13.68	-26.79**	5.13	41.51**	27.63	17.77
7	YP ⊗ 4 #07-3 x Prabha	70.49**	56.64**	48.95**	61.76**	46.67**	41.03**	41.7**	29.91*	19.55
8	YP ⊗ 4 #07-3 x KDMI -10	68.46**	42.05**	64.79**	83.54**	49.48**	85.9**	43.18**	18.93	37.97**
9	YP ⊗ 4 #07-3 x CI-5	88.43**	87.88**	49.62**	53.96**	37.18**	37.18**	61.15**	58.48**	21.58
10	YP ⊗ 4 #07-4 x Prabha	70.04**	66.54**	65.16**	68.05**	51.06**	82.05**	47.62**	43.17**	40.2**
11	YP ⊗ 4 #07-4 x KDMI -10	40.48**	30.29**	51.14***	1.57	0	24.36*	13.41	4.58	21.31
12	YP ⊗ 4 #07-4 x CI-5	61.05**	44.8**	43.61**	38.37**	26.6**	52.56**	31.74*	15.76	13.36
13	YP ⊗ 4 #07-5 x Prabha	61.51**	49.94**	42.58**	72.8**	44**	38.46**	34.49*	22.38	12.62
14	YP ⊗ 4 #07-5 x KDMI -10	41.91**	20.78*	40.11**	-17.01	-37.11**	-21.79	15	-5.1	10.09
15	YP ⊗ 4 #07-5 x CI-5	80.13**	77.58**	44.67**	3.13	-15.38	-15.38	49.75**	48.48**	12.04
16	YP ⊗ 4 #07-6 x Prabha	60.8**	53.86**	46.3**	14.46	4.4	21.79	35.27**	27.99	17.78
17	YP ⊗ 4 #07-6 x KDMI-10	33.34**	16.6	35.26**	13.83	10.31	37.18**	0.04	-14.57	-0.9
18	YP ⊗ 4 #07-6 x CI-5	69**	61.5**	40.31**	-26.63**	-31.87**	-20.51	35.26*	28.72	5.7
19	YP ⊗ 4 #07-7 x Prabha	45.41**	41.17**	42.55**	93.33**	54.67**	48.72**	14.46	10.01	9.77
20	YP ⊗ 4 #07-7 x KDMI-10	32.14**	23.58*	43.36**	12.68	-17.53	2.56	6.32	-1.11	14.72
21	YP ⊗ 4 #07-7 x CI-5	56.78**	39.85**	41.22**	80.49**	42.31**	42.31**	27.16*	10.85	10.61
22	YP ⊗ 4 #07-8 x Prabha	94.45**	71.65**	63.22**	110.46**	106.41**	106.41**	77.03**	51.21**	39.15**
23	YP ⊗ 4 #07-8 x KDMI-10	59.21**	29.56**	50.29**	108**	87.63**	133.33**	33.62*	4.35	21.05
24	YP ⊗ 4 #07-8 x CI-5	96.37**	88.46**	49.2**	39.74**	39.74**	39.74**	75.07**	64.46**	21.99
25	YP ⊗ 4 #07-9 x Prabha	60.47**	50.46**	43.07**	138.24**	116**	107.69**	33.3*	22.47	12.7

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Sl.No	Characters	Grain yield per plant (g)			Fodder yield (t/ha)			Grain yield (q/ha)		
	Single cross hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH
26	YP ⊗ 4 #07-9 x KDMI-10	57.66**	35.39**	57.05**	146.84**	101.03**	150**	36.32**	13.44	31.6*
27	YP ⊗ 4 #07-9 x CI-5	81.23**	76.81**	47.15**	58.27**	41.03**	41.03**	58**	55.03**	19.48
28	YP ⊗ 4 #07-10 x Prabha	78.19**	62.16**	54.2**	136.7**	72.0**	65.38**	53.01**	37.56**	26.59**
29	YP ⊗ 4 #07-10 x KDMI-10	54.32**	29.03**	49.67**	145.8**	65.98**	106.41**	28.17*	4.65	21.41
30	YP ⊗ 4 #07-10 x CI-5	78.08**	76.75**	39.93**	251.79**	152.56**	152.56**	49.87**	49.13**	10.62
31	YP ⊗ 4 #07-11 x Prabha	64.88**	48.8**	41.5**	-0.75	-12	-15.38	36.5*	22.3	12.54
32	YP ⊗ 4 #07-11 x KDMI-10	44.87**	20.24*	39.48**	8.39	-13.4	7.69	20.01	-2.3	13.34
33	YP ⊗ 4 #07-11 x CI-5	79.53**	76.56**	39.78**	47.06**	28.21*	28.21*	48.2**	46.91*	8.97
34	YP ⊗ 4 #07-12 x Prabha	55.25**	45.27*	58.52**	56.42**	34.62**	79.49**	30.26*	19.61	31.58*
35	YP ⊗ 4 #07-12 x KDMI-10	24.48**	20.78*	40.11**	22.39**	18.27*	57.69**	0.02	-2.57	13.02
36	YP ⊗ 4 #07-12 x CI-5	45.5**	25.53*	36.98**	-7.69	-19.23*	7.69	17.34	-1.77	8.05
37	YP ⊗ 4 #07-13 x Prabha	56.45**	53.32**	51.87**	44.94**	25.24**	65.38**	32.24**	27.88*	26
38	YP ⊗ 4 #07-13 x KDMI-10	42.02**	31.64**	52.71**	79**	73.79**	129.49**	17.53	8.68	26.08
39	YP ⊗ 4 #07-13 x CI-5	69.9**	52.85**	51.4**	43.65**	26.21**	66.67**	45.34**	27.38*	25.51
40	YP ⊗ 4 #07-14 x Prabha	62.35**	53.75**	46.2**	41.76**	20.56*	65.38**	38.21**	28.99	18.71
41	YP ⊗ 4 #07-14 x KDMI-10	39.19**	20.59*	39.89**	40.2**	33.64**	83.33**	11.05	-6.3	8.69
42	YP ⊗ 4 #07-14 x CI-5	81.27**	75.04**	48.79**	39.46**	20.56*	65.38**	55.85**	50.39**	19.95
43	YP ⊗ 4 #07-15 x Prabha	56.7**	39.69**	32.83**	216.39**	157.33**	147.44**	23.66	6.64	-1.87
44	YP ⊗ 4 #07-15 x KDMI-10	58.25**	29.91**	50.7**	52.78**	13.4	41.03**	33.13*	4.83	21.61
45	YP ⊗ 4 #07-15 x CI-5	96.85**	90.98**	51.19**	76**	41.03**	41.03**	75.87**	66.99**	23.87
46	YP ⊗ 4 #07-16 x Prabha	77.08**	55.25**	47.63**	164.22**	92**	84.62**	56.3**	31.25*	20.78
47	YP ⊗ 4 #07-16 x KDMI-10	56.09**	26.25**	46.45**	93.89**	30.93**	62.82**	31.25*	0.99	17.16
48	YP ⊗ 4 #07-16 x CI-5	92.88**	83.72**	45.44**	92.86**	38.46**	38.46**	71.73**	58.24**	17.37

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Sl.No	Characters	Grain yield per plant (g)			Fodder yield (t/ha)			Grain yield (q/ha)		
	Single cross hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH
49	YP ⊗ 4 #07-17 x Prabha	55.95**	52.52**	45.03**	38.46**	33.33**	38.46**	28.56*	26.15	16.09
50	YP ⊗ 4 #07-17 x KDMI-10	35.71**	21.03*	40.4**	23.6**	13.4	41.03**	7.11	-5.56	9.56
51	YP ⊗ 4 #07-17 x CI-5	79.35**	67.76**	52.51**	103.77**	100**	107.69**	52.94**	40.52**	24.45
52	YP ⊗ 4 #07-18 x Prabha	58.3**	57.33**	51.47**	243.93**	145.33**	135.9**	34.73**	33.12*	25.51
53	YP ⊗ 4 #07-18 x KDMI-10	38.01**	26.27**	46.48**	151.16**	67.01**	107.69**	11.04	0.64	16.75
54	YP ⊗ 4 #07-18 x CI-5	65.19**	50.51**	44.9**	172.73**	92.31**	92.31**	38.57**	23.79	16.71
55	YP ⊗ 4 #07-19 x Prabha	64.79**	54.28**	46.7**	29.68**	-1.39	82.05**	40.35**	27.77	17.58
56	YP ⊗ 4 #07-19 x KDMI-10	41.14**	21.03*	40.4**	45.23**	21.53**	124.36**	15.99	-4.24	11.08
57	YP ⊗ 4 #07-19 x CI-5	76.35**	72.31**	42.95**	-1.8	-24.31**	39.74**	44.74**	43.44*	8.34
58	YP ⊗ 4 #07-20 x Prabha	56.22**	54.31**	46.74**	63.29**	55.42**	65.38**	34.11**	31.72*	21.21
59	YP ⊗ 4 #07-20 x KDMI-10	50.05**	35.03**	56.64**	-11.11	-17.53	2.56	24.49*	9.86	27.44*
60	YP ⊗ 4 #07-20 x CI-5	104.33**	89.35**	75.66**	-3.11	-6.02	0	88.21**	72.77**	53.3**
61	YP ⊗ 4 #07-21 x Prabha	79.77**	63.92**	55.87**	-13.82*	-38.01**	35.9**	60.42**	40.6**	29.39*
62	YP ⊗ 4 #07-21 x KDMI-10	42.95**	19.73*	38.9**	-22.39**	-39.18**	33.33**	16.47	-6.98	7.91
63	YP ⊗ 4 #07-21 x CI-5	88.18**	87.18**	48.18**	12.45*	-18.13**	79.49**	67.47**	61.96**	20.13
64	YP ⊗ 4 #07-22 x Prabha	47.15**	45.36**	41.68**	4.92	-11.11	23.08*	18.51	16.39	11.08
65	YP ⊗ 4 #07-22 x KDMI-10	35.06**	24.27*	44.16**	58.05**	50**	107.69**	8.79	-0.85	15.01
66	YP ⊗ 4 #07-22 x CI-5	66.34**	50.73**	46.9**	37.63**	18.52*	64.1**	41.3**	25.56	19.83
67	YP ⊗ 4 #07-23 x Prabha	34.97**	29.63**	33.86**	47.06**	16.28*	92.31**	7.39	3.04	3.19
68	YP ⊗ 4 #07-23 x KDMI-10	46.21**	38.19**	60.3**	19.47**	4.65	73.08**	25.45*	16.87	35.58**
69	YP ⊗ 4 #07-23 x CI-5	57.18**	38.84**	43.37**	35.27**	8.53	79.49**	28.31*	11.67	11.84
70	YP ⊗ 4 #07-24 x Prabha	78.89**	74.93**	66.34**	29.23*	12	7.69	54.84**	51.89**	39.78**
71	YP ⊗ 4 #07-24 x KDMI-10	38.06**	23.11*	42.82**	36.84**	7.22	33.33**	12.87	-0.5	15.42

Contd…

Sl.No	Characters	Grain yield per plant (g)			Fodder yield (t/ha)			Grain yield (q/ha)		
	Single cross hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH
72	YP ⊗ 4 #07-24 x CI-5	74.28**	63.04**	48.18**	118.05**	85.9**	85.9**	44.69**	32.96*	17.7
73	YP ⊗ 4 #07-25 x Prabha	78.64**	59.81**	51.96**	13.1	2.15	21.79	53.98**	36.23*	25.37
74	YP ⊗ 4 #07-25 x KDMI-10	59.11**	31.02**	51.99**	14.74	12.37	39.74**	35.58**	9.17	26.65
75	YP ⊗ 4 #07-25 x CI-5	107.7**	102.29**	60.15**	89.47**	74.19**	107.69**	86.77**	82.54**	35.4**
76	YP ⊗ 4 #07-26 x Prabha	79.3**	62.64**	54.65**	30.95**	18.28	41.03**	53.3**	37.91*	26.91*
77	YP ⊗ 4 #07-26 x KDMI-10	71.56**	43.02**	65.91**	2.11	0	24.36*	45.48**	18.85	37.88**
78	YP ⊗ 4 #07-26 x CI-5	78.47**	76.49**	39.72**	-1.75	-9.68	7.69	49.43**	48.79**	10.37
79	YP ⊗ 4 #07-27 x Prabha	65.61**	64.15**	56.09**	3.23	0	2.56	44.02**	42.76**	31.37*
80	YP ⊗ 4 #07-27 x KDMI-10	43.53**	29.56**	50.29**	45.76**	32.99**	65.38**	19.5	6.31	23.33
81	YP ⊗ 4 #07-27 x CI-5	85.59**	71.43**	60.15**	20.25*	18.75	21.79	64.53**	49.76**	35.4**
82	YP ⊗ 4 #07-28 x Prabha	63.82**	55.9**	48.24**	35.77**	24*	19.23	39.39**	31.28*	20.81
83	YP ⊗ 4 #07-28 x KDMI-10	58.78**	38.18**	60.29**	25.79**	3.09	28.21*	37.41**	16.86	35.57**
84	YP ⊗ 4 #07-28 x CI-5	93.34**	85.76**	59.56**	37.14**	23.08*	23.08*	68.79**	61.38**	31.23*
85	YP ⊗ 4 #07-29 x Prabha	60.99**	50.2**	42.82**	122.22**	100**	92.31**	36.37**	26.02	15.97
86	YP ⊗ 4 #07-29 x KDMI-10	55.86**	33.25**	54.57**	84.71**	49.48**	85.9**	28.62*	7.58	24.8
87	YP ⊗ 4 #07-29 x CI-5	88.69**	85.05**	52.37**	49.28**	32.05**	32.05**	63.45**	59.38**	24.41

RH = Relative heterosis HB = Heterobeltiosis SH = Standard heterosis

4.8.3 Plant height

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -10.42 (YP⊗4#07-6 x CI-5) to 46.58 (YP⊗4#07-29 x Prabha), -14.24 (YP⊗4#07-12 x CI-5) to 42.15 (YP⊗4#07-18 x Prabha) and -13.11 (YP⊗4#07-6 x CI-5) to 28.84 (YP⊗4#07-18 x Prabha and YP⊗4#07-9 x KDMI-10) percent respectively. Twenty-five crosses exhibited significantly positive heterosis over mid parent, nine crosses over better parent and seven crosses over best check. None of the crosses showed significant mid parent, better parent and standard check in positive direction. The highest positive significant standard heterosis was manifested by YP⊗4#07-9 x KDMI-10 and YP⊗4#07-18 x Prabha (28.84%) and the lowest positive standard heterosis was manifested by YP⊗4#07-7 x KDMI-10.

4.8.4 Ear length

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -21.35 (YP⊗4#07-5 x KDMI-10) to 44.99 (YP⊗4#07-8 x CI-5), -25.53 (YP⊗4#07-5 x KDMI-10) to 37.69 (YP⊗4#07-8 x CI-5) and -28.26 (YP⊗4#07-5 x KDMI-10) to 13.45 (YP⊗4#07-3 x KDMI-10) per cent respectively. Twelve crosses exhibited significantly positive heterosis over the mid parent, three crosses over the better parent and none of the crosses over the standard parent. Only one cross YP⊗4#07-5 x KDMI-10 showed significantly negative heterosis over mid parent, better parent and standard check. The highest standard heterosis was manifested by YP⊗4#07-3 x KDMI-10 and the lowest standard heterosis by YP⊗4#07-2 x CI-5 and YP⊗4#07-16 x CI-5 in the positive direction. The highest negative standard heterosis on the other hand was observed in cross YP⊗4#07-5 x KDMI-10 (-28.36%).

4.8.5 Ear circumference

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -7.35 (YP⊗4#07-11 x KDMI-10) to 22.56 (YP⊗4#07-16 x Prabha), -8.36 (YP⊗4#07-11 x KDMI-10) to 16.34 (YP⊗4#07-16 x Prabha) and -11.36 (YP⊗4#07-6 x CI-5) to 12.09 (YP⊗4#07-1 x KDMI-10) per cent respectively. Twenty-two crosses exhibited significant positive heterosis over mid parent, one cross (YP⊗4#07-16 x Prabha) over better parent and none of the crosses showed significant over the standard check. None of the crosses showed significant negative heterosis over the mid parent, better parent and standard parent. The highest standard heterosis was manifested by YP⊗4#07-1 x KDMI-10 (12.09%) and lowest standard heterosis by YP⊗4#07-2 x CI-5, YP⊗4#07-9 x CI-5, YP⊗4#07-19 x Prabha and YP⊗4#07-28 x Prabha.

4.8.6 Number of kernel rows per ear

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -12.82 (YP⊗4#07-12 x CI-5) to 11.11 (YP⊗4#07-8 x Prabha), -14.93 (YP⊗4#07-6 x KDMI-10) to 6.98 (YP⊗4#07-4 x Prabha) and -13.08 (YP⊗4#07-15 x Prabha) to 8.46 (YP⊗4#07-20 x CI-5) per cent respectively. Out of 87 crosses, two and six crosses exhibited significant positive and negative heterosis over mid parent. Four and 18 crosses exhibited significant negative heterosis over standard check and better parent respectively.

4.8.7 Number of kernels per row

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -14.29 (YP⊗4#07-23 x Prabha) to 41.31 (YP⊗4#07-8 x Prabha), -22.47 (YP⊗4#07-6 x KDMI-10) to 27.6 (YP⊗4#07-24 x Prabha) and -26.41 (YP⊗4#07-15 x Prabha) to 21.36 (YP⊗4#07-20 x CI-5) per cent respectively. Fifty seven crosses showed significantly positive heterosis over mid parent, 17 crosses over better parent and 12 crosses over standard check respectively. Four crosses showed significantly negative heterosis over mid parent, 14 crosses over better parent and nine crosses over standard check.

4.8.8 100-grain weight

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -20.41 (YP⊗4#07-6 x CI-5) to 102.56 (YP⊗4#07-28 x Prabha), -31.25 (YP⊗4#07-17 x Prabha) to 102.56 (YP⊗4#07-28 x Prabha) and -40.63 (YP⊗4#07-15 x Prabha) to 28.13 (YP⊗4#07-3 x KDMI-10) per cent respectively. Sixty-three crosses exhibited significant positive heterosis over the mid parent, 41 crosses over better parent and 19 crosses over the standard check. Five crosses exhibited significantly negative heterosis over mid parent, 14 crosses over better parent and 30 crosses over standard check. The lowest positive heterosis was manifested by YP⊗4#07-27 x KDMI-10 (0%).

4.8.9 Shelling percentage

The percentage of heterosis over shelling percentage over mid parent, better parent and commercial parent ranged from -5.49 (YP⊗4#07-22 x Prabha) to 11.85 (YP⊗4#07-5 x Prabha), -7 (YP⊗4#07-22 x Prabha) to 7.42 (YP⊗4#07-5 x Prabha) and -8.16 (YP⊗4#07-22 x Prabha) to 4.17 (YP⊗4#07-20 x CI-5) per cent respectively. Sixteen crosses exhibited significant positive heterosis over the mid parent, eight over better parent and none over standard check, while one crosses exhibited negative heterosis over the mid parent, four over better parent and seven over standard check.

4.8.10 Grain yield per plant

The percentage of heterosis over mid parent, better parent and commercial checks ranged from 24.48 (YP⊗4#07-12 x KDMI-10) to 107.7 (YP⊗4#07-25 x CI-5), 19.73 (YP⊗4#07-21 x KDMI-10) to 102.29 (YP⊗4#07-25 x CI-5) and 32.83 (YP⊗4#07-15 x Prabha) to 75.66 (YP⊗4#07-20 x CI-5) per cent respectively. Eighty-seven crosses exhibited significantly positive heterosis over mid parent, 86 crosses over better parent and 87 crosses over standard check.

4.8.11 Fodder yield per hectare

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -26.63 (YP⊗4#07-6 x CI-5) to 251.79 (YP⊗4#07-10 x CI-5), -39.18 (YP⊗4#07-21 x KDMI-10) to 157.33 (YP⊗4#07-15 x Prabha) and -21.79 (YP⊗4#07-5 x KDMI-10) to 152.56 (YP⊗4#07-10 x Prabha) per cent respectively. Sixty-two crosses exhibited significantly positive heterosis over mid parent, 52 crosses over better parent and 70 crosses over standard check. Three crosses exhibited significantly negative heterosis over mid parent, 8 crosses over better parent and none of the crosses over standard heterosis was significant in negative direction. The lowest standard heterosis (0%) was expressed by YP⊗4#07-20 x CI-5.

4.8.12 Grain yield per hectare

The percentage of heterosis over mid parent, better parent and commercial checks ranged from 0.02 (YP⊗4#07-12 x KDMI-10) to 88.21 (YP⊗4#07-20 x CI-5), -14.57 (YP⊗4#07-6 x KDMI-10) to 82.54 (YP⊗4#07-25 x CI-5) and -1.87 (YP⊗4#07-15 x Prabha) to 53.3 (YP⊗4#07-20 x CI-5) per cent respectively. Sixty-five crosses exhibited significantly positive heterosis over mid parent, 35 crosses over better parent and 18 crosses over standard check. None of the crosses showed significant negative heterosis over mid parent, better parent and standard check respectively. The lowest standard heterosis (-0.9%) was expressed by YP⊗4#07-6 x KDMI-10.

4.9 Inter character correlation

Selection for specific character is known to result in correlated response in certain other characters. Generally plant breeders make selection for one or two attributes at a time then it becomes important to know the effect on other characters. Improvement in yield is the most important target character in most of the crops. It is a complex one and can be achieved by direct selection through other easily observed characters. But this needs a good understanding of association of different traits with yield and their possible association among themselves. The phenotypic and genotypic correlations between grain yield and 11 yield component traits are computed and presented in Table 12 and 13 respectively. Phenotypic correlation coefficient were generally lower than genotypic correlation coefficients (Fig 3).

4.9.1 Days to 50 per cent tasseling

Days to 50 per cent tasseling showed negative and significant association with ear circumference (-0.277, -0.304), number of kernels per row (-0.215, -0.254), 100-grain weight (-0.236, -0.329), grain yield per plant (-0.370, -0.606) and grain yield per hectare (-0.248, -0.571) and positively significant for days to 50 per cent silking (0.804, 0.919) at phenotypic and genotypic levels respectively.

4.9.2 Days to 50 per cent silking

Days to 50 per cent silking showed negatively significant association with 100-grain weight (-0.205, -0.361), grain yield per plant (-0.278, -0.442) and grain yield per hectare (-0.223, -0.403) at phenotypic an genotypic level whereas for ear circumference (-0.223) showed negatively significant association at phenotypic level, while for number of kernels per row (-0.202) and shelling percentage (-0.202) showed negatively significant association at genotypic level.

4.9.3 Plant height

Plant height showed highly significant positive correlation with ear length (0.447, 0.233), number of kernels per row (0.341, 0.627), 100-grain weight (0.369, 0.716), shelling percentage (0.217, 0.362), grain yield per plant (0.344, 0.827), fodder yield per hectare (0.575, 0.998) and grain yield per hectare (0.297, 0.946) at phenotypic and genotypic level whereas ear circumference (0.565) showed significant positive correlation at phenotypic level and number of kernel per ear (0.906) at genotypic level.

4.9.4 Ear length

Ear length showed highly significant positive correlation with plant height (0.447, 0.233), ear circumference (0.741, 0.720), number of kernels per row (0.449, 0.412), 100-grain weight (0.327, 0.362), shelling percentage (0.216, 0.899), grain yield per plant (0.442, 0.948), fodder yield per hectare (0.378, 0.958) and grain yield per hectare (0.515, 0.911) at phenotypic and genotypic level whereas number of kernel rows per ear (0.275, -0.468) showed significant positive and negative correlation at phenotypic and genotypic level.

Table 12: Phenotypic correlation coefficient for grain yield and its components in maize

Sl.No	Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
1	Days to 50% tasseling	1.000	0.804**	-0.186	-0.161	-0.277*	0.024	-0.215*	-0.236*	-0.062	-0.370**	-0.124	-0.248*
2	Days to 50 % silking		1.000	-0.189	-0.163	-0.223*	-0.022	-0.178	-0.205*	-0.089	-0.278*	-0.071	-0.223*
3	Plant height (cm)			1.000	0.447**	0.565**	0.133	0.341**	0.369**	0.217*	0.344**	0.575**	0.297**
4	Ear length (cm)				1.000	0.741**	0.275**	0.449**	0.327**	0.216*	0.442**	0.378**	0.515**
5	Ear circumference (cm)					1.000	0.266**	0.517**	0.486**	0.225*	0.553**	0.509**	0.570**
6	No. of kernel rows per ear						1.000	0.700**	0.231*	0.323**	0.396**	0.143	0.515**
7	No. of kernels per row							1.000	0.418**	0.421**	0.761**	0.347**	0.803**
8	100 grain weight (g)								1.000	0.167	0.434**	0.300**	0.411**
9	Shelling (%)									1.000	0.364**	0.176	0.399**
10	Grain yield per plant (g)										1.000	0.462**	0.946**
11	Fodder yield (t/ha)											1.000	0.389**
12	Grain yield (q/ha)												1.000

*-Significant at 5% level **-Significant at 1% level

X1 - Days to 50% tasseling
X2 - Days to 50% silking
X3 - Plant height (cm)
X4- Ear length (cm)
X5 - Ear circumference (cm)
X6 – Number of kernel rows per cob
X7 – Number of kernels per row
X8- 100-grain weight (g)
X9 – Shelling percentage (%)
X10 – Grain yield per plant (g)
X11 – Fodder yield (t/ha)
X12-Grain yield (q/ha)

Table 13: Genotypic correlation coefficient for grain yield and its components in maize

Sl. No	Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
1	Days to 50% tasseling	1.000	0.919**	0.201	-0.144	-0.304**	-0.164	-0.254*	-0.329**	-0.145	-0.606**	-0.101	-0.571**
2	Days to 50 % silking		1.000	0.206	0.097	-0.189	-0.180	-0.202*	-0.361**	-0.202*	-0.442**	-0.014	-0.403**
3	Plant height (cm)			1.000	0.233*	0.188	0.906**	0.627**	0.716**	0.362**	0.827**	0.998**	0.946**
4	Ear length (cm)				1.000	0.720**	-0.468**	0.412**	0.362**	0.899**	0.948**	0.958**	0.911**
5	Ear circumference (cm)					1.000	0.679**	0.752**	0.423**	0.553**	0.968**	0.928**	0.926**
6	No. of kernel rows per ear						1.000	0.667**	0.493**	0.821**	0.797**	0.310**	0.962**
7	No. of kernels per row							1.000	0.473**	0.714**	0.898**	0.383**	0.954**
8	100 grain weight (g)								1.000	0.306**	0.486**	0.320**	0.549**
9	Shelling (%)									1.000	0.553**	0.303**	0.710**
10	Grain yield per plant (g)										1.000	0.523**	0.987**
11	Fodder yield (t/ha)											1.000	0.527**
12	Grain yield (q/ha)												1.000

*-Significant at 5% level **-Significant at 1% level

X1 - Days to 50% tasseling
X2 - Days to 50% silking
X3 - Plant height (cm)
X4- Ear length (cm)
X5 - Ear circumference (cm)
X6 – Number of kernel rows per cob
X7 – Number of kernels per row
X8- 100-grain weight (g)
X9 – Shelling percentage (%)
X10 – Grain yield per plant (g)
X11 – Fodder yield (t/ha)
X12-Grain yield (q/ha)

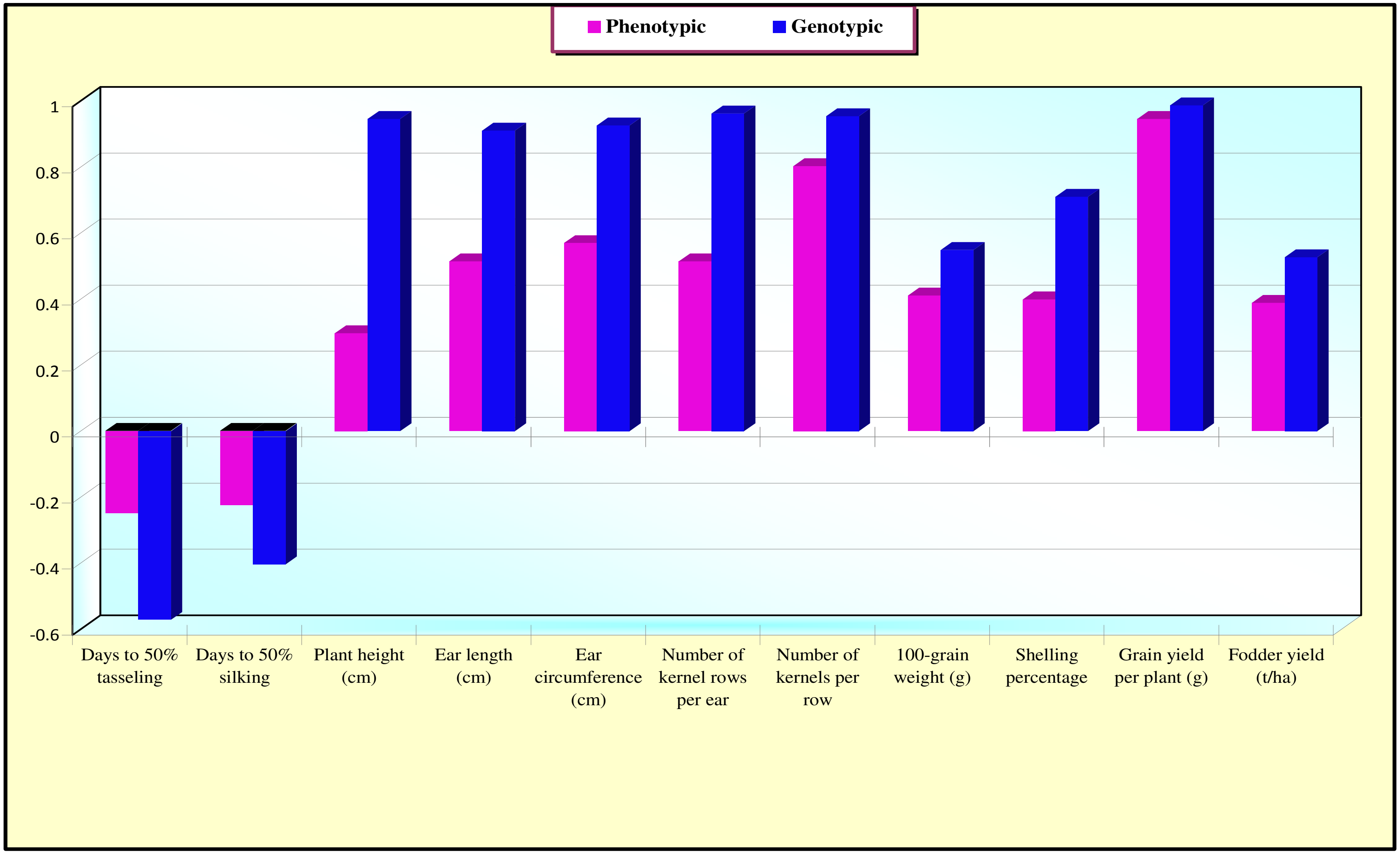


Fig.3. Comparison between phenotypic genotypic correlations with respect to 11 quantitative characters of maize

4.9.5 Ear circumference

Ear circumference showed highly significant positive correlation with ear length (0.741, 0.720), number of kernels per row (0.266, 0.679), number of kernels per row (0.517, 0.752), 100-grain weight (0.486, 0.423), shelling percentage (0.225, 0.553), grain yield per plant (0.553, 0.968), fodder yield per hectare (0.509, 0.928) and grain yield per hectare (0.570, 0.926) at phenotypic and genotypic level whereas days to 50 per cent tasseling (-0.277. -0.304) showed significant negative correlation at phenotypic and genotypic level. While for days to 50 per cent silking (-0.223) and plant height (0.565) showed negative and positive significant association at phenotypic level and no association was found at genotypic level.

