

**HETEROSIS AND COMBINING ABILITY STUDIES
IN ONION (*Allium cepa* L.)**

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**HETEROSIS AND COMBINING ABILITY STUDIES
IN ONION (*Allium cepa* L.)**

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BY

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CERTIFICATE

This is to certify that the thesis entitled “**HETEROSIS AND COMBINING ABILITY STUDIES IN ONION (*Allium cepa* L.)**” submitted by **Mr. BASAVANA GOWDA G. A.**, for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **HORTICULTURE** to the University of Agricultural Sciences, Dharwad is a record of research work done by him during the period of his study in this university under my guidance and the thesis has not been previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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With regardful memories

At last the moment has come to look into the deeper layers of heart, which is filled with the feelings of togetherness, loveliness, consolation and satisfaction, a sign of relief and a sense of fulfillment. Some are momentary and some are permanent, but both involve a number of near and dear persons to whom I acknowledge my warm regards and take this opportunity to express my feelings during the course of research and it is putting down in black and white.

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(BASAVANA GOWDA G. A.)

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1. INTRODUCTION

Onion (*Allium cepa* L., $2n = 16$) is the most important species of the *Allium* group belonging to family Alliaceae. It can be regarded as the single important vegetable species in the world after tomato.

Onion is known to have many important medicinal and therapeutic effects such as blood sugar lowering, antiplatelet aggregation and fibrinolytic effects. The nutritive value of onion varies among the varieties and generally 100 g of edible bulb contains moisture (86.8 g), carbohydrates (11.0 g), protein (1.2 g), fibre (0.6 g), minerals (0.4 g), calcium (180 mg), phosphorus (50 mg), vitamin C (11 mg), iron (0.7 mg), nicotinic acid (0.4 mg) and a little of thiamine (Anon., 2016). Although, onion has low nutritional value (average nutritional value = 2.06), it is one of the most widely used vegetable due to its flavoring and seasoning character of the food, both at mature and immature bulb stages. Besides, it is being used as salad and pickle. To a lesser extent, it is used by processing industry for extraction of oil, dehydration in the form of onion flakes and powder, which are in great demand in the world market.

In the world, India ranks first in total area and second in production after China and third after Netherlands and Spain in export. Indian onion is being exported to Malaysia, Singapore, Gulf Countries, Sri Lanka, Bangladesh, Pakistan and Nepal. At present, in the world, onion occupies an area of 3.64 million hectares with a production of 74.25 million tonnes and average productivity is 20.5 tonnes per ha. The area under onion in India is 1.17 million hectares with a production of 18.92 million MT, productivity being 17.12 tonnes /ha (Anon., 2015a). The major onion production states are Maharashtra, Gujarat, Uttar Pradesh, Rajasthan, Orissa, Karnataka, Tamil Nadu, Madhya Pradesh and Bihar. Maharashtra ranks first in onion production with a share of nearly 20 per cent in terms of area and 30 per cent in terms of production.

Karnataka is one of the leading state in onion cultivation next to Maharashtra and Madhya Pradesh. In Karnataka, Dharwad, Chitradurga, Vijayapura, Bellary, Kalaburgi and Chikkamagalore are the major districts occupying an area of 1.86 mha with a production of 3.22 mMT with a average productivity of 16.02 tonnes per ha (Anon., 2015b).

According to Vavilov (1951), the primary centre of origin lies in Central Asia. The near east and Mediterranean are the secondary centers of origin. It is an ancient crop utilized in medicine, rituals and as a food in Egypt and in India since 600 BC. Reference of onion as a food is also found in Bible and Quran. The genus *Allium* is very large with more than 500 species, which are perennial and mostly bulbous plants. Out of these, only seven species are in cultivation. However, *Allium cepa* (Onion) and *Allium sativum* (Garlic) are the two major cultivated species grown all over the world.

Onion is an outstanding biennial vegetable that shows severe inbreeding depression. Crossing among divergent groups shows significant improvement in traits. The discovery of the cytoplasmic male sterility in onion (Jones and Clarke, 1943), enabled commercial hybrid seed production and at present hybrid onions have dominated over the conventional varieties in western countries owing to improved yield and quality of bulb. There is also a growing interest on use of onion in food industries for canning and dehydration. Hence, there is an urgent need to develop cultivars suitable for processing industry.

The onion breeders must develop more sophisticated and efficient approaches in selecting and testing the parents, which will produce superior hybrids or varieties. Genetic diversity plays an important role in plant breeding either to exploit heterosis or to generate productive recombinants. The choice of parents is of paramount importance in breeding programme. Heterosis refers to superiority of F_1 hybrids in general vigour, yield and adoption. The magnitude of heterosis depends on accumulation of favourable dominant alleles in the F_1 population. If parental population differ from each other for more favourable alleles, the magnitude of heterosis will also be proportionately higher. The relationship is evidenced in the basic formula of heterosis (Falconer, 1981).

$$\text{Heterosis in } F_1 = \sum dy^2$$

Where,

'd' is magnitude of dominance and 'y' is difference between the parental population for allelic frequencies at the locus.

The genetic values of parents are expressed in terms of combining ability. Sprague and Tatum (1942) defined general combining ability (GCA) as the average performance of progeny of an individual when it is mated to a number of other individuals in a population. Specific combining ability (SCA) is a term that refers to the average performance of the progeny of a cross between two specific parents that are different from what would be expected on the basis of their general combining ability alone. Estimation of combining abilities provide quite relevant and vital information that is of direct utility to plant breeding programmes. Hybridisation is one of the means of obtaining increased yield. Choice of parents in such a programme is difficult due to the differential behaviour of the inbreds in relation to combining ability. A measure of general and specific combining ability of parents in terms of additive and non-additive portions of genetic variance would be of immense value in the choice of parents and effective crosses for plant improvement.

There is a large area under onion crop. Increase in productivity by small leap also makes a huge impact in terms of production. Hence, developing a hybrid with better productivity is meaningful. Development of hybrids in onion is also feasible. The present research is in this direction with following objectives:

- i. To know the performance of hybrids in onion,
- ii. To workout the magnitude of heterosis for growth parameters, yield components and yield and
- iii. To workout the general combining ability (GCA) and specific combining ability (SCA) for growth parameters, yield components and yield.

2. REVIEW OF LITERATURE

The purpose of this section is to give comprehensive upto date information on the various aspects of performance of hybrids, heterosis and combining ability in onion. The review pertaining to present investigation is presented under following headings:

2.1 Performance of hybrids in onion,

2.2 Heterosis and

2.3 Combining ability

2.1 Performance of hybrids in onion

F₁ hybrids with male sterile Macau as seed parent and eleven different pollen parents were compared with the parental varieties in trials in 1976 and 1978. Most of the hybrids out yielded the respective better parent in 1976 and all did so in 1978. In each year, the highest yield was obtained from Macau x Stuttgart (Suciu and Tempelman, 1979).

A study on the performance of different varieties/hybrids on medium black soil under rainfed situation was carried out during *kharif* season. The characters studied were plant height (cm), number of leaves per plant, neck thickness (cm), bulb yield (q/ha), bulb weight (g) and bulb diameter (cm). The varieties Baswant-780, Arka Kalyan and Agri Found Light Red (AFLR) which gave maximum bulb yield, bulb weight and bulb diameter can be taken up under rainfed situation for raising profitable crop of onion in Central Dry Zone of Karnataka, India (Mahanthesh *et al.*, 2008).

Ambresh *et al.* (2013), reported in onion that, parents differed significantly among themselves for total soluble solids and it range from 9.00 to 14.83 per cent among the testers, 9.50 to 11.00 per cent among the lines and 7.43 to 9.97 per cent among the hybrids. Lines, testers and hybrid combinations used in the investigation differed significantly among themselves for the character ten bulb weight and it ranged from 201.33 g to 403.33 g among the testers, 365.00 g to 400.00 g among the lines and 241.67 g to 427.00 g among the hybrids. This parameter is important for contributing to the total yield. The genotypes differed significantly among themselves for equatorial bulb diameter and it range from 2.93 cm to 4.20 cm among the testers, 4.10 cm to 4.47 cm among the lines and 3.73 cm to 4.67 cm among the hybrids. For total bulb yield, genotypes differed significantly and it range from 15.00 t/ha to 21.50 t/ha among the testers, 18.00 t/ha to 20.67 t/ha among the lines and 15.20 t/ha to 27.40 t/ha among the hybrids. Genotypes differed significantly among themselves for marketable bulb yield and it range from 9.00 t/ha to 18.27 t/ha among the testers, 15.33 t/ha to 18.67 t/ha among the line and 12.63 t/ha to 23.80 t/ha among the hybrids. Genotypes differed significantly among themselves for unmarketable bulb yield and it range from 2.00 t/ha to 6.00 t/ha among the testers, 2.00 t/ha to 3.77 t/ha among the lines and 2.00 t/ha to 6.40 t/ha among the hybrids.

Peter *et al.* (2012), studies show that double haploids can be used as onion inbred lines with high or higher levels of vigour than traditionally bred inbred lines. This agrees with prior observation of DH lines of other crops such as maize, rice, wheat, and brassica vegetables, which exhibit a relatively high level of vegetative vigour compared with traditional inbred lines, although they are entirely homozygous in onion. Similar findings were reported by Bohanec (2002), Bong and Swaminathan (1995) and Kim *et al.* (2007) in other crops.

Following the evaluation of onion varieties by Dwivedi *et al.* (2012), Pusa Hybrid 102 consistently exhibited tallest height. Variety Arka Kalyan had the shortest height and minimum number of leaves per plant. Significantly, maximum length of bulb was noticed in variety VL-3 as compared to other varieties. Varieties Arka Kalyan and Pusa White Flat were at par and exhibited lower length of bulb than others. The width of bulb recorded in Pusa Hybrid 102, Pusa White Flat, Pusa Red and VL-3 was in decreasing order with non significant difference. Similarly, Pusa hybrid 102 produced significantly heavy weight bulb as compared to others. Pusa White Flat stood next to it in this regard being at par with other varieties, barring Arka Kalyan which had the least weight per bulb. The variation in genetic constitution may be attributed to varied growth parameters which in turn resulted in different synthesis and utilization efficiency of photosynthetic product there by differences in yield characters of varieties. The neck diameter of bulb was at par in VL- 1 and VL-3 varieties which were significantly wider than others. The closest neck was observed in Arka Kalyan with a non-significant difference with Pusa White Flat. Highest TSS was observed in variety Pusa White Flat.

2.2 Heterosis

Hybrid vigour and heterosis are nearly synonymous. The word heterosis was coined by Shull (1914) and explained the concept as “Interpretation of increased vigour, size, fruitfulness, speed of development, resistant to diseases and insect pests, or climate vigour of any kind, manifested by crossbred organism as compared with corresponding inbreds, as the specific results of unlikeness in the constituents of the uniting parental gametes”. But it did not include the description of a genetic mechanism involved in its expression (Hallauer and Miranda, 1982). Whaley (1944) elaborated the term heterosis as the developmental stimulation resulting from the fusion of different gametes. The manifested effect was termed as hybrid vigour.

Moll and Stuber (1974) listed three possible causes of hypothesis *viz.*, partial to complete dominance, over dominance and epistatis.

Heterosis refers to superiority of F_1 hybrids in general vigour, yield and adoption. The magnitude of heterosis depends on accumulation of favourable dominant alleles in the F_1 population. If parental population differ from each other for more favourable dominant alleles, the magnitude of heterosis will also be proportionately higher. The relationship is evidenced in the basic formula for heterosis (Falconer, 1981).

$$\text{Heterosis in } F_1 = \sum dy^2$$

Where,

‘d’ is magnitude of dominance and ‘y’ is difference between the parental population for allelic frequencies at the locus.

Onion was the first vegetable crop to be exploited for heterosis commercially (Jones and Clarke, 1943), where they identified cytoplasmic genetic male sterility in "Italian red". Since, the classic paper by Jones and Davis (1944) demonstrating inbreeding depression and recovery of vigour of hybrids after crossing among inbred lines, there has been constant efforts to develop hybrid onion by the public and private sectors. Heterosis has been exploited in onion breeding for the past four decades except in India where very little research has been done.

Soluble solid is an important quality attribute of onion. The genotypes with high total soluble solids store better than others. McCollum (1968) and Padda *et al.* (1973) obtained a high heterosis for total soluble solids in onion.

Bulb weight is an important character directly related to bulb yield. Joshi and Tandom (1976), noted heterosis to the extent of 72 per cent over the mid parent value and upto 37 per cent over the better parent in onion hybrids.

Hosfield *et al.* (1977a) have observed a significant heterosis for bulb weight, total yield based on the mid parent. However, the heterosis over better parent was significant but comparatively low.

Vadivel *et al.* (1982) evaluated 30 hybrids and 13 parents of *Allium cepa* L. *aggregatum* and noted the significant positive heterosis over mid parent in fourteen hybrids and over better parent in 12 hybrids, only two hybrids had positive significant heterosis over best parent for plant height, whereas for bulb weight, both positive and negative heterosis was recorded. One cross recorded significant heterosis for yield and most yield components.

A study was conducted by Madalageri (1983), in onion for plant height in 9 x 9 complete diallel crosses. Significant expression of heterosis over mid parent in F₁s. Only one hybrid was distinct with a favourable significant heterotic value on both mid and better parent for plant height. Recorded significant positive heterosis over mid parent in six crosses and two crosses have exceeded their better parental value for number of leaves. With respect to bulb dimensions and P/E ratio (shape index) reported three crosses showed significant positive heterosis with favourable effects for bulb length and four crosses for bulb diameter over the best parent. The studies revealed that significant mid parental heterosis for globular bulbs with shape index around 1.00, but this was observed only in three crosses out of 72 hybrids. In relation to total soluble solids, non significant heterosis in a large number of crosses over mid parent was reported. Only two crosses with positive significant heterosis and nine crosses with negative significance were found. None of the crosses had the significance level in the favourable direction over better parent.

Following line x tester analysis for studying heterosis and combining ability studies in onion, Aghora (1985) observed significant positive heterosis for plant height in four crosses over better parent. Reported significant positive heterosis for number of leaves over mid parent in five crosses, whereas only one F₁ recorded significant positive heterosis over the better parent. Similar results was also exhibited significant positive heterosis for the total bulb yield. Observed that the seven crosses of onion were having significant heterosis over better parent and 13 crosses over mid parent for bulb weight. Observed majority of crosses with negative significance and there were only 12 crosses with positively significant heterosis for the polar diameter. Reported positive heterosis over mid parent in four crosses, heterosis over better parent was not observed in any of the crosses for total soluble solids.

Doruchowsk (1986) crossed eight male sterile lines with 8 pollen parents. Heterosis was observed only for bulb weight in onion, for bulb diameter over better parent. Similarly, Pal *et al.* (1988), in a 8 x 8 diallel cross noticed heterosis for bulb diameter (horizontal and vertical) over better parent and best parent.

For number of leaves, heterosis was expressed only in seven crosses out of 28 cross combination over better parent and the study concluded that at least one parent should be included in crosses having more leaves to contribute to increase for number of leaves in F₁s of onion. There was significant positive heterosis recorded over better and best parent for plant height in 8 x 8 diallel cross. For total soluble solids only one hybrid was observed with heterosis over both the better and best parent among 29 crosses (Netrapal *et al.*, 1988).

Veere Gowda (1988) observed significant heterosis in four and three crosses over mid parent and better parent respectively for plant height. Among all crosses, only one cross showed significant positive heterosis over mid, better and best parent, respectively for plant height. While for number of leaves, recorded significant positive heterosis only for three crosses and remaining all crosses were having negative heterosis out of 55 crosses of onion. Observed significant positive heterosis for onion bulb weight in seven crosses over better parent. Revealed that out of 55 crosses of onion, twenty two, ten and two crosses recorded negative heterosis over mid, better and best parent, respectively for neck thickness. Recorded significant positive heterosis for polar diameter in two crosses and for equatorial diameter in nine crosses. Observed significant positive heterosis for total soluble solids in bulbs of onion over mid parent in 16 crosses, over better parent in four crosses.

Hays and Randle (1996) have conducted the factorial mating design using three male sterile F₁ lines in test crosses with a sample of open pollinated onion population to estimate combining ability and heterosis. The results were significant for heterosis with respect to soluble solids.

The parents and F₁ hybrids from a half diallel cross of onion were evaluated for earliness (days from transplanting to harvest date), bulb ratio (neck diameter/bulb diameter), number of leaves per plant and polar diameter. F₁ hybrids expressed significant heterosis for above characters (Sayed *et al.*, 1999).

In 10 x 10 half diallel crosses of onion, Divakar (2001), observed the positive heterosis for 41 and 40 crosses over mid and better parent for plant height, respectively. Noticed in his study was that positive heterosis was in 28 crosses out of 45 hybrids for leaf number over mid parent, whereas 18 and 11 crosses recorded positive heterosis over better parent and standard check, respectively. Eight crosses had significant positive heterosis over mid parent, 30 crosses over better parent and 15 crosses over standard check for bulb weight. Fifteen crosses had negative heterosis for neck thickness over mid parent, six crosses over better parent and 35 crosses over check. Seven crosses which showed significant positive heterosis for P/E ratio (shape index) over mid parent, five crosses over better parent and two crosses over standard check. Twenty one crosses exhibited significant positive heterosis for total soluble solid over mid parent, 12 crosses over better parent and ten crosses exhibited over standard check in onion hybrids. There was significant negative heterosis in two crosses over mid parent and better parent for rotten bulbs.

Mallikarjun (2006) observed significant positive heterosis for 12 characters in onion. Three crosses exhibited significant positive heterosis over better parent for yield *viz.*, DOGR-937 x DOGR-327, Bellary Red x DOGR-327 and Telgi Red x Arka Kalyan.

A study for yield, yield components and quality traits in onion, showed significant heterosis (Evoor *et al.*, 2007). The heterobeltiosis for plant height was found to be in the range of – 17.98 to 13.07 per cent with eight crosses registering significant positive heterobeltiosis. Out of 30 crosses, only three crosses registered significant positive standard heterosis for plant height and it range from - 7.22 to 17.46 per cent. For ten bulb weight, the variation for heterobeltiosis was from -35.67 to 8.11 per cent with three crosses recording significant heterosis, while, for standard heterosis variation was from -39.69 to 6.25 per cent with only one cross recording the significant positive heterosis. The heterobeltiosis and standard heterosis for polar bulb diameter was observed in the range of -26.80 to 15.67 and -24.87 to 11.11 per cent, respectively. In respect to equatorial bulb diameter, the heterobeltiosis range from -22.65 to 11.55 per cent with only three crosses registering significant positive heterosis. However, two crosses exhibited positive significant heterosis over standard check Arka Kalyan which was ranging from -24.29 to 9.76 per cent. Further, the magnitude of heterobeltiosis for marketable bulb yield range from -30.14 to 45.31 per cent with four crosses recording significant positive heterosis. However, only two crosses exhibited significant positive heterosis over standard check Arka Kalyan. For neck thickness of bulb, the heterobeltiosis and standard heterosis was observed in the range of -26.47 to 77.42 per cent and -29.63 to 12.96 per cent, respectively. Almost all (21) crosses registered significant negative (desirable) standard heterosis for this trait. For total soluble solids, two and five crosses expressed positive heterobeltiosis and standard heterosis, respectively but none of the crosses were significant.

Abubakar and Ado (2008), reported in their study, heterosis for purple blotch resistance (*Alternariaporri* (Ellis) Cif.), yield and earliness in tropical onions (*Allium cepa* L.). The crosses recorded highly significant positive heterosis over mid parent for bulb diameter, bulb weight, number of leaves/plant and fresh bulb yield.

The heterosis value of observed characters varied from -76 to 111 per cent. The cross combination of Kuning x Tiron had highest heterosis value and the greatest yield potential. Therefore, this cross combination was potential to be used for producing hybrid cultivar. Heterosis for yielding potential has been used as the basic consideration for breeding of hybrid onion (Noor Farid *et al.*, 2012).

In the studies on heterosis for purple blotch disease and bulb yield using male sterile lines in onion (*Allium cepa* L.), Ambresh and Veere Gowda (2013), observed a significant and positive heterosis over mid parent by thirteen crosses for total bulb yield. The highest positive mid parent heterosis was observed in the cross $L_2 \times T_4$ (37.63 %) followed by $L_2 \times T_1$ (36.03 %) and $L_3 \times T_5$ (33.66 %). Twelve crosses registered positive significant heterosis over better parent. Better parent heterosis range from 32.58 per cent ($L_3 \times T_5$) to -26.20 per cent ($L_4 \times T_3$). Seven crosses exhibited significant positive heterosis for bulb yield, of which two crosses $L_3 \times T_5$ (27.44 %) and $L_2 \times T_4$ (22.47 %) expressed significant positive heterosis over standard check Arka Kalyan for this trait.