4.9.6 Number of kernel rows per ear

Number of kernel rows per ear showed highly significant positive correlation with ear circumference (0.266, 0.679), number of kernels per row (0.700, 0.667), 100-grain weight (0.231, 0.493), shelling percentage (0.323, 0.821), grain yield per plant (0.396, 0.797) and grain yield per hectare (0.515, 0.962) at phenotypic and genotypic level whereas fodder yield per hectare (0.310) and plant height (0.906) showed significant positive correlation at genotypic level and ear length (0.275, -0.468) showed positive and negative association at phenotypic and genotypic level respectively.

4.9.7 Number of kernels per row

Number of kernels per row showed highly significant positive correlation with plant height (0.341, 0.627), ear length (0.449, 0.412), ear circumference (0.513, 0.752), number of kernels per row (0.700, 0.667), 100-grain weight (0.418, 0.473), shelling percentage (0.421, 0.714), grain yield per plant (0.761, 0.898), fodder yield per hectare (0.347, 0.383)) and grain yield per hectare (0.803, 0.954) at phenotypic and genotypic level whereas days to 50 per cent tasseling (-0.215, -0.254) showed significant negative correlation at phenotypic and genotypic level and days to 50 per cent silking (-0.202) at genotypic level.

4.9.8 100-grain weight

100-grain weight showed highly significant positive correlation with plant height (0.369, 0.716), ear length (0.327, 0.362), ear circumference (0.486, 0.423), number of kennel rows per ear (0.231. 0.493), number of kernels per row (0.418, 0.473), grain yield per plant (0.434, 0.486), fodder yield per hectare (0.300, 0.320) and grain yield per hectare (0.411, 0.549) at phenotypic and genotypic level whereas shelling percentage (0.306) showed significant positive correlation at genotypic level. Days to 50 per cent tasseling (-0.236, -0.329) and days to 50 per cent silking (-0.205, -0.361) showed significant negative correlation at phenotypic and genotypic level respectively

4.9.9 Shelling percentage

Shelling percentage showed highly significant positive correlation with plant height (0.217, 0.362), ear length (0.216, 0.899), ear circumference (0.225, 0.553), number of kernels per row (0.323, 0.821), number of kernels per row (0.421, 0.714), grain yield per plant (0.364, 0.553) and grain yield per hectare (0.399, 0.710) at phenotypic and genotypic level whereas 100-grain weight (0.306) and fodder yield per hectare (0.303) showed significant positive correlation at genotypic level and days to 50 per cent silking (-0.202) showed significant negative correlation at genotypic level.

4.9.10 Grain yield per plant

Grain yield per plant showed highly significant positive correlation with plant height (0.344, 0.827), ear length (0.442, 0.948), ear circumference (0.553, 0.968), number of kernel row per ear (0.396, 0.797), number of kernels per row (0.761, 0.898), 100-grain weight (0.434, 0.486), shelling percentage (0.364, 0.553), fodder yield per hectare (0.462, 0.523) and grain yield per hectare (0.946, 0.987) at phenotypic and genotypic level whereas days to 50 per cent tasseling (-0.370, -0.606) and days to 50 per cent silking (-0.278, -0.442) showed significant negative correlation at phenotypic and genotypic level respectively.

4.9.11 Fodder yield per hectare

Fodder yield per hectare showed highly significant positive correlation with plant height (.575, 0.998), ear length (0.378, 0.958), ear circumference (0.509, 0.928), number of kernels per row (0.347,0.383), 100-grain weight (0.300, 0.320), grain yield per plant (0.462, 0.523) and grain yield per hectare (0.389, 0.527) at phenotypic and genotypic level whereas shelling percentage (0.303) and number of kernel rows per ear (0.310) showed significant positive correlation at genotypic level.

4.9.12 Grain yield per hectare

Grain yield per hectare showed highly significant positive correlation with plant height (0.297, 0.946), ear length (0.515, 0.911), ear circumference (0.570, 0.926), number of kernel rows per ear (0.515, 0.962), number of kernels per row (0.803, 0.954), 100-grain weight (0.411,0.549), shelling percentage (0.399, 0.710), grain yield per plant (0.946, 0.987) and fodder yield per hectare (0.389, 0.527) at phenotypic as well as genotypic level. While negatively and significantly associated with days to 50per cent tasseling (-0.248, -0.571) and days to 50 per cent silking (-0.223, -0.403) at phenotypic and genotypic level respectively.

4.10 Path coefficient analysis

Path coefficient analysis was done to find the direct and indirect contributes of different quantitative traits to the grain yield. The grain yield per hectare was the dependent variable, while the other characters that influenced grain yield directly as well as indirectly under study were independent variables. The direct and indirect effects of component character on grain yield are presented in Table 14 and 15 (Fig 4 and 5).

4.10.1 Days to 50 per cent tasseling

Days to 50 per cent tasseling exerted negative direct effect of very high magnitude (-1.684) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent silking (1.207) plant height (0.09), ear length (0.033), ear circumference (0.098), grain yield per plant (0.076) were positive while number of kernel rows per ear (-0.022), number of kernels per row (-0.137), 100-grain weight (-0029), shelling percentage (-0.072), fodder yield per hectare (-0.049) were negative for genotypic path.

It exerted positive direct effect of low magnitude (0.172) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent silking (-0.075), ear length (-0.016), ear circumference (-0.013), number of kernels per row (-0.012), shelling percentage (-0.001), grain yield per plant (-0.326) were negative while plant height (0.011), number of kernel rows per ear (0.002), 100-grain weight (0.003) and fodder yield per hectare (0.008) were positive for phenotypic path.

4.10.2 Days to 50 per cent silking

Days to 50 per cent silking exerted positive direct effect of very high magnitude (1.314) on grain yield per hectare. Its indirect effects *viz.,* plant height (0.009), ear circumference (0.061), grain yield per plant (0.055) were positive while days to 50 per cent tasseling (-1.547), ear length (-0.022), number of kernel rows per ear (-0.024), number of kernels per row (-0.109), 100-grain weight (-0.032), shelling percentage (-0.101) and fodder yield per hectare (-0.007) were negative for genotypic path.

It exerted negative direct effect of negligible magnitude (-0.093) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent silking (0.138), plant height (0.011), 100-grain weight (0.003) and fodder yield per hectare (0.005) were positive while ear length (-0.017), ear circumference (-0.011), number of kernel rows per ear (-0.002), number of kernels per row (-0.010), shelling percentage (-0.002) and grain yield per plant (-0.245) were negative for phenotypic path.

Table 14: Direct and indirect effects of different characters on grain yield (Genotypic path)

Sl.no	Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	Correlation with grain yield
1	Days to 50% tasseling	-1.684	1.207	0.009	0.033	0.098	-0.022	-0.137	-0.029	-0.072	0.076	-0.049	-0.571**
2	Days to 50 % silking	-1.547	1.314	0.009	-0.022	0.061	-0.024	-0.109	-0.032	-0.101	0.055	-0.007	-0.403**
3	Plant height (cm)	-0.338	0.271	0.043	-0.053	-0.061	0.119	0.339	0.064	0.180	-0.103	0.486	0.946**
4	Ear length (cm)	0.242	0.127	0.010	-0.227	-0.232	-0.061	0.223	0.032	0.448	-0.118	0.466	0.911**
5	Ear circumference (cm)	0.512	-0.248	0.008	-0.163	-0.322	0.089	0.407	0.038	0.276	-0.121	0.452	0.926**
6	No. of kernel rows per ear	0.276	-0.237	0.039	0.106	-0.219	0.409	0.361	0.044	0.131	-0.100	0.151	0.962**
7	No. of kernels per row	0.428	-0.265	0.027	-0.093	-0.242	0.087	0.541	0.042	0.356	-0.112	0.186	0.954**
8	100 grain weight (g)	0.089	-0.474	0.031	-0.082	-0.136	0.065	0.256	0.554	0.153	-0.061	0.156	0.549**
9	Shelling (%)	0.244	-0.265	0.016	-0.204	-0.178	0.108	0.386	0.027	0.498	-0.069	0.147	0.710**
10	Grain yield per plant (g)	-0.125	-0.581	0.035	-0.215	-0.312	0.104	0.486	0.043	0.276	1.020	0.255	0.987**
11	Fodder yield (t/ha)	0.170	-0.018	0.043	-0.217	-0.299	0.041	0.207	0.029	0.151	-0.065	0.487	0.527**

R= 0.3816 *-Significant at 5% level **-Significant at 1% level

X1 - Days to 50% tasseling
X2 - Days to 50% silking
X3 - Plant height (cm)
X4- Ear length (cm)
X5 - Ear circumference (cm)
X6 – Number of kernel rows per cob
X7 – Number of kernels per row
X8- 100-grain weight (g)
X9 – Shelling percentage (%)
X10 – Grain yield per plant (g)
X11 – Fodder yield (t/ha)

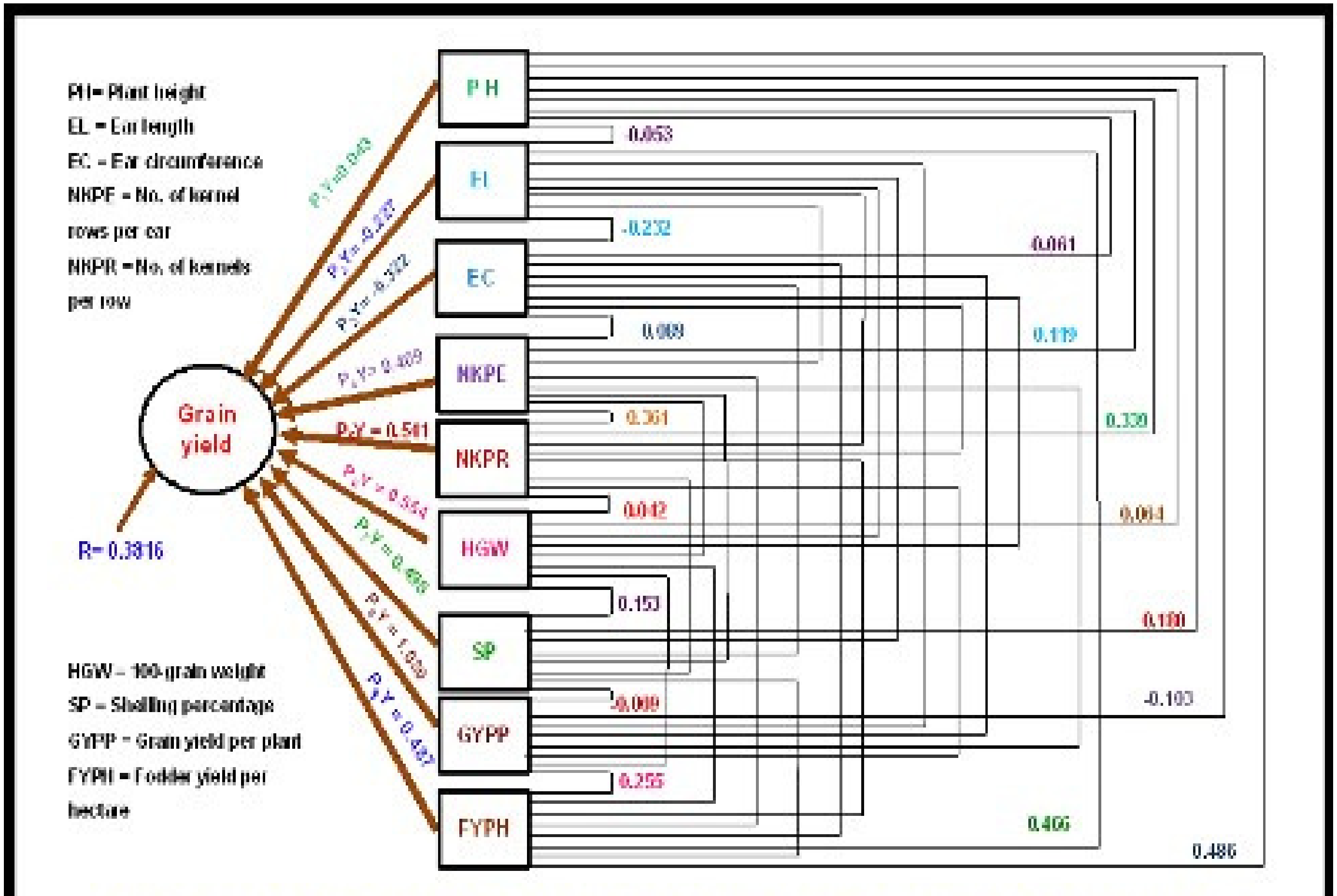


Fig 4: Genotypic path diagram showing the influence of nine characters on yield per hectare in maize

Fig.4. Genotypic path diagram showing the influence of nine characters on yield per hectare in maize

Table 15: Direct and indirect effects of different characters on grain yield (Phenotypic path)

Sl.no	Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	Correlation with grain yield
1	Days to 50% tasseling	0.172	-0.075	0.011	-0.016	-0.013	0.002	-0.012	0.003	-0.001	-0.326	0.008	-0.248*
2	Days to 50 % silking	0.138	-0.093	0.011	-0.017	-0.011	-0.002	-0.010	0.003	-0.002	-0.245	0.005	-0.223*
3	Plant height (cm)	-0.032	0.018	-0.058	0.046	0.027	0.012	0.020	-0.005	0.004	0.303	-0.038	0.297**
4	Ear length (cm)	-0.028	0.015	-0.026	0.102	0.036	0.026	0.026	-0.005	0.004	0.389	-0.025	0.515**
5	Ear circumference (cm)	-0.048	0.021	-0.033	0.076	0.048	0.025	0.030	-0.007	0.005	0.487	-0.033	0.570**
6	No. of kernel rows per ear	0.004	0.002	-0.008	0.028	0.013	0.093	0.040	-0.003	0.007	0.349	-0.009	0.515**
7	No. of kernels per row	-0.037	0.017	-0.020	0.046	0.025	0.065	0.058	-0.006	0.009	0.670	-0.023	0.803**
8	100 grain weight (g)	-0.041	0.019	-0.021	0.033	0.024	0.022	0.024	-0.014	0.003	0.382	-0.020	0.411**
9	Shelling (%)	-0.011	0.008	-0.013	0.022	0.011	0.030	0.024	-0.002	0.020	0.320	-0.012	0.399**
10	Grain yield per plant (g)	-0.064	0.026	-0.020	0.045	0.027	0.037	0.044	-0.006	0.007	0.880	-0.030	0.946**
11	Fodder yield (t/ha)	-0.021	0.007	-0.033	0.039	0.025	0.013	0.020	-0.004	0.004	0.407	-0.065	0.389**

R= 0.2354 *-Significant at 5% level **-Significant at 1% level

X1 - Days to 50% tasseling
X2 - Days to 50% silking
X3 - Plant height (cm)
X4- Ear length (cm)
X5 - Ear circumference (cm)
X6 – Number of kernel rows per cob
X7 – Number of kernels per row
X8- 100-grain weight (g)
X9 – Shelling percentage (%)
X10 – Grain yield per plant (g)
X11 – Fodder yield (t/ha)

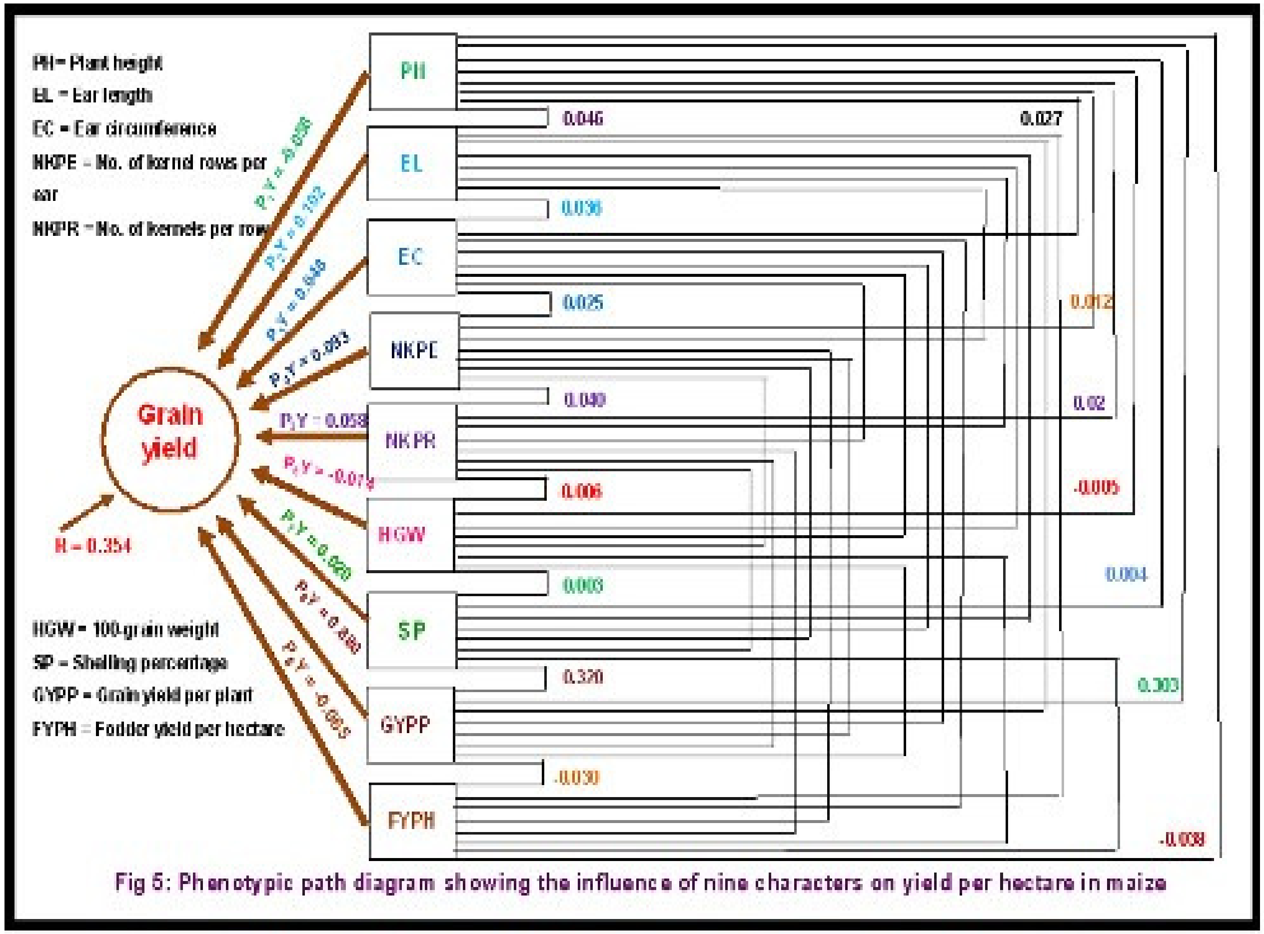


Fig 5: Phenotypic path diagram showing the influence of nine characters on yield per hectare in maize

Fig.5. Phenotypic path diagram showing the influence of nine characters on yield per hectare in maize

4.10.3 Plant height

Plant height exerted positive direct effect of negligible magnitude (0.043) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent silking (0.271), number of kernel rows per ear (0.119), number of kernels per row (0.339), 100-grain weight (0.064), shelling percentage (0.180), fodder yield per hectare (0.486) were positive while days to 50 per cent tasseling (-0.338), ear length (-0.053), ear circumference (-0.061), grain yield per plant (-0.103) were negative for genotypic path.

It exerted negative direct effect of negligible magnitude (-0.058) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent silking (0.018), ear length (0.046), ear circumference (0.027), number of kernel rows per ear (0.012), number of kernels per row (0.020), shelling percentage (0.004), grain yield per plant (0.303) were positive while days to 50 per cent tasseling (-0.032), 100-grain weight (-0.005) and fodder yield per hectare (-0.038) were negative for phenotypic path.

4.10.4 Ear length

Ear length exerted negative direct effect of moderate magnitude (-0.227) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent tasseling (0.242), days to 50 per cent silking (0.127), plant height (0.010), number of kernels per row (0.223), 100-grain weight (0.032), shelling percentage (0.448) and fodder yield per hectare (0.466) were positive while ear length (-0.232), number of kernel rows per ear (-0.061), grain yield per plant (-0.118) were negative genotypic path.

It exerted positive direct effect of low magnitude (0.102) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent silking (0.015), ear circumference (0.036), number of kernel rows per ear (0.026), number of kernels per row (0.026), shelling percentage (0.004), grain yield per plant (0.389) were positive while days to 50 per cent tasseling (-0.028), plant height (-0.026), 100-grain weight (-0.005) and fodder yield per hectare (-0.025) were negative for phenotypic path.

4.10.5 Ear circumference

Ear circumference exerted negative direct effect of high magnitude (-0.322) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent tasseling (0.512), plant height (0.008), number of kernel rows per ear (0.089), number of kernels per row (0.407), 100-grain weight (0.038), shelling percentage (0.276), fodder yield per hectare (0.452) were positive while days to 50 per cent silking (-0.248), ear length (-0.163), grain yield per plant (-0.121) were negative for genotypic path.

It exerted positive direct effect of negligible magnitude (0048) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent silking (0.021), ear length (0.076), number of kernel rows per ear (0.025), number of kernels per row (0.030), shelling percentage (0.005), grain yield per plant (0.487) were positive while days to 50 per cent tasseling (-0.048), plant height (-0.033), 100 grain weight (-0.007) and fodder yield per hectare (-0.033) were negative for phenotypic path.

4.10.6 Number of kernel rows per ear

Number of kernel rows per ear exerted positive direct effect of high magnitude (0.409) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent tasseling (0.276), plant height (0.039), ear length (0.106), number of kernels per row (0.361), 100-grain weight (0.044), shelling percentage (0.131) and fodder yield per hectare (0.151) were positive while days to 50 per cent silking (-0.237), ear circumference (-0.219), grain yield per plant (-0.100) were for genotypic path.

It exerted positive direct effect of negligible magnitude (0.048) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent tasseling (0.004), days to 50 per cent silking (0.002), ear length (0.028), ear circumference (0.013), number of kernels per row (0.040), shelling percentage (0.007), grain yield per plant (0.349) were positive while plant height (-0.008), 100-grain weight (-0.003) and fodder yield per hectare (-0.009) were negative for phenotypic path.

4.10.7 Number of kernels per row

Number of kernels per row exerted positive direct effect of high magnitude (0.541) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent tasseling (0.428), plant height (0.027), number of kernel rows per ear (0.087), 100-grain weight (0.042), shelling percentage (0.356), fodder yield per hectare (0.186) were positive while days to 50 per cent silking (-0.265) , ear length (-0.093), ear circumference (-0.242), grain yield per plant (-0.112) were negative for genotypic path.

It exerted positive direct effect of negligible magnitude (058) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent silking (0.017), ear length (0.046), ear circumference (0.025), number of kernel rows per ear (0.065), shelling percentage (0.009), grain yield per plant (0.670) were positive while days to 50 per cent tasseling (-0.037), plant height (-0.020), 100-grain weight (-0.006), fodder yield per hectare (-0.023) were negative for phenotypic path.

4.10.8 100-grain weight

100-grain weight exerted positive direct effect of negligible magnitude (0.554) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent tasseling (0.089), plant height (0.031), number of kernel rows per ear (0.065), number of kernels per row (0.256), shelling percentage (0.153), fodder yield per hectare (0.156) were positive while days to 50 per cent silking (-0.474), ear length (-0082), ear circumference (-0.136), grain yield per plant (-0.062) were negative for genotypic path.

It exerted negative direct effect of negligible magnitude (-0.014) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent silking (0.019), ear length (0.033), ear circumference (0.024), number of kernel rows per ear (0.022), number of kernels per row (0.024), shelling percentage (0.003), grain yield per plant (0.382) were positive while days to 50 per cent tasseling (-0.041), plant height (-0.021) and fodder yield per hectare (-0.020) were negative for phenotypic path.

4.10.9 Shelling percentage

Shelling percentage exerted positive direct effect of high magnitude (0.498) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent tasseling (0.244), plant height (0.016)), number of kernel rows per ear (0.108), number of kernels per row (0.386), 100-grain weight (0.027) and fodder yield per hectare (0.147) were positive while days to 50 per cent silking (-0.265), ear length (-0.204), ear circumference (-0.178) and grain yield per plant (-0.069) were negative for genotypic path.

It exerted positive direct effect of negligible magnitude (0.020) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent silking (0.008), ear length (0.022), ear circumference (0.011), number of kernel rows per ear (0.030), number of kernels per row (0.024), grain yield per plant (0.320) were positive while days to 50 per cent tasseling (-0.011), plant height (-0.013), 100-grain weight (-0.002) and fodder yield per hectare (-0.012) were negative for phenotypic path.

4.10.10 Grain yield per plant

Grain yield per plant exerted positive direct effect of very high magnitude (1.020) on grain yield per hectare. Its indirect effects *viz.,* plant height (0.035), number of kernel rows per ear (0.104), number of kernels per row (0.486), 100-grain weight (0.043), shelling percentage (0.276) and fodder yield per hectare (0.255) were positive while days to 50 per cent tasseling (-0.125), days to 50 per cent silking (-0.581), ear length (-0.215), ear circumference (-0.312) were negative for genotypic path.

It exerted positive direct effect of high magnitude (0.880) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent silking (0.026), ear length (0.045), ear circumference (0.027), number of kernel rows per ear (0.037), number of kernels per row (0.044) and shelling percentage (0.007) were positive while days to 50 per cent tasseling (-0.064), plant height (-0.020), 100-grain weight (-0.006) and fodder yield per hectare (-0.030) were negative for phenotypic path.

4.10.11 Fodder yield per hectare

Fodder yield per hectare exerted positive direct effect of high magnitude (0.487) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent tasseling (0.170), plant height (0.043), number of kernel rows per ear (0.041), number of kernels per row (0.207), 100-grain weight (0.029), shelling percentage (0.151) were positive while days to 50 per cent silking (-0.018), ear length (-0.217), ear circumference (-0.299) and grain yield per plant (-0.065) were negative for genotypic path.

It exerted negative direct effect of negligible magnitude (-0.065) on grain yield per hectare. Its indirect effects *viz.,* days to 50 per cent silking (0.007), ear length (0.039), ear circumference (0.025), number of kernel rows per ear (0.013), number of kernels per row (0.020), shelling percentage (0.004), grain yield per plant (0.407) were positive while days to 50 per cent tasseling (-0.021), plant height (-0.033), 100-grain weight (-0.004) were negative for phenotypic path.

5. DISCUSSION

In the recent years considerable emphasis has been given for the development of high yielding single cross and hybrids in maize. The main aim of any plant breeding programme is to develop high yielding genotypes. The breeding programme can efficiently be planned with prior knowledge of the genetic makeup of complex quantitative character like yield and its attributes. So there is a need to examine the genetic architecture of various quantitative characters in relation to breeding behaviour of the genetic material available.

Exploitation of heterosis or hybrid vigour is an important method of crop improvement adopted in many of the crops especially in cross pollinated crops. This phenomenon of heterosis was attracted the attention of plant breeders due to its conspicuous effect on economic characters especially grain yield and this heterosis has been successfully exploited in many cross pollinated crops among which maize is the major one.

In order to exploit hybrid vigour/heterosis choice of suitable parents is an important step. The selection of parents depends on factors like *per se* performance of the parents and their combining ability. The concept of general and specific combining ability (Sprague and Tatum, 1942) helps the breeder in assessing many of the lines to be used as parents in the production of hybrids and also in identifying the superior hybrids having additive and non-additive genes. It is therefore necessary to assess the genetic potentialities of the parents in hybrid combination through systematic studies in relation to general and specific combining ability which are due to additive and non-additive gene actions. Thus, the information regarding heterosis, combining ability and nature of gene action are the basic requirements for a thorough understanding of genetic architecture of yield and its components. The available literature on maize indicated the possibility of exploiting heterosis for realizing higher yield potentiality; being monoecious in nature it provides an ample scope to exploit heterosis commercially.

The present study therefore was undertaken to study the genetics of 12 quantitative traits using line x tester analysis (L x T), involving 29 lines (females) and 3 testers (males). The results obtained in the present investigations are discussed here under.

5.1 Analysis of variance

The analysis of variance for all entries, including parents, hybrids and checks for 12 characters revealed that the treatment variances were highly significant for days to 50 per cent tasseling, days to 50 per cent silking, number of kernel rows per ear, number of kernels per row, 100-grain weight, shelling percentage and fodder yield per hectare. This indicates the presence of variability among treatments.

From the analysis of variance of parents and hybrids it was clear that the mean sum of squares and females were highly significant for all the traits. This indicated the presences of sufficient variability among parents and hybrids.

The mean sum of squares of males were highly significant for five traits *viz.,* number of kernels per row, 100-grain weight, grain yield per plant, fodder yield per hectare and grain yield per hectare which signifies that males were diverse for these five traits. The mean sum of squares of females versus male were significant for eight traits viz., days to 50 per cent tasseling, days to 50 per cent silking, plant height, number of kernel rows per ear, number of kernels per row, 100-grain weight, grain yield per plant and grain yield per hectare. This implies that the divergence of testers from lines with respect to these eight characters.

The mean sum of squares for hybrids were highly significant for all traits except for plant height, ear length, ear circumference, grain yield per plant and grain yield per hectare including the diverse performance of different cross combinations for remaining seven traits. The parents versus hybrids mean sum of squares were highly significant for all the traits revealing the presence of average heterosis due to the significant differences in the mean performances of hybrids and parents.

The contribution to total hybrid variances was found to be higher from females than males for all characters under study as females were genetically diverse than males the contribution of the females x males interaction for the total hybrid was also higher than that of males for all characters. On the other hand, the contribution of the female x male interaction was higher than that of females for the characters *viz.,* ear length, number of kernel rows per ear, number of kernels per row, shelling per cent, grain yield per plant and grain yield per hectare, revealing the importance of either female or male parents for the expression of other traits in hybrids.

5.2 Genetic components of different characters

5.2.1 Maturity characters

Maturity is an important attribute of a given genotype, which directly or indirectly affects economic yield. Maturity itself is expressed by several components such as days to 50 per cent tasseling, days to 50 per cent silking *etc.* Normally, in maize it has been reported that the female inflorescence *i.e.*, ear formation is very sensitive to environment fluctuation, plant density etc., where as male inflorescence *i.e.,* tassel formation is less affected by such situations (Gieshercht, 1960). Therefore, the synchronization between male and female flowering is a very crucial phenomenon with direct bearing on yield.

5.2.1.1 Days to 50 per cent tasseling

Days from planting to pollen shedding is one of the important maturity characters. As many as six lines were found to be good combiners. Among these YP$\otimes$4#07-2, YP$\otimes$4#07-4, YP$\otimes$4#07-13, YP$\otimes$4#07-6 and YP$\otimes$4#07-26 were the best general combiners for earliness in developing tassel (Table 9 and 16). The combining ability analysis revealed the greater importance of SCA variance than GCA variance. The GCA variance was non-significant. Similar observation was reported by Lee (1983). However, Sanghi *et al.* (1982) indicated predominance of SCA variance for this trait, which supported the present finding.

The crosses *viz.,* YP$\otimes$4#07-13 x CI-5 in negative direction showed significant sca effects (Table 10 and 16). Forty-nine, 55 and 30 crosses showed significant relative heterosis, heterobeltiosis and standard heterosis respectively (Table 11 and 17) in the desired direction. As many as 74 hybrids took shorter period as compared to hybrid check, DMH-2 and EH-434042 (Arjun) (Table 6). Among them YP$\otimes$4#07-13 x CI-5, YP$\otimes$4#07-2 x Prabha, YP$\otimes$4#07-2 x KDMI-10, YP$\otimes$4#07-4 x KDMI-10, YP$\otimes$4#07-6 x CI-5 were the top five crosses showed earliness to best check, DMH-2 and EH-434042 (Arjun). The cross combination, YP$\otimes$4#07-13 x CI-5 also exhibited significant relative heterosis and standard heterosis while, the hybrid YP$\otimes$4#07-6 x CI-5 expressed heterobeltiosis in the desired direction. Earlier workers Hassaballa *et al.* (1980), Turgut *et al.* (1995) and Perez Velasquez *et al.* (1995) also reported highly significant heterosis effects for early tasseling. Satyanarayana *et al.* (1994) reported the heterobeltiosis for earliness.

The ratio of additive to dominance was lesser than unity this indicated the importance of dominance gene action for the inheritance of this character. These results are in agreement with those of Hassaballa *et al.* (1980) and Guo *et al.* (1986). Those crosses, which exhibited significant heterosis are obtained from parent with good general combining ability for earliness. Hence, it is suggested that these hybrids will serve as useful genetic material for development of early parents by selection in advanced generations.

5.2.1.2 Days to 50 per cent silking

Days to 50 per cent silking is another maturity character often used and more reliable to predict maturity (Shaw and Thom, 1951). Studies on gca effects revealed that seven parental lines viz., YP$\otimes$4#07-2, YP$\otimes$4#07-26, YP$\otimes$4#07-24, YP$\otimes$4#07-25, YP$\otimes$4#07-13, YP$\otimes$4#07-11, YP$\otimes$4#07-27 showed significant gca effects. However, none of the testers showed significant gca effects.

The SCA variance was significant and higher than GCA variance in the inheritance of this trait. Similar results were reported by Sedhom (1994) and Dehghanapour *et al.* (1997). The cross combination YP⊗4#07-6 x CI-5 showed significant sca effects revealing that this cross can be used as specific combiner for this trait (Table 10 and 16). Heterosis study expressed that 25 crosses exhibited significant relative heterosis, 38 for heterobeltiosis and 6 for standard heterosis in the desired direction (Table 11 and 17).

As many as 60 hybrids exhibited early silking as compared to the check EH-434042 (Arjun). Among these YP⊗4#07-13 x CI-5, YP⊗4#07-2 x CI-5, YP⊗4#07-4 x KDMI-10, YP⊗4#07-24 x KDMI-10 and YP⊗4#07-26 x KDMI-10 are the top five crosses which showed earliness in silking. The ratio of additive to dominance variance was lesser than unity. Thus again confirms the importance of dominance gene action in the inheritance of this trait. These findings support the earlier report of Paul and Duara (1991).

5.2.2 Plant characters

5.2.2.1 Plant height

Plant height is one of the major concerns to plant breeders since yield has positive correlation with plant height (Rupak *et al.,* 1979). Only three lines *viz.,* YP⊗4#07-19, YP⊗4#07-29 and YP⊗4#07-1 were found to be good general combiners for increased plant height.

Analysis of variance for combining ability revealed that variance component due to GCA was lower than SCA. Predominant role of SCA variance was also reported by Herbert and Gallis (1986) and El-Hosary *et al.* (1994a). However, Vasal *et al.* (1992) and Zheng-Zuping *et al.* (1995) reported predominant role of GCA variance for this trait.

The additive and non-additive ratio was also lower then unity indicating the importance of non-additive gene action. From earlier workers Guo *et al.* (1986), Pal *et al.* (1986), Dehghanapour *et al.* (1997) and Petrovic (1998) reported the importance of non-additive component. None of the crosses showed significant sca effects indicated that the contribution of non-additive gene action in the inheritance of this character was nil.

Twenty-five, nine and seven crosses exhibited significant positive relative heterosis, heterobeltiosis and standard heterosis respectively. The highest positive standard heterosis was registered by YP⊗4#07-9 x KDMI-10 and YP⊗4#07-18 x Prabha (Table 11 and 17). This expression of high heterosis and sca effects also indicates the presence of non-additive gene action. Several workers like Beck *et al.* (1990), Vasal *et al.* (1992), Reddy and Agarwal (1992) and Alvarez *et al.* (1993) reported low heterosis for these traits which contradicted the present investigation. Gomes-e-Gama *et al.* (1993) noticed average and also non-significant heterosis, which also antagonised the present results.

Thus, in the present investigation the preponderance of non-additive component for the inheritance of plant height was realized. As many as seven crosses, which had significant positive standard heterosis *viz.,* YP⊗4#07-18 x Prabha, YP⊗4#07-9 x KDMI-10, YP⊗4#07-19 x KDMI-10, YP⊗4#07-1 x KDMI-10, YP⊗4#07-1 x Prabha, YP⊗4#07-19 x KDMI-10 and YP⊗4#07-15 x Prabha were obtained from parents which had good general combining ability, so one can expect transgressive segregants in later generations in these crosses for carrying out selection to improve this trait.

5.2.3 Ear characters

Several workers reported that yield of maize can be increased by increasing the ear length and ear circumference.

Table 16: Number of parents and crosses which showed significant gca and sca effects to the positive and negative direction and ranges

Sl.No	Characters	Number of parents with gca effects				Number of crosses with sca effects			
		Positive	Negative	Total	Range	Positive	Negative	Total	Range
1.	Days to 50 % tasseling	6	6	12	-2.46 - 1.71	0	1	1	-1.82 – 1.51
2.	Days to 50 % silking	2	7	9	-2.07 - 1.76	1	1	2	-2.56 – 4.4
3.	Plant height (cm)	3	5	8	-19.75 - 13.42	0	0	0	-15.57 – 14.26
4.	Ear length (cm)	1	1	2	-1.81 - 1.64	0	0	0	-2.05 – 1.99
5.	Ear circumference (cm)	2	2	4	-1.06 - 1.17	0	0	0	-0.96 – 1.06
6.	Number of kernel rows per ear	1	3	4	-0.73 – 0.71	1	1	2	-1.05 – 1
7.	Number of kernels per row	9	7	16	-4.01 – 3.56	11	12	23	-6.99 – 5.1
8.	100-grain weight (g)	12	13	25	-5.7 - 5.3	24	24	48	-9.91 – 7.76
9.	Shelling percentage	3	6	9	-1.81 – 2.09	6	4	10	-3.88 – 3.19
10.	Grain yield per plant (g)	1	0	1	-6.94 – 8.73	1	0	1	-10.71 – 13.23
11.	Fodder yield (t/ha)	13	11	24	-2.19 – 2.16	20	32	52	-1.91 – 2.57
12.	Grain yield (q/ha)	1	1	2	-5.67 – 5.95	1	0	1	-7.51 – 8.82

Table 17: Number of crosses showing significant heterosis levels with respective directions and ranges

Sl. No	Characters	Relative heterosis			Heterobeltiosis			Standard heterosis		
		Positive	Negative	Range	Positive	Negative	Range	Positive	Negative	Range
1.	Days to 50 % tasseling	0	49	-8.82 - 1.89	0	55	-10.71 - 0	0	30	-7.46 - 0.75
2.	Days to 50 % silking	0	25	-8.51 - 3.14	0	38	-9.15 - 2.07	1	6	-6.52 - 7.25
3.	Plant height (cm)	25	0	-10.42 - 45.58	9	0	-14.24 - 42.15	7	0	-13.11 - 28.84
4.	Ear length (cm)	12	1	-21.35 - 44.99	3	1	-25.53 - 37.69	0	1	-28.26 - 13.45
5.	Ear circumference (cm)	22	0	-7.35 - 22.56	1	0	-8.36 - 16.34	0	0	-11.36 - 12.09
6.	Number of kernel rows per ear	2	6	-12.82 –11.11	0	18	-14.93 - 6.98	0	4	-13.08 – 8.46
7.	Number of kernels per row	53	4	-14.29- 41.31	17	14	-22.47- 27.6	12	9	-26.41 - 21.36
8.	100-grain weight (g)	63	5	-20.41- 102.5	41	14	-31.25 - 102.56	19	30	-40.63 - 28.13
9.	Shelling percentage	16	1	-5.49 - 11.85	8	4	-7.0 - 7.42	0	7	-8.16 - 417
10.	Grain yield per plant (g)	87	0	24.48 - 107.7	86	0	24.48 - 107.7	87	0	32.83 - 75.66
11.	Fodder yield (t/ha)	62	3	-26.63 - 251.79	52	8	-39.18 - 157.33	70	0	-21.79 - 152.26
12.	Grain yield (q/ha)	65	0	0.02 - 88.21	35	0	-14.57 - 82.54	18	0	-1.87 - 53.3

5.2.3.1 Ear length

Ear length has much effect on grain yield and it is the only component which affects the ear traits like kernel number and to lesser degree the kernel weight (Herczecjji, 1970). The general combining ability effects studies revealed that only one line YP⊗4#07-16 expressed significant gca effects and found to be good general combiner.

Higher SCA variance than GCA variance was observed which resulted in the ratio of GCA/SCA variance to be less than unity indicated the predominance of SCA variance both being significant. This finding is in the line with that of Mohammad (1993), Pal and Prodhan (1994), Sedhom (1994) and Sinobas and Monteagudo (1994).

None of the crosses exhibited significant sca effects in any direction indicated that the contribution of non-additive gene action in the inheritance of this character was nil. Twelve crosses showed significant relative heterosis, three crosses showed heterobeltiosis in the positive direction and only one cross YP⊗4#07-5 x KDMI-10 showed significant standard heterosis in the negative direction because there existed no genetic variability among hybrids for this character as analysis of variance for hybrids showed no significant mean sum of squares. These results are in accordance with those of Verma and Singh (1980), Debnath (1987) and Turgut *et al.* (1995).

From this study the importance of non-additive gene action for the inheritance of ear length was evident. Similar results were also reported by Khristova *et al.* (1995) and Ali and Topera (1986).

5.2.3.2 Ear circumference

There was an indication that selection for a character such as ear circumference could lead to considerable importance in the yield (Williams *et al.*, 1965).

From gca study it was found that only two parents; YP⊗4#07-1 and YP⊗4#07-26 were found to be good general combiners for this trait. From the combining ability analysis it was known that the GCA variance was relatively less than the SCA variance indicating the preponderance of non-additive gene action for this character. Such findings are reported by Mohammad (1993), El-Hosary et al. (1994a) and Sinobas and Monteagudo (1994). None of the crosses showed significant sca effects in any direction.

Twenty-two crosses showed significant heterosis for relative heterosis and one cross for heterobeltiosis. None of the crosses showed significant standard heterosis because there is no genetic variability among hybrids for this character as analysis of variance for hybrids showed no significant mean sum of squares. None of the crosses showed significant sca effects indicated that the contribution of non-additive gene action in the inheritance of this character was nil. Moreover, the additive to non additive variance ratio was found to be slightly lesser than unity. These results indicated the equal importance of additive and non-additive gene action. These findings support the work of Quadri *et al.* (1983).

5.2.3.3 Number of kernel rows per ear

This character is positively correlated with grain yield. Parents viz., YP⊗4#07-20, YP⊗4#07-5, YP⊗4#07-6 and YP⊗4#07-7 were good sources of favourable genes for increase in number of kernel rows. From the combining ability analysis it was clear that, GCA variance was less than SCA indicating predominance of SCA variance. Crosses YP⊗4#07-23 x KDMI-10 and YP⊗4#07-15 x Prabha was found to be good general specific combiner.

Out of 87 crosses, only two crosses exhibited positive mid parent heterosis and none of the crosses exhibited positive heterosis over better parent and standard check. Presolska and Kamara (1991) also reported heterosis for this trait. Salillari and Hoxha (1998) however reported that there was no heterosis for this trait. Four crosses viz., YP⊗4#07-6 x Prabha, YP⊗4#07-6 x KDMI-10, YP⊗4#07-15 x Prabha and YP⊗4#07-23 x Prabha exhibited negative standard heterosis and their performance was rather on par with the best check, Pinnacle and they also had negative relative heterosis and heterobeltiosis for six and 18 crosses respectively.

The additive to non-additive variance ratio was lower than unity, which again confirms the predominance of non-additive gene action for the inheritance of their character. The results were in line with the findings of Pal and Prodhan (1994), Dehganapour *et al.* (1997) and Kumar *et al.* (1998).

5.2.3.4 Number of kernels per row

Nine parents viz., YP⊗4#07-1, YP⊗4#07-3, YP⊗4#07-4, YP⊗4#07-8, YP⊗4#07-13, YP⊗4#07-20, YP⊗4#07-25, YP⊗4#07-27 and YP⊗4#07-28 were identified as good combiners for this trait. From the combining ability analysis, it was learnt that ratio of GCA/SCA variance was far less than unity indicating the importance of SCA variance. Eleven crosses exhibited significant sca effects in positive direction. Very less additive variance was observed indicating the importance of non-additive gene action in inheritance of this character. These results were in agreement with that of Pal and Prodhan (1994), Dehganapour *et al.* (1997) and Kumar *et al.* (1998).

Fifty-three, 17 and 12 crosses showed significant positive relative heterosis, heterobeltiosis and standard heterosis, respectively. This was in line with the findings of Presolska and Kamara (1991), Salillari and Hoxha (1998) who reported considerable heterosis for this character.

5.2.3.5 100-grain weight

It is one of the important grain characters. The grains are the net result of various components. The total yield in maize is influenced by several grain component characters. Ultimate grain yield of a plant depends mainly on 100-grain weight through various other component characters. The study of 100 grain weight deserves much attention because grain yield is product of interaction of various grain components so improvement will be quite easier and study will help in understanding the complex trait and grain yield.

From the study of general combining ability, out of 12 lines *viz.,* YP⊗4#07-28, YP⊗4#07-26, YP⊗4#07-21, YP⊗4#07-1, YP⊗4#07-3 were found to be the top five good general combiner for this character. Among testers, CI-5 and KDMI-10 also found to be the good general combiner for this character.

Greater SCA variance was observed from the combining ability study. The GCA/SCA variance was lower than unity, which indicated the importance of non-additive gene action. This supports the findings of Mohammad (1993) and Dehghanapour *et al.* (1997). As many as 24 crosses showed significant for sca effects. Among these *viz.,* YP⊗4#07-14 x Prabha, YP⊗4#07-15 x KDMI-10, YP⊗4#07-3 x KDMI-10, YP⊗4#07-19 x CI-5, YP⊗4#07-7 x Prabha, YP⊗4#07-25 x KDMI-10, YP⊗4#07-15 x CI-5, YP⊗4#07-8 x CI-5, YP⊗4#07-28 x Prabha, YP⊗4#07-6 x KDMI-10 were top 10 crosses indentified as good specific combiner. The additive to non-additive ratio was lesser than one indicating the predominance of non-additive variance in the inheritance of this trait. These results are in agreement with the investigation of Pal *et al.* (1986).

Sixty-three, 41 and 19 crosses revealed that relative heterosis, heterobeltiosis and standard heterosis respectively. Similar results were reported by different authors like, Turgut *et al.* (1995), Salillari and Hoxha (1998) and Petrovic (1998).

5.2.6 Shelling percentage

From the study of general combining ability effects it was evident that parents, YP⊗4#07-17, YP⊗4#07-20 and YP⊗4#07-25 were good general combiners. The combining ability analysis showed higher SCA variance than the GCA variance and GCA/SCA ratio was lower than the unity indicating the performance of SCA variance. Crosses viz., YP⊗4#07-4 x Prabha, YP⊗4#07-5 x Prabha, YP⊗4#07-6 x Prabha, YP⊗4#07-20 x CI-5, YP⊗4#07-22 x CI-5 and YP⊗4#07-27 x CI-5 were found to be good specific combiners.

Sixteen, eight and none of the crosses showed significant positive relative heterosis, heterobeltiosis and standard heterosis, respectively. A good number of crosses with sca effects indicated the contribution of non-additive gene action. This finding is in accordance with Mathur *et al.* (1998).

5.2.7 Fodder yield per hectare

From the study of general combining ability it was evident that lines YP⊗4#07-18, YP⊗4#07-10, YP⊗4#07-9, YP⊗4#07-8 and YP⊗4#07-13 were top five good general combiners. Among testers, Prabha and KDMI-10 were also found to be good general combiners. The combining ability analysis showed higher SCA variance than GCA variance and GCA/SCA variance ratio was lower than unity indicating the predominance of non-additive gene action.

The cross combination; YP⊗4#07-15 x Prabha, YP⊗4#07-25 x CI-5, YP⊗4#07-17 x CI-5, YP⊗4#07-10 x CI-5, YP⊗4#07-24 x CI-5, YP⊗4#07-9 x KDMI-10, YP⊗4#07-21 x CI-5, YP⊗4#07-22 x KDMI-10, YP⊗4#07-19 x KDMI-10 and YP⊗4#07-13 x KDMI-10 were found to be the top 10 good specific combiners and the additive / dominance variance ratio studies showed importance of non-additive gene action. These findings were in agreement with Suneeta *et al.* (2000).

Sixty-two, 52 and 70 crosses showed positive relative heterosis, heterobeltiosis and standard heterosis, respectively. A good number of crosses with sca effect indicate non-additive gene action. As many as 73 crosses showed high fodder yield over best check 900-M. Among them, crosses viz., YP⊗4#07-10 x CI-5, YP⊗4#07-9 x KDMI-10, YP⊗4#07-15 x Prabha, YP⊗4#07-18 x Prabha, YP⊗4#07-8 x KDMI-10, YP⊗4#07-13 x KDMI-10, YP⊗4#07-19 x KDMI-10, YP⊗4#07-25 x CI-5, YP⊗4#07-22 x KDMI-10 and YP⊗4#07- 18 x KDMI-10 were top 10 crosses found to be better than the 900M.

5.2.5 Yield characters

Grain yield is a complex quantitative character, which is influenced by other ancillary and component characters, which may tend to counter balance each other giving in effect, homeostasis for yield. Hence all changes in the components would not be expressed as changes in yield but any changes in yield would be accompanied by changes in one or more components.

Johnson (1973) reported that genetic variability for grain yield in single ear attributed to additive and non-additive genetic variance expressed through yield components. Because of influence from various ancillary characters and environmental factors, comprehensive study is very difficult and it is the focal point about which plant breeding experiments are centered around.

5.2.5.1 Grain yield per plant

From the study of general combining ability, the line YP⊗4#07-20 found to be good general combiner for this trait. Analysis of variance showed higher SCA variance than GCA variance as reported by El-Hosary *et al.* (1994a).

The cross combination; YP$\otimes$4#07-20 x CI-5 showed significant sca effects in desirable direction. The additive to non- additive variance ratio revealed the importance of non-additive gene action for the inheritance of this character, such findings were also reported by Joshi *et al.,*(1998).

Eighty-seven, 86 and 87 crosses showed significant relative heterosis, heterobeltiosis and standard heterosis respectively. The crosses such as YP$\otimes$4#07-20 x CI-5, YP$\otimes$4#07-24 x Prabha, YP$\otimes$4#07-26 x KDMI-10, YP$\otimes$4#07-4 x Prabha, YP$\otimes$4#07-3 x KDMI-10, YP$\otimes$4#07-8 x Prabha, YP$\otimes$4#07-23 x KDMI-10, YP$\otimes$4#07-28 x KDMI-10, YP$\otimes$4#07-27 x CI-5 and YP$\otimes$4#07-25 x CI-5 was found to be far better than the standard check *i.e.,* Pinnacle and these crosses involve parents with high general combining ability effects, that selection for segregating materials from this cross can also be employed for improvement of this trait.

5.2.5.2 Grain yield per hectare

From the gca effects studies only one parent *viz.*, YP$\otimes$4#07-20 was found to have significantly high gca effects. Combining ability studies revealed higher SCA variance than GCA variance and thus the GCA/SCA variance ratio was lower than one, indicating the importance of SCA variance than GCA variance. These results are in line with findings of Paul and Duara (1991) and Sedhom (1994), Mohammad (1993) and Satyanarayana *et al.* (1994).

The cross YP$\otimes$4#07-20 x CI-5 which showed significant sca effects in positive direction. The additive to dominance variance ratio result also revealed the preponderance of non-additive gene action in the inheritance of this trait. Sixty-five, 35 and 18 crosses showed significant positive heterosis, heterobeltiosis and standard heterosis respectively. Crosses *viz.,* YP$\otimes$4#07-20 x CI-5, YP$\otimes$4#07-24 x Prabha, YP$\otimes$4#07-26 x KDMI-10, YP$\otimes$4#07-4 x Prabha, YP$\otimes$4#07-3 x KDMI-10, YP$\otimes$4#07-8 x Prabha, YP$\otimes$4#07-23 x KDMI-10, YP$\otimes$4#07-28 x KDMI-10, YP$\otimes$4#07-27 x CI-5 and YP$\otimes$4#07-25 x CI-5 showed higher grain yield per hectare over standard check, Pinnacle. Such levels of heterosis were also reported by Verma and Singh (1980), Debnath (1984). Jha and Khehra (1992) and Larish and Brewbaker (1999).

Among these, which showed positive standard heterosis, relative heterosis and heterobeltiosis in the desired direction. The hybrid YP$\otimes$4#07-20 x CI-5 had high sca effects, so one can go for selection in the segregating materials to improve yield per hectare. But for the rest of the crosses, hybrid development is the only way of attaining high grain yield per hectare as the non fixable components is operating in these crosses with high sca effects.

From this study it was found that grain yield per hectare was predominantly governed by non-additive gene action as reported by Guo *et al.* (1986), Crossa *et al.* (1990), Joshi *et al.* (1998), Murthy *et al.* (1981) and Shanti *et al.* (2002).

5.3 Inter character correlation

Yield is a complex quantitative character governed by large number of genes and in greatly effected by environmental factor. Hence, the selection of superior genotypes on yield is not effective. For a rational approach towards the improvement of yield selection has to be made for their component association of yield with their attributes thus, assumed special importance as the basis for selecting desired strains. Genetic correlation between different characters of plant often also because of either linkage or plieotrophy (Harland, 1939).

The results of phenotypic (Table 12) and genotypic (Table 13) correlation between yield and their components in the present investigation are discussed below. In this investigation, genotypic correlation coefficient were higher than phenotypic value (Fig. 3) indicating that strong intrinsic association are reduced at phenotypic level due to environmental effects.

The data presented in Table 12 and 13 revealed that genotypic correlation coefficient were slightly higher in magnitude than phenotypic once. This low magnitude is due to modifying effects of environment on the association characters. There was a general agreement in both sign and magnitude between estimates of genotypic and phenotypic correlations. The characters which are genotypically but not phenotypically correlated may not be of practical value in selection since selection is based on phenotype.

5.3.1 Grain yield per hectare

Grain yield per hectare was positively and significantly associated with plant height, ear length, ear circumference, number of kernel rows per ear, number of kernels per row, 100-grain weight, shelling percentage, grain yield per plant and fodder yield per hectare but days to 50 per cent tasseling and days to 50 per cent silking were negatively and significantly associated with yield per hectare at phenotypic level.

Similarly the grain yield per hectare was significantly and negatively associated with days to 50 per cant tasseling and days to 50 per cent silking in desirable direction but it was significantly and positively associated with all the characters *viz.,* plant height, ear length, ear circumference, number of kernel rows per ear, number of kernels per row, 100-grain weight, shelling percentage, grain yield per plant, fodder yield per hectare at genotypic level.

The positive association of yield with plant height (Sharma et al., 1982, Tyagi *et al.*, 1988, Singh *et al.*, 1991, Debnath and Khan 1991, Krishna and Natrajan 1995, Packiaj 1995, Swarnalatha Devi and Shaik Mohammad 2001), ear length, ear circumference (Appadurai and Nagarajan 1975, Alok Kumar *et al.,* 1999, Pradeep Kumer and Satyanarayana, 2001), number of kernels per row (Appadurai and Nagarajan, 1975, Tyagi *et al.,* 1988, Geeta and Jayaram 2000a), fodder yield per hectare (Krishnan and Nararajan, 1995), 100-grainweight (Saha and Mukherjee, 1985, Tyagi *et al.,* 1988, Umakanth and Khan, 2001) and grain yield per plant (Nawar *et al.,*1999) was reported. The negative association was observed between grain yield and maturity characters by Netaji *et al.* (2000).

5.4 Path analysis

The correlation value denotes only the nature and extent of association existing between pairs of characters. The yield is dependent on several component characters that are mutually associated, which will in turn impair the true association existing between a component and economic characters and change in any one component is likely to disturb the whole network of cause and effect. Each component has two parts of action *viz.* (1) the direct effect and (2) indirect effects through components on economic characters which are not revealed from the correlation studies. Path analysis first suggested by Wright (1921). In the present study 11 characters were considered for path analysis (Table 14 and 15).

5.4.1 Grain yield per hectare

The characters *viz.,* days to 50 per cent silking, plant height, number of kernel rows per ear, number of kernels per row, 100-grain weight, shelling percentage, grain yield per plant and fodder yield per hectare has positive direct effect on yield while days to 50 per cent tasseling, ear length and ear circumference has negative direct effect (Fig 4) for genotypic path.

The characters *viz.*, days to 50 per cent tasseling, ear length, ear circumference, number of kernel rows per ear, number of kernels per row, shelling percentage and grain yield per plant has positive direct effect on yield while days to 50 per cent silking, plant height, 100-grain weight and fodder yield per hectare had negative direct effect (Fig 5) for phenotypic path.