Veere Gowda and Ambresh (2014), conducted experiment on heterosis for yield and quality traits and resistance to purple blotch in onion and found significant heterosis for following characters. Out of 28 crosses, 19 crosses showed significant negative heterosis for plant height over better

parent. Four crosses over commercial check showed positive significant heterosis for plant height. Magnitude of heterosis over better parent and commercial check was positively significant for number of leaves per plant, 11 crosses over better parent and six crosses over commercial check. Magnitude of heterosis was negatively significant over better parent and commercial check for bulb neck thickness, four crosses over better parent and 17 cross over commercial check. The positive significant heterosis for ten bulb weight was observed in three crosses over better parent and three crosses over commercial check. Heterosis for polar bulb diameter was significantly positive in the 16 crosses over better parent and 11 crosses over commercial check. The magnitude of heterosis over better parent and commercial check for equatorial bulb diameter was significant, nine crosses over better parent and 11 crosses over commercial check. Magnitude of heterosis was significantly positive over better parent and commercial check for total bulb yield per hectare. Out of 28 crosses, 12 crosses over better parent and seven crosses over commercial check showed positive significant heterosis for total bulb yield per hectare. Maximum positive significant heterosis was observed in the cross $L_2 \times T_4$ (43.83 %) over better parent and $L_3 \times T_5$ (28.65 %) over commercial check for marketable bulb yield per hectare. The heterosis for days to maturity were negatively significant in the cross $L_4 \times T_1$ (-10.21 %) over better parent and $L_3 \times T_1$ (-8.89 %) over commercial check which is desirable to get early harvesting, 14 crosses over commercial check showed negative and significant heterosis.

Quartiero *et al.* (2014), recorded mean of heterosis for the average mass of bulbs as 38 per cent, range from 16 per cent (HC3485) to 63 per cent (hybrid HC3483) and for yield 36 per cent, range from 16 per cent (HC3485) to 57 per cent (HC3483).

2.3 Combining ability

The genetic values of parents are expressed in terms of combining abilities. Sprague and Tatum (1942) defined general combining ability (gca) as the average performance of the progeny of an individual when it is mated to a number of other individuals in a population. Specific combining ability (sca) is a term that refers to the average performance of the progeny of a cross between two specific parents that are different from what would be expected on the basis of their general combining ability alone. Estimation of combining abilities provide quite relevant and vital information that is of direct utility to plant breeding programmes. Hybridization is one of the means of obtaining increased yield and choice of parents in such a programme is difficult owing to the differential behaviour of the inbreds in relation to combining ability. A measure of general and specific combining ability of the parents in terms of additive and non-additive portions of genetic variance would be of immense value in the choice of parents and of effective crosses for plant improvement.

Generally, general combining ability is associated with genes, which are additive in their effects, while specific combining ability is attributed to deviation from the additive scheme caused by dominance and epistasis. General combining ability involves both additive effects as well as additive x additive, additive x dominance and dominance x dominance type of interactions (Griffing, 1956).

The extent of hybrid vigour is dependent on the combining ability of the lines used as parents. If a line with an outstanding combining ability could be found, it might be used as a common parent for obtaining superior combinations. Generally, 'top crossing', 'line x tester' analysis and 'diallel crossing technique' are employed for this purpose. Following review presents the available genetic information on combining ability for different characters in onion.

All possible crosses including reciprocals among 10 inbred lines of diverse origin were tested in a diallel cross at three sites in 1973 to evaluate performance and estimate combining ability for yield, maturity, bulb weight. Cytoplasmic male sterility was used to insure that all seed from maternal plants was hybrid. Cross variances were highly significant for all traits at all sites. General combining ability effects accounted for most of these differences. Specific combining ability effects were significant at all sites for yield, bulb weight and firmness, and percentage storage loss. In all instances, variance components of general combining ability were larger than those of specific combining ability. Specific rankings of the best and poorest lines for the traits measured according to the effects of their general combining ability were not identical at each site but the same inbreds were generally in the same positive or negative grouping (Hosfield *et al.*, 1976).

General combining ability variances were predominant for yield and six other characters studied. Small but significant specific combining ability effects were observed for maturity, bulb firmness and percentage storage loss. The five highest yielding crosses involved the highest yielding inbreds M728 and B2190 (Hosfield *et al.*, 1977b).

Analysis of data on yield and six component traits from 30 hybrids involving ten lines and three testers revealed that non additive gene action conditioned all traits. AC863 and the tester AC874 were the best general combiners for yield (Vadivel *et al.*, 1982).

Madalageri (1983) evaluated forty five hybrids and parents for number of leaves for their sca and gca effect in which, he found the significance of gca and sca variance. This revealed additive and non-additive effect playing a role in the inheritance for number of leaves. For plant height, study observed the significant variance for gca and sca in onion and magnitude of gca was higher, indicating the predominant additive effects. For bulb weight the variances of gca, sca and reciprocals were significant. The gca variance were much higher than sca suggesting high portion of additive effects in onion hybrids. Although, gca and sca variance were significant for neck thickness, the greater magnitude of sca might be due to epistatic effect of additive x additive type. The variances of gca and sca for polar and equatorial diameter were significant, suggesting the importance of additive and non-additive effects in the inheritance of these characters. Even though variance for gca and sca were low but it was significant indicating both additive and non-additive gene controlling the inheritance of P/E ratio (shape index). For total soluble solids the gca, sca and reciprocal variances were significant. The gca/sca value was suggestive of higher magnitude of additive effects than dominance effects.

The magnitude of mean square of the specific combining ability appeared to be small in comparison with that of the general combining ability indicating that additive genetic variance is more important in determining characters like earliness, bulb ratio, number of leaves per plant and bulb height. A pronounced hybrid vigour was detected for most of the traits studied, indicating that non-additive gene effects were having a significant role in the inheritance of characters like earliness, bulb ratio, number of leaves per plant and bulb height (Sayed *et al.*, 1999).

Divakar (2001), observed that the variance of gca and sca were significant and magnitude of gca was higher than sca indicating the predominant additive genetic effects. GCA variance were positive and significant for three parents and sca variance for 22 crosses for plant height. For number of leaves per plant, the magnitude of gca variance was higher than sca variance, indicating the major influence of additive genetic variance. Significant and positive sca effect were found in 29 crosses for number of leaves per plant. Parent 10 was found to be a good general combiner and three crosses had significant and positive sca effect, high sca effect was found in cross 4x8 involving one parent having positive and another parent having negative gca effect for bulb weight. For neck thickness, the variance due to gca was found to be significant and sca variance was non-significant indicating the importance of additive genetic variance in the inheritance. The significant negative gca effects were found in two parents and none of the crosses had negative and significant sca effect for neck thickness. Noticed that the variance for gca and sca were low but significant, indicating both additive and non-additive genes controlling the inheritance of shape index. Generally, the parents with tarpedo (very high shape index) and flat (very low index) shape have exhibited, significantly positive and negative gca effects, respectively for this trait. Variance for combining ability revealed significant variance due to sca and gca indicating importance of both additive and non-additive genetic effects in the inheritance for total soluble solids and rotten bulbs.

Analysis of variance for combining ability indicated significant differences among parents. The estimated components of variance due to sca were greater than those due to gca for eight characters. The estimates of effects of general combining ability among the lines, L-2 proved to be a good combiner for the plant height. The cross L-3 x T-12 has shown good sca for plant height. The components of variance due to sca were greater than those due to gca for number of leaves per plant, the cross L-3 x T-14 is found to be good specific combiner for this character. Among the testers, T-6 was found to be good general combiner and cross L-2 x T-8 was found good specific combiner for bulb weight. Among the testers, T-19 was found good general combiner for neck thickness. Revealed the estimated components of variance due to sca were greater than those due to gca for shape index. For total soluble solids the combining ability variance components reveals that relative magnitude on non-additive component for all the characters except vertical bulb diameter was greater than additive component indicating predominance of non-additive gene action governing above characters (Sundari *et al.*, 2003).

Mallikarjun (2006), observed for bulb yield that tester Arka Pragati was only the parent to show good GCA effect significantly and highest SCA effect for this trait was show by cross Telgi Red x Arka Kalyan followed by DOGR-937 x DOGR-327.

The variations due to gca and sca were found to be significant for 10 characters studied indicating that both additive and non-additive gene actions played significant role for the expression of different characters. Parent P₅ showed the highest positive significant combining ability for bulb length, neck diameter, neck length, plant height, leaf length, number of leaves and bulb volume except bulb diameter, bulb weight and bulb yield characters. So, P₅ performed as better combiner followed by P₄ with the exception of non-significant gca value for neck length (Ara *et al.*, 2011).

Analysis for combining ability was carried out using F_1 hybrids derived from half diallel cross of seven parental genotypes. Among the evaluated genotypes, Tiron and Timor displayed the greatest GCA on seven characters except plant height and bulb diameter. The greatest SCA for plant height was observed in the cross of Kuning x Sibolangit, followed by Tiron x Timor and Kuning x Bima Juna, while the greatest SCA for number of bulblets and number of bulbs were observed in the cross of Kuning x Sibolangit, followed by Tiron x Maja, and Tiron x Timor. The greatest SCA for bulb diameter was observed in the cross of Kuning x Timor, followed by then Bima x Maja and Kuning x Bima. The greatest SCA for bulb fresh weight was observed in the cross of Kuning x Sibolangit, followed by Kuning x Tiron and Timor x Bima Juna. In bulb dry weight, however, the greatest SCA was observed in the cross of Kuning x Tiron, followed by Kuning x Sibolangit, and Timor x Bima Juna (Noor *et al.*, 2012). Selection of parental genotypes used in crossing program for development of new varieties based on the value of GCA, SCA and heterosis.

3. MATERIAL AND METHODS

The study on heterosis and combining ability in onion was undertaken during the year 2014-16 at network project on onion and garlic site, Department of Horticulture, Main Agricultural Research Station, Dharwad. The details of material and methods used for the development of F₁ hybrids and their evaluation, experimental designs adopted and statistical procedures followed are revealed in this chapter under following headings :

3.1 Experimental site and location

The experiment was conducted in the black soils (*Vertisols*) of the network project on onion and garlic site, Department of Horticulture, Main Agricultural Research Station, Dharwad. Soil belongs to clay textural class with good amount of available nutrients. The physical and chemical properties of the soil are presented in Appendix I.

Geographically, Dharwad is located at 15° 26' North latitude, 76° 07' East longitude and at an altitude of 678 m above the mean sea level. Dharwad is situated in the agro-climatic zone-VIII.

The details of the meteorological data during the period of experimentation (December 2014 to April 2016) as recorded at the meteorological observatory of Main Agricultural Research Station, University of Agricultural Sciences, Dharwad is presented in Appendix II.

The rainfall during experimentation period (December 2014 to April 2016) range from 0 mm (February, 2015) to 179.8 mm (October, 2015) per month. The number of rainy days range from 0 (January, 2015) to 11 (June, 2015). The mean monthly maximum temperature range from 27.9 °C (December, 2014) to 38 °C (April, 2016). Mean monthly minimum temperature range from 13.3 °C (January) to 21.6 °C (April) during 2015. Mean monthly minimum relative humidity (RH) range between 24.2 per cent (February, 2015) and 80.0 per cent (September, 2015). Mean monthly maximum relative humidity (RH) range between 52.6 per cent (February, 2015) and 91.6 per cent (September, 2015).

3.2 Hybridisation programme

The experiment consisted of 13 parents (5 lines as females and 8 testers as males). The salient features of the parents are presented in the table1.

Generating material- Hybridisation programme – 40 hybrids were generated by using 5 lines as female parents and 8 testers as male parents. In order to generate F₁ hybrid seeds, the bulbs of lines as well as testers (parents) were planted on 24th December, 2014. Together the bulbs were treated with vitavax @ 3g/litre before they were planted.

Table 1.Genotypes used for generating F₁ hybrids and their source

Genotype	Source	Features
Lines		
1.Kumata local	UAS, Dharwad	Average bulb weight 90-110g, pink coloured, yield 30 t/ha.
2.Bhima Shakti	DOGR, Rajagurunagar	Average bulb weight 80-100 gm, red colour, yield 32 t/ha.

3.GKD-75	UAS, Dharwad	Medium sized bulbs, average yield 15 t/ha, medium red in colour.
4.ASKO-1201	DOGR, Rajagurunagar	Average bulb weight 90-110g, medium red coloured, yield 20.9 t/ha.
5.ASKO-1299	DOGR, Rajagurunagar	Average bulb weight 80-100g, medium red coloured, yield 22.5 t/ha.
Testers		
1.Cross-5	DOGR, Rajagurunagar	Average sized bulbs, medium red, yield 22 t/ha.
2.GKD-45	UAS, Dharwad	Medium sized bulbs, average yield 17.1 t/ha, light red in colour.
3.GKD-77	UAS, Dharwad	Medium to large sized bulbs, deep to medium red coloured, yield 25 t/ha.
4.ASKO-1222	DOGR, Rajagurunagar	Average bulb weight 75-105 g , deep red colour, yield 21.9 t/ha.
5.Arka Kalyan	IIHR, Hesarghatta	Bulbs 4-6 cm across, 33 t/ha, deep red in colour.
6.Line-25	UAS, Dharwad	Medium sized bulbs, medium red colour, yield 27 t/ha.
7. N-53	UAS, Dharwad	Average yield is 25 t/ha, red in colour, TSS is 11 to 12 %.
8.Line-13	UAS, Dharwad	Dark red, medium sized bulbs, yield 20 t/ha.

3.2.1 Generating F₁ hybrid seeds

Bulbs were planted according to the design *i.e.*, bulbs of each line were planted along with the bulbs of respective testers desired for crossing. After a week they started sprouting and they were given the recommended fertilizer dose and the plant protection measures were taken. Just before flowering (approximately 45 to 50 days after planting bulbs) the desired line and tester which were planted together for crossing purpose were caged with nylon nets to prevent cross pollination from unknown sources (Plate 1), since it is a cross pollinated crop. Umbels were gently shaken on day to day basis in the morning hours between 7:30am to 8:00am till seed set was ensured. The seeds were harvested at physiological mature stage (10th April 2015). The seeds were dried for about 8 to 10 days, till the seeds approximately had a moisture content of 0.06 to 0.08 H₂O per gdw. Then, they were cleaned and packed in polythene bag and stored in refrigerator at temperature of 5°C. These F₁ seeds were utilized for raising the seedlings during ensuing *kharif* and *rabi* season. In order to evaluate the hybrids + parents and check (Bhima Super - *kharif* ; Bhima Shakti - *rabi*) seeds totalling to an entry of 54 per season were sown on raised nursery. Beds of 3.0 x 1.2 m with 15 cm height were prepared and sterilized. Each bed was applied with 500 g of 15:15:15 NPK complex fertilizer and were mixed thoroughly. The F₁ seeds of 40 hybrids, 13 parents and one check were sown in rows spaced at 10 cm apart on 16th June, 2015 during *kharif*. The beds were watered regularly. The plant protection measures were taken to protect the seedlings from soil borne diseases. The seedlings were ready for transplanting in 45 days and were transplanted on 31th July, 2015 in the main field with 40 hybrids + 13 parents and one check in randomized block design with two replications. The spacing between the seedlings was 10 cm and between the row was 15 cm. The plants were fertilized with 120 kg of N, 50 kg of P₂O₅ and 60 kg of K₂O per ha and were grown under protective irrigation.



Plate 1 : Steps in crossing programme to develop hybrids



Plate 1 : Steps in crossing programme to develop hybrids



Plate 1 : Steps in crossing programme to develop hybrids

Plate 1: Steps in crossing programme to develop hybrids

Then same procedure was followed for evaluating hybrids + parents and one check in *rabi* also. The seeds of 40 entries, 13 parents and one check were sown on nursery bed with the above spacing on 20th November, 2015. Then they were transplanted on 7th January, 2016.

Details of the experiment

Design	RBD
Replications	2
Genotypes	40 hybrids + 13 parents and check (Bhima Super during <i>kharif</i> and Bhima Shakti during <i>rabi</i>)
Plot size	1.2m x 2m
Season	<i>Kharif</i> and <i>Rabi</i> (2015-16)
Spacing	15 cm x 10 cm
Location	Department of Horticulture, College of Agriculture, Dharwad

The experiment was carried out during 2014-16 and the recommended package of practices were followed.

3.3 Experiment-I : Evaluation of F₁ hybrids

The experiment was carried out by using RBD design with two replications. The seeds of all the 40 hybrids were sown in a seed bed on 16th June, 2015. Then they were transplanted to main field on 31th July, 2015 (Plate 2) for *kharif* season evaluation. Again F₁ seeds were sown on 20th November, 2015. Then they were transplanted to main field on 7th January, 2016 (Plate 3) for *rabi* season evaluation.

3.4 Cultural practices

Recommended package of practices were followed for raising onion crop.

3.5 Observations recorded

The following observations were recorded and used for evaluation of parents, hybrids and commercial check. The five randomly selected plants from each entry was used for recording the observations, and the average from these five plants was worked out for the purpose of statistical computation. The details of observations recorded in each experiment and techniques adopted for recording the observations were as follows.

The observations for plant height, leaf length, and number of functional leaves were collected on 30 and 60 days after transplanting.

The data on remaining characters were collected after the harvest from the total bulbs harvested. Five competitive bulbs were selected randomly for recording the bulb weight, bulb dimension and total soluble solids.

The bulbs with good shape and size obtained from the plot was used to calculate the marketable yield in tonnes per ha. The undersized bulbs obtained from the plot was used to calculate the non marketable yield in tonnes per ha. Total of marketable yield and non marketable yield per plot was used to calculate the total yield per ha.



Plate 2 : General view of layout of *kharif* experimental plot in onion

Plate 2. General view of layout of kharif experimental plot in onion



Plate 3 : General view of layout of *rabi* experimental plot in onion

Plate 3. General view of layout of rabi experimental plot in onion

3.5.1 Number of leaves per plant

The number of fully grown, green functional leaves were recorded from five randomly selected plants at 30 and 60 days after transplanting and average number of leaves per plant was calculated.

3.5.2 Leaf length

The maximum leaf length was measured from below the joint of leaf lamina to tip of longest leaf (when held vertically) at 30 and 60 days after transplanting. The mean of the five plants in a treatment was worked out in centimetre (cm).

3.5.3 Plant height

The maximum plant height was measured from ground level to tip of longest leaf (when held vertically) at 30 and 60 days after transplanting. The mean of the five plants in a treatment was worked out in centimetre (cm).

3.5.4 Neck thickness

The neck thickness was measured with the help of Vernier caliper below the joint of leaf lamina. The observations recorded on five plants were averaged to get a mean value was worked out in centimetre (cm).

3.5.5 Bulb weight

Five competitive bulbs were weighed individually on an electronic balance and then mean value was worked out in grams (g).

3.5.6 Polar diameter

The length between two polar ends was recorded with the help of a Vernier caliper. The mean length of bulb was calculated in centimetre (cm).

3.5.7 Equatorial diameter

The bulb diameter at the middle of the bulb across the polar length was measured in centimetre (cm) with the help of a Vernier caliper and the mean was calculated.

3.5.8 P/E ratio

The P/E ratio (bulb shape index) was determined by dividing the polar diameter with equatorial diameter. The bulb with 1.00 index was considered as globular, those with less than 1.00 as flat and those with more than 1.00 as torpedo types.

3.5.9 Total soluble solids

Total soluble solids was recorded with the help of Refractometer ($^{\circ}$ Brix) and average was computed.

3.5.10 Colour of the bulbs

Colour of the bulbs were assigned based on the visual observation.

3.5.11 Marketable yield per hectare

The bulbs with good shape and size obtained from the plot was used to calculate the marketable yield in tonnes per hectare (t/ha).

3.5.12 Non marketable yield per hectare

The undersized bulbs obtained from the plot was used to calculate the non marketable yield in tonnes per hectare (t/ha).

3.5.13 Rotten bulbs

Rotten bulbs sorted out from each plot was used to calculate the yield of rotten bulbs in tonnes per hectare (t/ha).