The direct effect on grain yield by plant height, 100-grain weight (Packiaraj, 1995), number of kernel rows per ear, number of kernels per row (Manivannan, 1998), ear

Table 18: Scoring of parents based on their gca effects for 12 characters in maize

Sl.No	Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X112	Total	Rank
	Females (Lines)														
1	YP ⊗ 4 #07-1	0	0	1	0	1	0	1	1	-1	0	1	0	4	1
2	YP ⊗ 4 #07-2	-1	-1	0	0	0	0	0	1	0	0	-1	0	-2	7
3	YP ⊗ 4 #07-3	0	0	0	0	0	0	1	1	0	0	0	0	2	3
4	YP ⊗ 4 #07-4	-1	0	0	0	0	0	-1	1	0	0	0	0	-1	6
5	YP ⊗ 4 #07-5	0	0	-1	-1	0	-1	-1	-1	0	0	-1	0	-6	11
6	YP ⊗ 4 #07-6	-1	0	-1	0	-1	-1	-1	-1	-1	0	-1	-1	-9	14
7	YP ⊗ 4 #07-7	0	0	0	0	0	-1	1	-1	0	0	-1	0	-2	7
8	YP ⊗ 4 #07-8	0	0	0	0	0	0	1	-1	0	0	1	0	1	4
9	YP ⊗ 4 #07-9	0	0	0	0	0	0	0	-1	0	0	1	0	0	5
10	YP ⊗ 4 #07-10	0	0	0	0	0	0	0	0	0	0	1	0	1	4
11	YP ⊗ 4 #07-11	0	-1	-1	0	-1	0	-1	-1	0	0	-1	0	-6	11
12	YP ⊗ 4 #07-12	0	0	0	0	0	0	0	-1	-1	0	0	0	-2	7
13	YP ⊗ 4 #07-13	-1	-1	-1	0	0	0	1	0	0	0	1	0	-1	6
14	YP ⊗ 4 #07-14	1	0	0	0	0	0	0	0	0	0	1	0	2	3
15	YP ⊗ 4 #07-15	0	0	0	0	0	0	-1	-1	0	0	1	0	-1	6
16	YP ⊗ 4 #07-16	0	0	0	1	0	0	0	1	0	0	1	0	3	2
17	YP ⊗ 4 #07-17	1	0	0	0	0	0	0	-1	1	0	1	0	2	3
18	YP ⊗ 4 #07-18	1	1	0	0	0	0	0	0	-1	0	1	0	2	3
19	YP ⊗ 4 #07-19	1	1	1	0	0	0	-1	0	0	0	1	0	3	2
20	YP ⊗ 4 #07-20	0	0	0	0	0	1	1	0	1	1	-1	1	4	1
21	YP ⊗ 4 #07-21	1	0	0	0	0	0	0	1	0	0	0	0	2	3
22	YP ⊗ 4 #07-22	0	0	0	0	0	0	0	0	-1	0	0	0	-1	6

Contd.…

Sl. No.	Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X112	Total	Rank
	Females (Lines)														
23	YP ⊗ 4 #07-23	0	0	0	0	0	0	-1	-1	0	0	1	0	-1	6
24	YP ⊗ 4 #07-24	0	-1	0	0	0	0	0	0	0	0	-1	0	-2	7
25	YP ⊗ 4 #07-25	0	-1	0	0	0	0	1	1	1	0	0	0	2	3
26	YP ⊗ 4 #07-26	-1	-1	0	0	1	0	0	1	0	0	-1	0	-1	6
27	YP ⊗ 4 #07-27	-1	-1	0	0	0	0	1	1	-1	0	-1	0	-2	7
28	YP ⊗ 4 #07-28	0	0	0	0	0	0	1	1	1	0	-1	0	2	3
29	YP ⊗ 4 #07-29	1	0	1	0	0	0	0	-1	0	0	1	0	2	3
	Males (Testers)														
30	Prabha	0	0	0	0	0	0	0	-1	0	0	1	0	0	5
31	KDMI-10	0	0	0	0	0	0	0	1	0	0	1	0	2	3
32	CI-5	0	0	-1	0	0	0	0	1	0	0	-1	0	-1	6

Scoring: 1= Significant gca effects in desired direction, 0 = Non-significant gca effects and 1 = Significant gca effects in undesired direction

X1 - Days to 50% tasseling
X2 - Days to 50% silking
X3 - Plant height (cm)
X4- Ear length (cm)
X5 - Ear circumference (cm)
X6 – Number of kernel rows per cob
X7 – Number of kernels per row
X8- 100-grain weight (g)
X9 – Shelling percentage (%)
X10 – Grain yield per plant (g)
X11 – Fodder yield (t/ha)
X12-Grain yield (q/ha)

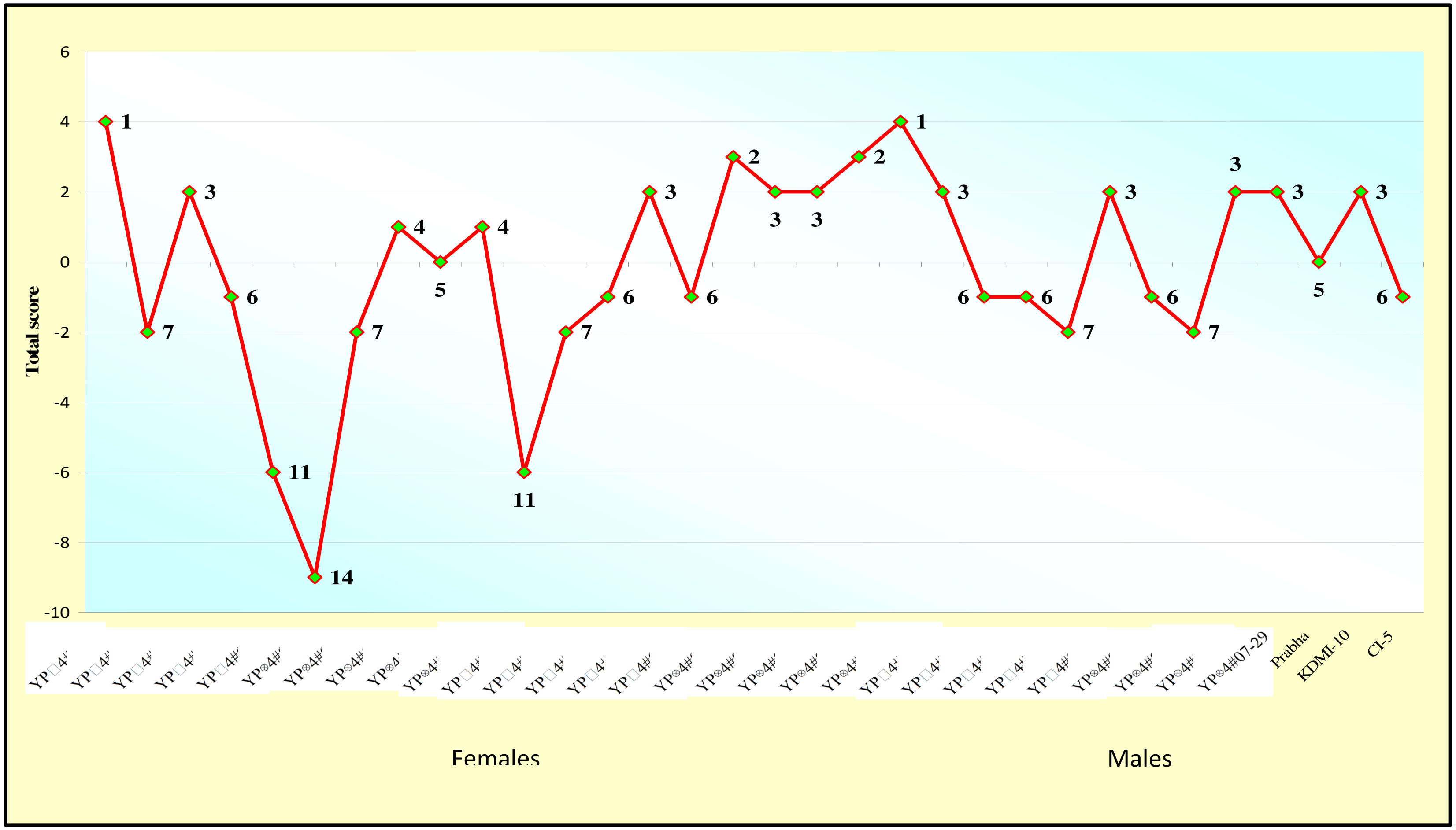


Fig.6. Scoring of parents based on their gca effects

Table 19: Performance of promising hybrids for grain yield

Sl.No	Single cross hybrids	Mean grain yield (q/ha)	Heterosis			gca effects female x male	sca effects	Other characters with significant sca effects
			SH	HB	RH			
1.	YP⊗4#07-20 X CI-5	67.29	53.3**	72.77**	88.21**	High x Low	8.82*	HGW,GYP,NKPR,SP
2.	YP⊗4#07-4 X Prabha	61.54	40.2**	43.17**	47.62**	Low x Low	6.38	HGW,FYH, NKPR,SP
3.	YP⊗4#07-24 X Prabha	61.35	39.78**	51.89**	54.84**	Low x Low	6.49	NKPR, FYH
4.	YP⊗4#07-8 X Prabha	61.07	39.15**	51.21**	77.03**	High x Low	4.85	HGW
5.	YP⊗4#07-3 X KDMI-10	60.55	37.97**	18.93	43.18**	High x High	5.06	HGW,FYH
6.	YP⊗4#07-26 X KDMI-10	60.52	37.88**	18.85	45.48**	Low x High	5.60	NKPR
7.	YP⊗4#07-23 X KDMI-10	59.51	35.58**	16.87	25.45*	Low x High	8.18	NKRPE, NKPR
8.	YP⊗4#07-28 X KDMI-10	59.50	35.57**	16.86	37.41**	High x High	2.76	HGW
9.	YP⊗4#07-27 X CI-5	59.42	35.4**	49.76**	64.53**	Low x Low	2.69	SP
10.	YP⊗4#07-25 X CI-5	59.42	35.4**	82.54**	86.77**	High x Low	3.09	FYH

*-Significant At 5% Level **-Significant at 1% level

NKRPE= Number of kernel rows per ear, NKPR= Number of kernels per row, SP= Shelling percentage, HGW = 100-grain weight, GYP = Grain yield per plant, FYH = Fodder yield per hectare, GYH = Grain yield per hectare.

Plate.2. Potential single cross experimental hybrids for grain yield

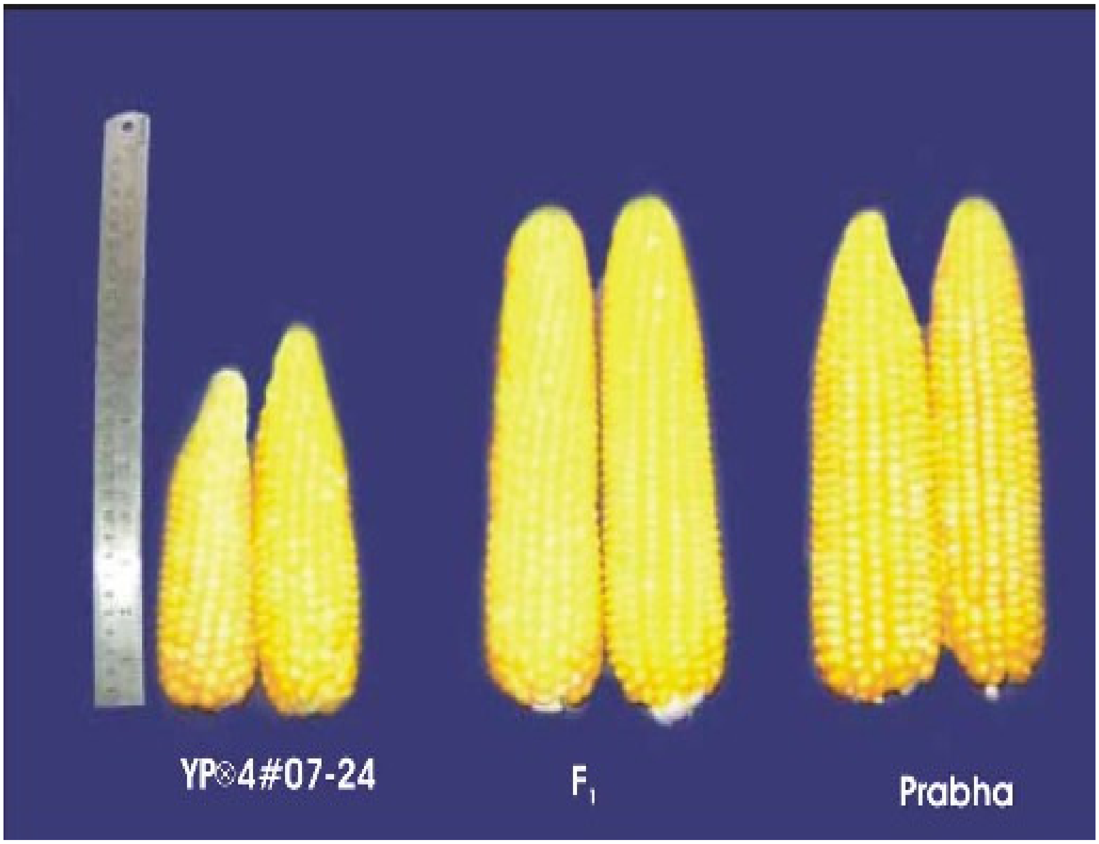
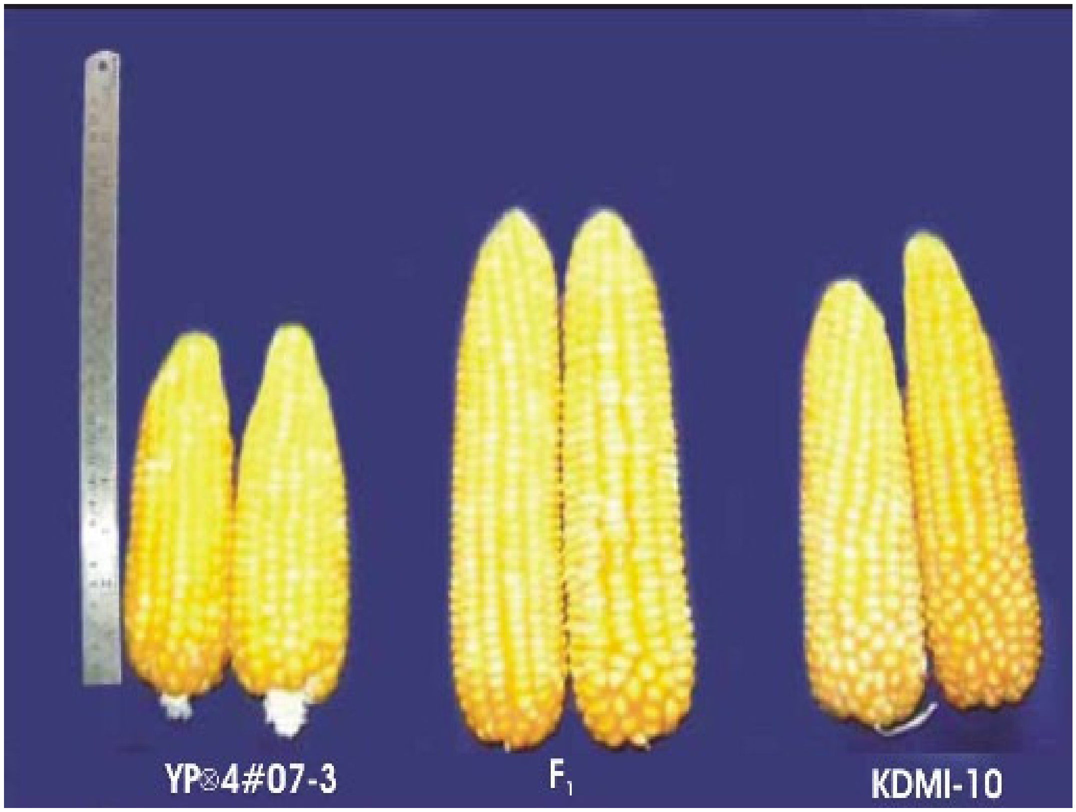


Plate.2. Contd….



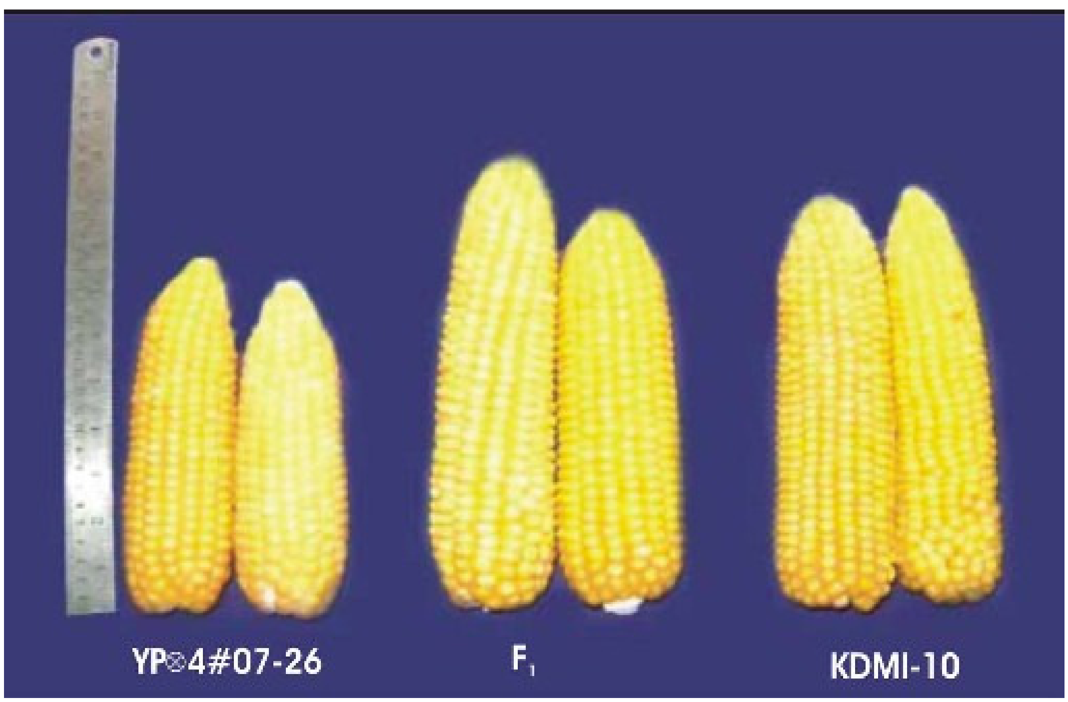


Plate.2. Contd….

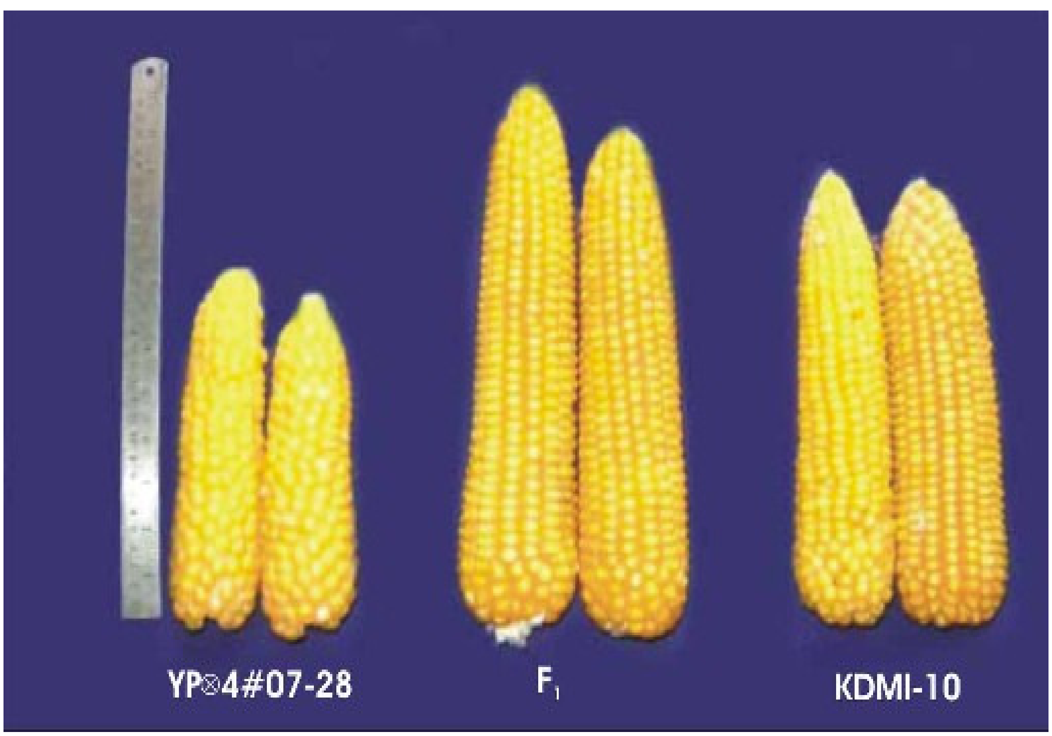


Plate.2. Contd….

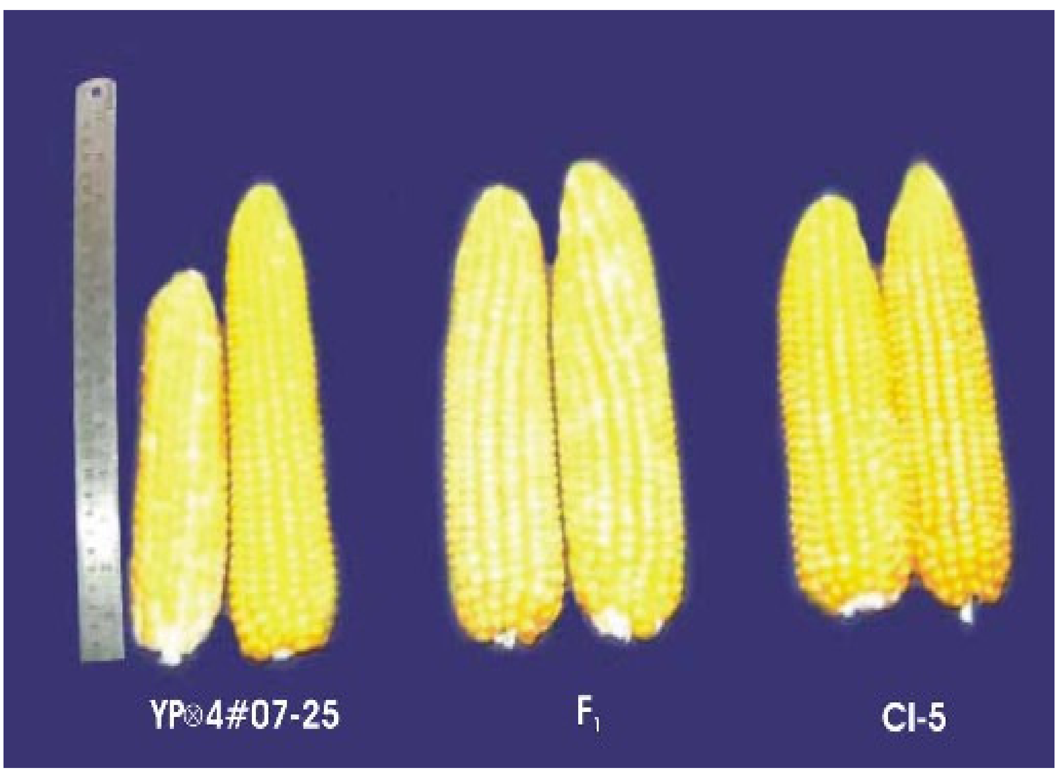


Plate.2. Contd…..

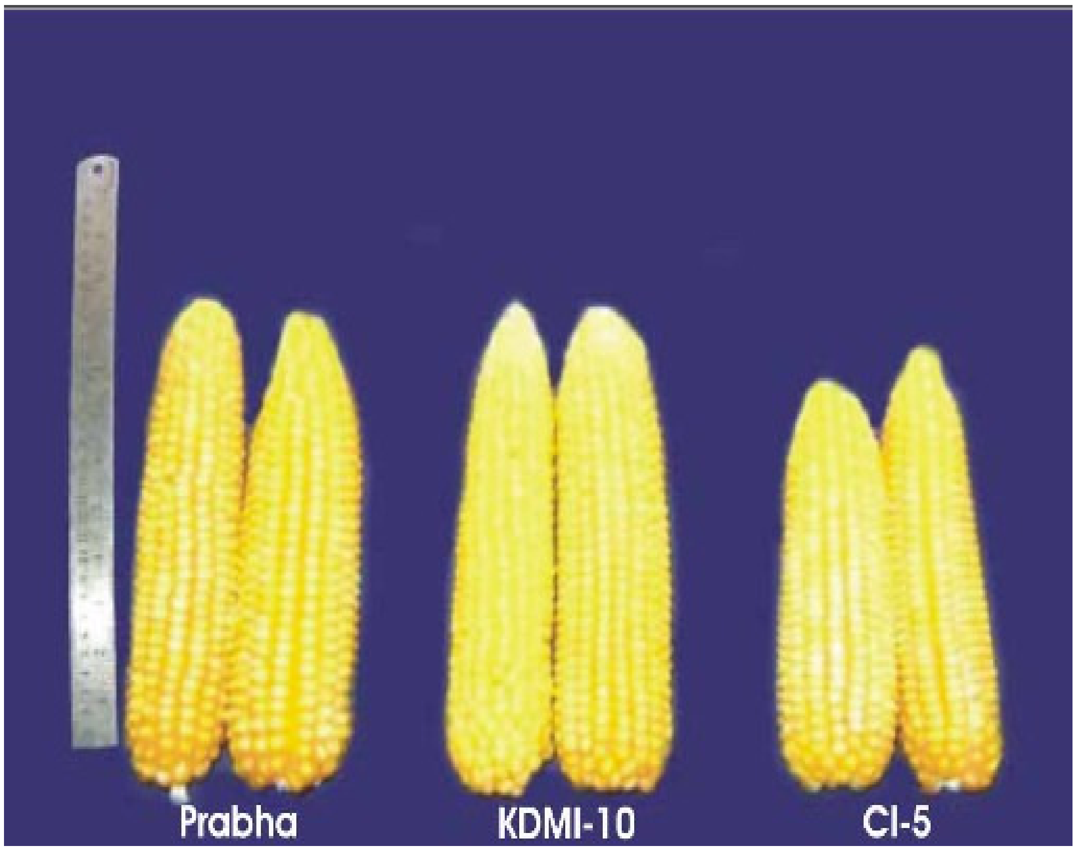


Plate.3. Testers used for hybridization programme

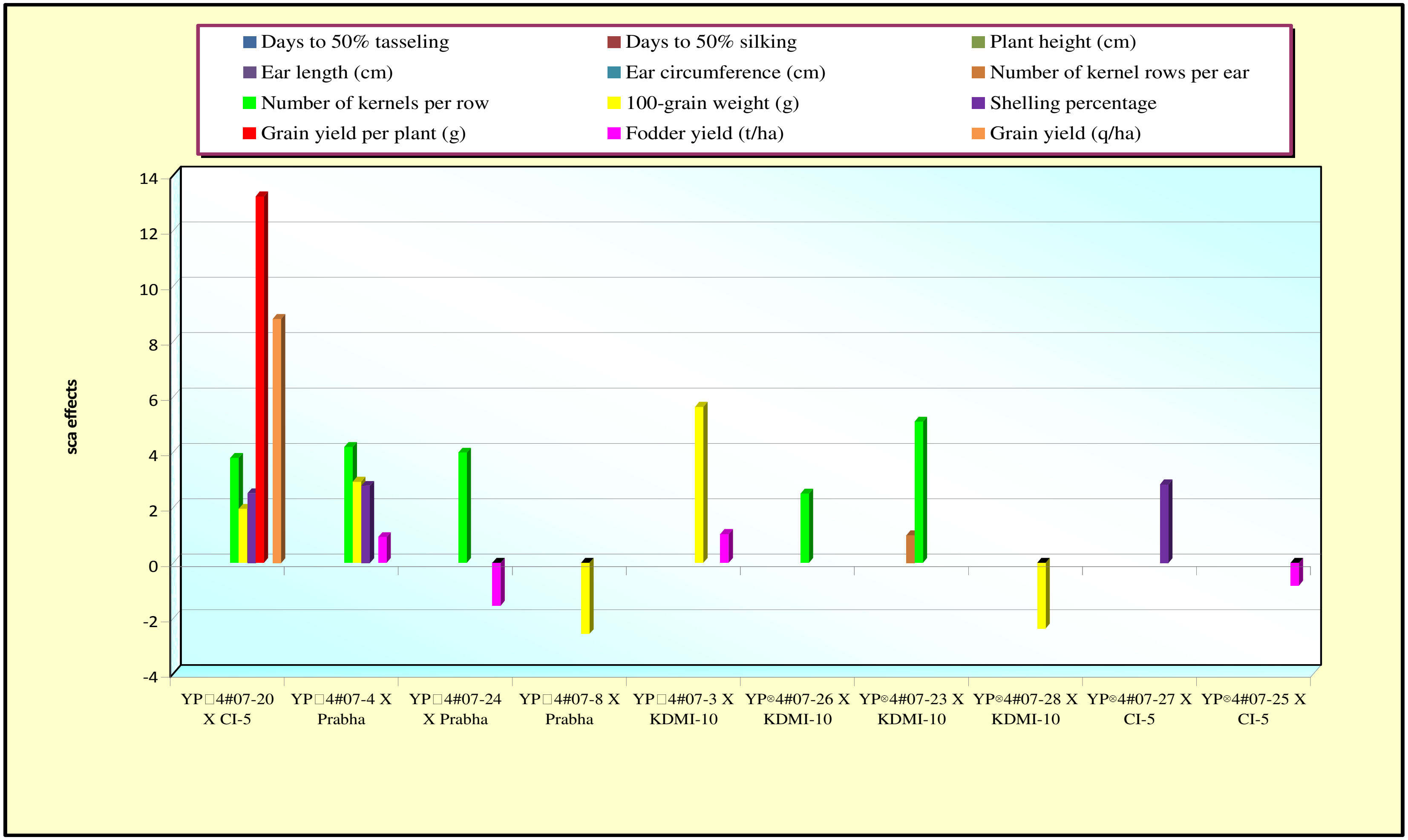


Fig.7. Specific combining ability (Sca) effects of top ten single cross experimental hybrids of maize in respect of 12 characters

Table 20: Standard heterosis for top 10 experimental hybrids of maize with respect to 12 quantitative characters over the five commercial checks

Sl. No	Experimental hybrids	Days to 50 per cent tasseling					Days to 50 per cent silking					Plant height (cm)				
		C1	C2	C3	C4	C5	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
1.	YP⊗4#07-20 X CI-5	-1.5	-1.5	-6.43**	-5.7**	-6.43**	-0.71	0.00	-4.79*	-4.79*	-4.79*	10.29	-0.37	1.9	2.29	16.02
2.	YP⊗4#07-4 X Prabha	-3.76*	-3.76*	-8.57**	-7.91**	-8.57**	-2.86	-2.16	-6.85**	-6.85**	-6.85**	24.69*	12.64	15.21	15.65	31.17*
3.	YP⊗4#07-24 X Prabha	-2.26	-2.26	-7.1**	-6.47**	-7.14**	-4.29	-3.6	-8.22**	-8.22**	-8.22**	21.81	10.04	12.55	12.98	28.14*
4.	YP⊗4#07-8 X Prabha	0.00	0.00	-5**	-4.32*	-5**	-0.71	0.00	-4.7*	-4.79*	-4.79*	22.22	10.41	12.93	13.36	28.57*
5.	YP⊗4#07-3 X KDMI-10	-1.5	-1.5	-6.43**	-5.76**	-6.43**	0.00	0.72	-4.11	-4.11	-4.11	27.16*	14.87	17.49	17.49	33.77**
6.	YP⊗4#07-26 X KDMI-10	-3.76*	-3.76*	-8.57**	-7.91**	-8.57**	-5.71*	-5.04*	-9.59**	-9.59**	-9.59**	29.22*	16.73	19.39	19.85	35.93**
7.	YP⊗4#07-23 X KDMI-10	-1.5	-1.5	-6.43**	-5.76**	-6.43**	-1.43	-0.72	-5.48*	-5.48*	-5.48*	28.4*	15.99	18.63	19.08	35.06**
8.	YP⊗4#07-28 X KDMI-10	-3.01	-3.01	-7.86**	-7.19**	-7.86**	-3.57	-2.88	-7.53**	-7.53**	-7.53**	19.75	8.18	10.65	11.07	25.97*
9.	YP⊗4#07-27 X CI-5	-1.5	-1.5	-6.43**	-5.76**	-6.43**	-2.86	-2.16	-6.85**	-6.85**	-6.85**	11.11	0.37	2.66	3.05	16.88
10.	YP⊗4#07-25 X CI-5	-3.01	-3.01	-7.86**	-7.19**	-7.86**	-5.0*	-4.32	-8.9**	-8.9**	-8.9**	18.52	7.06	9.51	9.92	24.68

*-Significant At 5% Level **-Significant at 1% level

C1 = DMH-2 C2 = EH434042 (Arjun), C3 = 900M C4 = Bio9681 C5 = Pinnacle

Sl. No	Experimental hybrids	Ear length (cm)					Ear circumference (cm)					Number of kernel rows per ear				
		C1	C2	C3	C4	C5	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
1.	YP⊗4#07-20 X CI-5	13.53	-2.58	-4.43	7.09	1.68	-4.09	-8.83	-7.86	-1.9	-4.44	17.5**	5.22	11.9*	9.3	2.92
2.	YP⊗4#07-4 X Prabha	29.7*	11.29	9.18	22.34	16.16	11.52	6.01	7.14	14.07	11.11	15**	2.99	9.52	6.98	0.73
3.	YP⊗4#07-24 X Prabha	36.09*	16.77	14.56	28.37*	21.89	6.32	1.06	2.14	8.75	5.93	13.33**	1.49	7.94	5.43	-0.73
4.	YP⊗4#07-8 X Prabha	35.34*	16.13	13.92	27.66	21.21	2.83	-2.26	-1.21	5.17	2.44	12.5*	0.75	7.14	4.65	-1.46
5.	YP⊗4#07-3 X KDMI-10	45.86**	25.16	22.78	37.59**	30.64*	9.29	3.89	5	11.79	8.89	12.5*	0.75	7.14	4.65	-1.46
6.	YP⊗4#07-26 X KDMI-10	36.09*	16.77	14.56	28.37*	21.89	13.01	7.42	8.57	15.59*	12.59	11.67*	0	6.35	3.88	-2.19
7.	YP⊗4#07-23 X KDMI-10	27.44	9.35	7.28	20.21	14.14	8.55	3.18	4.29	11.03	8.15	11.67*	0	6.35	3.88	-2.19
8.	YP⊗4#07-28 X KDMI-10	17.29	0.65	-1.27	10.64	5.05	3.72	-1.41	-0.36	10.65	7.78	11.67*	0	6.35	3.88	-2.19
9.	YP⊗4#07-27 X CI-5	5.64	-9.35	-11.1	-0.35	-5.39	3.12	-1.98	-0.93	5.48	2.74	11.67*	0	6.35	3.88	-2.19
10.	YP⊗4#07-25 X CI-5	30.08*	11.61	9.49	22.7	16.5	9.29	3.89	5.00	11.79	8.89	10.83*	-0.75	5.56	3.1	-2.92

*-Significant At 5% Level **-Significant at 1% level

C1 = DMH-2 C2 = EH434042 (Arjun), C3 = 900M C4 = Bio9681 C5 = Pinnacle

Sl. No	Experimental hybrids	Number of kernels per row					100-grain weight (g)					Shelling percentage (%)				
		C1	C2	C3	C4	C5	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
1.	YP⊗4#07-20 X CI-5	53.2**	14.9**	47.1**	27.2**	7.35	3.08	-2.9	24.1**	15.5**	26.4**	10.5**	4.4*	8.5**	5.8**	3.8*
2.	YP⊗4#07-4 X Prabha	49.8**	12.4*	43.8**	24.2**	4.99	9.23*	2.9	31.5**	22.4**	33.9**	8.7**	2.45	6.5**	3.81*	1.9
3.	YP⊗4#07-24 X Prabha	47.2**	10.4*	41.4**	22.5**	3.15	-7.69	-13.0**	11.1*	3.45	13.21*	7.9**	2.09	6.1**	3.45	1.54
4.	YP⊗4#07-8 X Prabha	41.6**	6.2	35.9**	17.4**	-0.79	-29.3**	-33.3**	-14.8**	-20.7**	-13.2*	7.8**	1.79	5.8**	3.15	1.25
5.	YP⊗4#07-3 X KDMI-10	40.8**	5.6	35.3**	16.7**	-1.31	26.2**	18.84**	51.8**	41.4**	54.7**	7.2**	1.43	5.5**	2.79	0.89
6.	YP⊗4#07-26 X KDMI-10	40.8**	5.6	35.5**	16.7**	-1.31	18.5**	11.59**	42.6**	32.8**	45.3**	6.9**	1.19	5.2**	2.54	0.65
7.	YP⊗4#07-23 X KDMI-10	40.8**	5.6	35.3**	16.7**	-1.31	-18.5**	-23.2**	-1.85	8.62	0	6.6**	0.96	4.97*	2.3	0.42
8.	YP⊗4#07-28 X KDMI-10	40.8**	5.6	35.5**	16.7**	-1.31	6.15	0	27.8**	18.9**	30.2**	6.6**	0.9	4.91*	2.24	0.36
9.	YP⊗4#07-27 X CI-5	39.7**	4.8	34.7**	15.8**	-2.1	7.69	1.45	29.6**	20.7**	32.2**	6.2**	0.54	4.53*	1.8	0
10.	YP⊗4#07-25 X CI-5	39.3**	4.5	33.8**	15.5**	-2.36	4.62	-1.45	25.9**	17.3**	28.3**	6**	0.3	4.26*	1.63	-0.24

*-Significant At 5% Level **-Significant at 1% level

C1 = DMH-2 C2 = EH434042 (Arjun), C3 = 900M C4 = Bio9681 C5 = Pinnacle

Sl. No	Experimental hybrids	Grain yield per plant (g)					Fodder yield (t/ha)					Grain yield (q/ha)				
		C1	C2	C3	C4	C5	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
1.	YP⊗4#07-20 X CI-5	35.7**	10.78	18.4*	12.7	10.03	-15.22	-2.5	-17.02	30*	30*	51.8**	15.93	30.6*	22.1	15.6
2.	YP⊗4#07-4 X Prabha	27.6**	4.16	11.34	6.04	3.46	54.5**	77.5**	51.6**	136.7**	136.7**	38.9**	6.02	19.49	11.67	5.72
3.	YP⊗4#07-24 X Prabha	28.51	4.9	12.13	6.8	4.2	-8.7	5	-10.64	40**	40**	38.5**	5.7	19.13	11.33	5.4
4.	YP⊗4#07-8 X Prabha	26.1**	2.94	10.03	4.8	2.25	75**	101.3**	71.3**	168.3**	168.4**	37.8**	5.23	18.59	10.83	4.93
5.	YP⊗4#07-3 X KDMI-10	27.3**	3.92	11.08	5.8	3.22	57.6**	81.25**	54.3**	141.7**	141.7**	36.8*	4.33	17.58	9.89	4.04
6.	YP⊗4#07-26 X KDMI-10	28.2**	4.63	11.84	6.53	3.93	5.43	21.5*	3.19	61.7**	61.7**	36.6*	4.26	17.5	9.82	3.97
7.	YP⊗4#07-23 X KDMI-10	23.8*	1.09	8.06	2.92	0.42	46.7**	68.7**	43.6**	125**	125**	34.3*	2.52	15.54	7.98	2.23
8.	YP⊗4#07-28 X KDMI-10	23.8*	1.09	8.05	2.91	0.41	8.7	25	6.38	66.7**	66.7**	34.3*	2.52	15.53	7.98	2.22
9.	YP⊗4#07-27 X CI-5	23.7*	1	7.95	2.82	0.32	3.26	18.75	1.06	58.3**	58.3**	34.3*	2.39	15.39	7.84	2.1
10.	YP⊗4#07-25 X CI-5	23.7*	1	7.95	2.82	0.32	76.1**	102.5**	72.4**	170**	170**	34.3*	2.39	15.39	7.84	2.1

*-Significant At 5% Level **-Significant at 1% level

C1 = DMH-2 C2 = EH434042 (Arjun), C3 = 900M C4 = Bio9681 C5 = Pinnacle

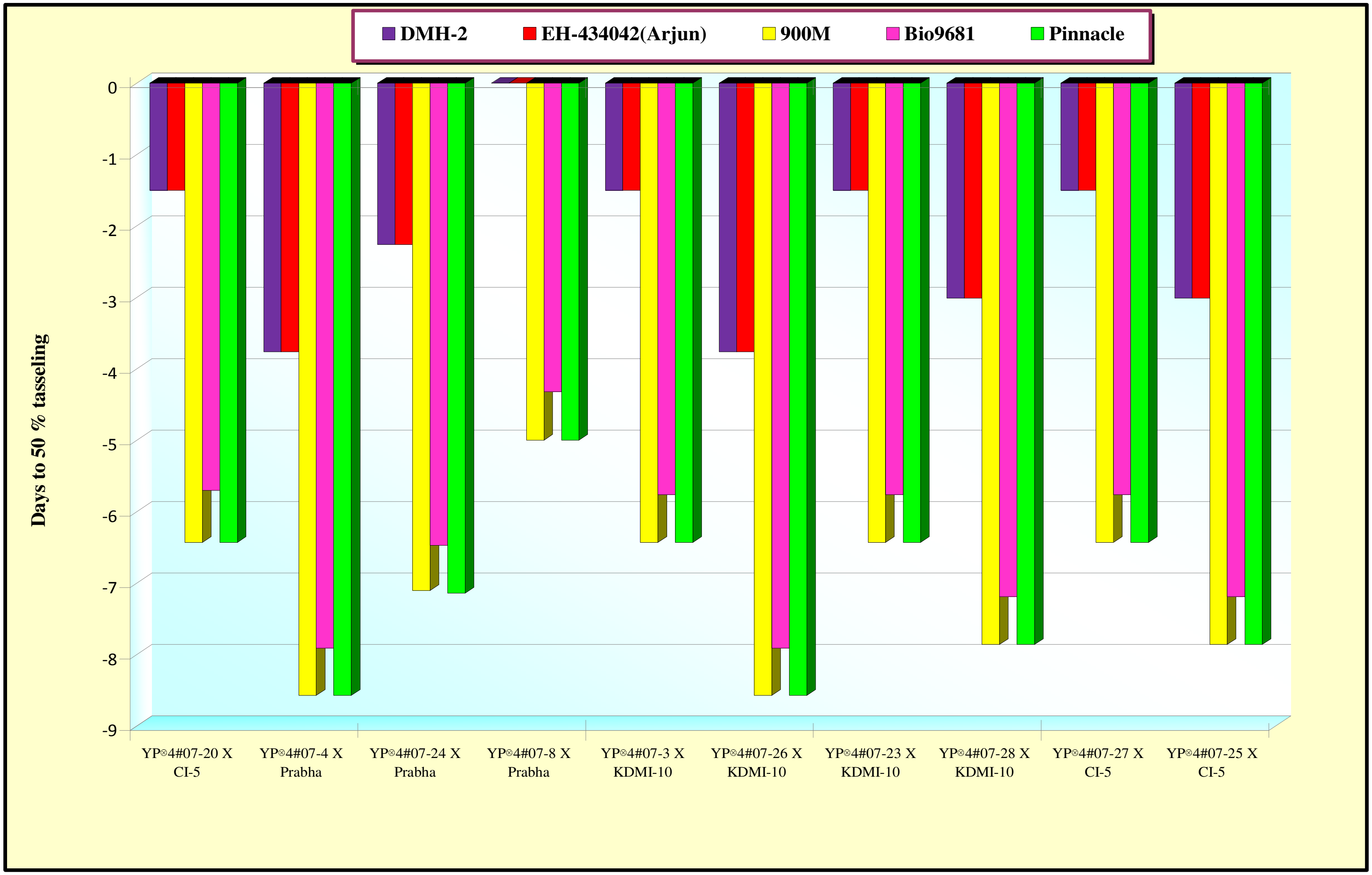


Fig.8. Standard heterosis for top 10 experimental hybrids for days to 50 percent tasseling

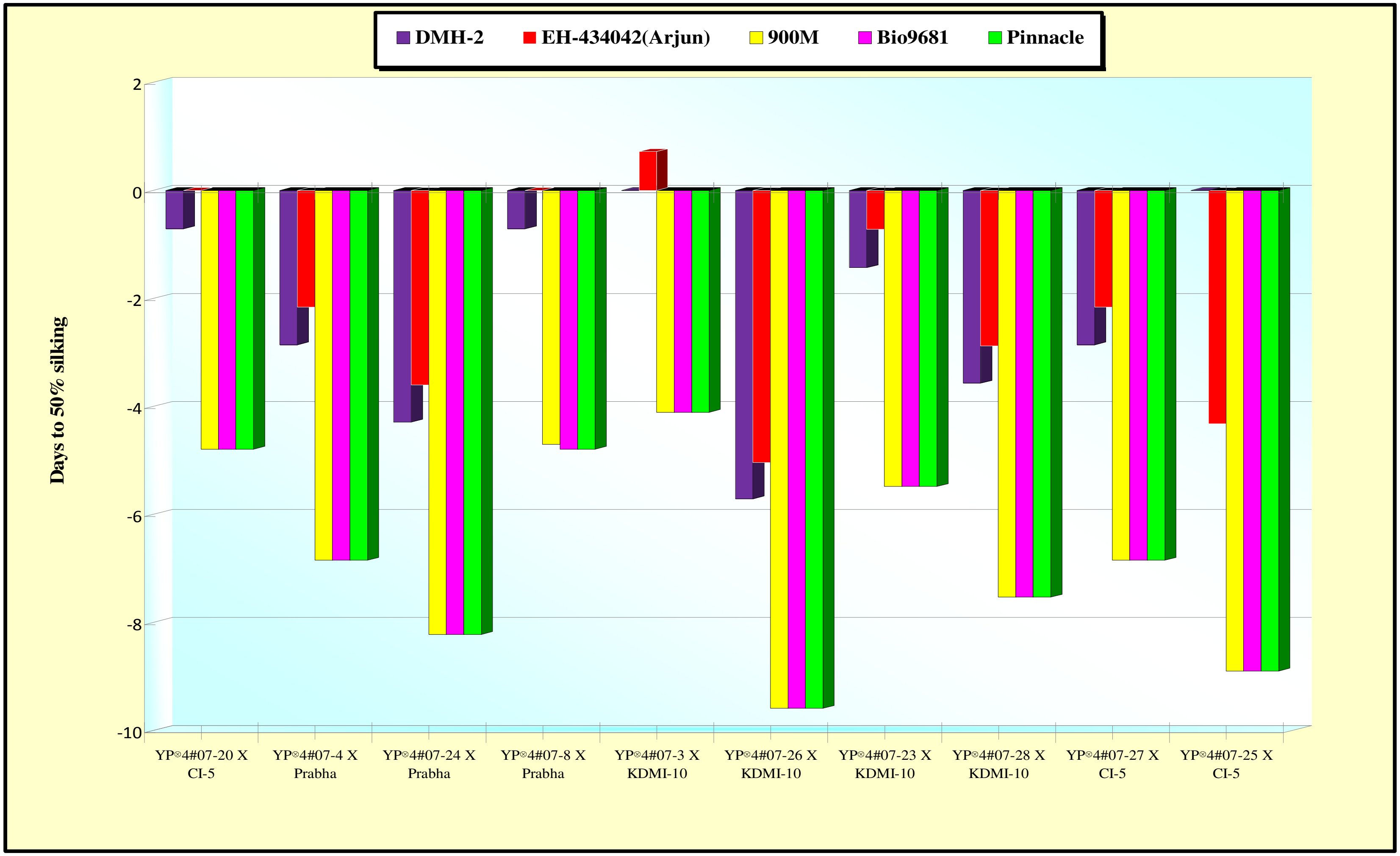


Fig.9. Standard heterosis for top 10 experimental hybrids for days to 50 percent silking

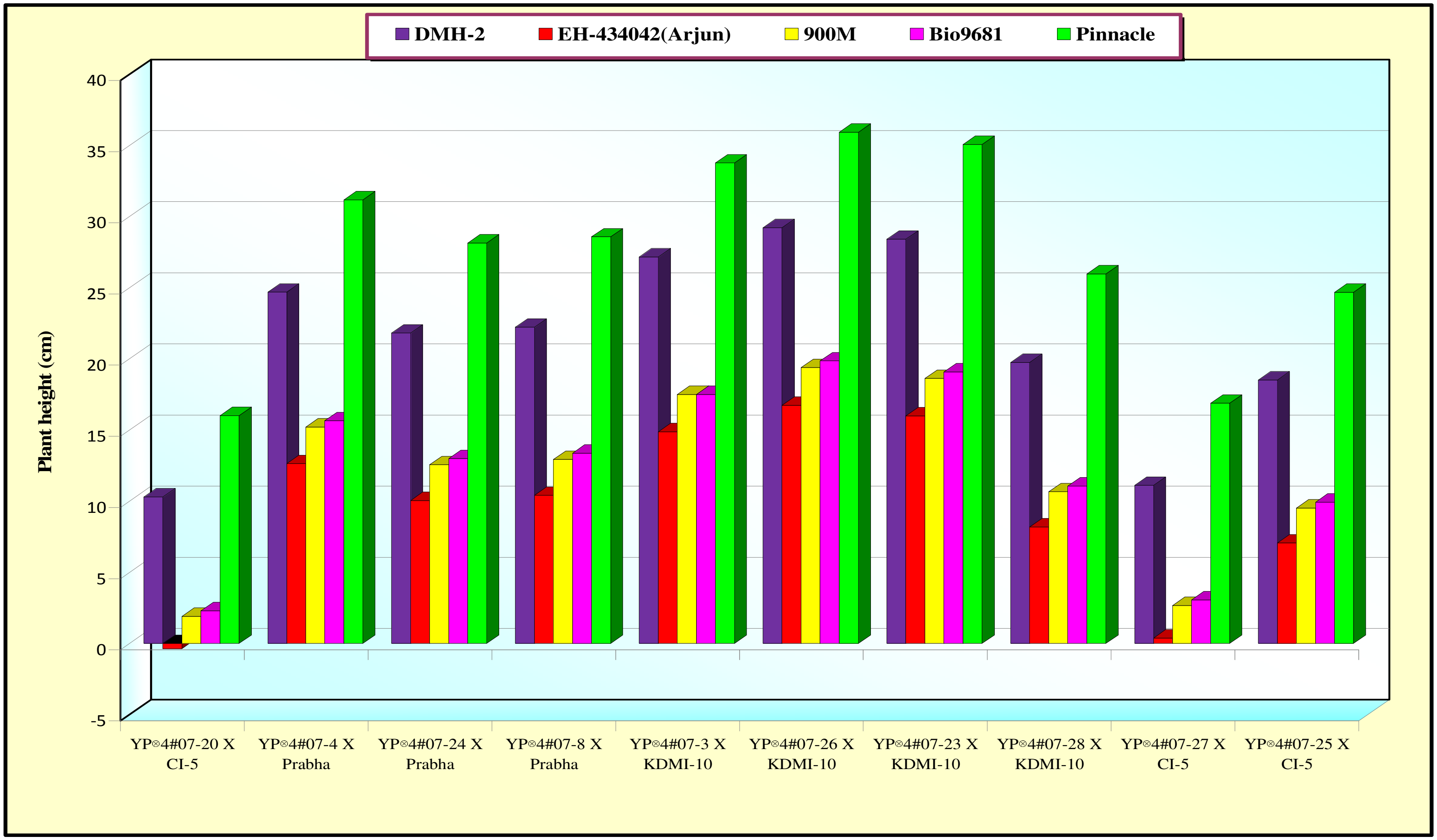


Fig.10. Standard heterosis for top 10 experimental hybrids for plant height (cm)

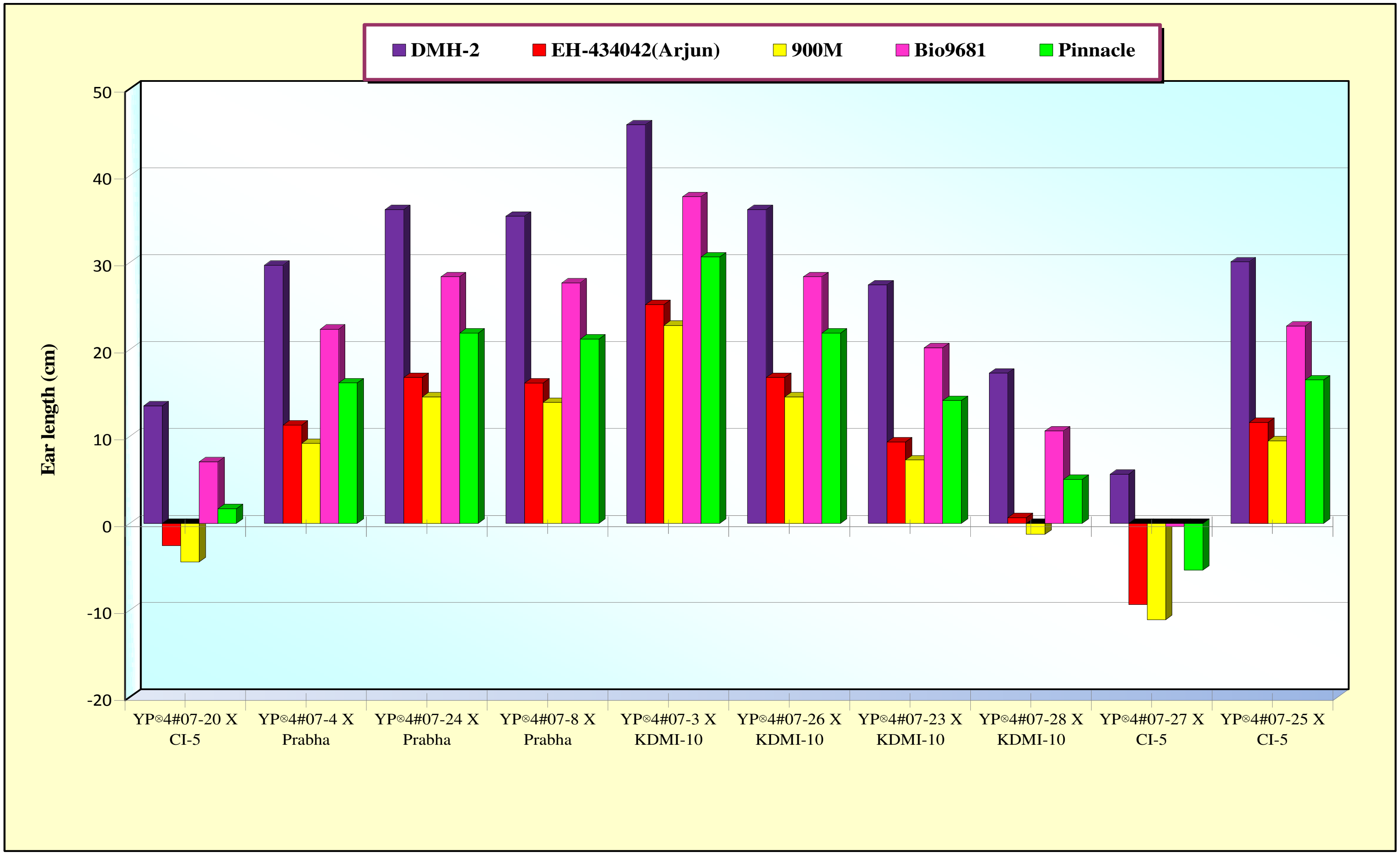


Fig.11. Standard heterosis for top 10 experimental hybrids for ear length (cm)

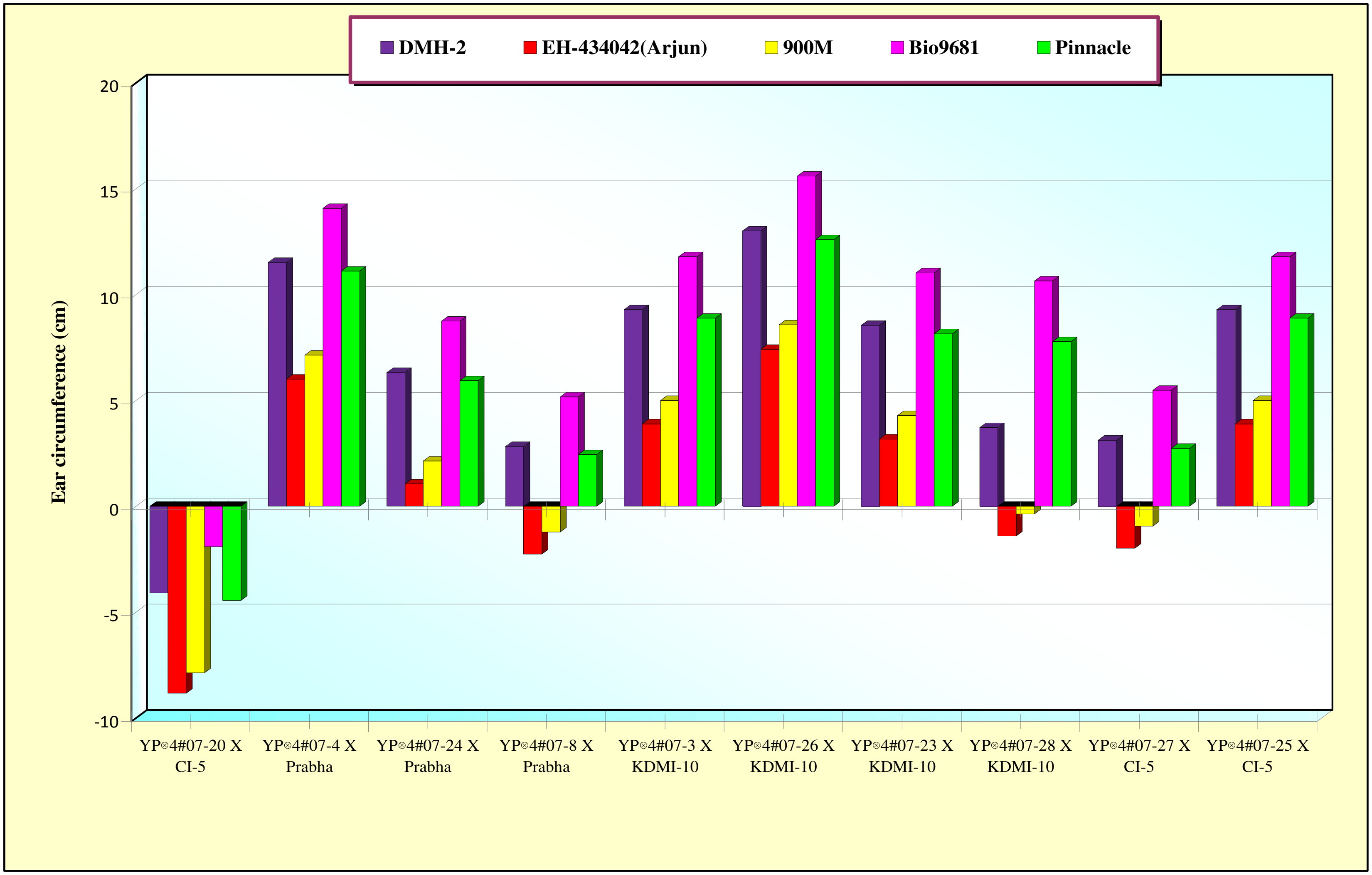


Fig.12. Standard heterosis for top 10 experimental hybrids for ear circumference (cm)