3.2.14 Number of Days to Maturity

The number of days taken from the transplanting to the day when more than half of the population in each treatments reached neck fall or leaf yellowing stage.

3.2.15 Total yield

Total of marketable yield and non marketable yield per plot was used to calculate the total yield per hectare (t/ha).

3.6 Statistical analysis

The data recorded for each character of observational plants were averaged and the mean values obtained from this were used for statistical analysis.

The data collected under various parameters were analyzed using software INDOSTAT 7.5 version developed by Indian Statistical Research Institute, New Delhi.

3.6.1 Analysis of variance

Analysis of variance for individual character was done on the basis of mean values as suggested by Panse and Sukhatme (1942). The model of variance adopted is given below;

Source	d.f.	SS	MSS	F ratio
Replication	(r-1)	RSS	Mr (M ₁)	M ₁ /M ₃
Treatment	(t-1)	TSS	Mt (M ₂)	M ₂ /M ₃
Error	(r-1) (t-1)	ESS	E (M ₃)	

r = Number of replications

t = Number of treatments

Significance of treatment was tested at five and one per cent probability.

3.6.2 Line x tester

3.6.2.1 Analysis of variance

The first step in line x tester analysis is performing analysis of variance for Randomized Block Design to test the significance of difference among genotypes including crosses and parents. The analysis of variance was conducted for all the characters as per the method given by Kempthorne (1957). The variances were estimated as under.

Sl. No.	Source	d.f.	SS	MSS	F ratio
1	Replication	(r-1)	RSS	RSS/r-1	RMSS/EMSS
2	Treatment	(n-1)	TSS	TrSS/n-1	TrMSS/EMSS
3	Error	(r-1)(n-1)	ESS	ESS/(r-1)(n-1)	
	Total	(rn-1)	Total SS		

1. $C.F. = (G.T.)^2 / r \times n$
2. Total S.S. = Total sum of square of all the observations - C.F.
3. Replication S.S. = $\frac{\text{S.S. for all replication total}}{t}$ - C.F.
4. Treatment S.S. = $\frac{\text{S.S. for all the treatments total}}{r}$ - C.F.
5. Error S.S. = Total S.S. - (Replication S.S. + Treatment S.S.)

Where,

r = Number of replications

n = Number of treatments

The metric traits which appeared to be significant were further subjected to line x tester analysis.

In order to test the significance of the crosses and parents individually, further partitioning of treatment S.S. was done for males, females, males vs females and hybrids vs. parents as follows;

Sl. No.	Source	d.f.	Mean of squares	Calculated F value
1	Replication	(r-1)		
2	Treatment	(n-1)		
3	Parents	(p-1)		
4	Hybrids	(h-1)		
5	Parents vs Hybrids	1		
6	Males	(M-1)		
7	Females	(f-1)		
8	Males vs Females	1		
9	Error	(r-1)(n-1)		
	Total			

Where,

r = number of replications

n = number of treatments

h = number of hybrids

m = number of males

f = number of females

3.6.2.2 Heterosis

3.6.2.2.1 Heterosis over mid parent (MP)

The heterosis expressed as percentage increase or decrease in the mean value of hybrids over its mid parental value.

$$\text{Per cent heterosis over its mid parent (MP)} = \frac{\mathbf{F_1(\text{mean}) - MP(\text{mean})}}{\mathbf{MP(\text{mean})}} \times 100$$

Where,

F₁ (mean) = Mean of the hybrid

MP (mean) = Mean of the two parents of that particular F₁ cross

3.6.2.2.2 Heterosis over better parent (BP)

The heterosis expressed as percentage increase or decrease in the mean value of hybrids over its better parent.

$$\text{Per cent heterosis over its better parent (BP)} = \frac{\mathbf{F_1(\text{mean}) - BP(\text{mean})}}{\mathbf{BP(\text{mean})}} \times 100$$

Where,

F₁ (mean) = Mean of the hybrid

BP (mean) = Mean of the better parent of that particular F₁ cross

3.6.2.2.3 Standard heterosis or commercial heterosis

The heterosis expressed as percentage increase or decrease in the mean value of hybrids over a popular or best variety growing over that particular area.

$$\text{Standard heterosis} = \frac{\mathbf{F_1(\text{mean}) - \text{Commercial check (mean)}}}{\mathbf{\text{Commercial check (mean)}}} \times 100$$

Where,

F_1 (mean) = Mean of the hybrid

Commercial check (mean) = Mean of the commercial check

Calculation of critical difference for heterosis over BP and MP:

- (i) C.D. for MP = $\frac{3 Me}{2r} \times t$ value at 5 % and 1 %
 (ii) C.D. for BP = $\frac{2 Me}{2r} \times t$ value at 5 % and 1 %

Where,

M = Error mean sum of square

r = Number of replications

3.6.2.3 Combining ability

Combining ability analysis for the F_1 hybrids was based on the procedure developed by Kempthorne (1957). The sum of squares due to different factors was partitioned as shown below.

Sl. No.	Source	d.f.	SS	MS	Expected
1	Replication	(r-1)	$\frac{\sum x^2 \dots k}{Mf} + \frac{X^2}{mfr}$		
2	Hybrids	(mf-1)	$\frac{\sum x^2 ij}{r} + \frac{X^2}{mfr}$		
3	(i)Males	(m-1)	$\frac{\sum x^2 i \dots}{Fr} + \frac{x^2}{mfr}$	M_1	$\sigma^2 e + r ((\text{Cov. (F.S.)} - 2\text{Cov. (H.S.)}) + (\text{frCov. (H.S.)}))$
	(ii)Females	(f-1)	$\frac{\sum x^2 j \dots}{mr} + \frac{x^2}{mfr}$	M_2	$\sigma^2 e + r ((\text{Cov. (F.S.)} - 2\text{Cov. (H.S.)}) - (\text{mrCov. (H.S.)}))$
	(iii)Males Vs Females	1	$\frac{\sum \sum x^2 ij \dots}{r} + \frac{x^2}{mfr}$	M_3	$\sigma^2 e + r ((\text{Cov. (F.S.)} - 2\text{Cov. (H.S.)}))$
	Error	(r-1) (mf-1)	$\frac{\sum \sum x^2 ij \dots}{r} + \frac{x^2}{mfr}$	M_4	$\sigma^2 e$
	Total	(Mfr-1)	$\sum \sum \sum x^2 ijk \dots - \frac{x^2}{mfr}$		

Where,

m = Number of male parents

f = Number of female parents

r = Number of replications

x = grand total

x_{.....k} = Sum total of kth replication

x_{.j.} = Sum of the jth female parents overall males and replications

x_(ij) = Sum of the ijth hybrid combination overall replications

x_(i) = Sum of the ith male parents overall females and replications

x_(ijk) = (ij)th observation in kth replication

M₁ = Mean sum of square of males

M₂ = Mean sum of square of females

M₃ = Mean sum of square of males and females interaction

M₄ = Error mean sum of squares

From the expectation of mean square co-variance of full sibs (Cov(F.S.)) and co-variance of half sib (Cov(H.S.)) were estimated as follows.

$$\text{Cov(H.S.)} = \frac{(M_1 - M_3) + (M_2 - M_3)}{r(m+f)}$$

$$\text{Cov(F.S.)} = \frac{(M_1 - M_4) + (M_3 - M_4)}{3r} + \frac{\sigma^2 \text{Cov(H.S.)} - r(m+f)}{3}$$

After estimating the (Cov(H.S.)) and (Cov(F.S.)) by above equations, variance due to general combining ability (σ^2_{gca}) and variance due to specific combining ability (σ^2_{sca}) were estimated as:

$$(\sigma^2_{gca}) = \text{Cov(H.S.) here breeding coefficient} = 1$$

$$(\sigma^2_{sca}) = (\text{Cov. (F.S.)} - 2 \text{Cov.(H.S.)})$$

3.6.2.3.1 Estimation of general and specific combining ability effects

The model used to estimate the general and specific combining ability effects of the ijk observations was

$$X_{ijk} = \mu + g_i + g_j + S_{ij} + e_{ijk}$$

Where,

μ = Population mean

g_i = *gca* effects of i^{th} male plant

g_j = *gca* effects of j^{th} female plant

S_{ij} = *sca* effects of ij^{th} combination

e_{ijk} = Error associated with the observation X^{ijk}

The individual effects were estimated as follows

$$(a) \quad \hat{\mu} = \frac{X_{....}}{mfr} = \text{grand total}$$

$$(b) \quad \hat{g}_i = \frac{x_{i....}}{fr} - \frac{X_{....}}{mfr}$$

x_i = Sum of the i^{th} male parents overall females and replications

$$(c) \quad \hat{g}_j = \frac{x_{.j.}}{mr} - \frac{X_{....}}{mfr}$$

$x_{.j.}$ = Sum of the j^{th} female parents overall males and replications

$$(d) \quad \hat{S}_{ij} = \frac{x_{ij}}{r} - \frac{x_{i....}}{fr} - \frac{x_{.j.}}{mr} + \frac{X_{....}}{mfr}$$

Where,

X_{ij} = (ij)th combination total overall replications

m = Number of male parents

f = Number of female parents

r = Number of replications

3.6.2.3.2 Calculation of S.E. of differences between general and specific combining ability effect of two parents

(i) var. ($g_{i1} - g_{i2}$) males = 2 (error variance) / rf

$$\text{S.E. } (g_{i1} - g_{i2}) \text{ males} = \sqrt{\text{var. } (g_{i1} - g_{i2}) \text{ males}}$$

(ii) var. ($g_{i1} - g_{i2}$) females = 2 (error variance) / rm

$$\text{S.E. } (g_{i1} - g_{i2}) \text{ females} = \sqrt{\text{var. } (g_{i1} - g_{i2}) \text{ females}}$$

(iii) var. ($S_{ij1} - S_{ij2}$) = 2 (error variance) / r

$$\text{S.E. } (S_{ij1} - S_{ij2}) = \sqrt{\text{var. } (S_{ij1} - S_{ij2}) \text{ males} \times \text{females}}$$

1. S.E. (*gca* for lines) = M / rl

2. S.E. (*gca* for testers) = M / rt

3. S.E. (*sca* effects) = M / r

Positive significant heterosis, positive significant GCA and SCA is desirable for following characters - Plant height; Leaf length; Number of leaves per plant; Bulb weight; Polar diameter; Equatorial diameter; P/E ratio; Total soluble solids; Total yield and marketable yield.

Negative significant heterosis, negative significant GCA and SCA is desirable for following characters - Neck thickness; Non-marketable yield; Rotten bulbs and number of days to maturity.

4. EXPERIMENTAL RESULTS

The results of the present investigation on performance, heterosis, general and specific combining ability of onion are presented separately for *kharif* season as well as for *rabi* season under the following sections:

- 4.1 Analysis of variance,
- 4.2 Performance and Heterosis and
- 4.3 Combining ability

4.1 Analysis of variance in onion F₁ hybrids during *kharif* season

Analysis of variance carried out for seventeen traits is presented in table 2.

The analysis of variance for 17 characters in onion crosses is presented in table 2. There is a presence of significant difference among treatments for all seventeen characters studied: plant height at 30 and 60 DAT, leaf length at 30 and 60 DAT, number of leaves at 30 and 60 DAT, polar diameter, equatorial diameter, P/E ratio, neck thickness, marketable yield, non-marketable yield, average bulb weight, total soluble solids, bulbs rotten, total yield and days to maturity.

4.2 Performance and Heterosis

4.2.1 Plant height at 30 days after transplanting (Table 3)

The *per se* performance of parents showed that plant height range from 42.40 cm (ASKO-1201) to 54.90 cm (GKD-77), where as in hybrids it was from 38.40 cm (Bhima Shakti x N-53) to 54.9 cm (ASKO-1299 x GKD-45). Among 54 entries studied, ASKO-1299 x GKD-45 recorded highest plant height and it was at par with the commercial check (Bhima Super) and there were eight F₁ hybrids which were at par with this. Out of 13 parents, five were at par with F₁ (ASKO-1299 X GKD-45). Commercial check (Bhima Super) recorded the plant height of 55.5 cm.

The heterosis over mid parent for plant height range from -6.35 per cent (Bhima Shakti x GKD-77) to 46.29 per cent (ASKO-1299 x Line-25). Out of 40 crosses, 30 crosses recorded significant positive heterosis. With respect to heterosis over better parent out of 40 hybrids studied, 22 hybrids recorded heterosis in positive direction. Among them ASKO-1299 x GKD-45 recorded highest positive heterosis. None of the hybrids recorded the significant positive heterosis over the commercial check.

4.2.2 Leaf length at 30 days after transplanting (Table 4)

Among 5 lines, Bhima Shakti recorded lowest leaf length (38.50 cm) and highest was recorded in ASKO-1299 (50.90 cm). Further, among testers lowest leaf length was recorded by Line-13 (39.60 cm) and highest by Cross-5 (49.30 cm). The range for leaf length in hybrids was from 30.75 cm (Bhima Shakti x N-53) to 50.90 cm (ASKO-1201 x Line-25). Hybrid ASKO-1201 x Line-25 possessed higher leaf length than commercial check, which was at par with 9 other F₁s.

Table 2. Analysis of variance (mean sum of squares) for 17 characters in onion during *kharif*

Source of variation	Df	Plant height (cm) at 30 DAT	Leaf length (cm) at 30 DAT	No of leaves at 30 DAT	Plant height (cm) at 60 DAT	Leaf length (cm) at 60 DAT	No of leaves at 60 DAT	P/E ratio	Neck thickness (cm)	TSS %brix	Market-able yield (t/ha)	Non market-able yield (t/ha)	Average bulb weight (g)	Total yield (t/ha)	Rotten bulbs (t/ha)	Days to maturity
Replications	1	7.10	0.42	0.02	19.42	0.65	0.40	0.02	0.01	0.04	0.11	0.05	11.34	0.58	0.05	24.44
Treatments	53	51.87*	43.34*	0.61*	31.25*	18.16*	1.09*	0.05*	0.03*	3.95*	7.97**	1.26*	157.4**	9.76**	0.55**	25.46**
Error	53	5.25	8.99	0.14	7.19	0.32	0.33	0.01	0.01	0.35	0.14	0.07	13.02	0.58	0.15	9.92

* and ** indicates significant at 5 and 1 % respectively
Soluble Solids

Df, : Degrees of freedom

DAT : Days After Transplanting TSS : Total

Table 3. Per se performance and magnitude of heterosis for plant height at 30 days after transplanting during kharif

Sl. No.	Entries	Plant height at 30 days after transplanting						
		Per se value (cm)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	48.05	54.80	51.43	40.70	2.52	0.37	-24.28**
2	Kumata local x GKD-45		53.70	50.88	46.20	22.22**	18.92**	-14.05**
3	Kumata local x GKD-77		54.90	51.48	45.95	9.02**	1.10	-14.51**
4	Kumata local x ASKO-1222		48.15	48.10	42.75	3.45	-2.40	-20.47**
5	Kumata local x Arka Kalyan		50.15	49.10	43.70	-0.46	-10.73**	-18.70**
6	Kumata local x Line-25		52.20	50.13	41.15	15.35**	5.92	-23.44**
7	Kumata local x N-53		50.90	49.48	45.65	23.38**	17.50**	-15.07**
8	Kumata local x Line-13		54.75	51.40	48.00	20.23**	17.07**	-10.70**
9	Bhima Shakti x Cross 5	48.05	54.80	51.43	48.10	14.46**	10.57**	-10.51**
10	Bhima Shakti x GKD-45		53.70	50.88	46.30	15.39**	6.44	-13.86**
11	Bhima Shakti x GKD-77		54.90	51.48	41.65	-6.35*	-8.36**	-22.51**
12	Bhima Shakti x ASKO-1222		48.15	48.10	44.75	2.52	2.17	-16.74**
13	Bhima Shakti x Arka Kalyan		50.15	49.10	48.65	5.25	-0.61	-9.49**
14	Bhima Shakti x Line-25		52.20	50.13	52.50	38.16**	20.69**	-2.33
15	Bhima Shakti x N-53		50.90	49.48	38.40	-2.35	-11.72**	-28.56**
16	Bhima Shakti x Line-13		54.75	51.40	42.40	0.36	-2.53	-21.12**
17	GKD-75 x Cross-5	44.80	54.80	49.80	45.80	15.00**	12.95**	-14.79**
18	GKD-75 x GKD-45		53.70	49.25	48.50	27.88**	24.04**	-9.77**
19	GKD-75 x GKD-77		54.90	49.85	46.60	10.23**	2.53	-13.30**
20	GKD-75 x ASKO-1222		48.15	46.48	48.60	17.25**	10.96**	-9.58**
21	GKD-75 x Arka Kalyan		50.15	47.48	47.60	8.12**	-2.76	-11.44**
22	GKD-75 x Line-25		52.20	48.50	45.90	28.21**	17.39**	-14.60**
23	GKD-75 x N-53		50.90	47.85	46.50	25.25**	18.93**	-13.49**
24	GKD-75 x Line-13		54.75	49.78	46.20	15.36**	12.68**	-14.05**
25	ASKO-1201 x Cross-5	42.40	54.80	48.60	45.15	13.51**	11.34**	-16.00**
26	ASKO-1201 x GKD-45		53.70	48.05	48.05	26.86**	23.21**	-10.60**
27	ASKO-1201 x GKD-77		54.90	48.65	44.80	6.10*	-1.43	-16.65**
28	ASKO-1201 x ASKO-1222		48.15	45.28	42.40	2.42	-3.20	-21.12**
29	ASKO-1201 x Arka Kalyan		50.15	46.28	43.95	-0.06	-10.21**	-18.23**
30	ASKO-1201 x Line-25		52.20	47.30	47.90	33.99**	22.82**	-10.88**
31	ASKO-1201 x N-53		50.90	46.65	49.60	33.78**	27.18**	-7.72**
32	ASKO-1201 x Line-13		54.75	48.58	54.80	37.00**	33.66**	1.95
33	ASKO-1299 x Cross-5	43.95	54.80	49.38	53.70	35.01**	32.43**	-0.09
34	ASKO-1299 x GKD-45		53.70	48.83	54.90	44.95**	40.77**	2.14
35	ASKO-1299 x GKD-77		54.90	49.43	48.15	14.03**	5.94	-10.42**
36	ASKO-1299 x ASKO-1222		48.15	46.05	50.15	21.14**	14.50**	-6.70*
37	ASKO-1299 x Arka Kalyan		50.15	47.05	52.20	18.70**	6.64*	-2.88
38	ASKO-1299 x Line-25		52.20	48.08	52.30	46.29**	34.10**	-2.70
39	ASKO-1299 x N-53		50.90	47.43	50.90	37.29**	30.51**	-5.30*
40	ASKO-1299 x Line-13		54.75	49.35	54.75	36.88**	33.54**	1.86
	CC (Bhima Super)				55.5			
	S.Em. ±				1.61	1.2044	1.3907	1.3907
	C.D. at 5 %				4.55	2.4361	2.8130	2.8130
	. at 1 %				6.06	3.2614	3.7659	3.7659

* and ** indicates significant at 5 and 1 % respectively
MP-Mid parent, BP-Better parent, CC-Commercial check

The magnitude of heterosis for the trait under consideration range from -13.26 per cent (Bhima Shakti x N-53) to 44.4 per cent (ASKO-1201 x Line-25) over mid parent; -22.26 per cent (Bhima Shakti x Arka Kalyan) to 36.10 per cent (ASKO-1201 x Line-25) over better parent; -18.87 per cent (Bhima Shakti x N-53) to 34.3 per cent (ASKO-1201 x Line-25) over commercial check (Bhima Super).

Among 40 hybrids studied, 17 hybrids were positively significant over mid parent, 10 hybrids over better parent and 11 hybrids over commercial check (Bhima Super).

4.2.3 Number of leaves at 30 days after transplanting (Table 5)

The performance and magnitude of heterosis is presented in the table 5. The variation for this character range between 5.5 (ASKO-1222) and 6.9 (GKD-75) in parents; 5.5 (ASKO-1299 x GKD-77) and 7.1 (Kumata local x GKD-77 and Kumata local x GKD-45) in hybrids. Out of 40 hybrids studied 17 hybrids were significantly higher than commercial check.