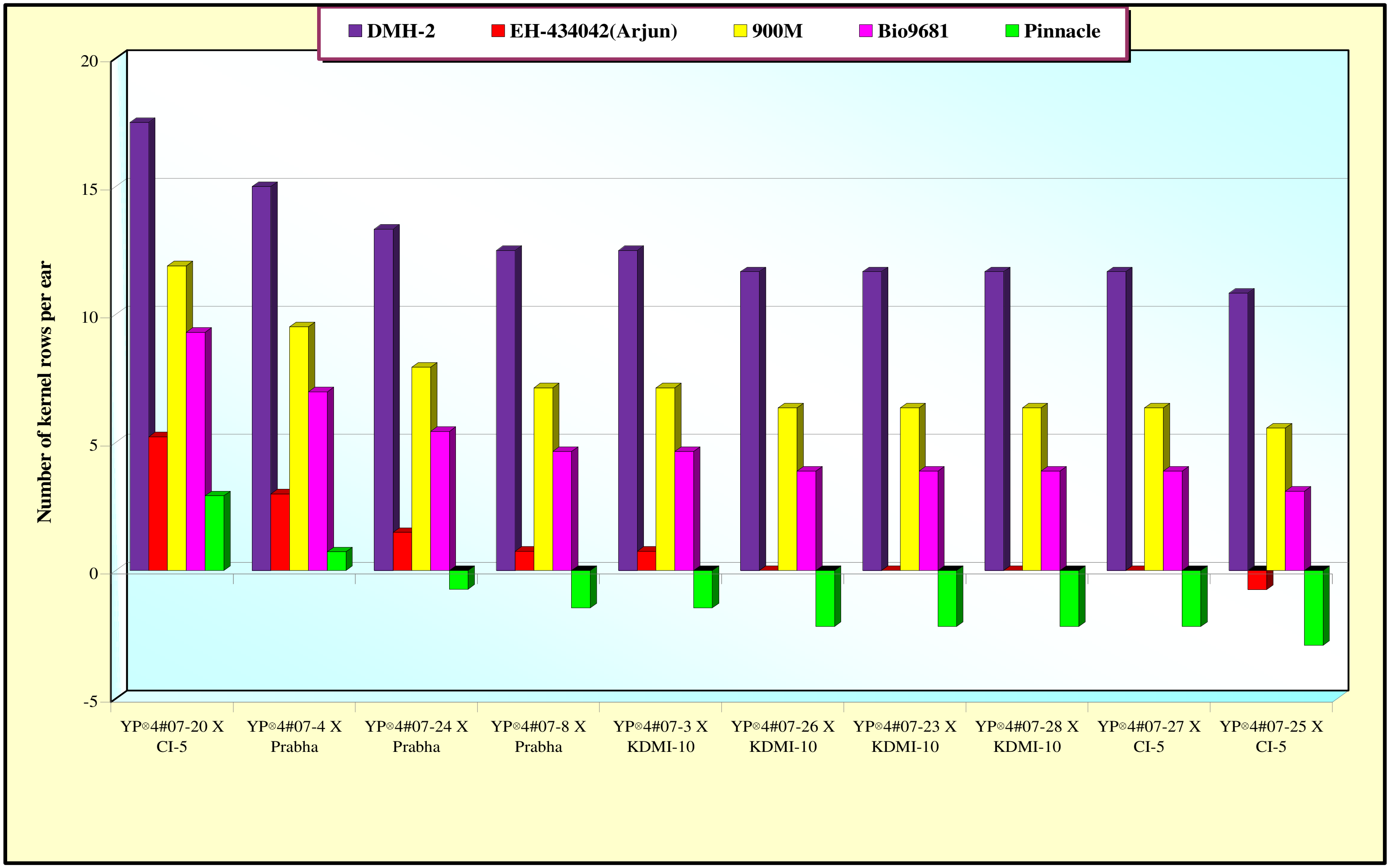


Fig.13. Standard heterosis for top 10 experimental hybrids for number of kernel rows per ear

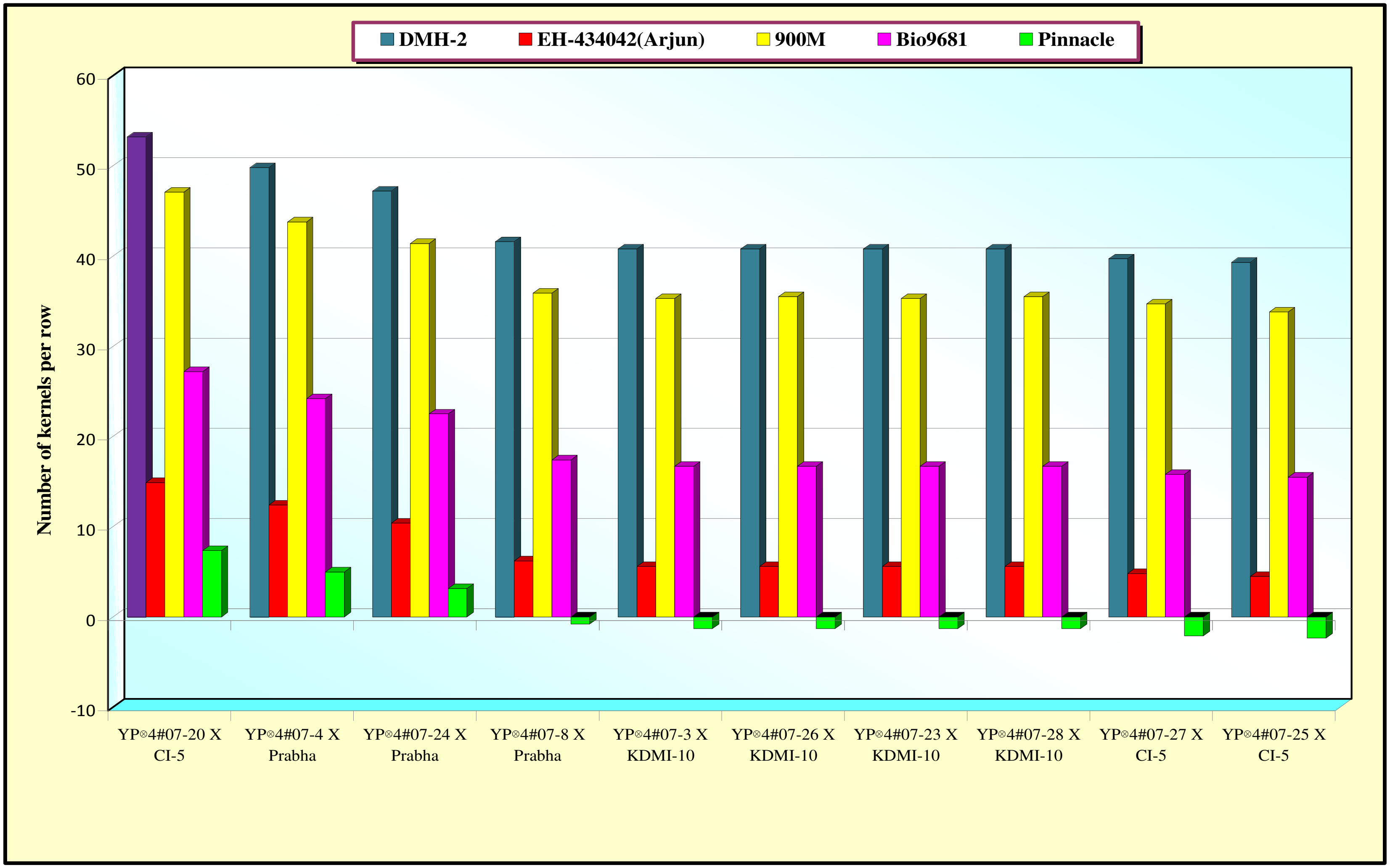


Fig.14. Standard heterosis for top 10 experimental hybrids for number of kernels per row

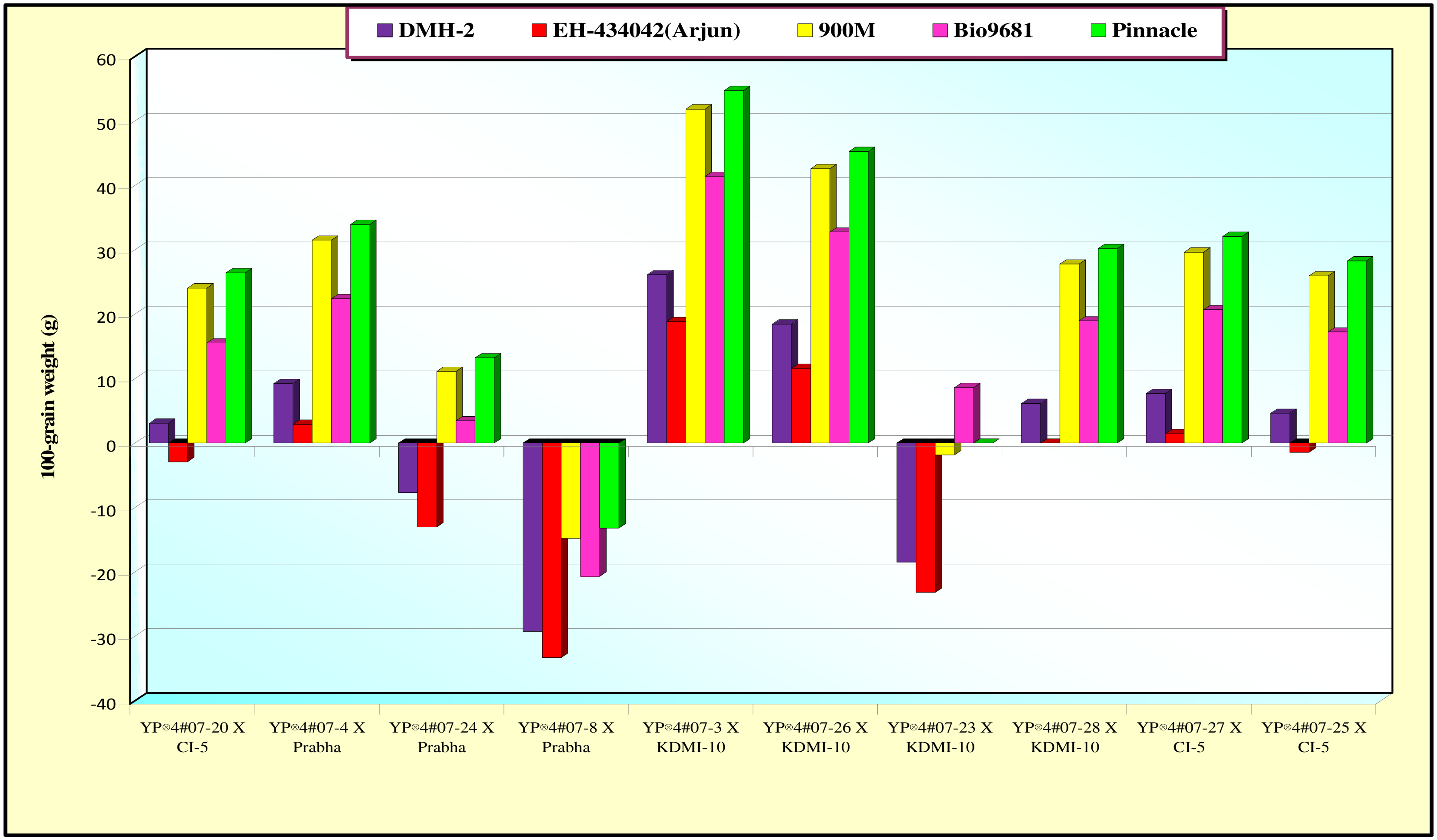


Fig.15. Standard heterosis for top experimental hybrids for 100-grain weight (g)

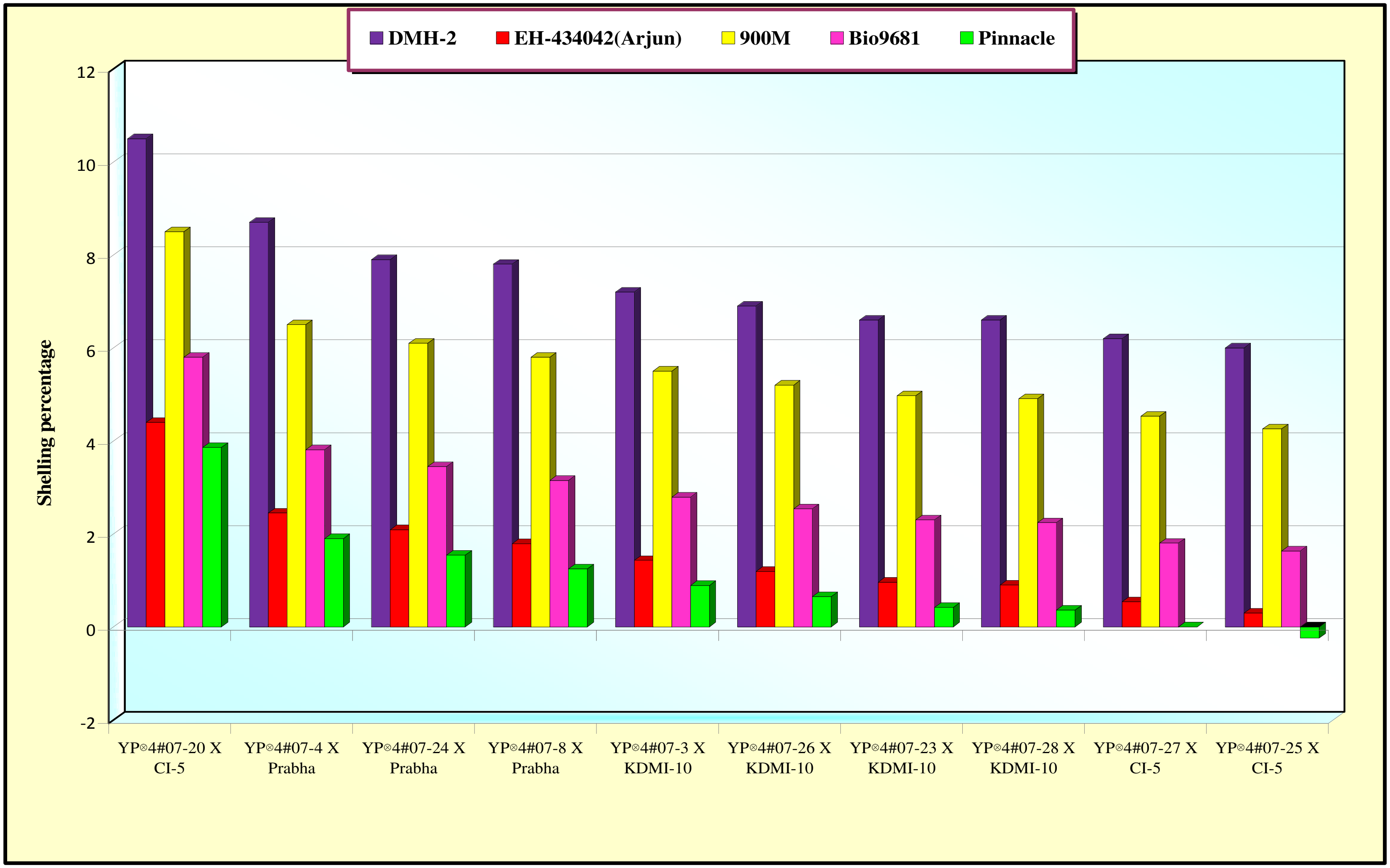


Fig.16. Standard heterosis for top 10 experimental hybrids for shelling percentage

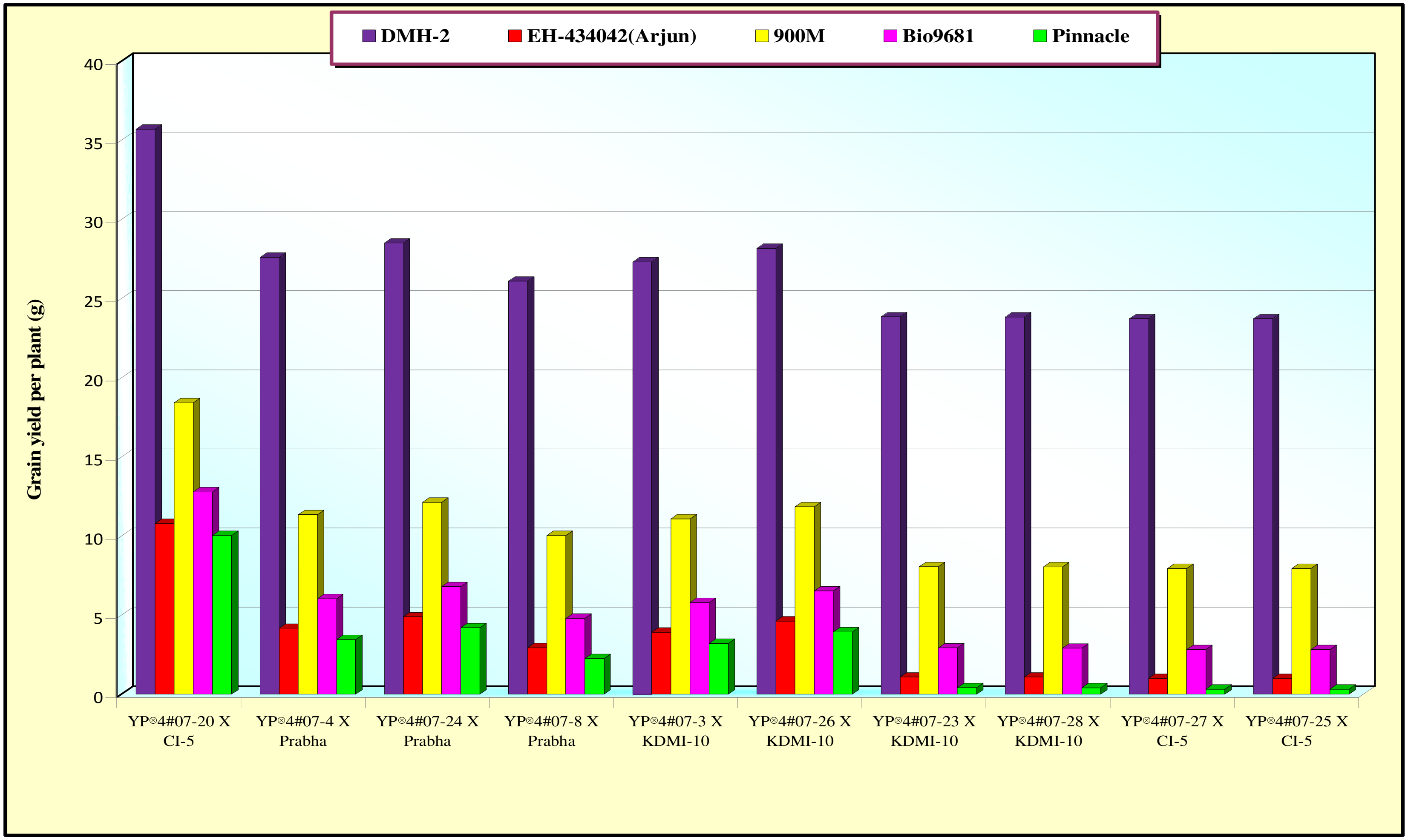


Fig.17. Standard heterosis for top 10 experimental hybrids for grain yield per plant(g)

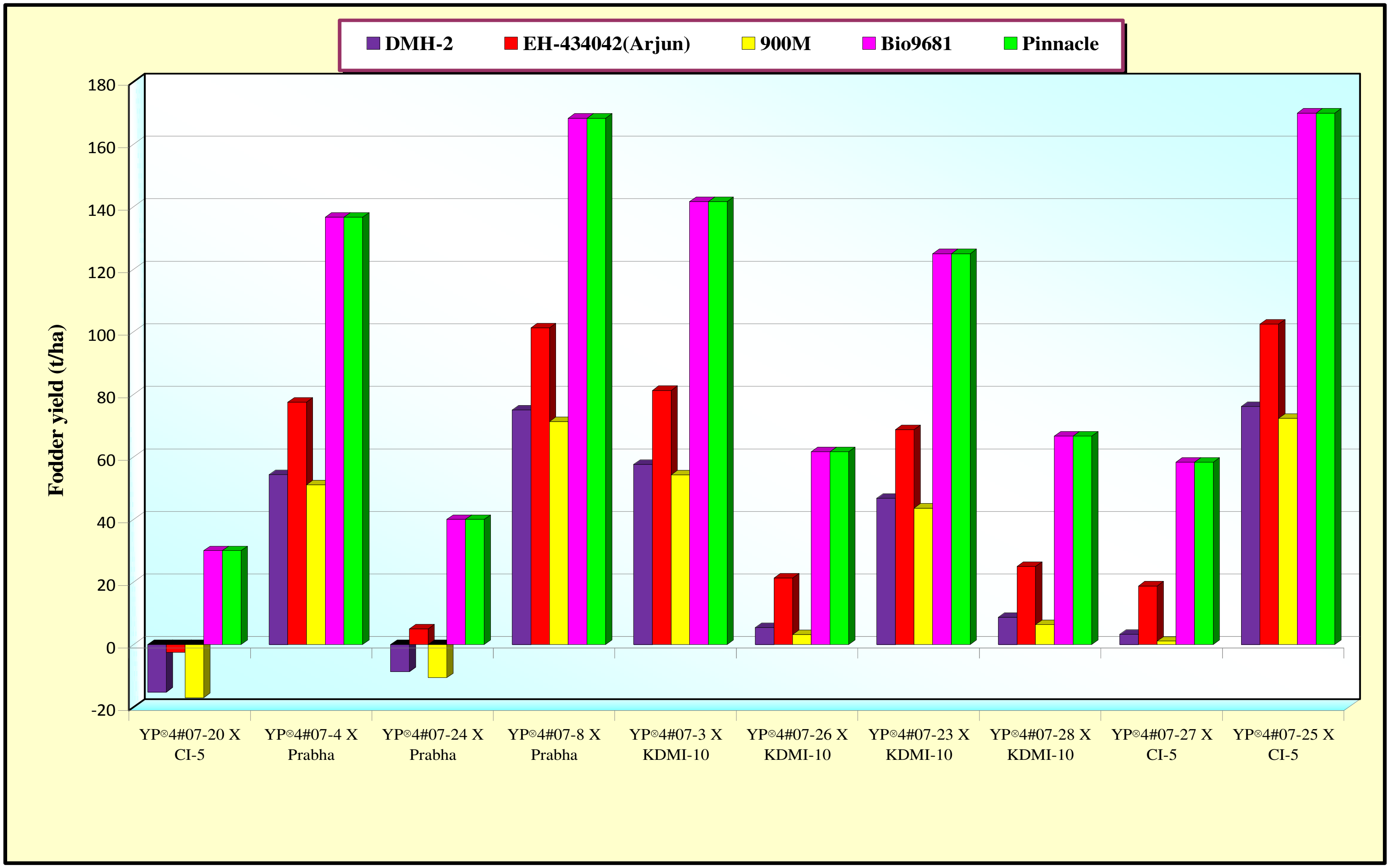


Fig.18. Standard heterosis for top 10 experimental hybrids for foder yield per hectare (t/ha)

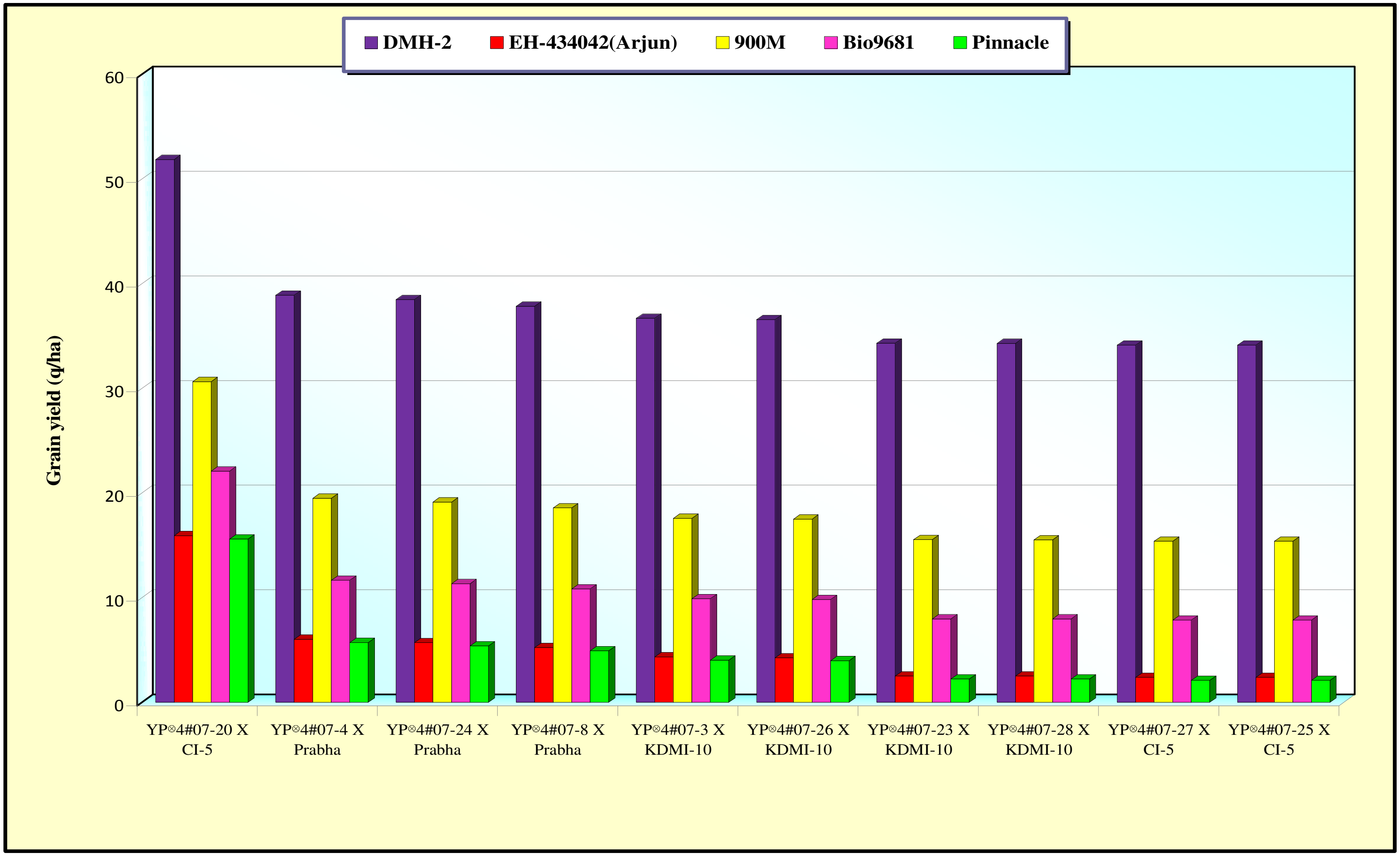


Fig.19. Standard heterosis for top 10 experimental hybrids for grain per hectare (q/ha)

circumference (Gautam, 1999) and fodder yield per hectare (Krishan and Natarajan, 1995) as also reported by several workers. The negative direct effect was observed by Umakantha et al. (2001).

The indirect effects on yield were excreted by grain yield per plant, 100-grain weight, days to 50 per cent silking and ear circumference. These findings were in accordance with Shaik Mohmmed (2001).

5.5 Selection of desirable line and hybrids for future use

Based on the general combining ability effects best lines were used for scoring techniques (Table 9 and 18). Among 29 lines, YP⊗4#07-1 and YP⊗4#07-20 exhibited high gca effects for maximum number of yield contributing characters. It is evident from the pooled score analysis of parents for gca effects that these females parents stood out as top potential combiners with highest pooled score of +4. The second rank was taken by YP⊗4#07-16 and YP⊗4#07-19 with pooled score of +3, YP⊗4#07-3, YP⊗4#07-14, YP⊗4#07-17, YP⊗4#07-18, YP⊗4#07-21, YP⊗4#07-25, YP⊗4#07-28 and YP⊗4#07-29 with pooled score of +2 ranked third. Among the male parents (testers), KDMI-10 was the best combiner with pooled score value of +2 (Fig 6).

Based on the performance, top 10 single cross hybrids are selected for grain yield (Table 19). These single cross hybrids were on par with standard check Pinnacle for grain yield. The hybrids viz., YP⊗4#07-20 x CI-5, YP⊗4#07-4 x Prabha, YP⊗4#07-24 x Prabha, YP⊗4#07-8 x Prabha, YP⊗4#07-3 x KDMI-10, YP⊗4#07-26 x KDMI-10, YP⊗4#07-23 x KDMI-10, YP⊗4#07-28 x KDMI-10, YP⊗4#07-27 x CI-5 and YP⊗4#07-25 x CI-5 topped the list of crosses for grain yield per hectare. This high yielding ability may be due to possession of significant plant height, ear length, ear circumference, number of kernel rows per ear, number of kernels per row, 100-grain weight and grain yield per plant. These hybrids had combination of parents with low x low, low x high and high x high gca effects (Fig 7).

These also had considerably high sca effects through they were not significant. Thus, these can be directly used as hybrids or apply standard selection procedure in segregating populations. This holds true for the crosses, which were obtained from high x high gca effect parent combinations.

But these high yielding crosses obtained from low x low gca effects and also low x high gca effects which indicates that even though the individual lines have less gca effects, but when they are crossed the gene contributing for grain yield from female and male combines well with each other without any negative effects. Thus low x low gca effect crosses show higher yield when compared to high x high crosses.

Future line of work

- ✓ From this investigation, 10 promising single cross hybrids viz., YP⊗4#07-20 x CI-5, YP⊗4#07-4 x Prabha, YP⊗4#07-24 x Prabha, YP⊗4#07-8 x Prabha, YP⊗4#07-3 x KDMI-10, YP⊗4#07-26 x KDMI-10, YP⊗4#07-23 x KDMI-10, YP⊗4#07-28 x KDMI-10, YP⊗4#07-27 x CI-5 and YP⊗4#07-25 x CI-5 identified for grain yield need to be tested in multilocation trials or on farmer's fields in large area to study the performance of these crosses across different environments for their wider adaptability.
- ✓ These 10 promising single cross hybrids need to be screened for pest and disease resistance.

- ✓ Parents with high gca can be used in multiple crosses and their segregating population can be screened for segregation which posses all favourable alleles distributed among the parents for the desired characters.
- ✓ The promising lines (females) may be evaluated with large number of other testers to identify still better single cross hybrids.

6. SUMMARY AND CONCLUSIONS

An experiment was conducted to evaluate single cross experimental hybrids of maize, which were obtained by crossing 29 lines with three testers in a line x tester fashion. An attempt was made to understand the genetic nature of 12 quantitative characters *viz.*, days to 50 per cent tasseling, days to 50 per cent silking, plant height, ear length, ear circumference, number of kernel rows per ear, number of kernels per row, 100-grain weight, shelling percentage, grain yield per plant, fodder yield per hectare and grain yield per hectare. 87 F_1s, 29 lines, three testers and five commercial checks viz., DMH-2, EH-434042 (Arjun), 900M, Bio-9681 and Pinnacle were evaluated in a randomized block design during *Rabi*, 2009 at All India Co-ordinated Maize Improvement Project, Agricultural Research Station (ARS), Arabhavi.

The objectives of the study were

1. To evaluate the performance of single cross experimental maize hybrids for grain and fodder yield.
2. To estimate the gca and sca effects in respect to grain yield and its components.
3. Assessing of combining ability of single cross experimental hybrids and parents by involving line x tester analysis.

The salient features of experimental findings are summarized below

Analysis of variance clearly indicated the presence of significant differences among parents, hybrids and checks for all the traits indicating the presence of genetic variability in the materials used for the study. The analysis of variance revealed higher magnitude of SCA variance to GCA variance for all characters. Hence, the ratio of additive to dominance variance was lesser than unity for all traits. This indicated that all traits posses higher dominance variance than additive variance.

Among 29 lines, YP⊗4#07-1 was the best general combiner for plant height, ear circumference, 100-grain weight and fodder yield per hectare and YP⊗4#07-20 was the best general combiner for plant height and fodder yield per hectare. Among testers, KDMI-10 was the best general combiner for 100 grain weight and fodder yield per hectare.

The hybrids such as YP⊗4#07-20 x CI-5, YP⊗4#07-4 x Prabha, YP⊗4#07-24 x Prabha, YP⊗4#07-8 x Prabha, YP⊗4#07-3 x KDMI-10, YP⊗4#07-26 x KDMI-10, YP⊗4#07-23 x KDMI-10, YP⊗4#07-28 x KDMI-10, YP⊗4#07-27 x CI-5 and YP⊗4#07-25 x CI were the five top crosses with higher sca effects.

Heterosis studies indicated the expression of relative heterosis and heterobeltiosis in several crosses for most of the character in both desirable and undesirable direction. The cross combination YP⊗4#07-20 x CI-5, YP⊗4#07-4 x Prabha, YP⊗4#07-24 x Prabha, YP⊗4#07-8 x Prabha, YP⊗4#07-3 x KDMI-10, YP⊗4#07-26 x KDMI-10, YP⊗4#07-23 x KDMI-10, YP⊗4#07-28 x KDMI-10, YP⊗4#07-27 x CI-5 and YP⊗4#07-25 x CI were found to be promising for grain yield as they had high standard heterosis. These crosses had the combinations of low x low, low x high and high x high gca effects.

Correlation and path analysis indicated that plant height, ear length, ear circumference, number of kernel rows per ear, number of kernels per row, 100-grain weight, grain yield per plant had strong association and directly affected grain yield.

From this investigation, it is suggested to evaluate best hybrids viz., YP⊗4#07-20 x CI-5, YP⊗4#07-4 x Prabha, YP⊗4#07-24 x Prabha, YP⊗4#07-8 x Prabha, YP⊗4#07-3 x KDMI-10, YP⊗4#07-26 x KDMI-10, YP⊗4#07-23 x KDMI-10, YP⊗4#07-28 x KDMI-10, YP⊗4#07-27 x CI-5 and YP⊗4#07-25 x CI-5 for grain yield for commercial utilization. Further, the promising single cross experimental hybrids having parental combinations with low x low, high x high and low x high gca effects for yield may be used for improvement of parental lines by selection in advanced generation.

REFERENCES

Abdel Hady, M. S., Abdel Sattar, A. A and Mahmoud, I. M., 2004, Prediction of heterosis and combining ability in maize using tissue cultures. *Bull. National Res. Centre Cairo,* 29(1): 109-119.

Abdul, S., 1995, Effect of heterosis on the stover yield and some local and exotic hybrid lines of maize. *Pakistan J. Agric. Res.*, 45: 27-30.

Abdolhamid Rezaei., Bahman Yazdisamadi., Abasali Zali., Alireza Tallei., Hosein Zeinali and Abdolmajid Rezaei., 2004, Estimate of heterosis and combining ability in maize (Zea mays L.) using diallel crossing method. *Genetic Variation for Plant Breeding Proceedings of the 17th EUCARPIA General Congress.*, 395-397

Abelardo, J., De la Vega and Scott, C. C., 2006, Multivariate analysis to display interactions between environment and general or specific combining ability in hybrid crops. *Crop Sci.,* 46: 957-967.

Abirami, S., Vanniarajan, C., Arumugachamy, S and Uma, D, 2007, Correlation and path coefficient analysis for morphological and biochemical traits in maize genotypes. *Plant Archives.* 7(1): 109-113.

Akhtar, S. A. and Singh, T. P., 1981, Heterosis in varietal crosses of maize. *Madras Agric. J.,* 68: 47-51.

Alamnie Atanaw, Nayakar, N. Y and Wali, M. C., 2003, Combining ability, heterosis and per se performance of height characters in maize. *Karnataka J. Agric. Sci.*: 16 (1): 131-133.

Al Ahmad,S. A., El Shouny, K. A., Olfat, H. E. and Ibrahim, K. I. M., 2004, Heterosis and combining ability in yellow maize (Zea mays, L.) crosses under two planting dates. *Annals Agric. Sci. Cairo*: 49 (2): 531-543

Ali, M. L. and Topara, N. M., 1986, Comparative performance of four types of factors for evaluating corn lines from two populations. *Philippines J. Crop Sci.,* 3: 175-179.

Alika, J. E., 1994, Diallel analysis of ear morphological characters in maize (*Zea mays* L.). *Indian J. Genet.*, 54: 22-36.

Alok Kumar, Gangashetti and Arju Dahiya, H. G., 1999, Analysis of direct and indirect effects of quantitative traits in diallel crosses of maize. *Ann. Biol.*, 15: 173-176.

*Altinbos, M., 1995, Heterosis and combining ability in maize for grain yield and some plant characters. *Adadolu,* 5 (2): 35-51.

*Altinbos, M. and Tosum, M., 1998, A study on utilizing combining ability co-variances in hybrid maize (*Zea mays* L.) breeding. *Anadohi,* 8: 90-100.

Alvarez, A., Garay, G., Gimenez, J., Ruiz, D. E. and Galarreta, J. I., 1993, Heterosis in two synthetic varieties of maize based on morphological and reproductive traits. *Invest. Agraria*, 8 (3) : 333-340.

Amit Dadheech and Joshi, V. N., 2007, Heterosis and combining ability for quality and yield in early maturing single cross hybrids of maize (*Zea mays* L.). *Indian J. Agric. Res.* 41 (3): 210-214.

Annapurna, D., Khan, K. H. A. and Shaik Mohammad, 1998, Genotypic phenotypic correlations and path coefficient analysis between seed yield and other associated characters in tall genotypes of maize. *Crop Res.*, 16: 205-209.

*Annenkova, Z. M., 1973, The effect of the pollen parent on heterosis in maize. *Nauch tr. Voroneryh*, 8: 70-75.

Anonymous, 2009, Agriculture, Centre for monitoring Indian economy (CMIE).

Appadurai, R. and Nagarajan, R., 1975, Hybrid vigour in popcorn. *J. Madras Agric. Univ.*, 62: 122-126.

Arun Kumar., 2001, Combining ability studies in maize (*Zea mays* L.). *New Botanist* 2001, 28 (1/4): 69-81.

Arun Kumar and Singh, N. N., 2004, Identification of yield contributors through path analysis in maize. *Annb Agric. Res.*, 25(3): 448-450.

Ashby, E., 1930, Studies on the inheritance of physiological characteristics. I. A physiological investigation of the nature of hybrid vigour in maize. *Ann. Bot.*, 44: 457-467.

Ashby, E., 1932, Studies in the inheritance of physiological characters. II. Further experiments upon the basic of hybrid vigour and upon the inheritance of efficiency index and respiration rate in maize. *Ann. Bot.,* 46: 1007-1032.

Ashish Srivastava and Singh, I. S., 2002, Evaluation and classification of exotic inbreds over locations based on line x tester analysis in maize (*Zea mays* L.). *Crop Improv*, 29 (2): 184-189.

Ashish Srivastava and Singh, I. S., 2003, Heterosis and combining ability for yield and maturity involving exotic and indigenous inbred lines of maize (*Zea mays* L.). *Indian J. Genet. Plant Breeding.,* 63 (4): 345-346.

Bao-HC-Ping, Zhang-Jun, Zhao-Lizhi, Yu-Yanshan and Dou Maottai, 2004, path analysis of ear characters in spacing inbred maize lines. *J. Agric. Sci.*, 3 : 29-45.

Bassey, E. E., 2002, Evaluation of the heterosis and combining ability for yield and yield components in maize. *J. Sustainable Agri. Environ.,* 4 (2): 192-200.

Beck, D. L., Vasal, S. K. and Crossa, J., 1990, Heterosis and combining ability of CIMMYT'a tropical early and intermediate maturity maize (*Zea mays* L.) germplasm. *Maydica,* 35 (3): 279-285.

Betran, F. J., Ribaut, J. M., Beek, D. and Gonzalez de Leon, D., 2003, Genetic diversity, specific combining ability and heterosis in tropical maize under stress and non-stress environments. *Crop Sci.,* 43: 797-806.

Bhalla, S. K. and Khehra, A. S., 1977, Analysis of combining ability in maize at varying plant densities. *Maydica*, 22: 19-26.

Bhatnagar, S. K., Ranwaz, B. R. and Sunderesan, R., 1993, Heterosis in early maize. *Ind. J. Genet.*, 53 : 94-96.

Boraneog, S. and Duara, P. K., 1993, Phenotypic performance and correlation in maize, *IASS*, 6: 29-33.

Brar, S. P. S., Chawla, J. S and Pritpal Singh., 2008, Studies on different selection indices and path analysis in maize (*Zea mays* L.). *Crop Improv..* 35(1): 16-19.

Bruce, A. B., 1910, The Mendelian theory of heredity and the augmentation of vigour. *Sci.*, 32: 627-628.

Choudhary, A. K., Chaudhary, L. B. and Sharma, K. C., 2000, Combining ability estimates of early generation inbred lines derived from to maize populations. *Indian J. Genet.,* 60(1): 55-61.

Crossa, I., Gardaner, C. O. and Mumm, R. F., 1987, Heterosis among populations of maize (*Zea mays* L.) with different levels of exotic germplasm. *Theor. Applied Genet.*, 73: 445-450.

Crossa, J., Vasal, S. K. and Beck, D. L., 1990, Combining ability estimates of CIMMYT's tropical late yellow maize germplasm. *Maydica*, 35 (3): 273- 278.

Cruz Lazaro, E de La., Gutierrez del Rio, E., Palomo Gil, A and Rodriguez Herrera, S., 2003, Combining ability and heterosis of maize inbred lines at the Comarca Lagunera. *Revista Fitotecnia Mexicana,* 26 (4): 279-284

*Damborsky, M., Chloupek, O. and Ehrenbergerova, J., 1994, Variability of maize lines and diallel cross hybrids. *Gebetika-a-Slechteni*, 30 (4): 297-303.

Dass, S., Aror, P. and Singh, M., 1997, genetics of grain yield and cob traits in maize. *Ann. Biol.*, 13: 288-287.

Davis, R. L., 1927, Report of the plant breeder. Uerto Rico Agricultural Experimental Station Annual Report, pp. 14-15.

Debnath, S. C., 1984, Heterosis in maize I: grain yield and some of its attributes (in India). *Bangladesh J. Agric. Res.,* 9 (2): 78-83.

Debnath, S. C., 1987, Heterosis in maize (*Zea mays* L.) *Bangladesh J. Agric.*, 12 (3): 161-168.

Debnath, S. C. and Khan, M. F., 1991, Genotypic variation, covariance and path coefficient analysis in maize. *Pakistan J. Sci. and Industrial Res.*, 34: 391- 394.

Debnath, S. C. and Sarkar, K R., 1987, Genetic analysis of grain yield and some of its attributes in maize (*Zea mays* L.). *Thailand J. Agric. Sci.*, 20: 263-276.

Debnath, S. C. and Sarkar, K. R., 1990, Combining ability analysis of grain yield and some of its attributes in maize (*Zea mays* L.). *Indian J. Genet.*, 50: 57-61.

Dehghanapour, Z., Ehdaie, B., Moghaddam, M., Griffing, B. and Hayman, B., 1997, Diallel analysis of agronomic characters in white endosperm corn. *J. Genet. and Breed.,* 50 (4) 3757-365.

Desai, S. A. and Singh, R. D., 2001, Combining ability studies for some morphological, physiological and biochemical traits related to drought tolerance in maize. *Indian J. Genet. Plant Breeding*, 61: 34-36.

Dewey, D. R. and Lu, K. H., 1959, A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.*, 51 : 515-518.

Dhillon, B. S. and Singh, J., 1976, Diallel analysis of yield and other traits of maize varieties. *SABRAO J.*, 8: 147-152.

Dodiya, N. S. and Joshi, V. N., 2002, Gene action for grain yield and its attributes in maize (*Zea mays* L.). *Indian J. Genet. Plant Breeding*: 62(3): 253-254.

Dodiya, N. S. and Joshi, V. N., 2003, Heterosis and combining ability for quality and yield in early maturing single cross hybrids of maize (*Zea mays*). *Crop Res*., 26 (1): 114-118.

*Dornescu, A., 1973, Heterosis for yield components in maize. *Cecetari Agronomica*, 6: 63-69.

Downsell, C. R., Paliwal, R. L. and Cantrell, R. P., 1996, Maize in the third world. West view press, pp. 1-37.

*Dutu, H., 1998, Phenotypic and genetic correlations between vegetative period and grain yield and other agronomic trait in early maize. *Analete Instutului d Cercetari pentra cereale Si plante Technice Fundulea*, 65: 101-109.

*Dutu, M., 1999, Phenotypic and genetic correlations between growing season, plant height and leaf number in maize. *Corcetari Agronomice in Moldova*, 31: 69-78.

East, E. M. and Hayes, H. K., 1912, Heterozygosis in evolution and in plant breeding. *U. S. Department Agric. Bulletin,* pp. 243.

East, E. M., 1936, Heterosis. *Genet.*, 21: 375-397.

El-Hosary, A. A. Mohamed, M. K., Sedhom, S. A. and Abo-El-Hassan, G.K.A., 1994a, Performance and combining ability in diallel crosses of maize, *Ann. Agric. Sci.,* 32 (1): 203-216.

El-Hosary, A. A., Mohamed, M. K., Sedhom, S. A. and Abo-El-Hassan, G. K. A., 1994b, General and specific combining interactions with year in maize. *Ann. Agric. Sci.,* 32: 247-288.

El-Moula, M. A. A., Barakat, A. A. and Ahmed, A. A., 2004, Combining ability and typed gene action for grain yield and other attributes in maize (*Zea mays* L.). *Aust. J. Agric. Sci.*, 35(3) : 129-142.

El-Nagouly, O. O., Abul-fadol, M. A., Ismail, A. A. and Khamis, M. N., 1983, Genotypic and phenotypic correlations and path analysis in maize and their implications in selection. *Agronomy Abstract*, Madison Square, Wisconsin, USA, *American Soc. Agron.*, 15: 62-63.

El-Shouny, K. A., Ei-Bagoury, O. H., Ibrahim, K. I. M. and Al-Ahmed, S. A., 2005, Correlation and path coefficient analysis in four yellow maize crosses under two planting dates. *Arab Univ. J. Agric. Sci.*, 13(2) : 327-339.

Firoza Khatun, Sajeda Begum, Abdul Motin Suraja Yasmin and Islam, M. R., 1999, Correlations coefficient and path analysis of some maize hybrids. *Bangladesh J. Bot.*, 28: 9-15.

Ganguli, D. K., Haque, M. F. and Sinha, P. K., 1989, Heterosis in inter-population crosses in maize. *J. Res., Birsa Agric. Univ.*, 1 (1): 59-65.

Gardner, C. O., 1963, Estimation of genetic parameters in cross-pollinated plants and their implications in plant breeding. Statistical Genetics and Plant Breeding. *NAS-NRS Washington D. C. Publication*, 982: 228-24.

Gautam, A. S., Mittal, R. K. And Bhandari, J. C., 1999, Correlations and path coefficient analysis in maize (*Zea mays* L.). *Ann. Agric. Biotech. Res.*, 4 : 169-171.

Geetha, K., 1997, Genetic analysis of yield, starch and downy mildew resistance in maize (*Zea mays* L.). *Ph. D. Thesis*, Tamil Nadu Agric. Univ., Coimbatore.

Geetha, K. and Jayaraman, N., 2000a, Path analysis in maize (*Zea mays* L.). *Agric. Sci. Digest*, 20: 60-61.

Geetha, K. and Jayaraman, N., 2000b, Genetic analysis of yield in maize (*Zea mays* L.). *Madras Agric. J.,* 87: 638-640.

Geetha, K., 2001, Heterosis in maize (*Zea mays* L.). *Agric. Sci. Digest*, 21: 202-203.

*Genova, I., 1984, Inheritance of quantitative characters in maize and variation in genetic parameters. Yield and yield components. *Geneticka I selektsiya,* 17: 323-332

Gieshercht, J., 1960, Inheritance of maturity in maize. *Canadian J. Genet. Cytology*, 40: 490-499.

Giridharan, S., Prasad, M. N. and Rangaswamy, S. R., 1996, Diallel, triallel and quadriallel analysis for grain yield in maize. *Madras Agric. J.*. 83 (4): 230- 236.

*Gomes-E-Gamma, E. E., Mahnavaca, R., Parentoni, S. N., Acjecp Cap and Guimaraes, P. E. O., 1993, Evaluation of maize top crosses for their potential use in breeding programme. *Pesquia-Agropecua ria-Brasilerria*, 28 (4): 481-487.

Goulden, G., 1959, Methods of statistical analysis. *Asia Publication House*, Culcatta, pp. 47-49.

Griffing, B. and Zsiros, E., 1971, Heterosis associated with genotype-environment interactions. *Genet.*, 68: 443.

Griffing, B., 1956, Concept of general combining ability and specific combining ability in relation to diallel crossing system. *Australian J. Biological Sci.,* 9: 463-493.

Guang Cheng, Xue Yan and Gou-Shongue, 2002, Path analysis of eight yield components of maize. *J. Maize Sci.*, 10(3) : 33-35.

*Guo, P. Z., Gardner, C. O. and Obaidi, M., 1986, Genetic variations and gene effect controlling prolificacy and other traits in maize (*Zea mays* L.) *Acta Genetica Sinica,* 13: 35-42.

Guirong, W., Shui, Z. De., Decai, C. and Yi, Y. C., 1997, Genetic analysis of various yield components of maize hybrids. *J. Shandong Agric. Univ.,* 28: 33-36.

Gupta, S. C. and Nagda, A. K., 2000, Analysis of variety diallel cross for yield and its components in winter maize. *Indian J. Genet. Plant Breeding*, 60: 301- 303.

Gupta, S. C., Nagda, A. K. and Kulmi, G. K., 1994, Economic heterosis in double cross hybrids of maize. *Crop Res.*, 8: 634-636.

Hallauer, A. R., Lamkey, K. R., Russell, W. A. and White, P. R., 1994, Regression of B97 and B98. Tow parental inbred lines of maize. *Crop Sci.*, 34: 318-319.

Han Li Jun, Yang Weiguang, Wang, Qi and Zhang Jan, 2001, Inheritance of ear width of maize. *J. Jilin Agric. Univ.*, 23: 12-15.

Harland, S. C., 1939, The genetics of cotton, John Than Cape, London, pp. 18-23.

Harjinder Singh., Chawla, J. S and Grewal, M. S., 2006, Correlation and path coefficient analysis on some elite maize genotypes. *Crop Improv.,* 33 (1): 31-33.

Hassaballa, E. S., El-Morshidy, M. A., Kalifa, M. A. and Shal.Aby, E. M., 1980, Combining ability analysis in maize, I. *Flowering Res. Bulletin Faculty of Agric. Ain. Sham's Univ.*, 1291, p. 8.

Hayes, H. K., Immer, F. R. and Smith, D. C., 1955, Methods of Plant Breeding. Mc. Grow Hill Book. Co., Inc., New York

Heidrich-Sobrinho and Cordeiro, A. R., 1975, Co-dominant isoenzymic alleles as maker of genetic diversity correlated with heterosis in maize (*Zea mays* L.) *Theor. Appl. Genet.*, 46: 197-199.

Herbert, Y. and Gallis, A., 1986, Heterosis and genetics and variation for quantitative characters in a 12 x 12 diallel mating design maize, In: Biomentrics in Plant Breeding. (M. J. Kearse and C. P. Werner, (eds.) Briminlgham, U. K., pp.140-152.

Herczecjji, M., 1970, Importance of yield components in the phenotype. In : *Some Methodological Achievements of the Hungraian Hybrid Maize Breeding,* pp. 229-236.

Hossain, F., Tripathi, S. and Warsi, M. Z. K., 2004, Combining ability analysis in flood tolerant maize inbred lines and their hybrids under waterlogged situation. *Crop Res.*, 27 (2 & 3):266-269

Hull, F. H., 1945, Recurrent selection for specific combining ability in corn. *Agron. J.*, 37: 134-145.

Hull, F. H., 1946, Over-dominance and Corn. Breeding where hybrid seed is not feasible. *Agron. J.,* 38: 1100-1103.

Hull, F. H., 1948, Evidence of over-dominance in yield of corn. *Genet.*, 33: 20-25.

Hull, F. H., 1952, Recurrent selection and over-dominance. Heterosis, Iowa State Col. Press America, pp. 40-52.

Jayakumar, J. and Sundaram, T., 2007, Combining ability studies for grain yield and other yield components in maize (*Zea mays* L.). *Crop Res. Hisar:* 33(1/3): 179-186.

Jenkins, M. T. and Brunson, A. M., 1932, Methods of testing inbred lines of maize ill crosses bred combinations. *Agron. J.*, 24: 523-530.

Jha, P. B. and Khehra, A. S., 1992, Evaluation of maize inbred lines derived from two heterotic populations. *Indian J. Genet.,* 52 (2): 126-131.

Jha, P. B., Singh, D. N. and Ghosh, J., 2002, Heterosis and gene action for fodder yield in maize. *Forage Res.*, 28(1): 49-51.

Johanson, G. R., 1973, Relationship between yield and several yield components in a set of maize hybrids. *Crop Sci.*, 13: 649-652.

Johnson, H. W., Robinson, H. F. and Comstock, R. E., 1955, Estimates of genetic and environmental variability in soyabean. *Agron. J.*, 47 : 314-318.

Johnson, I. J. and Hayes, H. K., 1940, The value in hybrid combinations of inbred lines of corn selected from single crosses by the pedigree method of breeding. *Agron. J.*, 32: 479-485.

Jones, D. F., 1918, The effects of inbreeding and cross breeding upon development of corn. *Agronomy Experimental Station Bulletin*, p. 207.

Jones, D. F., 1922, The productiveness of single and double first generation corn hybrids. *Agron. J.*, 14: 241-252.

Joshi, V. N., Pandiya, N. K. and Dubey, R. B., 1998, Heterosis and combining ability for quality and yield in early maturing single cross hybrids of maize (*Zea mays* L.). *Indian J. Genet. Plant Breeding*, 58(4): 519-524.

Jugenheimer, R. W., 1949, Efficient development and testing of corn inbred lines and hybrids. *American Soc. Agron. Abstracts*, p. 6.

Jumbo, M B and Carena, M. J., 2008, Combining ability, maternal, and reciprocal effects of elite early-maturing maize population hybrids. *Euphytica*: 162(3): 325-333.

Jyoti Kumari., Gadag, R. N and Singh, B. B., 2007, Combining ability studies among the inbred lines of sweet corn (*Zea mays* L. *saccharata*). *Indian J. Genet. Plant Breeding* . 67(1): 77-78.

Jyoti Kumari., Gadag, R. N and Jha, G. K., 2008, Combining ability and heterosis in field vs sweet corn (*Zea mays* L.) hybrids using line by tester mating design. *Indian. J. Agric. Sci*. 78 (3): 261-264.

Kabdal, M. K., Verma, S. S., Kumar, A. and Panwar, U. B. S., 2003, Combining ability and heterosis analysis for grain yield and its components in maize (*Zea mays* L.). *Indian J. Agric. Res.,* 37(1): 39-43.

*Kadlubiec, W. I., Karwowkka, C., Kuzezych, Z., Kuriata, R. and Walczowska – Kurizych, S., 2000, Combining ability of maize inbred lines. *Biueltyn Instytutu Hodowlii Aklimatyzacji Roslin*, 216: 371-378.

Kalla, V., Kumar, R and Basandrai, A. K., 2001, Combining ability analysis and gene action estimates of yield and yield contributing characters in maize (*Zea mays* L.). *Crop Res. Hisar*. 22 (1): 102-106.

Kanta, G., Singh, H. B. and Sharma, J. H., 2002, Combining ability studies for yield and its related traits in maize (*Zea mays* L.). *Crop Improv.,* 29(2) : 177-183.

Kara, S. M., 2001, Evaluation of yield and components in maize inbred lines. I Heterosis and line × tester analysis of combining ability. *Turkish J. Agric. Forest.*, 25: 383-391.

*Karvencheko, V. A., Kozol Chuk, M. C. and Morshed, G. A., 1971, Heterosis in maize in respect of some economically valuable characters after interline crossing. *Nauk Pratse Ukr, sils kogospod Akad,* 40: 47-49.

Katna, G., Singh, H. B., Sharma, J. K. and Guleria, S. K., 2005, Heterosis and combining ability studies for yield and its related traits in Maize (*Zea mays* L.). *Crop Res*, Hisar, 30(2): 221-226.

Keeble, F. and Pellow, E., 1910, The mode of inheritance of stature and time of flowering in peas. *Genet.,* 1: 47-56.

Kempthorne, O., 1957, An introduction to genetic statistics, John Wiley and Sons, New York.

*Khakim, A., Stoyanova, S. and Tsankova, G., 1998, Establishing the correlation between yield and some morphologic reproductive and biochemical characters in maize. *Rantenie dini Nauki*, 35: 419-422.

*Khotylera, L. V., Tarutina, L. A. and Kapusta, I. P., 1986, Genetic interpretation of the combining ability of maize lines for quantitative characters following use of different crossing systems. *Sel'skokhozyaist Vennaya Biologia*, 8 :78-82.

*Khristova, I., Todorova, L. and Lindanski, T., 1995, Inheritance of economic characters in intergeneric hybrids of maize with teosinte. *Genetika Selaktsiya*, 18: 99-110.

Kim, S. K., 1975, Genotype × environment interactions of several agronomic traits of maize. *Korean J. Breeding*, 7: 163-169.

Kimani, P. M., 1984, Diallel analysis of rate and duration of grain fill and other economic traits in eight inbred lines of maize (*Zea mays* L.). *Dissertation Abstracts International,* 44: 3262.

Konak, C., Unay, A., Serter, E. and Basal, H., 1999, Estimation of combining ability effects, heterosis and heterobeltiosis by line x tester method in maize. . *Turkish J. Field Crops*, 4 (1): 1- 9.

*Konak, C., Unay, A., Basal, H. and Nd Serter, E., 2001, Combining ability and heterotic effect in some characteristics of second crop maize. *Turkish J. Field Crops*, 16: 64-70.

Krishnan, V. and Natarajan, N., 1995, Correlation and component analysis in maize. *Madras Agric. J.*, 82: 391-393.

Kumar, P., 1995, Heterosis in varietal crosses of maize (*Zea mays* L.). *Maize Abstract*, 11: 755.

Kumar, P. S., 2008, Combining ability studies in maize (Zea mays L.). *Advan. Plant Sci..* 21(1): 167-169

Kumar, A., Ganshetti, M. G. and Kumar, A., 1998, Gene effects in some metric traits of maize (*Zea mays* L.). *Ann. Agric. Biological Res.*, 3 (2): 139-143.

Kumar, A. and Kumar, D., 1997, Correlation studies in maize (*Zea mays* L.). *Ann. Soil*, Ludhiana, 13: 271-273.

Kumar, M. V. N., Kumar, S. S and Ganesh, M., 1999, Combining ability studies for oil improvement in maize (*Zea mays* L.). *Crop-Research-Hisar*. 18(1): 93-99

Kumar, M. V. N and Kumar, S. S., 2000, Studies on characters association and path coefficient for grain yield and oil content in maize (*Zea mays* L.). *Ann. Agric. Res.*, 21: 73-78.

Kumar, S., Shahi, J. P., Singh, J and Singh, S. P, 2006, Correlation and path analysis in early generation inbreds of maize (Zea mays L.). *Crop Improv.*, 33 (2): 156-160

*Lamkey, K. R., 1995, Mean performance of heterosis for high × high, high × low and low × low crosses of maize synthetic. *Dissertation Abstracts –International,* 4699: 2884.

Larish, L. L. B. and Brewbaker, J. L., 1999, Diallel analyses of temperature and tropical popcorns. *Maydica*, 44 (4): 279-284.

Lee, T. C., 1983, Test cross and diallel cross analysis of maize. *J. Agric. Res.*, China, 32 : 312-324.

Lee, T. C., Shieh, G. S., Ho, C. L. and Juang, J. R., 1986, Analysis of diallel sets of dent and flint maize inbreds of combining ability and heterosis. *J. Agric. Res.,* China, 35 : 145-164.

Leng, E. R., 1954, Effects of heterosis on the major components of grain yield in corn. *Agron. J.*, 46: 502-506.

Lenka, D. and Mishra, B., 1973, Path coefficient analysis of yield in rice varieties. *Indian J. Agril. Stat.,* 143 : 376-379.

*Li-Jizhu, Wang-Shung, Guo-Baogui and Tang-Weiguang, 2004, Genetic study of ear kernel characters of maize. *J. Jilin Agric. Univ.*, Chang Chaun, 26 (6) : 494-498.

Lindstorm, E. W., 1931, Prepotency of inbred sires of commercial varieties in I maize. *Agron. J.*, 23: 652-661.

*Ling, C., Cuishaoping and Sunyiaobang, 1996, Analysis of the gene effects on ear characteristics in maize. *Acta Agriculturae Boreali – Sinica,* 11: 28-32.

*Lou Xiang Yang, Zhang Quan De, Yu Zhang Liang and Zhao Junhua, 1998, A study of the genetic effects of maize ears and related traits. *Zhejian Nongye Texue*, 1: 21-24.

*Mabo, Z. H. P., 1977, Heterosis in maize hybrids in relation to the number of grain rows in the parental forms. *Nauch. Tr. Ukr. S. Kh. Akad.*, 196: 48-49.

Mahajan, V., Khehra, A. S., Dhillon, B. S. and Sharma, V. K., 1990, Inter-relationship of yield and other traits in maize in monsoon and winter season. *Crop Improv.*, 17: 128-132.

Mahajan, V., Khehra, A. S and Malhotra, V. V., 1991, Combining ability studies for silking and maturity in diverse seasons in maize. *J. Res. Punjab Agric. Univ.* 28 (3): 315-319

Mahmoud, I. M., Rashed, M. A., Fashmy E. M. and Abo Dheaf, M. H., 1990, Heterosis combining ability and types of gene action in a 6 x 6 diallel of maize. *Ann. Agril. Sci. Cairo*, sp. Issue, pp. 307-317.