The magnitude of heterosis for number of leaves over mid parent range from 0 per cent (ASKO-1299 x GKD-77 and ASKO-1299 x ASKO-1222) to 35.24 per cent (Kumata local x GKD-45); over better parent there was no significant negative heterosis but positive was recorded by Kumata local x N-53 (31.37); over commercial check it range from -16.67 per cent (ASKO-1299 x GKD-77 and ASKO-1299 x ASKO-1222) to 7.58 per cent (Kumata local x GKD-45 and Kumata local x GKD-77). Out of 40 crosses studied, 33 crosses expressed significant positive heterosis over better parent, 37 crosses over mid parent and only two crosses over commercial check.

4.2.4 Plant height at 60 days after transplanting (Table 6)

The observation on hybrids for plant height at 60 DAT point that the entry ASKO-1299 x N-53 had the highest plant height (58.65 cm). As many as 18 hybrids were at par with commercial check. Among the lines (female) Bhima Shakti has highest plant height (55.80 cm) while in testers (male) it was N-53 (58.65 cm).

The hybrid Bhima Shakti x GKD-77, exhibited the least heterosis over mid parent (-13.77 %). Further, the cross combination Bhima Shakti x Arka Kalyan recorded least heterosis over better parent (-21.79 %).

The number of hybrids which showed low or negative heterosis over mid parent were 15, 27 over better parent and 34 over commercial check. Only one hybrid exhibited significant positive heterosis over commercial check ASKO-1299 x N-53 (5.68 %).

4.2.5 Leaf length at 60 days after transplanting (Table 7)

For leaf length at 60 DAT, the performance of parents range from 40.90 cm (GKD-77) to 48.85 cm (ASKO-1299) and 39.85 cm (Bhima Shakti x N-53) to 51.75 cm (Kumata local x N-53) in hybrids. Among the 13 parents used, two parents (ASKO-1201, Line-25) were at par with ASKO-1299 (48.85 cm).

Table 4. Per se performance and magnitude of heterosis for leaf length at 30 days after transplanting during kharif

Sl. No.	Entries	Leaf length at 30 days after transplanting						
		Per se value (cm)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	41.90	49.30	45.60	34.20	-12.20	-16.18 *	-9.76
2	Kumata local x GKD-45		48.40	45.15	40.90	9.50	8.78	7.92
3	Kumata local x GKD-77		45.50	43.70	41.20	13.81	11.05	8.71
4	Kumata local x ASKO-1222		46.00	43.95	38.70	-6.18	-14.76 *	2.11
5	Kumata local x Arka Kalyan		47.90	44.90	38.20	-9.48	-19.24 **	0.79
6	Kumata local x Line-25		45.20	43.55	40.00	13.96	7.82	5.54
7	Kumata local x N-53		48.00	44.95	40.70	14.97 *	9.70	7.39
8	Kumata local x Line-13		39.60	40.75	40.80	2.38	-4.23	7.65
9	Bhima Shakti x Cross 5	38.50	49.30	43.90	41.70	6.92	2.21	10.03
10	Bhima Shakti x GKD-45		48.40	43.45	42.90	14.71 *	14.10	13.19
11	Bhima Shakti x GKD-77		45.50	42.00	41.70	15.03 *	12.10	10.03
12	Bhima Shakti x ASKO-1222		46.00	42.25	35.90	-13.08 *	-20.93 **	-5.28
13	Bhima Shakti x Arka Kalyan		47.90	43.20	36.80	-12.90 *	-22.20 **	-2.90
14	Bhima Shakti x Line-25		45.20	41.85	43.80	24.61 **	17.74 *	15.57
15	Bhima Shakti x N-53		48.00	43.25	30.75	-13.26	-17.34 *	-18.87 *
16	Bhima Shakti x Line-13		39.60	39.05	37.40	-6.27	-12.21	-1.32
17	GKD-75 x Cross-5	38.80	49.30	44.05	44.10	16.36 *	8.09	16.36 *
18	GKD-75 x GKD-45		48.40	43.60	35.00	-3.58	-6.91	-7.65
19	GKD-75 x GKD-77		45.50	42.15	40.50	15.22 *	14.73	6.86
20	GKD-75 x ASKO-1222		46.00	42.40	40.20	0.00	-11.45	6.07
21	GKD-75 x Arka Kalyan		47.90	43.35	39.70	-3.52	-16.07 *	4.75
22	GKD-75 x Line-25		45.20	42.00	39.70	16.59 *	13.43	4.75
23	GKD-75 x N-53		48.00	43.40	40.70	18.49 *	16.29	7.39
24	GKD-75 x Line-13		39.60	39.20	41.30	6.44	-3.05	8.97
25	ASKO-1201 x Cross-5	43.60	49.30	46.45	43.90	12.28	7.60	15.83
26	ASKO-1201 x GKD-45		48.40	46.00	41.90	11.73	11.44	10.55
27	ASKO-1201 x GKD-77		45.50	44.55	38.50	5.91	2.94	1.58
28	ASKO-1201 x ASKO-1222		46.00	44.80	38.80	-6.28	-14.54 *	2.37
29	ASKO-1201 x Arka Kalyan		47.90	45.75	43.60	2.95	-7.82	15.04
30	ASKO-1201 x Line-25		45.20	44.40	50.90	44.40 **	36.10 **	34.30 **
31	ASKO-1201 x N-53		48.00	45.80	50.70	42.62 **	35.56 **	33.77 **
32	ASKO-1201 x Line-13		39.60	41.60	49.30	23.25 **	15.73 *	30.08 **
33	ASKO-1299 x Cross-5	50.90	49.30	50.10	48.40	23.63 **	18.63 *	27.70 **
34	ASKO-1299 x GKD-45		48.40	49.65	45.50	21.17 **	21.01 *	20.05 *
35	ASKO-1299 x GKD-77		45.50	48.20	46.00	26.37 **	22.67 **	21.37 *
36	ASKO-1299 x ASKO-1222		46.00	48.45	47.90	15.56 *	5.51	26.39 **
37	ASKO-1299 x Arka Kalyan		47.90	49.40	45.20	6.60	-4.44	19.26 *
38	ASKO-1299 x Line-25		45.20	48.05	47.00	33.14 **	25.33 **	24.01 **
39	ASKO-1299 x N-53		48.00	49.45	48.00	34.83 **	28.00 **	26.65 **
40	ASKO-1299 x Line-13		39.60	45.25	39.60	-1.12	-7.04	4.49
	CC (Bhima Super)				38.35			
	S.Em. ±				2.11	2.6162	3.0209	3.0209
	C.D. at 5 %				5.98	5.2917	6.1104	6.1104
	C.D. at 1 %				7.96	7.0844	8.1804	8.1804

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

Table 5. Per se performance and magnitude of heterosis for number of leaves at 30 days after transplanting during kharif

Sl. No.	Entries	Number of leaves at 30 days after transplanting						
		Per se value				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	6.50	6.50	6.50	6.60	26.92 **	20.00 **	0.00
2	Kumata local x GKD-45		6.70	6.60	7.10	35.24 **	26.79 **	7.58 *
3	Kumata local x GKD-77		6.30	6.40	7.10	33.96 **	24.56 **	7.58 *
4	Kumata local x ASKO-1222		5.50	6.00	6.90	30.19 **	21.05 **	4.55
5	Kumata local x Arka Kalyan		5.50	6.00	6.90	25.45 **	13.11 **	4.55
6	Kumata local x Line-25		5.80	6.15	6.50	30.00 **	27.45 **	-1.52
7	Kumata local x N-53		5.70	6.10	6.70	34.00 **	31.37 **	1.52
8	Kumata local x Line-13		6.70	6.60	6.30	20.00 **	12.50 **	-4.55
9	Bhima Shakti x Cross 5	6.30	6.50	6.40	6.70	21.82 **	21.82 **	1.52
10	Bhima Shakti x GKD-45		6.70	6.50	6.70	20.72 **	19.64 **	1.52
11	Bhima Shakti x GKD-77		6.30	6.30	6.20	10.71 **	8.77 *	-6.06
12	Bhima Shakti x ASKO-1222		5.50	5.90	6.70	19.64 **	17.54 **	1.52
13	Bhima Shakti x Arka Kalyan		5.50	5.90	6.90	18.97 **	13.11 **	4.55
14	Bhima Shakti x Line-25		5.80	6.05	6.30	18.87 **	14.55 **	-4.55
15	Bhima Shakti x N-53		5.70	6.00	6.30	18.87 **	14.55 **	-4.55
16	Bhima Shakti x Line-13		6.70	6.50	6.60	18.92 **	17.86 **	0.00
17	GKD-75 x Cross-5	6.90	6.50	6.70	6.40	17.43 **	16.36 **	-3.03
18	GKD-75 x GKD-45		6.70	6.80	6.90	25.45 **	23.21 **	4.55
19	GKD-75 x GKD-77		6.30	6.60	6.70	20.72 **	17.54 **	1.52
20	GKD-75 x ASKO-1222		5.50	6.20	6.50	17.12 **	14.04 **	-1.52
21	GKD-75 x Arka Kalyan		5.50	6.20	6.50	13.04 **	6.56	-1.52
22	GKD-75 x Line-25		5.80	6.35	6.30	20.00 **	16.67 **	-4.55
23	GKD-75 x N-53		5.70	6.30	6.30	20.00 **	16.67 **	-4.55
24	GKD-75 x Line-13		6.70	6.80	6.30	14.55 **	12.50 **	-4.55
25	ASKO-1201 x Cross-5	6.30	6.50	6.40	6.60	20.00 **	20.00 **	0.00
26	ASKO-1201 x GKD-45		6.70	6.50	6.50	17.12 **	16.07 **	-1.52
27	ASKO-1201 x GKD-77		6.30	6.30	6.30	12.50 **	10.53 **	-4.55
28	ASKO-1201 x ASKO-1222		5.50	5.90	6.90	23.21 **	21.05 **	4.55
29	ASKO-1201 x Arka Kalyan		5.50	5.90	6.30	8.62 **	3.28	-4.55
30	ASKO-1201 x Line-25		5.80	6.05	6.30	18.87 **	14.55 **	-4.55
31	ASKO-1201 x N-53		5.70	6.00	6.50	22.64 **	18.18 **	-1.52
32	ASKO-1201 x Line-13		6.70	6.50	6.50	17.12 **	16.07 **	-1.52
33	ASKO-1299 x Cross-5	6.30	6.50	6.40	6.70	24.07 **	21.82 **	1.52
34	ASKO-1299 x GKD-45		6.70	6.50	6.30	15.60 **	12.50 **	-4.55
35	ASKO-1299 x GKD-77		6.30	6.30	5.50	0.00	-3.51	-16.67 **
36	ASKO-1299 x ASKO-1222		5.50	5.90	5.50	0.00	-3.51	-16.67 **
37	ASKO-1299 x Arka Kalyan		5.50	5.90	5.80	1.75	-4.92	-12.12 **
38	ASKO-1299 x Line-25		5.80	6.05	5.90	13.46 **	11.32 **	-10.61 **
39	ASKO-1299 x N-53		5.70	6.00	5.70	9.62 **	7.55	-13.64 **
40	ASKO-1299 x Line-13		6.70	6.50	6.70	22.94 **	19.64 **	1.52
	CC (Bhima Super)				6.75			
	S.Em. ±				0.26	0.1813	0.2093	0.2093
	C.D. at 5 %				0.74	0.3666	0.4233	0.4233
	C.D. at 1 %				0.99	0.4908	0.5667	0.5667

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

Magnitude of heterosis over mid parent range from -13.56 per cent (Bhima Shakti x N-53) to 24.94 per cent (ASKO-1201 x Line-25); over better parent from -18.17 per cent (Bhima Shakti x N-53) to 20.92 per cent (ASKO-1201 x Line-25) and; over commercial check (Bhima Super) from -14.85 per cent (Bhima Shakti x N-53) to 10.58 per cent (Kumata local x N-53).

Pertaining to manifestation of heterosis, ASKO-1201 x Line-25, Kumata local x N-53, GKD-75 x Line-25, exhibited 24.94 per cent, 20.14 per cent, 19.78 per cent significant positive heterosis over mid parent respectively. Out of 40 hybrids 11 hybrids recorded significant positive heterosis over commercial check (Bhima Super).

4.2.6 Number of leaves at 60 days after transplanting (Table 8)

The *per se* performance data on number of leaves revealed that the maximum number of leaves was 7.25 (parents N-53 and ASKO-1299), minimum was 3.30 (parent GKD-77). Of the 40 hybrids, the cross Bhima Shakti x N-53 (7.25) had maximum number of leaves while minimum was recorded in cross ASKO-1299 x GKD-45 (3.30). Out of 13 parents, seven parents (Cross-5, GKD-45, ASKO-1222, Line-25, ASKO-1201, Bhima Shakti and N-53) were at par with ASKO-1299 (7.25).

The data on per cent heterosis revealed that, none of the hybrids showed positive significant heterosis over the mid parent, better parent and commercial check. ASKO-1299 x GKD-45 hybrid recorded significant negative heterosis over mid parent (-49.03 %), better parent (-50.38 %), and commercial check (-54.79 %).

4.2.7 Polar Diameter (Table 9)

Parents exhibited as low as 4.30 cm (Kumata local) to as high as 5.23 cm (ASKO-1201). Among 13 parents, five (GKD-75, ASKO-1299, GKD-45, GKD-77, Line-13) were at par with ASKO-1201 (5.23 cm). In the F₁s the polar diameter varied from 3.97 cm (GKD-75 x Line-25) to 5.3 cm (GKD-75 x Line-13).

Out of 40 hybrids, 11 hybrids expressed significant positive heterosis over mid parent and seven hybrids over better parent and three hybrids over commercial check. Kumata local x Line-13 showed highest significant positive heterosis over mid parent (14.30 %) and Kumata local x N-53 over better parent (11.56 %). GKD-75 x Line-13 recorded highest significant positive heterosis (6 %) over commercial check.

4.2.8 Equatorial diameter (Table 10)

The *per se* performance of parents and hybrids is presented in table 10. Among the parents, maximum equatorial diameter was noticed in Bhima Shakti (5.29 cm) while minimum was in Cross-5 (4.52 cm). Of the 13 parents, two (Line-13, GKD-75) were at par with Bhima Shakti (5.29 cm). The hybrid ASKO-1299 x GKD-77 exhibited maximum equatorial diameter of 5.3 cm and minimum was observed in Kumata local x GKD-45 (4.08 cm).

The magnitude of heterosis over mid parent, better parent and commercial check was found significant in both the directions. Maximum positive heterosis over mid parent and better parent was observed in ASKO-1299 x GKD-77 (6.85 and 6.05 per cent, respectively). None of the hybrids recorded significant positive heterosis over commercial check.

Table 6. Per se performance and magnitude of heterosis for plant height at 60 days after transplanting during kharif

Sl. No.	Entries	Plant height at 60 days after transplanting						
		Per se value (cm)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	50.00	49.75	49.88	51.65	-8.26 **	-11.63 **	-6.94 **
2	Kumata local x GKD-45		51.65	50.83	51.85	-2.08 *	-11.29 **	-6.58 **
3	Kumata local x GKD-77		50.10	50.05	50.65	-11.53 **	-13.34 **	-8.74 **
4	Kumata local x ASKO-1222		47.00	48.50	53.10	-4.58 **	-9.15 **	-4.32 **
5	Kumata local x Arka Kalyan		52.50	51.25	55.20	11.57 **	-5.56 **	-0.54
6	Kumata local x Line-25		51.30	50.65	52.70	-0.80	-9.84 **	-5.05 **
7	Kumata local x N-53		58.65	54.33	51.75	0.15	-11.46 **	-6.76 **
8	Kumata local x Line-13		43.35	49.58	50.65	-3.71 **	-13.34 **	-8.74 **
9	Bhima Shakti x Cross 5	55.80	49.75	52.78	48.85	-12.02 **	-14.15 **	-11.98 **
10	Bhima Shakti x GKD-45		51.65	53.73	49.90	-4.36 **	-12.30 **	-10.09 **
11	Bhima Shakti x GKD-77		50.10	52.95	48.70	-13.77 **	-14.41 **	-12.25 **
12	Bhima Shakti x ASKO-1222		47.00	51.40	48.40	-11.80 **	-14.94 **	-12.79 **
13	Bhima Shakti x Arka Kalyan		52.50	54.15	44.50	-8.62 **	-21.79 **	-19.82 **
14	Bhima Shakti x Line-25		51.30	53.55	54.15	3.44 **	-4.83 **	-2.43 *
15	Bhima Shakti x N-53		58.65	57.23	50.65	-0.49	-10.98 **	-8.74 **
16	Bhima Shakti x Line-13		43.35	49.58	55.25	6.61 **	-2.90 **	-0.45
17	GKD-75 x Cross-5	54.90	49.75	52.33	49.25	-5.52 **	-9.05 **	-11.26 **
18	GKD-75 x GKD-45		51.65	53.28	50.70	3.95 **	1.20	-8.65 **
19	GKD-75 x GKD-77		50.10	52.50	52.20	-1.65	-6.87 **	-5.95 **
20	GKD-75 x ASKO-1222		47.00	50.95	55.10	7.04 **	4.26 **	-0.72
21	GKD-75 x Arka Kalyan		52.50	53.70	53.25	17.55 **	6.29 **	-4.05 **
22	GKD-75 x Line-25		51.30	53.10	47.45	-3.06 **	-5.29 **	-14.50 **
23	GKD-75 x N-53		58.65	56.78	47.80	0.63	-4.59 **	-13.87 **
24	GKD-75 x Line-13		43.35	49.13	51.65	6.66 **	3.09 *	-6.94 **
25	ASKO-1201 x Cross-5	52.25	49.75	51.00	50.45	0.75	-6.83 **	-9.10 **
26	ASKO-1201 x GKD-45		51.65	51.95	50.00	7.01 **	5.37 **	-9.91 **
27	ASKO-1201 x GKD-77		50.10	51.18	55.80	9.36 **	-0.45	0.54
28	ASKO-1201 x ASKO-1222		47.00	49.63	54.90	11.08 **	3.88 **	-1.08
29	ASKO-1201 x Arka Kalyan		52.50	52.38	52.25	20.81 **	13.59 **	-5.86 **
30	ASKO-1201 x Line-25		51.30	51.78	53.05	13.11 **	10.98 **	-4.41 **
31	ASKO-1201 x N-53		58.65	55.45	51.15	12.54 **	11.20 **	-7.84 **
32	ASKO-1201 x Line-13		43.35	47.80	49.75	7.28 **	6.42 **	-10.36 **
33	ASKO-1299 x Cross-5	53.05	49.75	51.40	51.65	-3.32 **	-4.62 **	-6.94 **
34	ASKO-1299 x GKD-45		51.65	52.35	50.10	0.05	-4.93 **	-9.73 **
35	ASKO-1299 x GKD-77		50.10	51.58	47.00	-13.56 **	-16.15 **	-15.32 **
36	ASKO-1299 x ASKO-1222		47.00	50.03	52.50	-0.52	-0.66	-5.41 **
37	ASKO-1299 x Arka Kalyan		52.50	52.78	51.30	10.09 **	-2.66 *	-7.57 **
38	ASKO-1299 x Line-25		51.30	52.18	50.80	1.09	-3.61 **	-8.47 **
39	ASKO-1299 x N-53		58.65	55.85	58.65	20.18 **	11.29 **	5.68 **
40	ASKO-1299 x Line-13		43.35	48.20	43.35	-12.82 **	-17.74 **	-21.89 **
	CC (Bhima Super)				56.75			
	S.Em. +				1.97	0.5247	0.6059	0.6059
	C.D. at 5 %				5.59	1.0613	1.2255	1.2255
	C.D. at 1 %				7.44	1.4209	1.6407	1.6407

* and ** indicates significant at 5 and 1 % respectively
MP-Mid parent, BP-Better parent, CC-Commercial check

Table 7. Per se performance and magnitude of heterosis for leaf length at 60 days after transplanting during kharif