*Mahto, R. N. and Ganguly, D. K., 2001, Heterosis and combining ability studies in maize (*Zea mays* L.). *J. Res. Brisa Agric. Univ.*, 13(2): 197-199.

*Malhi, N. S., Dhillon, B. S., Saxena, V. K., Sharma, S., Verma, M. M., Virk, D. S. and Chahal, G. S., 1993, Relative performance of single and double cross hybrids in maize.

Heterosis Breeding in Crop Plants, Theory and Application: Short Communications Symposium, Ludhiana, 23-24, February, pp. 36-37.

Malhotra, V. V. and Khehra, A. S., 1986, Genotypic variation and co-variation in indigenous germplasm of maize. *Indian J. Agric. Sci.*, 56: 811-816.

Malik, S. I., Malik, H. N., Minhas, N. M., Muhammad, M., 2004, General and specific combining ability studies in maize diallel crosses. *Int. J. Agric. And Biol.,* 6 (5) : 856-859.

Mandal, S. S., Mandal, H. K., Verma, D. K. and Akhtam, S. A., 2001, Combining ability analysis for grain yield and component traits in maize. *J. Inter Academicia*, 5: 132-137.

Mani, V. P., Singh, N. K., Bisht, G. S. and Sinha, M. K., 1999, Variability and path coefficient study in indigenous maize (*Zea mays* L.) germplasm. *Environ. Ecol.*, 17: 658-653.

Manivannan, N., 1998, Character association and component analysis in maize. *Madras Agric. J.*, 85: 293-294.

Martin, J. H. and Hallauer, A. R., 1976, Relation between heterozygosis and yield for four types of maize inbred lines. *Egyptian J. Genet.*, pp. 119-135.

Masikevich, Yu. G., Shakabar, T. L. and Chernetskaya, S. V., 1989, Biochemical basis for yield heterosis in maize. *Plant Breeding and Genet.; Plant Physiol. Bio-Chem.*, 138-144.

Mathur, R. K. and Bhatnagar, S. K., 1995, Partial diallel cross analysis for grain yield and its component characters in maize (*Zea mays* L.). *Ann. Agric. Res.*, 16 (3): 324-329.

Mathur, R. K., Chunilal, Bhatnagar, S. K. and Singh, V., 1998, Combining ability for yield, phonological and ear characters in white seeded maize. *Indian J. Genet. Plant Breed.*, 58 (2): 117-182.

Mejiya, M. J. and Lambert, R. J., 1992, Improving peffor maize for adapted corn hybrid using exotic inbred. *Crop Sci.*, 32(2): 55-62.

Melchinger, A. E., Geiger, H. H. and Schnell, F. W., 1986, Epistasis in maize (*Zea mays* L.). Genetic effects in crosses among early flint and dent inbred lines determined by three methods. *Theor. Appl. Genet.*, 72: 231-239.

Menkir, A., Melake Berhan, A., Ingelbrecht, I and Adepoju, A., 2004, Grouping of tropical mid-altitude maize inbred lines on the basis of yield data and molecular markers. *Theor. Appl. Genet.,* 108 (8): 1582-1590

*Mikhailov, H. E. and Chernov, A. A., 1999, Genetic-statistical of kernel row number in maize. *Tsitologiya-i-Gnetika*, 35: 19-25.

Mohammad Basheruddin, M., Balakrishna Reddy and Phaik Mohammad, 1999, Correlation coefficient and path analysis of component character as influenced by the environments in forage maize. *Crop Res.*, 17: 85-89.

Mohammed, A. A., 1993, Effect of nitrogen fertilization levels on the performance and combining ability of maize hybrids (*Zea mays* L.). *Ann. Agric. Sci.*, 38(2): 531-549.

Moll, R. H., Lonnquist, J., Fortuno, J. V. and Johnson, E. C., 1967, The relation of heterosis and genetic divergence in maize. *Genet.*, 52: 139-144.

Moll, R. H., R. H., Salhauna, W. S. and Robinson, 1962, Heterosis and genetic diversity in varietal crosses of maize. *Crop Sci.*, 2: 197-198.

Mufti, M. U. and Rao, H. R., 1995, Quantitative studies on heterosis in maize (*Zea mays* L.) diallel crosses. *Sarhad J. Agric.*, 11 (1): 71-77.

Mukherjee, B. K., Agarwal, K. N., Singh, S. B., Gupta, N. P. and Singh, N. N., 1974, Studies on diverse germplasm complexes of maize. Gene effects and nature of heterosis in germplasm complexes and their crosses. *Genetica*, 6: 33-41.

Mukherjee, B. K. and Shah, B. C., 1984, An analysis of heterosis and manifest for yield characteristics in intervarietal crosses of maize (*Zea mays* L.). *Egyptian J. Genet. Cytology*, 13: 41-52.

Murthy, A. R., Kajjari, N. B. and Goud, J. V., 1981, Diallel analysis of yield and maturity components in maize. *Indian J. Genet. and Plant Breed.*, 41: 30-33.

*Mustyaysa, S. I., Nuzhnaya, I. P., Pozhoga, V. N. and Litun, P. P., 1991, Combining ability of source material for producing early maize hybrids. *Urozhai-i- Adaptivni Potential Ekologicheskoi Sistemy Polya*, pp. 88-93.

Muthiah, A. R., 1989, Genetic analysis and inheritance of sorghum downy mildew resistant in maize (*Zea mays* L.). *Ph. D. Thesis*, Tamil Nadu Agric. Univ., Coimbatore.

Nagda, A. K., Dubey, R. B. and Pandiya, N. K., 1995, Studies on combining ability in *rabi* maize (*Zea mays* L.). *Crop Res.*, 9: 309-312.

Nagesh Kumar, M. V., Sudheer Kumar, S. and Ganesh, M., 1999, Combining ability studies for oil improvement in maize (*Zea mays* L.). *Crop Res.*, 18: 93-99.

Nawar, A. A., Fahmi, A. I. and Salma, S. A., 1999, Genetic analysis of yield components and callus growth characters in maize (*Zea mays* L.). *J. Genet. Plant Breed.*, 53: 119-127.

Neha Singhal., Verma, S. S., Baskheti, D. C and Anil Kumar., 2006, Heritability, genetic advance, correlation and path-coefficient estimation in high quality protein maize (Zea mays L.). *Asian J. Bio-Sci.,* 1 (2): 54-56

Netaji, S. V. S. R. K., Satyanarayana, E. and Suneetha, V., 2000, Heterosis studies for yield and yield component characters in maize (*Zea mays* L.). *The Andhra Agric. J.*, 47: 39-42.

Nigussie, M. and Zelleke, H., 2001, Heterosis and combining ability in a diallel among eight elite maize populations. *African Crop Sci. J.*, 9 (3): 471- 479.

Nirala, R. B. P and Jha, P. B., 2001, Combining ability analysis for fodder traits of maize. *Range Management and Agroforestry*: 22(1): 51-59.

Packiaraj, D., 1995, Genetic studies of yield and its components in maize (*Zea mays* L.). *Ph. D. Thesis*, Tamil Nadu Agric. Univ., Coimbatore.

Pal, A. K. and Prodhan, H. S., 1994, Combining ability analysis of grain yield and oil content along with some other attributes in maize (*Zea mays* L.). *Indian J. Genet. Plant Breed.*, 54 (4): 376-380.

Pal, S. S., Khera, A. S. and Dhillon, B. S., 1986, Genetic analysis and selection advance in maize population. *Maydica*, 31: 153-162.

Panse, V. G. and Sukhatme, P. V., 1961, *Statistical Methods for Agric. Workers*, ICAR Publication, New Delhi, p. 145.

Patel, D. A., Patel, J. S., Bhatt, M. M and Bhatt, H. M, 2005, Correlation and path analysis in forage maize (Zea mays L.). *Res. Crops*. 6(3): 502-504

Paternani, E. and Lonnquist, J. H., 1964, Heterosis in intervarietal crosses of corn. *Crop Sci.*, 4 : 504-507.

Paul, K. K. and Debanth, S. C., 1999, Combining ability analysis in maize (*Zea mays* L.). *Pakistan J. Scientific Industrial Res.*, 42 (3): 141-144.

Paul, S. K. and Duara, P. K., 1991, Combining ability studies in maize (*Zea mays* L.). *International J. Tropical Agric.*, 9 (4): 245-249.

Pavilikova, E. and Rood, S. B., 1987, Cellular basis of heterosis for leaf area in maize. *Canadian J. Plant Sci.*, 67: 99-104.

Perez-Velasquez, J. C., Ceballos, H., Pandei, S. and Diaz-Amaris, C., 1995, Analysis of diallel crosses among Colombian landraces and improved populations of maize. *Crop Sci.,* 35 (2): 572-578.

Petrenko, A. L., 1980, Heterosis in maize hybrids under irrigated and unirrigated conditions in South of Ukraine. *Plant Breeding Abstract*, 52: 186.

*Petrovic, Z., 1998, Combining abilities and mode of inheritance of yield and yield components in maize (*Zea mays* L.). *Novi Sad* (Yugoslavia), p. 85.

Pradeep Kumar, P. and Satyanarayana, E., 2001, Variable and correlation studies of full season inbred lines of maize. *J. Res.*, *ANGARU*, 29: 71-75.

Prasad, R., Singh, S. and Paroda, R.S., 1988, Combining ability analysis in a maize diallel. *Indian J. Genet.,* 48 (1): 19-23.

Prasad, S. K. and Singh, T. P., 1986, Heterosis in relation to genetic divergence in maize (*Zea mays* L.). *Euphytica*, 35: 919-924.

Preolska, P. A. and Kamara, A. I., 1991, Expression of heterosis and extent of dominance for some characters in the single interline hybrid KnezhaVp556 and the modified single hybrid Knezha MVP556, II, Number of rows per ear and number of grains per row. *Genetika-i-seletsiya,* 24 (2) : 120-125.

*Probecky, O., 1976, Yield and its components in newly bred high yielding, grain maize hybrids. *Rostlinna Vjroba*, 22: 1021-1027.

Quadri, I., Agrawal, K. N. and Sanghi, A. K., 1993, Combining ability under two population sizes for ear trait in maize. *Indian J. Generics and Plant Breed.*, 43: 201-211.

Raghuram Reddy, P., Vidyasagar, R., Kishen, N. and Mehaboobali, S., 1987, relationship of single crosses to double and three way cross hybrids in maize for yield. *Genetica* (Iberica), 39 : 117-129.

Rahman, M. M., Islam, M. R., Sultan, M. K. and Mitra, B., 1995, Correlation and path coefficient in maize (*Zea mays* L.). *Scientific and Indus Res.*, 30: 87-92.

Ramamurthy, A., 1980, Genetic analysis of some quantity characters in maize (*Zea mays* L.). *Mysore J. Agric. Sci.*, 14: 126.

Rameeh, V., Rezai, A. and Arzani, A., 2000, Estimates of genetic parameters for yield and yield components in corn inbred lines using diallel crosses. *J. Sci. Technol. Agric. Natural Resources*, 4: 95-104.

Rana, M. K and Vinod Kumar., 2001, Combining ability analysis for grain yield and yield components and phenological characters in maize (*Zea mays* L.). *New Botanist*. 28 (1/4): 39- 44.

Rao, G. P. B., Rai, S. V. Singh and Shai, J. P., 1996, Heterosis and combining ability in intervarietal crosses of maize. *Madras Agric. J.,* 83 (5): 291-295.

Rather, A. G., Sheikh, F. A. and Wani, S. A., 1999, Variability and correlation studies in an improved population of maize (*Zea mays* L.) under rainfed conditions. *Advances in Plant Sci.*, 12: 539-542.

Rastogi, N. K and Rastogi, V. K., 1997, Combining ability studies under varying environments in top cross derivatives of maize (*Zea mays* L). *Advances in Plant Sci.,* 10(2): 199-205.

Reddy, K. H. D. and Agarwal, B. D., 1992, Estimation of genetic variation in an improved population of maize (*Zea mays* L.). *Madras Agric. J.*, 79: 714- 719.

*Rosa, A. De. La., Leon, De. H., Hartinez, G. and Rincon, F., 2000, Heterosis combining ability and genetic diversity in commercial hybrids of maize (*Zea mays* L.). *Agronomic Mesoamericana*, 11: 113-122.

Rupak, K., Verma and Singh, T. P., 1979, Interrelations among certain quantitative traits in popcorn. *Mysore J. Agric. Sci.*, 13: 1-17.

Russell, W. A., 1968, Development and evaluation of maize inbred lines. *In: Proceedings of 23rd Corn Res. Conference,* American Seed Trade Association, pp. 37-44.

Saha, B. C. and Mukherjee, B. K., 1985, Analysis of heterosis for number of grains in maize (*Zea mays* L.). *Indian J. Plant Breed.*, 45: 240-246.

Saha, B. C. and Mukherjee, B. K., 1993, Grain yield of maize in relation to grain forming potential and other traits. *J. Res.*, Birsa-Agric. Univ., 5: 27-31.

Saha, B. C. and Mukherjee, B. K., 1996, Grain yield of maize in relation to grain forming potential and other traits. *J. Res.*, Birsa Agric. Univ.

Sain Dass and Pawan Arora, 1999, Heterosis for phenological traits in maize. *Agric. Sci. Digest*, 19: 12-14.

Sain Dass, Mohindersiongh, Sehtya, H. I., Aneja, D. R., Anilkumar, Dass, S., Singh, M. and Kumar, A., 1992, Genetics of harvest index in maize. *Agric. Sci., Digest*, 12 (3): 117-120.

Saleh, G. B., Abdullah, D. and Anuar, A. R., 2002, Performance of heterosis and heritability in selected, tropical maize single, double and three way cross hybrids. *J. Agric. Sci.*, 138: 21-28.

*Salillari, A. and Hoxha, S., 1998, The performance of kernel and spike characters some maize hybrid crossings in relations to parental inbred lines. *Bulletinii- Shkenacave Bujqesore*, (Albania), 3: 51-54.

San Vicente, F., Bejarano, A., Crossa, J and Marin, C., 2001, Heterosis and combining ability of tropical yellow endosperm maize populations. *Agronomia Tropical Maracay,* 51 (3): 301-318.

Sanghi, A. K., Agarwal, K. N. and Qadri, M. I., 1982, Gene effects and heterosis for grain yield and ear traits in maize. *Indian J. Genet.*, 42: 360-363.

Sanghi, A. K., Agwrwal, K. N. and Qadri, M. I., 1983, Combining ability for yield and maturity I early maturing maize under high plant population densities. *Indian J. Genet. Plant Breed.*, 43: 123-128.

Satyanarayana, E. Kumar, R. S. and Sharma, M. Y., 1994, Inheritance studies of maturity components and yield in selected hybrids of maize (*Zea mays* L.). *Mysore J. Agric. Sci.*, 28(1): 25-30.

Satyanarayana, E., 1995, Genetic analysis of flowering period in *rabi* maize (*Zea mays* L.) involving different maturity groups. *Crop Improv.*, 9: 42-47.

Satyanarayana, E., 1996, Combining ability for quantitative traits of early single cross maize hybrids under rainfed conditions. *Mysore J. Agric. Sci.*, 30: 204-208.

Sedhom, S. A., 1994, Estimation of general and specific combining ability in maize under different planting dates. *Ann. Agric. Sci*., 28 (1): 25-30.

*Setiyono, R. T. and Subandi, 1996, Heterosis and combining ability analysis of maize in a diallel cross. *Penelitian Pertanian* (Indonesia): 15(1): 30-34.

Shahi, J. P. and Singh, I. S., 1985, Estimation of genetic variability for grain yield and its components in a random mating population of maize. *Crop Improv.,* 12: 126-129.

Shahi, J. P. and Singh, I. S., 1986, Analysis of genetic variation in Navin population of maize (*Zea mays* L.). *Crop Improv*., 13: 181-185.

Shahwani, M. N., Salarzai, A., Bangulzai, B. A., Shahwani, M. A. and Hengl, N. M., 2001, Hybrid vigour for grain yield and its components in maize crosses. *Sarhad J. Agric*., 17: 571-576.

Shakoor, A., 1988, Effect of heterosis on the stover yield components of some local and exotic inbred lines of maize. *Pakistan J. Agric. Res*., 9: 61-66.,

Shakoor, M. S., Muhammad Akbar and Amer Hussain., 2007, Correlation and path coefficients studies of some morphophysiological traits in maize double crosses. *Pakistan J. Agric. Sci.,* 44(2): 213-216.

Shanthi, P., Satyanarayana, E. and Reddy, G. J. M., 2002, Genetic studies for grain yield and oil improvement in maize. *Res. Crops*, 3(3) : 588-591.

Sharma, S. R., Khera, A. S., Dhillon, B. S. and Malhotra, V. V., 1982, Evaluation of S1 lines of maize crossed in a diallelic system. *Crop Improv*., 9: 42- 47.

Shaw, R. H. and Thom, H. C. S., 1951, Study on phenology of field corn, silking to maturity. *Agron. J*., 43: 541-546.

*Shen, G. Z. and Lai, Z. M., 1987, Studies on interactions of combining ability I with environment for main traits of maize inbreds. *Acta Agronomica Sinica*, 13: 69-76.

Shieh Guang Jauh and Thseng Fu Sheng, 2001, The combining ability and relation on yield among different generations of F1 hybrid of Tainan-white maize (*Zea mays* L.) inbred lines. *J. Agric. Res. China.,* 50 (3): 33-39.

Shull, G. H., 1908, The composition of a field maize. American Breeders Association Republic, 4: 296-301.

Shull, G. H., 1911, The genotypes of maize. *American Naturalist*, 45: 234-252.

Singh, S. B and Jamwal, B. S., 2004, Combining ability analysis for yield and its components in varietal crosses of maize (*Zea mays*. L). *Prog. Agric.,* 4(1): 25-28.

Singh, S. N., Singh, K. N. and Sinch, H. G., 1983, Combining ability studies in maize. *Crop Improv.,* 10(1): 6-9.

Singh, S. N., Singh, K. N. and Singh, H. G., 1991, Genetic variability and interrelationship in maize. *Narendra Deva J. Agric. Res*., 6: 233-237.

Singh, A. K., Shahi, J. P., Singh, J. K. and Singh, R. N., 1998, Combining ability for maturity and height traits in maize (*Zea mays* L.). *Ann. Agric. Res.,* 19 (2): 162-166.

Singh, D. N. and Singh, I. S., 1998, Line × tester analysis in maize (*Zea mays* L.). *J. Res. Agric. Univ*., 10: 177-182.

Singh, R. D., Tejpal Yadav and Bhat, J. S., 2000, Combining ability analysis in varietal crosses of maize. *New Botanist.m* 27 (1/4): 29-36.

Singh, P. K., Chaudhary, L. B., Akhtar, S. A., 2002, Heterosis in relation to combining ability in maize. *J. Res. Birsa Agric. Univ.,* 14 (1): 37- 43.

Singh, P. K., Jha, P. B. and Kumar, P., 2003, Path coefficient of green fodder yield and grain yield in maize (*Zea mays* L.). *J. Appl. Biol*., 13 (1/2) : 29-32.

*Sinobas, J. and Monteagudo, I., 1994, Genetic analysis of a diallel cross between Spanish and American maize populations. *Investigation Agraria Production-y-Protection Vegetables*, 9(2): 167-179.

Snedecor, G. W. and Cochran, 1967, *Statistical Methods*, Oxford and IBH, New Delhi, p. 338.

Sofi, P. A. and Rather, A. G, 2007, Studies on genetic variability, correlation and path analysis in maize (*Zea mays* L.). *Maize Genet. Cooperation Newslett*., 81: 26-27.

Sprague, G. F. and Tatum, L. A., 1942, General vs specific combining ability in single crosses of corn. *Agron. J*., 34: 923-932.

Sree Kumar, S. G. and Suma Bai, D. I., 1995, Genetic analysis of yield and its components in fodder maize. *J. Tropic. Agric*., 33: 8-10.

Srivas, S. K and Singh, U. P., 2004, Genetic variability, character association and path analysis of yield and its component traits in forage maize (*Zea mays* L.). *Range Management and Agro-Forestry*. 25 (2): 149-153.

Srivastava, A. and Singh, I. S., 2003, Heterosis and combining ability for yield and maturity involving exotic and indigenous inbred lines of maize (*Zea mays* L.). *Indian J. Genet. Pl. Breed.,* 63(4): 345-346.

*Stojokovic, M., Jockovic, D., Bekavac, G. and Nastasic, A., 1999, Heterosis in maize breeding. *Selekcija-i-Semenarstro*, 5: 39-44.

Sujiprihati, S. S., Saleh, G. B and Ali, E. S., 2001, Combining ability analysis of yield and related characters in single cross hybrids of tropical maize (*Zea mays* L.). *SABRAO J. Breed. Genet*., 33 (2): 111-120.

Suneetha, Y., Patel, J. R. and Srinivas, T., 2000, Studies on combining ability for forage characters in maize (*Zea mays* L.). *Crop Res*., 9: 226-270.

Surya Prakash and Ganguli, D. K., 2004, Combining ability for various yield component characters in maize (*Zea mays* L.). *J. Res.,* Birsa Agric. Univ., 16(1) : 55-60.

Swaranalatha Devi, I. and Shaik Mohmmed, 2001, Character association and path coefficient analysis of grain yield and components in double crosses of maize. *Cop Res*., 21: 255-359.

Talleei, A. and Kochaksaraei, H. N. K., 1999, Study of combining ability and cytoplasmic effects in maize diallel crosses. *Iranian J. Agric. Sci*., 30(4): 761-769.

Tandon, J. P., Joshi, A. N. and Jain, K. B. L., 1970, Comparison of graphic and combining ability analysis of diallel crosses in wheat. *Ind. J. Genet*., 30: 91-103.

Tarutina, L. H. and Khotyleva, L. V., Polonetskaya, L. and Kapusta, I. B., 1980, Variability of the heterotic effect diallel maize hybrids under different environmental conditions. *Referativnyi Zhurnal,* 10 (65): 192.

Turner, J. K., 1953, A study of heterosis in upland cotton – II. Combining ability and inbreeding effects. *Agron. J*., 45: 487-490.

*Turgut, I., Yuce, S. and Altinbos, M., 1995, Inheritance of some agronomic traits in a diallel cross of maize inbreds II. Grain yield and its components. *Anadolu*, 5 (1): 74-92.

Turgut, I. and Duman, A., 2004, Determination of combining ability effects and heterosis in dent maize (*Zea mays* indentata Sturt.). *Ziraat Fakultesi Dergisi Akdeniz Univ.,* 17 (2): 189-197.

Tyagi, A. P., Pokhariyal, G. P. and Odongo, O. M., 1988, Correlation and path coefficient analysis for yield components and maturity traits in maize (*Zea mays* L.). *Maydica*, 33: 109-119.

Umakanth, A. V. and Khan, H. A., 2001, Correlation and path analysis of grain yield and yield components in maize (*Zea mays* L.). *J. Res.,* ANGRAU, 29: 87-90.

Umakanth, A. V., Satyanarayana, E. and Kumr, M. V. N., 2000, Correlation and heritability studies in Ashwini maize composite. *Ann. Agric. Res.*, 21: 328- 330.

*Vacaro, E., Barbosa, Neto, J. F., Pegoraro, D. G., Nuss, C. N. and Conceicao, L. D. H., 2002, Combining ability of 12 populations. *Pesuisa gropecuria Brasilerira*, 37: 67-72.

Vaezi, S., Abd-Mishani, Yazdi-Samadi, B. and Ghannadha, M. R., 2000, Correlation and path analysis of grain yield and its components in maize. *Iranian J. Agric. Sci.*, 31: 71-83.

Vafias, B. N. and Ipsilandis, C. G., 2005, Combining ability, gene action and yielding performance in maize. *Asian J. Plant Sci.,* 4 (1): 50-55.

Vaidya, S. B., 1986, Studies on the performance of single cross hybrids in maize (*Zea mays* L.). *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad.

Vasal, S. K., Ganeson Srinivasan, F., Gonzalez, C., David Beck, L. and Crassa, J., 1993, Heterosis and combining ability of CIMMYT's quality protein, maize germplasm II. sub-tropical. *Crop Sci.*, 33: 51-57.

Vasal, S. K., Ganeson Srinivasan, F., Beck, D. L., Crossa, J., Pandey, S. and De Leon, C., 1992, Heterosis and combining ability of CIMMYT's tropical late white maize germplasm. *Maydica*, 37 (2): 217-223.

Venkatesh, S., Singh, N. N. and Gutpa, N. P., 2001, Early generation identification and utilization of potential inbred lines in modified single cross hybrids of maize (*Zea mays* L.). *Indian J. Genet.,* 61(3): 213-217.

Venugopal, M., Ansari, N. A and Rajanikanth, T., 2003, Correlation and path analysis in maize (*Zea mays* L.). *Crop Res.*, Hissar, 25(3) : 525-529.

Verma, R. K. and Singh, T. P., 1980, Heterosis and combining ability studies for certain quantitative traits in popcorn. *Mysore J. Agric. Sci.*, 14: 15-17.

Verma, R. P. S. and Singh, I. S., 1996, Residual heterosis in population crosses in maize (*Zea mays* L.) involving different maturity groups. *Crop Improv.*, 9: 42-47.

*Vidal Martinez, V. A., Clegg, M., Johnson, B. and Valdivla, Be\Rnal, R., 2001, Phenotypic and genotypic relationship between pollen and grain yield components in maize. *Agrociencia* (Montecillo), 35: 503-511.

Welcker, C., Andreau, B., De Leon, C., Parentoni, S. N., Bernel, J., Felicite, J., Zonkeng, C., Salazar, F., Narro, L., Charcosset, A. and Horst, W. J., 2005, Heterosis and combining ability for tropical acid soils: Implications for future breeding strategies. *Crop Sci.*, 45: 2405-2413.

Wellhausen, E. J., 1965, Exotic germplasms for improvement of corn belt maize. *In: Proceedings of 20th Annual Indian Res. Conference*, pp. 31-34.

Williams, J. C., Penny, L. H. and Sprague, G. F., 1965, Full sib and half sib estimate of genetic variance in an open pollinated variety of corn. *Crop Sci.*, 5 : 125- 129.

Wright, S., 1921, Correlation and causation. *J. Agric. Res.*, 20: 557-585.

Wu Guang Cheng., Xue Yan and He Dai Yuan, 2003, Combining ability analysis on maize inbred lines. *J. Maize Sci.,* 11 (2): 32-53.

*Yang, A. G., 1982, Gene effects for several economic characters in maize. *Acta Agronomica Sinica*, 8: 153-162.

Yousif, D. P., Ali, H. C. and Baker, R. H., 2003, Estimation of heterosis and combining ability in local maize inbred lines. *Dirasat Agric. Sci.*, 30(2): 246-259.

*Yurankova, S. I., Tsitok, U. V., Rusinova, V. and Ramhes, V. A., 1996, Features of the expression of heterosis for yield components in first generation maize hybrids. *Vesti-Akadenji-Navuk,* USSR, 2 : 40-44.

Yu HaiQiu., Xu KeZhang., Chen XueQiu., Wu ZhiHai., Jiang ZiLian and Shen XiuYing., 2003, Analysis of combining ability and hereditary parameters of major drought-resistant maize yield traits. *J. Maize Sci.*, 11 (1): 12-18.

Yu-Zhongliang, Zhao Junhua and Lou Xiang, 1999, Analysis of genetic effects on kernel traits in maize (*Zea mays* L.). *Zhejiang Nongye Kexue*, 4: 171-174.

Zambezi, B. T., Hornar, E. S. and Martin, F. G., 1986, Inbred lines as testers for general combining ability in maize. *Crop Sci.,* 26 : 610-908.

Zargar, G. H. and Singh, R. H., 1990, Genetic architecture of an improved version of a maize composite. In L Genetic analysis of grain yield, yield components and same agronomic traits. *Indian J. Genet.*, 50: 221-227.

Zelleke, H., 2000, Combining ability for grain yield and other agronomic characters in inbred lines of maize (*Zea mays* L.). *Indian J. Genet. Plant Breed.*, 60: 63-70.

Zheng-Zuping, Du-Kenzhu, Z. P. and Du, K. Z., 1995, A study of the genetic parameters of several quantitative characters of maize. *J. Southwest Agric. Univ.*, 17(4): 359-362.

* Originals not seen

GENE ACTION AND COMBINING ABILITY STUDIES IN SINGLE CROSS HYBRIDS OF MAIZE (*Zea mays* L.)

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ABSTRACT

The study was conducted to assess the nature of gene action and combining ability studies in single cross hybrids of maize. The crossing programme was carried out at Main Agricultural Research Station, Agricultural College, Dharwad during *kharif* 2008. The main experiment was executed at All India Co-ordinated Maize Improvement Project, Agricultural Research Station, Arbhavi during *rabi/summer* 2008-09. The experiment comprised of 29 S_4 lines derived from national yellow pool, three testers, 87 single crosses and five commercial checks. The 87 single cross experimental hybrids were generated by crossing 29 lines and three testers in line × tester design and evaluated in randomized block design with two replications.

Hybrids exhibited significant variability for 12 characters studied. The computed variance ratios (σ^2GCA/σ^2SCA, σ^2A/σ^2D) revealed non-additive gene action in the inheritance of all the traits studied. The study on the combining ability revealed that the tester KDMI-10 was found to be best general combiner among three testers. The sca effect of YP⊗4#07-20 × CI-5 single cross hybrid was highest for grain yield. The cross YP⊗4#07-20 × CI-5 showed highest heterosis percentage with gca combination of high x low.

The correlation studies depicted that plant height, ear length, ear circumference, number of kernel rows per ear, number of kernels per row, 100-grain weight, shelling percentage, grain yield per plant, fodder yield per hectare were positively associated with grain yield per hectare while negatively associated with days to 50 per cent flowering. The characters *viz.,* days to 50 per cent silking, plant height, number of kernel rows per ear, number of kernels per row, 100-grain weight, shelling percentage, grain yield per plant and fodder yield per hectare has positive direct effect while days to 50 per cent tasseling, ear length and ear circumference has negative direct effect on grain yield for genotypic path.