Sl. No	Entries	Leaf length at 60 days transplanting						
		Per se value (cm)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	46.10	45.85	45.98	46.05	2.79 *	-1.92	-1.6
2	Kumata local x GKD-45		43.65	44.88	46.45	12.61 **	8.91 **	-0.75
3	Kumata local x GKD-77		40.90	43.50	44.65	8.24 **	4.69 **	-4.59 **
4	Kumata local x ASKO-1222		45.00	45.55	45.50	-0.11	-6.09 **	-2.78 *
5	Kumata local x Arka Kalyan		46.30	46.20	46.60	3.84 **	-1.06	-0.43
6	Kumata local x Line-25		47.90	47.00	43.70	8.64 **	2.46	-6.62 **
7	Kumata local x N-53		44.85	45.48	51.75	20.14 **	18.97 **	10.58 **
8	Kumata local x Line-13		41.35	43.73	48.65	19.53 **	14.07 **	3.95 **
9	Bhima Shakti x Cross 5	44.20	45.85	45.03	46.45	-2.88 **	-4.62 **	-0.75
10	Bhima Shakti x GKD-45		43.65	43.93	45.50	2.77 *	-6.57 **	-2.78 *
11	Bhima Shakti x GKD-77		40.90	42.55	46.70	5.48 **	-4.11 **	-0.21
12	Bhima Shakti x ASKO-1222		45.00	44.60	46.40	-4.48 **	-4.72 **	-0.85
13	Bhima Shakti x Arka Kalyan		46.30	45.25	43.30	-9.60 **	-11.09 **	-7.48 **
14	Bhima Shakti x Line-25		47.90	46.05	43.75	1.16	-10.16 **	-6.52 **
15	Bhima Shakti x N-53		44.85	44.53	39.85	-13.56 **	-18.17 **	-14.85 **
16	Bhima Shakti x Line-13		41.35	42.78	48.45	10.81 **	-0.51	3.53 **
17	GKD-75 x Cross-5	42.90	45.85	44.38	43.65	-4.12 **	-7.03 **	-6.73 **
18	GKD-75 x GKD-45		43.65	43.28	49.30	17.45 **	11.79 **	5.34 **
19	GKD-75 x GKD-77		40.90	41.90	44.60	6.25 **	1.13	-4.70 **
20	GKD-75 x ASKO-1222		45.00	43.95	45.50	-1.67	-6.09 **	-2.78 *
21	GKD-75 x Arka Kalyan		46.30	44.60	46.25	1.43	-1.80	-1.18
22	GKD-75 x Line-25		47.90	45.40	49.05	19.78 **	11.22 **	4.81 **
23	GKD-75 x N-53		44.85	43.88	48.10	9.82 **	9.07 **	2.78 *
24	GKD-75 x Line-13		41.35	42.13	47.25	14.06 **	7.14 **	0.96
25	ASKO-1201 x Cross-5	48.05	45.85	46.95	40.35	-7.61 **	-14.06 **	-13.78 **
26	ASKO-1201 x GKD-45		43.65	45.85	46.10	14.89 **	14.11 **	-1.5
27	ASKO-1201 x GKD-77		40.90	44.48	44.20	10.16 **	9.41 **	-5.56 **
28	ASKO-1201 x ASKO-1222		45.00	46.53	42.90	-3.43 **	-11.46 **	-8.33 **
29	ASKO-1201 x Arka Kalyan		46.30	47.18	48.05	9.83 **	2.02	2.67 *
30	ASKO-1201 x Line-25		47.90	47.98	48.85	24.94 **	20.92 **	4.38 **
31	ASKO-1201 x N-53		44.85	46.45	47.90	14.18 **	10.11 **	2.35
32	ASKO-1201 x Line-13		41.35	44.70	45.85	15.86 **	13.49 **	-2.03
33	ASKO-1299 x Cross-5	48.85	45.85	47.35	43.65	-7.37 **	-7.72 **	-6.73 **
34	ASKO-1299 x GKD-45		43.65	46.25	40.90	-6.14 **	-13.53 **	-12.61 **
35	ASKO-1299 x GKD-77		40.90	44.88	45.00	3.27 **	-4.86 **	-3.85 **
36	ASKO-1299 x ASKO-1222		45.00	46.93	46.30	-3.29 **	-4.44 **	-1.07
37	ASKO-1299 x Arka Kalyan		46.30	47.58	47.90	1.48	1.27	2.35
38	ASKO-1299 x Line-25		47.90	48.38	46.60	9.52 **	-1.48	-0.43
39	ASKO-1299 x N-53		44.85	46.85	44.85	-1.21	-5.18 **	-4.17 **
40	ASKO-1299 x Line-13		41.35	45.10	41.35	-3.89 **	-12.58 **	-11.65 **
	CC (Bhima Super)				49.55			
	S.Em. ±				2.02	0.4949	0.5715	0.5715
	C.D. at 5 %				5.72	1.0010	1.1559	1.1559
	C.D. at 1 %				7.63	1.3401	1.5474	1.5474

* and ** indicates significant at 5 and 1 % respectively

MP-Mid parent, BP-Better parent, CC-Commercial check

Table 8. Per se performance and magnitude of heterosis for number of leaves at 60 days after transplanting during kharif

Sl. No.	Entries	Number of leaves at 60 days after transplanting						
		Per se value				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	6.30	7.05	6.68	6.05	-13.57	-18.79	-17.12 *
2	Kumata local x GKD-45		6.65	6.48	5.85	-17.02 *	-21.48	-19.86 *
3	Kumata local x GKD-77		3.30	4.80	5.25	-25.53 **	-29.53	-28.08 **
4	Kumata local x ASKO-1222		7.20	6.75	6.10	-10.95	-18.12	-16.44 *
5	Kumata local x Arka Kalyan		5.50	5.90	5.60	-17.34 *	-24.83	-23.29 **
6	Kumata local x Line-25		6.90	6.60	6.50	-10.03	-12.75	-10.96
7	Kumata local x N-53		7.25	6.78	6.35	-8.96	-14.77	-13.01
8	Kumata local x Line-13		6.75	6.53	6.85	2.24	-8.05	-6.16
9	Bhima Shakti x Cross 5	6.60	7.05	6.83	6.45	-9.47	-16.23	-11.64
10	Bhima Shakti x GKD-45		6.65	6.63	5.90	-17.77 *	-23.38	-19.18 *
11	Bhima Shakti x GKD-77		3.30	4.95	5.50	-23.34 **	-28.57	-24.66 **
12	Bhima Shakti x ASKO-1222		7.20	6.90	5.80	-16.85 *	-24.68	-20.55 *
13	Bhima Shakti x Arka Kalyan		5.50	6.05	5.90	-14.49 *	-23.38	-19.18 *
14	Bhima Shakti x Line-25		6.90	6.75	6.95	-5.44	-9.74	-4.79
15	Bhima Shakti x N-53		7.25	6.93	7.45	4.93	-3.25	2.05
16	Bhima Shakti x Line-13		6.75	6.68	5.45	-20.15 **	-29.22	-25.34 **
17	GKD-75 x Cross-5	5.90	7.05	6.48	5.85	-10.34	-10.69	-19.86 *
18	GKD-75 x GKD-45		6.65	6.28	6.70	1.90	0.75	-8.22
19	GKD-75 x GKD-77		3.30	4.60	6.60	0.38	-0.75	-9.59
20	GKD-75 x ASKO-1222		7.20	6.55	5.50	-13.73	-15.38	-24.66 **
21	GKD-75 x Arka Kalyan		5.50	5.70	6.05	-3.97	-6.92	-17.12 *
22	GKD-75 x Line-25		6.90	6.40	6.45	-4.44	-7.86	-11.64
23	GKD-75 x N-53		7.25	6.58	6.60	1.54	1.54	-9.59
24	GKD-75 x Line-13		6.75	6.33	7.05	13.25	8.46	-3.42
25	ASKO-1201 x Cross-5	6.65	7.05	6.85	5.75	-11.20	-12.21	-21.23 **
26	ASKO-1201 x GKD-45		6.65	6.65	6.30	-3.45	-5.26	-13.70
27	ASKO-1201 x GKD-77		3.30	4.98	6.60	1.15	-0.75	-9.59
28	ASKO-1201 x ASKO-1222		7.20	6.93	5.90	-6.72	-7.81	-19.18 *
29	ASKO-1201 x Arka Kalyan		5.50	6.08	6.65	6.40	3.91	-8.90
30	ASKO-1201 x Line-25		6.90	6.78	7.25	8.21	3.57	-0.68
31	ASKO-1201 x N-53		7.25	6.95	7.00	8.53	7.69	-4.11
32	ASKO-1201 x Line-13		6.75	6.70	7.05	14.17	10.16	-3.42
33	ASKO-1299 x Cross-5	7.25	7.05	7.15	6.65	3.50	1.53	-8.90
34	ASKO-1299 x GKD-45		6.65	6.95	3.30	-49.03 **	-50.38	-54.79 **
35	ASKO-1299 x GKD-77		3.30	5.28	7.20	11.20	8.27	-1.37
36	ASKO-1299 x ASKO-1222		7.20	7.23	5.50	-12.35	-12.70	-24.66 **
37	ASKO-1299 x Arka Kalyan		5.50	6.38	6.90	11.29	9.52	-5.48
38	ASKO-1299 x Line-25		6.90	7.08	6.70	0.75	-4.29	-8.22
39	ASKO-1299 x N-53		7.25	7.25	7.25	13.28	11.54	-0.68
40	ASKO-1299 x Line-13		6.75	7.00	6.75	10.20	7.14	-7.53
	CC (Bhima Super)				7.5			
	S.Em. ±				0.41	0.4901	0.5660	0.5660
	C.D. at 5 %				1.15	0.9914	1.1447	1.1447
	C.D. at 1 %				1.54	1.3272	1.5325	1.5325

* and ** indicates significant at 5 and 1 % respectively
MP-Mid parent, BP-Better parent, CC-Commercial check

Table 9. Per se performance and magnitude of heterosis for polar diameter during kharif

Sl. No.	Entries	Polar diameter						
		Per se value (cm)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	4.30	4.72	4.51	4.99	5.79 **	7.99 **	-2.4
2	Kumata local x GKD-45		5.11	4.70	4.89	1.98	-7.21 **	-1.91
3	Kumata local x GKD-77		5.14	4.72	4.75	-10.78 **	-3.63**	-3.11**
4	Kumata local x ASKO-1222		4.95	4.63	4.51	-5.10 *	-13.09 **	-9.43 **
5	Kumata local x Arka Kalyan		4.97	4.63	4.81	6.06 **	1.26	-3.51
6	Kumata local x Line-25		4.91	4.60	5.01	5.80 **	11.87	0.40
7	Kumata local x N-53		4.62	4.46	5.00	10.19 **	11.56**	0.30
8	Kumata local x Line-13		5.02	4.66	5.21	14.30 **	8.53 **	4.61 *
9	Bhima Shakti x Cross 5	4.87	4.72	4.79	5	1.21	0.30	0.30
10	Bhima Shakti x GKD-45		5.11	4.99	4.38	-4.39 **	-3.51**	-11.43 **
11	Bhima Shakti x GKD-77		5.14	5.00	4.83	-2.87	-3.11	-3.11
12	Bhima Shakti x ASKO-1222		4.95	4.91	4.7	-7.66 **	-9.53 **	-5.72 *
13	Bhima Shakti x Arka Kalyan		4.97	4.92	4.38	-9.54 **	-10.84 **	-11.84 **
14	Bhima Shakti x Line-25		4.91	4.89	4.37	-9.15 **	-12.34 **	-12.34 **
15	Bhima Shakti x N-53		4.62	4.74	5.09	10.34**	8.16**	2.21
16	Bhima Shakti x Line-13		5.02	4.94	5.06	7.10 **	5.17 *	1.98
17	GKD-75 x Cross-5	5.17	4.72	4.94	5.03	-1.64	-5.76 **	1.68
18	GKD-75 x GKD-45		5.11	5.14	4.3	-18.96	-19.51	-13.74 **
19	GKD-75 x GKD-77		5.14	5.15	4.61	-10.41 **	-13.62 **	-7.42 **
20	GKD-75 x ASKO-1222		4.95	5.06	4.91	-6.81 **	-8.10 **	-1.50
21	GKD-75 x Arka Kalyan		4.97	5.07	5	-0.92	-6.41 **	0.30
22	GKD-75 x Line-25		4.91	5.04	3.97	-20.32 **	-25.60 **	-20.26 **
23	GKD-75 x N-53		4.62	4.89	4.97	-5.02 **	-6.97 **	-0.30
24	GKD-75 x Line-13		5.02	5.09	5.3	2.87 **	1.56 **	6.00 *
25	ASKO-1201 x Cross-5	5.23	4.72	4.97	5.28	4.92 *	2.08**	5.97 **
26	ASKO-1201 x GKD-45		5.11	5.17	4.81	-7.80 **	-8.63 **	-3.41
27	ASKO-1201 x GKD-77		5.14	5.18	4.62	-8.83 **	-10.72 **	-7.32 **
28	ASKO-1201 x ASKO-1222		4.95	5.09	4.83	-3.68 *	-4.47 **	-8.04 **
29	ASKO-1201 x Arka Kalyan		4.97	5.12	4.62	-4.42 **	-4.93 *	-6.93 **
30	ASKO-1201 x Line-25		4.91	5.07	4.6	-7.09 **	-8.35 *	-8.32 **
31	ASKO-1201 x N-53		4.62	4.92	4.71	-8.42 **	-8.89 **	-5.42 *
32	ASKO-1201 x Line-13		5.02	5.12	4.03	-19.24 **	-22.13 **	-19.16 **
33	ASKO-1299 x Cross-5	5.18	4.72	4.95	4.92	2.66	0.61	-1.20
34	ASKO-1299 x GKD-45		5.11	5.14	4.74	-4.86 *	-10.01 **	-4.86 *
35	ASKO-1299 x GKD-77		5.14	5.16	4.89	1.35	-1.31	-1.81
36	ASKO-1299 x ASKO-1222		4.95	5.06	5	1.06	-3.75	0.30
37	ASKO-1299 x Arka Kalyan		4.97	5.07	4.59	-2.75	-3.26	-7.82 **
38	ASKO-1299 x Line-25		4.91	5.04	4.87	4.34 *	3.62	-2.31
39	ASKO-1299 x N-53		4.62	4.90	4.35	-11.43 **	-15.08 **	-12.74 **
40	ASKO-1299 x Line-13		5.02	5.10	5.09	7.21 **	6.04 **	2.21
	CC (Bhima Super)				5.00			
	S.Em. \pm				0.08	0.0927	0.1071	0.1071
	C.D. at 5 %				0.22	0.1876	0.2166	0.2166
	C.D. at 1 %				0.29	0.2511	0.2900	0.2900

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

Table 10. Per se performance and magnitude of heterosis for equatorial diameter during kharif

Sl. No.	Entries	Equatorial diameter						
		Per se value (cm)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	4.68	4.52	4.60	4.4	-4.27 *	-5.88 **	-14.34 **
2	Kumata local x GKD-45		5.07	4.87	4.08	-16.26 **	-19.48 **	-20.61 **
3	Kumata local x GKD-77		5	4.84	4.71	-2.69	-5.80 **	-8.41 **
4	Kumata local x ASKO-1222		5.00	4.84	4.68	-3.38 *	-6.54 **	-8.99 **
5	Kumata local x Arka Kalyan		4.58	4.63	4.46	-3.51 *	-4.54 *	-13.13 **
6	Kumata local x Line-25		5.09	4.88	4.2	-14.02 **	-17.49 **	-18.33 **
7	Kumata local x N-53		4.84	4.76	4.67	-1.89	-3.51	-9.19 **
8	Kumata local x Line-13		5.14	4.91	4.3	-13.87 *	-10.78 **	-15.83 **
9	Bhima Shakti x Cross 5	5.29	4.52	4.90	5.02	2.32	-5.10 **	-2.38
10	Bhima Shakti x GKD-45		5.07	5.18	4.47	-13.56 **	-15.36 **	-12.93 **
11	Bhima Shakti x GKD-77		5	5.14	4.94	-3.94 *	-6.57 **	-3.89 *
12	Bhima Shakti x ASKO-1222		5.00	5.14	4.52	-12.11 **	-14.46 **	-12.01 **
13	Bhima Shakti x Arka Kalyan		4.58	4.93	5.06	2.58	-4.30 *	-1.56
14	Bhima Shakti x Line-25		5.09	5.19	4.75	-8.48 **	-10.21 **	-7.63 **
15	Bhima Shakti x N-53		4.84	5.06	4.48	-11.55 **	-15.31 **	-12.88 **
16	Bhima Shakti x Line-13		5.14	5.21	5.14	-1.29	-2.69	0.10
17	GKD-75 x Cross-5	5.11	4.52	4.82	4.7	-2.49	-8.16 **	-8.60 **
18	GKD-75 x GKD-45		5.07	5.09	4.69	-7.93 **	-8.35 **	-8.80 **
19	GKD-75 x GKD-77		5	5.05	4.4	-13.02 **	-14.02 **	-14.44 **
20	GKD-75 x ASKO-1222		5.00	5.06	4.26	-15.85 **	-16.76 **	-17.16 **
21	GKD-75 x Arka Kalyan		4.58	4.84	4.43	-8.48 **	-13.29 **	-13.71 **
22	GKD-75 x Line-25		5.09	5.10	4.8	-5.90 **	-6.16 **	-6.61 **
23	GKD-75 x N-53		4.84	4.97	5.14	3.34 *	0.54	0.05
24	GKD-75 x Line-13		5.14	5.12	4.3	-15.73 **	-15.50 **	-15.44 **
25	ASKO-1201 x Cross-5	5.02	4.52	4.77	4.4	-8.85 **	-13.39 **	-15.41 **
26	ASKO-1201 x GKD-45		5.07	5.04	4.82	-4.48 **	-4.93 **	-6.27 **
27	ASKO-1201 x GKD-77		5	5.01	4.66	-6.86 **	-7.07 **	-9.24 **
28	ASKO-1201 x ASKO-1222		5.00	5.01	4.36	-13.06 **	-13.19 **	-15.22 **
29	ASKO-1201 x Arka Kalyan		4.58	4.80	4.61	-3.98 *	-8.21 **	-10.35 **
30	ASKO-1201 x Line-25		5.09	5.05	4.74	-6.25 **	-6.88 **	-7.83 **
31	ASKO-1201 x N-53		4.84	4.93	4.7	-4.69 **	-6.42 **	-8.60 **
32	ASKO-1201 x Line-13		5.14	5.08	4.73	-6.77 **	-7.83 **	-7.88 **
33	ASKO-1299 x Cross-5	4.92	4.52	4.72	4.4	-6.80 **	-10.61 **	-14.39 **
34	ASKO-1299 x GKD-45		5.07	4.99	4.17	-16.46 **	-17.65 **	-18.81 **
35	ASKO-1299 x GKD-77		5	4.96	5.3	6.85 **	6.05 **	3.11
36	ASKO-1299 x ASKO-1222		5.00	4.96	5.05	1.69	0.85	-1.80
37	ASKO-1299 x Arka Kalyan		4.58	4.75	4.4	-7.42 **	-10.66 **	-14.44 **
38	ASKO-1299 x Line-25		5.09	5.00	4.76	-4.79 **	-6.34 **	-7.29 **
39	ASKO-1299 x N-53		4.84	4.88	4.51	-7.63 **	-8.43 **	-12.30 **
40	ASKO-1299 x Line-13		5.14	5.03	4.8	-1.74**	-0.39**	-0.44**
	CC (Bhima Super)				5.15			
	S.Em. ±				0.07	0.0749	0.0864	0.0864
	C.D. at 5 %				0.19	0.1514	0.1748	0.1748
	C.D. at 1 %				0.25	0.2027	0.2341	0.2341

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

4.2.9 P/E ratio (Table 11)

The *per se* performance of parents and hybrids for P/E ratio indicated that the minimum (0.82) was in parent Line-13 as against the maximum (1.31) in ASKO-1299. Out of 40 crosses, cross GKD-75 x Line-13 showed highest P/E ratio (1.23), while lowest was in GKD-75 x Line-25 (0.83).

The hybrid Kumata local x GKD-45 exhibited the higher significant positive heterosis over mid parent. Meanwhile, cross Kumata local x Cross-5 depicted higher significant positive heterosis over better parent. The positive heterosis over commercial check revealed that none of the hybrids expressed in positive direction. However, 10 crosses showed significant positive heterosis over mid parent, whereas seven hybrids showed significant positive heterosis over better parent.

4.2.10 Neck thickness (Table 12)

All the thirteen parents were at par with each other for neck thickness. The cross combination Bhima Shakti x Arka Kalyan recorded the highest neck thickness (1.37 cm), whereas, lowest neck thickness was observed in ASKO-1299 x ASKO-1222 (0.82 cm) which is desirable.

The maximum heterosis over mid parent and better parent was observed in the cross combination Bhima Shakti x Arka Kalyan (29.14 per cent and 28.69 percent respectively). None of the hybrids recorded significant positive heterosis over the commercial check (Bhima Super). Seventeen hybrids recorded the significant positive heterosis over mid parent and 12 over better parent.

4.2.11 Total soluble solids (Table 13)

The mean value of 13 parents for total soluble solids was dispersed between 9.10 °Brix (Cross-5) to 12.75 °Brix (GKD-45). Among the 40 hybrids, lower TSS was observed in Kumata local x N-53 (8.70 °Brix) and higher was recorded in ASKO-1299 x Cross 5 (12.75 °brix). None of the hybrids showed higher TSS than the commercial check {Bhima Super (13.0 °Brix)}.

The magnitude of heterosis for the trait under consideration range from -36.32 per cent (ASKO-1299 x GKD-45) to 14.73 per cent (ASKO-1299 x Cross-5) over mid parent. None of the hybrids showed significant positive heterosis over the better parent and over the commercial check.

4.2.12 Marketable yield (Table 14)

Per se performance for marketable yield in parents range from 3.75 t/ha (Kumata local) to 8.61 t/ha (ASKO-1299). In hybrid combination, GKD-75 x Line-13 recorded significantly higher marketable yield (11.83 t/ha), whereas Kumata local x Arka Kalyan possessed lowest (3.60 t/ha). Mean value of commercial check (Bhima Super) was 6.55 t/ha. Of all the entries tested, cross GKD-75 x Line-13 (11.83 t/ha) was significantly superior including the commercial check (Bhima Super). This was followed by Kumata local x Line-13 (10.57 t/ha), ASKO-1201 x Cross-5 (9.60 t/ha), Kumata local x Cross-5 (8.88 t/ha), ASKO-1201 x Line-25 (8.61 t/ha), GKD-75 x N-53 (7.90 t/ha), Kumata local x GKD-77 (7.40 t/ha) and ASKO-1201 x GKD-77 (7.10 t/ha). Majority of the hybrids showed significant positive heterosis over commercial check were having GKD-75, Kumata local, ASKO-1201 as their female parents.

Table 11. Per se performance and magnitude of heterosis for P/E ratio during kharif

Sl. No.	Entries	P/E ratio						
		Per se value				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	0.95	1.25	1.10	1.13	22.25 **	40.41 **	-15.81
2	Kumata local x GKD-45		0.92	0.94	1.20	40.32 **	35.23 **	1.28
3	Kumata local x GKD-77		1.04	1.00	1.01	22.35	13.47	-6.41
4	Kumata local x ASKO-1222		1.03	0.99	0.96	-11.44	-16.51	-22.22 *
5	Kumata local x Arka Kalyan		1.07	1.01		1.08	-15.94	-24.17 **
6	Kumata local x Line-25		0.93	0.94	1.19	18.56 **	20.48 *	8.12
7	Kumata local x N-53		0.88	0.92	1.07	12.90	8.81	-10.26
8	Kumata local x Line-13		0.82	0.89	1.21	15.58**	10.70**	2.82
9	Bhima Shakti x Cross 5	1.15	1.25	1.20	1.06	31.68 **	30.06 *	-9.40
10	Bhima Shakti x GKD-45		0.92	1.04	0.98	33.73 **	26.26 *	-3.42
11	Bhima Shakti x GKD-77		1.04	1.10	0.98	-30.74 **	-35.18 **	-2.56
12	Bhima Shakti x ASKO-1222		1.03	1.09	1.04	7.69	-6.88	-13.25
13	Bhima Shakti x Arka Kalyan		1.07	1.11		0.87	15.79	-3.75
14	Bhima Shakti x Line-25		0.93	1.04	0.92	-4.61	-16.19	-24.79 **
15	Bhima Shakti x N-53		0.88	1.02	1.14	-7.10	-12.29	-32.91 **
16	Bhima Shakti x Line-13		0.82	0.99	0.98	12.56	13.15	-3.42
17	GKD-75 x Cross-5	0.99	1.25	1.12	1.07	-9.32	-5.8	-1.71
18	GKD-75 x GKD-45		0.92	0.96	0.92	-4.66	-11.11	-21.37 *
19	GKD-75 x GKD-77		1.04	1.02	1.05	13.98	2.42	-9.40
20	GKD-75 x ASKO-1222		1.03	1.01	1.15	15.12 **	12.14	-7.26
21	GKD-75 x Arka Kalyan		1.07	1.03	1.13	12.75	5.00	-7.69
22	GKD-75 x Line-25		0.93	0.96	0.83	-2.16**	-1.43**	-8.97**
23	GKD-75 x N-53		0.88	0.94	0.97	-3.82	-11.68	-19.23 *
24	GKD-75 x Line-13		0.82	0.91	1.23	29.16 **	14.49**	3.85
25	ASKO-1201 x Cross-5	1.17	1.25	1.21	1.20	-5.91	17.39	1.28
26	ASKO-1201 x GKD-45		0.92	1.05	1.00	-3.82	-11.68	-19.23 *
27	ASKO-1201 x GKD-77		1.04	1.11	0.99	-12.37 *	-7.48**	-1.71
28	ASKO-1201 x ASKO-1222		1.03	1.10	1.11	7.87*	-8.72	-12.96
29	ASKO-1201 x Arka Kalyan		1.07	1.12	1.00	-3.52	-2.08	-0.43**
30	ASKO-1201 x Line-25		0.93	1.05		0.97	23.58	-22.43
31	ASKO-1201 x N-53		0.88	1.03	1.00	17.05	7.48	-10.71**
32	ASKO-1201 x Line-13		0.82	1.00	0.85	-3.16 **	-16.36**	-6.41 *
33	ASKO-1299 x Cross-5	1.31	1.25	1.28	0.92	10.18	7.60	-21.37 *
34	ASKO-1299 x GKD-45		0.92	1.12	1.04	18.86	16.20	-11.11
35	ASKO-1299 x GKD-77		1.04	1.18	1.02	22.02 *	19.88	-12.39
36	ASKO-1299 x ASKO-1222		1.03	1.17	1.07	10.03	-1.83	-8.55
37	ASKO-1299 x Arka Kalyan		1.07	1.19	0.93	-9.49	-22.50 *	-20.51 *
38	ASKO-1299 x Line-25		0.93	1.12		0.85	-10.76	-19.05
39	ASKO-1299 x N-53		0.88	1.10	0.88	0.00	-2.23	-25.21 **
40	ASKO-1299 x Line-13		0.82	1.07	0.82	-0.91	-4.09	-29.91 **
	CC (Bhima Super)				1.17			
	S.Em. ±				0.07	0.0905	0.1045	0.1045
	C.D. at 5 %				0.21	0.1830	0.2114	0.2114
	C.D. at 1 %				0.27	0.2451	0.2830	0.2830

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

Table 12. Per se performance and magnitude of heterosis for neck thickness during kharif

Sl. No.	Entries	Neck thickness						
		Per se value (cm)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	1.16	0.99	1.08	1.25	18.22 **	13.42 **	-4.62
2	Kumata local x GKD-45		1.13	1.15	1.09	3.30	-1.35	-17.05 **
3	Kumata local x GKD-77		1.05	1.10	1.20	10.55 **	8.56 **	-8.71 **
4	Kumata local x ASKO-1222		1.16	1.16	1.19	11.74 **	7.21 *	-9.85 **
5	Kumata local x Arka Kalyan		0.82	0.99	1.18	8.62 **	6.67 *	-10.30 **
6	Kumata local x Line-25		1.09	1.12	1.30	17.83 **	17.30 **	-1.36
7	Kumata local x N-53		1.32	1.24	1.25	3.98	-3.62	-5.08 *
8	Kumata local x Line-13		1.04	1.10	1.11	-6.24 *	-11.83 **	-15.83 **
9	Bhima Shakti x Cross 5	1.14	0.99	1.07	1.07	3.34	1.27	-18.48 **
10	Bhima Shakti x GKD-45		1.13	1.14	1.24	19.66 **	16.71 **	-6.06 *
11	Bhima Shakti x GKD-77		1.05	1.12	1.17	10.39 **	10.00 **	-10.83 **
12	Bhima Shakti x ASKO-1222		1.16	1.15	1.17	13.23 **	10.96 **	-10.68 **
13	Bhima Shakti x Arka Kalyan		0.82	0.98	1.37	29.14 **	28.69 **	4.32
14	Bhima Shakti x Line-25		1.09	1.12	1.24	14.68 **	12.73 **	-6.06 *
15	Bhima Shakti x N-53		1.32	1.23	0.99	-16.02 **	-23.69 **	-24.85 **
16	Bhima Shakti x Line-13		1.04	1.09	1.32	14.27 **	5.32 *	0.53
17	GKD-75 x Cross-5	1.15	0.99	1.07	1.17	1.74	-8.59 **	-11.36 **
18	GKD-75 x GKD-45		1.13	1.14	1.35	18.34 **	5.86 *	2.65
19	GKD-75 x GKD-77		1.05	1.10	1.27	8.60 **	-0.31	-3.33
20	GKD-75 x ASKO-1222		1.16	1.16	1.15	0.43	-9.77 **	-12.50 **
21	GKD-75 x Arka Kalyan		0.82	0.99	1.26	7.66 **	-1.17	-4.17
22	GKD-75 x Line-25		1.09	1.12	1.34	13.03 **	5.08	1.89
23	GKD-75 x N-53		1.32	1.24	1.25	-3.10	-3.85	-5.30 *
24	GKD-75 x Line-13		1.04	1.10	1.22	-3.31	-4.06	-6.97 **
25	ASKO-1201 x Cross-5	1.20	0.99	1.10	1.21	8.00 **	-1.22	-7.95 **
26	ASKO-1201 x GKD-45		1.13	1.17	1.16	4.02	-5.28	-11.74 **
27	ASKO-1201 x GKD-77		1.05	1.12	1.14	-0.09	-6.59 *	-12.95 **
28	ASKO-1201 x ASKO-1222		1.16	1.18	1.15	2.84	-5.93 *	-12.35 **
29	ASKO-1201 x Arka Kalyan		0.82	1.01	1.20	4.87	-1.95	-8.64 **
30	ASKO-1201 x Line-25		1.09	1.14	1.11	-4.46	-9.51 **	-15.68 **
31	ASKO-1201 x N-53		1.32	1.26	1.07	-15.42 **	-17.69 **	-18.94 **
32	ASKO-1201 x Line-13		1.04	1.12	0.99	-19.84 **	-20.79 **	-24.39 **
33	ASKO-1299 x Cross-5	1.11	0.99	1.05	1.13	2.81	-4.54	-13.94 **
34	ASKO-1299 x GKD-45		1.13	1.12	1.05	-4.55	-11.76 **	-20.45 **
35	ASKO-1299 x GKD-77		1.05	1.08	1.16	3.45	-1.76	-11.44 **
36	ASKO-1299 x ASKO-1222		1.16	1.14	0.82	-25.07 **	-30.42 **	-37.27 **
37	ASKO-1299 x Arka Kalyan		0.82	0.97	1.09	-3.54	-8.40 **	-17.42 **
38	ASKO-1299 x Line-25		1.09	1.10	1.27	10.92 **	6.72 *	-3.79
39	ASKO-1299 x N-53		1.32	1.21	1.32	6.18 **	1.69	0.15
40	ASKO-1299 x Line-13		1.04	1.08	1.04	-14.65 **	-17.02 **	-20.80 **
	CC (Bhima Super)				1.32			
	S.Em. ±				0.06	0.0279	0.0323	0.0323
	C.D. at 5 %				0.16	0.0565	0.0653	0.0653
	C.D. at 1 %				0.21	0.0757	0.0874	0.0874

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

Table 13. Per se performance and magnitude of heterosis for total soluble solids during kharif

Sl. No.	Entries	Total soluble solids						
		Per se value (°brix)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	10.65	9.10	9.88	10.35	-5.05	-15.85 **	-22.18 **
2	Kumata local x GKD-45		12.75	11.70	11.65	-9.51 *	-28.31 **	-12.41 **
3	Kumata local x GKD-77		9.25	9.95	11.00	7.06	-0.45	-17.29 **
4	Kumata local x ASKO-1222		10.35	10.50	11.55	5.62	-6.63	-13.16 **
5	Kumata local x Arka Kalyan		9.85	10.25	9.50	-17.03 **	-29.10 **	-28.57 **
6	Kumata local x Line-25		10.75	10.70	10.65	3.40	-4.05	-19.92 **
7	Kumata local x N-53		9.80	10.23	8.70	-11.22 *	-13.86 *	-34.59 **
8	Kumata local x Line-13		10.40	10.53	10.90	-2.02	-14.51 **	-18.05 **
9	Bhima Shakti x Cross 5	9.70	9.10	9.40	9.10	-25.56 **	-26.02 **	-31.58 **
10	Bhima Shakti x GKD-45		12.75	11.23	10.10	-28.87 **	-37.85 **	-24.06 **
11	Bhima Shakti x GKD-77		9.25	9.48	11.70	0.86	-3.70	-12.03 **
12	Bhima Shakti x ASKO-1222		10.35	10.03	10.40	-15.17 **	-15.93 **	-21.80 **
13	Bhima Shakti x Arka Kalyan		9.85	9.78	9.40	-26.42 **	-29.85 **	-29.32 **
14	Bhima Shakti x Line-25		10.75	10.23	9.29	-20.09 **	-23.54 **	-30.15 **
15	Bhima Shakti x N-53		9.80	9.75	11.35	2.02	-6.58	-14.66 **
16	Bhima Shakti x Line-13		10.40	10.05	11.05	-11.24 **	-13.33 **	-16.92 **
17	GKD-75 x Cross-5	12.60	9.10	10.85	12.00	11.37 *	-2.44	-9.77 *
18	GKD-75 x GKD-45		12.75	12.68	10.30	-19.22 **	-36.62 **	-22.56 **
19	GKD-75 x GKD-77		9.25	10.93	10.95	7.88	-0.90	-17.67 **
20	GKD-75 x ASKO-1222		10.35	11.48	9.85	-8.88	-20.37 **	-25.94 **
21	GKD-75 x Arka Kalyan		9.85	11.23	12.00	5.96	-10.45 *	-9.77 *
22	GKD-75 x Line-25		10.75	11.68	11.60	14.00 **	4.50	-12.78 **
23	GKD-75 x N-53		9.80	11.20	11.10	1.59	9.90	-16.54 **
24	GKD-75 x Line-13		10.40	11.50	11.35	3.18	-10.98 *	-14.66 **
25	ASKO-1201 x Cross-5	11.30	9.10	10.20	12.30	0.20	0.00	-7.52
26	ASKO-1201 x GKD-45		12.75	12.03	10.65	-25.26 **	-34.46 **	-19.92 **
27	ASKO-1201 x GKD-77		9.25	10.28	9.70	-16.74 **	-20.82 **	-27.07 **
28	ASKO-1201 x ASKO-1222		10.35	10.83	12.60	2.36	1.86	-5.26
29	ASKO-1201 x Arka Kalyan		9.85	10.58	11.30	-11.89 **	-15.67 **	-15.04 **
30	ASKO-1201 x Line-25		10.75	11.03	9.90	-15.20 **	-19.18 **	-25.56 **
31	ASKO-1201 x N-53		9.80	10.55	9.95	-10.96 *	-18.78 **	-25.19 **
32	ASKO-1201 x Line-13		10.40	10.85	9.10	-27.20 **	-28.63 **	-31.58 **
33	ASKO-1299 x Cross-5	9.90	9.10	9.50	12.75	14.73 **	14.00 **	-4.14
34	ASKO-1299 x GKD-45		12.75	11.33	9.25	-36.32 **	-43.08 **	-30.45 **
35	ASKO-1299 x GKD-77		9.25	9.58	10.35	-13.21 **	-19.14 **	-22.18 **
36	ASKO-1299 x ASKO-1222		10.35	10.13	9.85	-21.73 **	-23.05 **	-25.94 **
37	ASKO-1299 x Arka Kalyan		9.85	9.88	10.75	-17.94 **	-19.78 **	-19.17 **
38	ASKO-1299 x Line-25		10.75	10.33	10.80	-9.62 *	-15.63 **	-18.80 **
39	ASKO-1299 x N-53		9.80	9.85	9.80	-14.41 **	-23.44 **	-26.32 **
40	ASKO-1299 x Line-13		10.40	10.15	10.40	-18.59 **	-18.75 **	-21.80 **
	CC (Bhima Super)				13.0			
	S.Em. ±				0.41	0.5056	0.5838	0.5838
	C.D. at 5 %				1.17	1.0226	1.1809	1.1809
	C.D. at 1 %				1.56	1.3691	1.5809	1.5809

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

The heterosis over mid parent for marketable yield range from -49.30 per cent (ASKO-1201 x GKD-45) to 93.58 per cent (GKD-75 x Cross-5). Out of 40 hybrids studied, 18 hybrids recorded significant positive heterosis over mid parent, eight hybrids over commercial check. The range of heterosis over better parent was from -78.57 per cent (ASKO-1201 x GKD-45) to 98.48 per cent (GKD-75 x Line-13). The range of heterosis over commercial check (Bhima Super) was from -42.86 per cent (Kumata local x Arka Kalyan) to 87.78 per cent (GKD-75 x Line-13).

4.2.13 Non marketable yield (Table 15)

In case of parents, the minimum mean value was 0.65 t/ha (GKD-45) and the maximum was 2.36 t/ha (Bhima Shakti). Similarly of the 40 hybrids, lower non marketable yield was recorded in GKD-75 x GKD-77 (0.72 t/ha) and higher in ASKO-1299 x Line-13 (2.46 t/ha).

There was no significant positive heterosis observed over mid parent, better parent and commercial check by any of the 40 hybrids. Over mid parent and better parent higher significant negative value exhibited by crosses ASKO-1299 x Cross-5 (-69.81 %) and GKD-75 x GKD-77 (-73.76 %), respectively.

4.2.14 Average bulb weight (Table 16)

The maximum mean performance among the parents for average bulb weight was noticed in Kumata local (78.50 g) and minimum was in GKD-75 (43.00 g). Of the hybrids GKD-75 x Line-13 (80.00 g) exhibited maximum average bulb weight and minimum was in ASKO-1201 x ASKO-1222 (43.00 g). Among the 13 parents, five were at par with Kumata local (78.50 g). Of the 40 hybrids, 11 entries were at par with GKD-75 x Line-13 (80.00 g).

The higher heterosis over mid parent was recorded in GKD-75 x ASKO-1222 (37.82 per cent), over better parent in ASKO-1201 x GKD-45 (36.52 per cent) and over commercial check in GKD-75 x Line-13 (16.15 per cent). Out of 40 crosses, 17 recorded significant positive heterosis over mid parent. Nine of the hybrids expressed significant positive heterosis over commercial check (Bhima Super).

4.2.15 Total yield (Table 17)

The performance of parents range from 4.78 t/ha (Kumata local) to 10.51 t/ha (ASKO-1299) and in hybrids it was from 5.1 t/ha (ASKO-1201 x Line-13) to 13.00 t/ha (GKD-75 x Line-13). Out of 40 hybrids, 12 over mid parent, seven over better parent and five over commercial check recorded highly significant positive heterosis.

The variation noticed in magnitude of heterosis over mid parent was from -47.58 per cent (ASKO-1299 x Cross-5) to 92.20 per cent (Kumata local x Line-13); -39.51 per cent (Bhima Shakti x N-53) to 75.09 per cent (GKD-75 x Line-13) over better parent and; -48.40 per cent (ASKO-1201 x Line-13) to 65.44 per cent (GKD-75 x Line-13) over commercial check.

Table 14. Per se performance and magnitude of heterosis for marketable yield during *kharif*

Sl. No.	Entries	Marketable yield						
		Per se value (t/ha)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	3.75	4.01	3.88	8.88	63.27 **	39.22 **	40.87 **
2	Kumata local x GKD-45		4.40	4.08	6.13	50.21 **	23.92 **	-2.78
3	Kumata local x GKD-77		4.05	3.90	7.40	47.63 **	16.08 **	17.46 **
4	Kumata local x ASKO-1222		6.13	4.94	4.63	-17.96 **	-27.45 **	-26.59 **
5	Kumata local x Arka Kalyan		4.26	4.01	3.60	-36.00 **	-43.53 **	-42.86 **
6	Kumata local x Line-25		5.20	4.48	6.33	60.76 **	12.71 **	0.48
7	Kumata local x N-53		4.65	4.20	6.88	27.61 **	17.84 **	9.13
8	Kumata local x Line-13		4.55	4.15	10.57	80.60 **	65.88 **	67.86 **
9	Bhima Shakti x Cross 5	7.10	4.01	5.56	4.90	19.37 *	-14.56**	-22.22 **
10	Bhima Shakti x GKD-45		4.40	5.75	4.25	-27.25 **	-13.27**	-32.54 **
11	Bhima Shakti x GKD-77		4.05	5.58	5.39	-26.08	-10.00 **	-14.44 *
12	Bhima Shakti x ASKO-1222		6.13	6.62	4.10	-16.33 *	-16.33 *	-34.92 **
13	Bhima Shakti x Arka Kalyan		4.26	5.68	5.11	-4.45	-14.18**	-18.97 **
14	Bhima Shakti x Line-25		5.20	6.15	6.12	91.09	-4.80	-2.94
15	Bhima Shakti x N-53		4.65	5.88	4.25	-8.60**	-13.27	-32.54 **
16	Bhima Shakti x Line-13		4.55	5.83	5.90	13.90 **	-18.41 **	-6.35
17	GKD-75 x Cross-5	5.96	4.01	4.99	5.43	93.58 **	-64.05	-13.81 *
18	GKD-75 x GKD-45		4.40	5.18	4.45	-53.14 **	-93.48	-29.37 **
19	GKD-75 x GKD-77		4.05	5.01	5.55	86.55 **	-25.05 **	-11.90 *
20	GKD-75 x ASKO-1222		6.13	6.05	4.35	-20.83 **	-11.22**	-30.95 **
21	GKD-75 x Arka Kalyan		4.26	5.11	6.51	81.60 **	33.64 **	3.41
22	GKD-75 x Line-25		5.20	5.58	4.38	-60.53 **	-10.43 **	-30.48 **
23	GKD-75 x N-53		4.65	5.31	7.90	86.82 **	79.55 **	25.40 **
24	GKD-75 x Line-13		4.55	5.26	11.83	90.50 **	98.48 **	87.78 **
25	ASKO-1201 x Cross-5	6.71	4.01	5.36	9.60	84.90 **	58.03 **	52.38 **
26	ASKO-1201 x GKD-45		4.40	5.56	3.75	-49.30 **	-78.57 **	-40.48 **
27	ASKO-1201 x GKD-77		4.05	5.38	7.10	65.96 **	74.52 **	12.70 *
28	ASKO-1201 x ASKO-1222		6.13	6.42	5.95	-45.14 **	-21.53 **	-5.48
29	ASKO-1201 x Arka Kalyan		4.26	5.49	6.70	92.26 **	0.15	6.43
30	ASKO-1201 x Line-25		5.20	5.96	8.61	83.06 **	78.76 **	36.59 **
31	ASKO-1201 x N-53		4.65	5.68	5.35	-64.62	21.59 *	-15.08 *
32	ASKO-1201 x Line-13		4.55	5.63	4.00	-48.33 **	-21.36**	-36.43 **
33	ASKO-1299 x Cross-5	8.61	4.01	6.31	4.40	-25.98 **	-19.73 *	-30.16 **
34	ASKO-1299 x GKD-45		4.40	6.51	4.05	-48.49 **	-10.20**	-35.71 **
35	ASKO-1299 x GKD-77		4.05	6.33	6.13	-17.24 **	26.63**	-2.78
36	ASKO-1299 x ASKO-1222		6.13	7.37	4.25	-10.76 **	-33.16**	-32.46 **
37	ASKO-1299 x Arka Kalyan		4.26	6.44	5.20	-21.64 **	-46.67**	-17.46 **
38	ASKO-1299 x Line-25		5.20	6.91	5.10	-36.10 **	-38.78 **	-19.05 **
39	ASKO-1299 x N-53		4.65	6.63	4.65	-15.17 **	-65.68**	-26.19 **
40	ASKO-1299 x Line-13		4.55	6.58	4.55	-30.47 **	-23.81 **	-27.78 **
	CC (Bhima Super)				6.55			
	S.Em. ±				0.25	0.3055	0.3527	0.3527
	C.D. at 5 %				0.75	0.6179	0.7135	0.7135
	C.D. at 1 %				1	0.8272	0.9552	0.9552

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

Table 15. Per se performance and magnitude of heterosis for non marketable yield during kharif

Sl. No.	Entries	Non marketable yield						
		Per se value (t/ha)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	1.03	1.60	1.32	2.41	-4.17	-8.52	83.65
2	Kumata local x GKD-45		0.65	0.84	2.25	-10.71	-14.77	71.10
3	Kumata local x GKD-77		1.10	1.07	0.99	-63.09 **	-63.67 *	-24.71
4	Kumata local x ASKO-1222		1.63	1.33	0.93	-69.46 **	-73.04 **	-29.28
5	Kumata local x Arka Kalyan		1.38	1.21	1.62	-32.57	-38.64	23.19
6	Kumata local x Line-25		0.80	0.92	1.58	-35.38	-40.15	20.15
7	Kumata local x N-53		1.80	1.42	1.40	-49.50 *	-51.81 *	6.46
8	Kumata local x Line-13		1.25	1.14	1.20	-45.39	-54.55 *	-8.75
9	Bhima Shakti x Cross 5	2.36	1.60	1.98	1.10	-49.20	-53.96	-15.97
10	Bhima Shakti x GKD-45		0.65	1.51	1.35	-37.93	-43.75	2.66
11	Bhima Shakti x GKD-77		1.10	1.73	1.31	-43.74	-51.74	0.00
12	Bhima Shakti x ASKO-1222		1.63	2.00	1.07	-60.19 *	-68.84 **	-18.25
13	Bhima Shakti x Arka Kalyan		1.38	1.87	1.48	-28.31	-31.87	12.17
14	Bhima Shakti x Line-25		0.80	1.58	1.42	-32.62	-37.11	7.60
15	Bhima Shakti x N-53		1.80	2.08	0.96	-60.45 *	-66.95 **	-27.00
16	Bhima Shakti x Line-13		1.25	1.81	0.85	-54.12	-56.41	-35.36
17	GKD-75 x Cross-5	1.17	1.60	1.39	0.91	-57.44 *	-61.88 *	-30.42
18	GKD-75 x GKD-45		0.65	0.91	1.03	-52.09	-57.08	-21.67
19	GKD-75 x GKD-77		1.10	1.14	0.72	-69.08 *	-73.76 **	-45.63
20	GKD-75 x ASKO-1222		1.63	1.40	1.65	-38.32	-52.17 *	25.48
21	GKD-75 x Arka Kalyan		1.38	1.28	1.29	-36.29	-40.18	-1.52
22	GKD-75 x Line-25		0.80	0.99	1.20	-42.17	-46.67	-8.75
23	GKD-75 x N-53		1.80	1.49	0.95	-60.46 *	-67.30 **	-27.76
24	GKD-75 x Line-13		1.25	1.21	1.15	-37.07	-39.47	-12.55
25	ASKO-1201 x Cross-5	1.29	1.60	1.45	0.75	-69.73 **	-70.65 *	-42.97
26	ASKO-1201 x GKD-45		0.65	0.97	2.11	-15.04	-17.61	60.08
27	ASKO-1201 x GKD-77		1.10	1.20	1.32	-50.00 *	-51.56	0.38
28	ASKO-1201 x ASKO-1222		1.63	1.46	1.58	-47.21 *	-54.06 *	20.53
29	ASKO-1201 x Arka Kalyan		1.38	1.34	1.45	-38.56	-43.25	10.27
30	ASKO-1201 x Line-25		0.80	1.05	1.65	-31.32	-35.42	25.48
31	ASKO-1201 x N-53		1.80	1.55	1.13	-58.79 *	-61.27 *	-14.45
32	ASKO-1201 x Line-13		1.25	1.27	1.10	-48.96	-56.95 *	-16.35
33	ASKO-1299 x Cross-5	1.90	1.60	1.75	0.80	-69.81 **	-72.41 **	-39.16
34	ASKO-1299 x GKD-45		0.65	1.28	1.45	-45.28	-50.00 *	10.27
35	ASKO-1299 x GKD-77		1.10	1.50	1.50	-46.67 *	-48.28	14.07
36	ASKO-1299 x ASKO-1222		1.63	1.77	1.05	-66.93 **	-69.57 **	-20.15
37	ASKO-1299 x Arka Kalyan		1.38	1.64	1.30	-48.67 *	-55.17 *	-1.14
38	ASKO-1299 x Line-25		0.80	1.35	0.88	-66.02 **	-69.83 **	-33.46
39	ASKO-1299 x N-53		1.80	1.85	1.45	-50.04 *	-50.09 *	10.27
40	ASKO-1299 x Line-13		1.25	1.58	2.46	5.91	-15.00	87.45
	CC (Bhima Super)				1.84			
	S.Em. ±				0.18	0.6038	0.6973	0.6973
	C.D. at 5 %				0.52	1.2214	1.4103	1.4103
	C.D. at 1 %				0.69	1.6352	1.8881	1.8881

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

4.2.16 Rotten bulbs (Table 18)

The mean performance of parents for rotten bulbs range from 1.10 t/ha (Bhima Shakti) to 2.30 t/ha (GKD-45) and in hybrids from 0.75 t/ha (Kumata local x GKD-45) to 2.75 t/ha (ASKO-1201 x Arka Kalyan). Among 40 hybrids, none of the hybrids showed negative significant heterosis over mid parent, better parent and commercial check.

4.2.17 Days to maturity (Table 19)

Per se performance in parents indicated 106.75 days (Line-13) as earliest to maturity while 119.92 (GKD-77) as late to maturity. In hybrid combination, Bhima Shakti x Line-25 recoded earliest days to maturity (103.5 days), whereas GKD-75 x Line-25 (120.0 days) matured late. Mean value of Bhima Super (commercial check) was 118.5 days.

The heterosis over mid parent for days to maturity range from -10.61 per cent (Bhima Shakti x Line-25) to 7.07 per cent (ASKO-1201 x Cross-5). Out of 40 hybrids studied 7 of the hybrids recorded significant negative heterosis over mid parent, 23 hybrids over commercial check. The range of heterosis over better parent was -11.85 per cent (GKD-75 x GKD-77) to 6.2 per cent (GKD-75 x Line-25). The range of heterosis over commercial check (Bhima Super) was from -12.84 per cent (Bhima Shakti x Line-25) to 2.17 per cent (GKD-75 x Line-25).

4.3 Combining ability

4.3.1 Combining ability effects

Variation due to female parents (lines) showed significant variation for only three characters. While, the male parents (testers) recorded significant variation for only one character (equatorial diameter). Lines vs. testers exhibited significant variation for all the characters except non marketable yield. The hybrids also exhibited significant variation for all the characters except non marketable yield. No significant variation was found in any of the sources for the character non marketable yield (Table 20).

The estimation of general combining ability and specific combining ability effects for the traits in 5 line x 8 tester mating design are presented in the table 21 and 22 and the results are highlighted below.

4.3.1.1 Plant height at 30 days after transplanting

Out of 13 parents, four parents had positive significant GCA effect, one parent ASKO-1299 had highly significant positive GCA effect. Line ASKO-1299 (4.975) showed highly significant positive GCA effect which is in desirable direction. Off the five lines, Kumata local (-2.894) exhibited highly significant negative GCA effect. Among the testers (male), Line-13 (2.074) exhibited significant positive GCA effects for plant height.

The significant negative SCA effect was observed in Bhima Shakti x N-53 (-5.998). The higher significant positive SCA effect was observed in Bhima Shakti x Line-25 (6.363) and involved parental combination of significant negative x significant positive general combiner. This was followed by ASKO-1201 x Line-13 (5.645) involved parental combination of significant negative x significant positive general combiner and ASKO-1201 x N-53 (3.465) involved parental combination of significant negative x significant negative general combiner.

Table 16. Per se performance and magnitude of heterosis for average bulb weight during kharif

Sl. No.	Entries	Average bulb weight						
		Per se value (g)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	78.50	49.00	63.75	63.50	-0.39	-3.05**	-6.62 *
2	Kumata local x GKD-45		63.00	70.75	50.50	-15.48 **	-18.55 **	-25.74 **
3	Kumata local x GKD-77		64.50	71.50	63.50	6.72 *	-2.42**	-6.62 *
4	Kumata local x ASKO-1222		62.00	70.25	60.50	7.56 *	-2.42**	-11.03 **
5	Kumata local x Arka Kalyan		59.00	68.75	59.00	-2.16**	-4.84**	-13.24 **
6	Kumata local x Line-25		75.00	76.75	49.00	-20.33 **	-20.97 **	-27.94 **
7	Kumata local x N-53		74.00	76.25	70.00	-24.26 **	-17.74 **	3.35 **
8	Kumata local x Line-13		73.50	76.00	78.00	27.87 **	9.08	14.71 **
9	Bhima Shakti x Cross 5	76.50	49.00	62.75	65.00	9.70 **	-0.76	-4.41
10	Bhima Shakti x GKD-45		63.00	69.75	61.50	11.31 **	-6.96 *	-9.56 **
11	Bhima Shakti x GKD-77		64.50	70.50	61.50	-11.82 **	-7.89 *	-9.56 **
12	Bhima Shakti x ASKO-1222		62.00	69.25	54.50	-5.31**	-33.83**	-19.85 **
13	Bhima Shakti x Arka Kalyan		59.00	67.75	66.50	5.32	-24.99 **	-10.50
14	Bhima Shakti x Line-25		75.00	75.75	60.50	-16.14 *	-16.82**	-11.03 **
15	Bhima Shakti x N-53		74.00	75.25	59.00	-8.76 **	-6.31**	-13.24 **
16	Bhima Shakti x Line-13		73.50	75.00	58.50	-18.18 **	-10.38 **	-13.97 **
17	GKD-75 x Cross-5	43.00	49.00	46.00	63.00	13.00 **	23.82**	-7.35 **
18	GKD-75 x GKD-45		63.00	53.00	59.00	14.01 **	-2.61**	-13.24 **
19	GKD-75 x GKD-77		64.50	53.75	63.50	23.30 **	11.40	-6.62 *
20	GKD-75 x ASKO-1222		62.00	52.50	66.50	37.82 **	31.68 **	-2.21
21	GKD-75 x Arka Kalyan		59.00	51.00	65.50	31.66 **	22.43 **	-3.68
22	GKD-75 x Line-25		75.00	59.00	54.00	-23.93**	-11.48 **	-20.59 **
23	GKD-75 x N-53		74.00	58.50	57.00	-12.32 *	-12.70**	-16.18 **
24	GKD-75 x Line-13		73.50	58.25	80.00	33.70 **	33.70 **	16.15 **
25	ASKO-1201 x Cross-5	65.50	49.00	57.25	74.00	37.04 **	19.35 **	8.82 **
26	ASKO-1201 x GKD-45		63.00	64.25	78.50	37.72 **	36.52 **	15.44 **
27	ASKO-1201 x GKD-77		64.50	65.00	68.50	14.80 **	22.21 **	-10.50
28	ASKO-1201 x ASKO-1222		62.00	63.75	43.00	-19.63 **	-23.89 **	-36.76 **
29	ASKO-1201 x Arka Kalyan		59.00	62.25	65.50	19.09 **	15.93	-3.68
30	ASKO-1201 x Line-25		75.00	70.25	70.00	31.06 **	26.23 **	13.24 **
31	ASKO-1201 x N-53		74.00	69.75	55.00	-12.79**	-2.65 **	-19.12 **
32	ASKO-1201 x Line-13		73.50	69.50	49.00	-34.39**	-13.27 **	-27.94 **
33	ASKO-1299 x Cross-5	77.00	49.00	63.00	63.00	0	-3.82	-7.35 **
34	ASKO-1299 x GKD-45		63.00	70.00	64.50	-14.16 **	-12.17 **	-5.15
35	ASKO-1299 x GKD-77		64.50	70.75	62.00	-10.22 **	-8.77 **	-8.82 **
36	ASKO-1299 x ASKO-1222		62.00	69.50	59.00	-11.32 **	-6.31**	-13.24 **
37	ASKO-1299 x Arka Kalyan		59.00	68.00	70.00	27.61 **	-15.14**	4.56**
38	ASKO-1299 x Line-25		75.00	76.00	69.00	-5.32 **	-19.67 **	7.35 **
39	ASKO-1299 x N-53		74.00	75.50	70.00	-3.33 **	-3.43 **	8.82 **
40	ASKO-1299 x Line-13		73.50	75.25	65.50	-24.83 **	-22.43 **	-8.09
	CC (Bhima Super)				69			
	S.Em. \pm				2.52	1.5781	1.8222	1.8222
	C.D. at 5 %				7.2	3.1919	3.6857	3.6857
	C.D. at 1 %				9.58	4.2733	4.9343	4.9343

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC- Commercial check

Table 17. Per se performance and magnitude of heterosis for total yield during kharif

Sl. No.	Entries	Total yield						
		Per se value (t/ha)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	4.78	5.61	5.20	11.29	76.50 **	51.16 **	32.55 **
2	Kumata local x GKD-45		5.05	4.92	8.38	45.44 **	39.79 **	0
3	Kumata local x GKD-77		5.15	4.97	8.39	23.20 *	12.74	-1.14
4	Kumata local x ASKO-1222		7.76	6.27	5.56	-23.36 *	-38.63 **	-42.19 **
5	Kumata local x Arka Kalyan		5.64	5.21	5.22	26.28	-2.70 **	-40.63 **
6	Kumata local x Line-25		6	5.39	7.91	28.96 **	-2.50	-6.31
7	Kumata local x N-53		6.45	5.62	8.28	35.32 **	0.12	-2.58
8	Kumata local x Line-13		5.8	5.29	11.77	92.20 **	58.22 **	38.74 **
9	Bhima Shakti x Cross 5	9.46	5.61	7.54	6.00	-26.92 **	26.67	-5.92
10	Bhima Shakti x GKD-45		5.05	7.26	5.6	-28.63 **	-11.92	-34.52 **
11	Bhima Shakti x GKD-77		5.15	7.31	6.70	-5.39 **	-5.86	-31.47 **
12	Bhima Shakti x ASKO-1222		7.76	8.61	5.17	-17.54 **	-24.17	-40.35 **
13	Bhima Shakti x Arka Kalyan		5.64	7.55	6.59	-14.91 *	25.58	-9.49
14	Bhima Shakti x Line-25		6	7.73	7.54	14.64	0.31	-3.60
15	Bhima Shakti x N-53		6.45	7.96	5.21	-30.50 **	-39.51 **	-41.14 **
16	Bhima Shakti x Line-13		5.8	7.63	6.75	-15.30 **	24.58	-10.21
17	GKD-75 x Cross-5	7.13	5.61	6.37	6.34	-1.75	-21.95 *	-32.73 **
18	GKD-75 x GKD-45		5.05	6.09	5.48	-4.79	-23.21 *	-33.81 **
19	GKD-75 x GKD-77		5.15	6.14	6.27	2.48 *	-28.50 *	-38.38 **
20	GKD-75 x ASKO-1222		7.76	7.45	6	-15.19 **	18.64 *	10.87
21	GKD-75 x Arka Kalyan		5.64	6.39	7.8	15.85**	-25.09 *	-35.44 **
22	GKD-75 x Line-25		6	6.57	5.58	-15.09 **	-26.06 **	-37.58 **
23	GKD-75 x N-53		6.45	6.79	8.85	34.68 **	-0.086	-33.45**
24	GKD-75 x Line-13		5.8	6.47	13.00	80.34**	75.09 **	65.44 **
25	ASKO-1201 x Cross-5	8	5.61	6.81	10.37	29.04 **	8.77	11.83**
26	ASKO-1201 x GKD-45		5.05	6.53	5.86	-12.36	-37.29 **	-23.12 *
27	ASKO-1201 x GKD-77		5.15	6.58	8.42	10.11	-12.25	7.57
28	ASKO-1201 x ASKO-1222		7.76	7.88	7.53	-23.86 **	-0.05	-6.12 *
29	ASKO-1201 x Arka Kalyan		5.64	6.82	8.15	-20.53	3.94	-3.54
30	ASKO-1201 x Line-25		6	7.00	10.26	31.66 **	46.88 **	27.15 **
31	ASKO-1201 x N-53		6.45	7.23	6.48	-39.91 **	-26.10 **	-33.93 **
32	ASKO-1201 x Line-13		5.8	6.90	5.1	-38.10 *	-20.38 **	-48.40**
33	ASKO-1299 x Cross-5	10.51	5.61	8.06	5.2	-47.58 **	-11.41	-30.51 **
34	ASKO-1299 x GKD-45		5.05	7.78	5.5	-7.59 **	-22.66	-39.34 **
35	ASKO-1299 x GKD-77		5.15	7.83	7.63	-4.49 **	28.93 **	-16.82
36	ASKO-1299 x ASKO-1222		7.76	9.14	5.3	-33.54 **	27.11	-30.23**
37	ASKO-1299 x Arka Kalyan		5.64	8.08	6.50	-13.77 **	5.67	-17.12
38	ASKO-1299 x Line-25		6	8.26	5.98	-10.87 **	-19.06	-22.22 *
39	ASKO-1299 x N-53		6.45	8.48	6.1	-18.93 *	7.41	4.50
40	ASKO-1299 x Line-13		5.8	8.16	7.01	-15.36 **	20.98	-5.11
	CC (Bhima Super)				8.39			
	S.Em. +				0.54	0.6638	0.7665	0.7665
	C.D. at 5 %				1.53	1.3426	1.5503	1.5503
	C.D. at 1 %				2.03	1.7975	2.0755	2.0755

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC- Commercial check

Table 18. Per se performance and magnitude of heterosis for rotten bulbs during kharif

Sl. No.	Entries	Rotten bulbs						
		Per se value (t/ha)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	1.20	1.67	1.44	1.25	69.49	38.89	61.29
2	Kumata local x GKD-45		2.30	1.75	0.75	-6.54	-16.67	-3.23
3	Kumata local x GKD-77		1.58	1.39	2.15	107.23 **	82.98 *	177.42 **
4	Kumata local x ASKO-1222		1.65	1.43	1.65	47.11	22.59	113.55 *
5	Kumata local x Arka Kalyan		1.75	1.48	0.75	-9.37	-16.67	-3.23
6	Kumata local x Line-25		1.30	1.25	2.56	228.62 **	183.89 **	229.68 **
7	Kumata local x N-53		1.92	1.56	2.20	238.46 **	144.44 **	183.87 **
8	Kumata local x Line-13		1.25	1.23	2.08	78.11 *	45.10	167.74 **
9	Bhima Shakti x Cross 5	1.10	1.67	1.39	1.54	64.27	18.46	98.71
10	Bhima Shakti x GKD-45		2.30	1.70	1.52	51.12	16.54	95.48
11	Bhima Shakti x GKD-77		1.58	1.34	2.45	97.98 **	88.46 *	216.13 **
12	Bhima Shakti x ASKO-1222		1.65	1.38	1.10	-16.98	-18.52	41.94
13	Bhima Shakti x Arka Kalyan		1.75	1.43	1.43	39.17	10.00	84.52
14	Bhima Shakti x Line-25		1.30	1.20	1.80	84.14 *	38.46	132.26 *
15	Bhima Shakti x N-53		1.92	1.51	1.37	60.59	5.00	76.13
16	Bhima Shakti x Line-13		1.25	1.18	1.20	-12.09	-16.08	54.84
17	GKD-75 x Cross-5	1.40	1.67	1.54	1.35	61.19	22.73	74.19
18	GKD-75 x GKD-45		2.30	1.85	0.90	-0.28	-18.18	16.13
19	GKD-75 x GKD-77		1.58	1.49	1.80	58.24	53.19	132.26 *
20	GKD-75 x ASKO-1222		1.65	1.53	1.87	52.24	38.15	140.65 *
21	GKD-75 x Arka Kalyan		1.75	1.58	1.33	42.86	20.45	70.97
22	GKD-75 x Line-25		1.30	1.35	0.91	4.27	-16.82	18.06
23	GKD-75 x N-53		1.92	1.66	0.78	3.33	-29.55	0.00
24	GKD-75 x Line-13		1.25	1.33	1.58	24.90	10.49	103.87
25	ASKO-1201 x Cross-5	2.75	1.67	2.21	2.25	227.27 **	181.25 **	190.32 **
26	ASKO-1201 x GKD-45		2.30	2.53	1.20	59.47	50.00	54.84
27	ASKO-1201 x GKD-77		1.58	2.17	1.10	11.39	-6.38	41.94
28	ASKO-1201 x ASKO-1222		1.65	2.20	1.40	30.23	3.70	80.65
29	ASKO-1201 x Arka Kalyan		1.75	2.25	2.75	253.70 **	243.75 **	254.84 **
30	ASKO-1201 x Line-25		1.30	2.03	1.67	128.87 *	108.12	114.84 *
31	ASKO-1201 x N-53		1.92	2.34	1.30	116.67	62.50	67.74
32	ASKO-1201 x Line-13		1.25	2.00	1.67	49.33	16.43	114.84 *
33	ASKO-1299 x Cross-5	1.67	1.67	1.67	2.30	308.89 **	300.00 **	196.77 **
34	ASKO-1299 x GKD-45		2.30	1.99	1.58	151.79 *	124.11 *	103.87
35	ASKO-1299 x GKD-77		1.58	1.63	1.65	91.30 *	40.43	112.90 *
36	ASKO-1299 x ASKO-1222		1.65	1.66	1.75	84.21 *	29.63	125.81 *
37	ASKO-1299 x Arka Kalyan		1.75	1.71	1.30	99.23	72.19	67.74
38	ASKO-1299 x Line-25		1.30	1.49	1.25	107.47	90.84	61.29
39	ASKO-1299 x N-53		1.92	1.80	1.92	303.16 **	248.18 **	147.10 *
40	ASKO-1299 x Line-13		1.25	1.46	1.25	26.26	-12.59	61.29
	CC (Bhima Super)				0.68			
	S.Em. ±				2.23	0.3718	0.4294	0.4294
	C.D. at 5 %				6.32	0.7521	0.8685	0.8685
	C.D. at 1 %				8.41	1.0069	1.1627	1.1627

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC- Commercial check

Table 19. Per se performance and magnitude of heterosis for days to maturity during kharif

Sl. No.	Entries	Days to maturity						
		Per se value				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	115.5	114.48	115.0	112.5	-2.16	-2.60	-5.26 *
2	Kumata local x GKD-45		108.73	112.1	111.8	-0.25	-3.18	-5.83 *
3	Kumata local x GKD-77		119.92	117.7	112.0	-4.85 *	-6.60 *	-5.68 *
4	Kumata local x ASKO-1222		113.67	114.6	114.6	0.02	-0.78	-3.49
5	Kumata local x Arka Kalyan		115.50	115.5	111.6	-3.38	-3.38	-6.02 *
6	Kumata local x Line-25		114.25	114.9	108.0	-5.98 *	-6.49 *	-9.05 **
7	Kumata local x N-53		108.75	112.1	113.0	0.78	-2.16	-4.84 **
8	Kumata local x Line-13		106.75	111.1	107.0	-3.71	-7.36 **	-9.89 **
9	Bhima Shakti x Cross 5	117.3	114.48	115.9	115.8	-0.06	-1.28	-2.46
10	Bhima Shakti x GKD-45		108.73	113.0	109.8	-2.83	-6.39 *	-7.51 **
11	Bhima Shakti x GKD-77		119.92	118.6	118.0	-0.52	-1.60	-0.63
12	Bhima Shakti x ASKO-1222		113.67	115.5	110.0	-4.76 *	-6.25 *	-7.37 **
13	Bhima Shakti x Arka Kalyan		115.50	116.4	116.0	-0.36	-1.13	-2.32
14	Bhima Shakti x Line-25					-10.61	-11.79	-12.84 **
			114.25	115.8	103.5	**	**	
15	Bhima Shakti x N-53		108.75	113.0	113.8	0.70	-2.98	-4.14
16	Bhima Shakti x Line-13		106.75	112.0	110.3	-1.60	-6.03 *	-7.16 **
17	GKD-75 x Cross-5	114.2	114.48	114.3	119.6	4.58 *	4.48	0.72
18	GKD-75 x GKD-45		108.73	111.5	111.9	0.33	-2.10	-5.81 *
19	GKD-75 x GKD-77					-9.72 **	-11.85	-10.99 **
			119.92	117.1	105.7		**	
20	GKD-75 x ASKO-1222		113.67	113.9	114.3	0.26	0.00	-3.79
21	GKD-75 x Arka Kalyan		115.50	114.9	111.0	-3.37	-3.90	-6.53 *
22	GKD-75 x Line-25		114.25	114.2	120.0	6.20 **	6.20 *	2.17
23	GKD-75 x N-53		108.75	111.5	113.3	1.64	-0.81	-4.56
24	GKD-75 x Line-13		106.75	110.5	114.5	3.62	0.22	-3.58
25	ASKO-1201 x Cross-5	108.7	114.48	111.6	119.5	7.07 **	4.39	0.63
26	ASKO-1201 x GKD-45		108.73	108.7	111.0	2.08	2.07	-6.53 *
27	ASKO-1201 x GKD-77		119.92	114.3	112.5	-1.60	-6.18 *	-5.26 *
28	ASKO-1201 x ASKO-1222		113.67	111.2	104.3	-6.18 *	-8.21 **	-12.14 **
29	ASKO-1201 x Arka Kalyan		115.50	112.1	111.5	-0.56	-3.46	-6.11 *
30	ASKO-1201 x Line-25		114.25	111.5	105.1	-5.74 *	-8.01 **	-11.49 **
31	ASKO-1201 x N-53		108.75	108.7	114.1	4.92 *	4.92	-3.92
32	ASKO-1201 x Line-13		106.75	107.7	111.0	3.02	2.07	-6.53 *
33	ASKO-1299 x Cross-5	107.0	114.48	110.7	114.0	2.93	-0.41	-4.00
34	ASKO-1299 x GKD-45		108.73	107.9	108.0	0.11	-0.67	-8.05 **
35	ASKO-1299 x GKD-77		119.92	113.5	114.8	1.19	-4.24	-3.30
36	ASKO-1299 x ASKO-1222		113.67	110.3	117.3	6.32 **	3.22	-1.20
37	ASKO-1299 x Arka Kalyan		115.50	111.3	119.0	6.95 **	3.03	0.21
38	ASKO-1299 x Line-25		114.25	110.6	116.0	4.84 *	1.53	-2.32
39	ASKO-1299 x N-53		108.75	107.9	110.5	2.41	1.61	-6.95 **
40	ASKO-1299 x Line-13		106.75	106.9	106.5	-0.37	-0.50	-10.32 **
	CC (Bhima Super)				118.5			
	S.Em. ±				2.23	2.5437	2.9372	2.9372
	C.D. at 5 %				6.32	5.1450	5.9410	5.9410
	C.D. at 1 %				8.41	6.8880	7.9536	7.9536

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC- Commercial check

Table 20. Analysis of variance (mean sum of squares) for combining ability for 17 characters in onion during *kharif*

Source of variation	Df	Plant height (cm) at 30 DAT	Leaf length (cm) at 30 DAT	No of leaves at 30 DAT	Plant height (cm) at 60 DAT	Leaf length (cm) at 60 DAT	No of leaves at 60 DAT	Neck thickness (cm)	TSS °Brix	Market-able yield (t/ha)	Non market-able yield (t/ha)	Average bulb weight (g)	Total yield (t/ha)	Rotten bulbs (t/ha)	Days to maturity
Replication	1	3.828	0.63	0.200 *	0.01	0.072	0.145	0.001	0.099	0.095	0.003	0.613	0.075	0.004	19.013
Crosses	39	32.615 **	40.990**	0.295**	17.785**	13.131**	1.159**	0.025**	2.074 **	7.326**	0.361	156.010**	10.55**	0.499**	36.928 **
Line Effect	4	145.811**	172.045**	1.206**	14.425	14.785	0.56	0.052	1.616	12.931	0.468	135.488	7.44	0.355	23.951
Tester Effect	7	19.615	15.085	0.222	8.305	7.679	2.181	0.022	1.156	9.405	0.252	118.37	6.618	0.361	43.218
Line * Tester Eff.ect	28	19.694**	28.745**	0.184**	20.635**	14.257**	0.988**	0.022**	2.369**	6.006**	0.373	168.352**	11.9**	0.553**	37.209 **
Error	39	1.888	7.289	0.045	0.47	0.419	0.413	0.001	0.369	0.155	0.317	3.459	0.626	0.192	7.833
Total	79	17.081	23.842	0.171	9.012	6.69	0.778	0.013	1.208	3.694	0.335	78.733	5.518	0.341	22.338
σ^2_{gca}		6.214**	6.495**	0.052**	0.846	0.839	0.081*	0.003**	0.08**	0.85**	-0.01	9.508	0.495	0.013	1.919
σ^2_{sca}		8.88**	9.809**	0.07**	10.134**	6.965**	0.334**	0.01**	1.014**	2.941**	-0.057	82.516**	5.695**	0.185**	14.290**
$\sigma^2_{gca}/\sigma^2_{sca}$		0.7	0.662	0.738	0.083	0.12	0.242	0.267	0.079	0.289	0.172	0.115	0.087	0.072	0.1343

* and ** indicates significant at 5 and 1 % respectively
TSS : Total Soluble Solids

Df, : Degrees of freedom

DAT : Days After Transplanting

4.3.1.2 Leaf length at 30 days after transplanting

Of the 13 parents, the GCA effects were significant in 10, of which line Bhima Shakti (-2.93) was highly significant negative general combiner in undesirable direction. The line ASKO-1299 (4.149) has highly positive significant GCA effect and none of the testers showed significant positive general combining ability in desirable direction. Among the testers, ASKO-1222 had significant negative GCA effect (-1.501).

Out of 40 hybrids studied, ASKO-1201 x N-53 (5.631) involved parental combination of significant positive x non significant positive combination, and ASKO-1201 x Line-13 (4.721) recorded the highly significant positive SCA effect. Among 40 hybrids, six F₁s had significant negative SCA effect, which is not desirable.

4.3.1.3 Number of leaves at 30 days after transplanting

Among the 13 parents, 9 recorded significant positive GCA effect. Four lines namely Kumata local (0.30), Bhima Shakti (0.09), GKD-75 (0.02) and ASKO-1201 (0.02) recorded significant positive GCA effect. Among the lines ASKO-1299 was significant combiner in negative direction. While, among the testers, Line-25 had significant GCA effect in negative direction.

Out of 40 hybrids, six crosses : Kumata local x GKD-77, Bhima Shakti x Arka Kalyan, GKD-75 x GKD-77, ASKO-1201 x ASKO-1222, ASKO-1299 x Cross-5, and ASKO-1299 x Line-13 expressed highly significant positive SCA effect. The highest SCA effect was recorded in ASKO-1299 x Line-13(0.66). This was followed by ASKO-1299 x Cross-5 (0.548) and Kumata local x GKD-77(0.438).

4.3.1.4 Plant height at 60 days after transplanting

It was evident from the table 21 that two out of five lines and three out of eight testers recorded significant positive GCA effect. Among lines (female) Kumata local had highly significant GCA effect in desirable positive direction (0.99). The tester ASKO-1222, had highly significant GCA effect in desirable positive direction (1.599) followed by N-53 (0.799) and Line-25 (0.429). Whereas, Bhima Shakti (-1.151) recorded significant negative GCA effect in non-desirable direction among 13 parents.

Out of 40 hybrids, 11 crosses showed significant positive SCA effect, out of these ASKO-1299 x N-53 (7.183) recorded highest SCA effect. While two crosses ASKO-1299 x Line-13 (-6.248) and Bhima Shakti x Arka Kalyan (-5.649) were at par with each other and they were in non-desirable direction.

4.3.1.5 Leaf length at 60 days after transplanting

Of the 13 parents, only six had significant positive GCA effect. GKD-75 , Kumata local and N-53 were at par with each other. Among lines, GKD-75 expressed highly significant positive GCA effect (1.008). The lines Bhima Shakti (-0.655), ASKO-1201 (-0.180) and ASKO-1299 (-1.136) recorded significant negative GCA effect.

The higher significant positive SCA effect was noticed in the cross Kumata local x N-53 (4.296) followed by Bhima Shakti x Cross-5 (3.075) and Bhima Shakti x Line-13 (2.795). Out of 40 crosses, 16 had significant positive SCA effect in desirable direction.

4.3.1.6 Number of leaves at 60 days after transplanting

Out of 13 parents, N-53 (0.642) exhibited significant positive GCA effect for number of leaves at 60 days after transplanting. There were two testers (Line-25 and Line-13) at par with this. ASKO-1201 (0.275) expressed significant positive GCA effects among lines.

The significant positive SCA effect was observed in 2 crosses, among 40 hybrids. Two crosses expressed significant negative SCA effects. The higher positive SCA effect was observed in GKD-75 x GKD-45 (1.028) which was at par with ASKO-1299 x GKD-77 (0.976).

4.3.1.7 Polar diameter

GCA effect was significant positive in six out of 13 parents. Among the lines, three lines (female) namely Kumata local (0.121), Bhima Shakti (0.134) and ASKO-1201 (0.075) showed highly significant positive GCA effect in desirable direction. While, GKD-75 had highly significant negative GCA effect which is in undesirable direction (-0.224). Among testers, Cross-5 had highly significant positive GCA effect (0.200), whereas, GKD-45 recorded significant negative GCA effect (-0.678).

There were 29 hybrids which showed significant SCA effect, of which 17 were in positive direction and 12 were in negative undesirable direction. The highest significant positive SCA effect was observed in the cross GKD-75 x Line-13 (0.608), followed by Kumata local x Line-13 (0.565) and ASKO-1201 x Cross-5 (0.480).

4.3.1.8 Equatorial diameter

Out of 13 parents, five recorded significant positive GCA effects. Among the lines, Bhima Shakti (0.118) showed higher positive GCA effect. Two lines, Kumata local (-0.145) and ASKO-1201 (-0.059) exhibited significant negative GCA effects in undesirable direction. In testers, Line-13 (0.423) recorded significant positive GCA effect in desirable direction followed by GKD-77 (0.122).

Out of 40 crosses studied, 12 crosses expressed significant positive SCA effect, 14 crosses recorded highly significant negative SCA effect in undesirable direction. Three crosses ASKO-1299 x GKD-77 (0.464), ASKO-1201 x GKD-45 (0.430) and GKD-75 x N-53 (0.394) were at par with each other.

4.3.1.9 P/E ratio

The line GKD-75 (0.065) has significant positive GCA effect. ASKO-1299 (-0.133) exhibited significant negative effect. Among the testers, Cross-5 (0.035) expressed significant positive GCA effect, whereas N-53 (-0.059) negative GCA effect.

Out of 40 hybrids tested, five crosses showed significant positive SCA effect. GKD-75 x Line-13 (0.206) showed significant positive SCA effect which were at par with four other crosses, while six other hybrids expressed significant negative SCA effect which were at par with each other.

4.3.1.10 Neck thickness

There were only six parents which showed significant positive GCA effects. The higher significant positive GCA effect was observed in GKD-75 (0.075) and negative GCA was observed in ASKO-1222 (-0.079) which is desirable.

Out of 40 crosses, 11 crosses expressed significant positive SCA effect, out of which one cross expressed ASKO-1299 x N-53 (0.212) highly significant positive SCA effect. While, ASKO-1299 x ASKO-1222 (-0.210) exhibited significant negative SCA effect which is desirable.

4.3.1.11 TSS (total soluble solids)

Out of five lines, GKD-75 (0.512) recorded highest significant positive GCA effect whereas, Bhima Shakti (-0.334) recorded highest significant negative GCA effect. But among eight testers, Cross-5 (0.668) and ASKO-1222 (0.208) showed significant positive GCA effect.

There were seven crosses which showed significant positive SCA effect. Higher was recorded by cross ASKO-1201 x ASKO-1222 (1.695) which was at par with ASKO-1299 x Cross-5 (1.589) and Bhima Shakti x N-53 (1.504).

4.3.1.12 Marketable yield

The range of GCA effect for marketable yield was from -1.331 (GKD-45) to 1.571 (Line-13) among testers, from -1.064 (ASKO-1299) to 0.945 (Kumuta local) among lines. Three lines and four testers showed significant positive GCA effects, highest positive significant GCA was given by Line-13 (1.571). While six of them recorded significant negative GCA effect, highest negative significant was given by GKD-45 (-1.331).

Seventeen of the crosses exhibited positive significant SCA effect. The range of SCA effect was from -3.895 (ASKO-1201 x Line-13) to 4.013 (GKD-75 x Line-13). GKD-75 x Line-13 (4.013) expressed highest significant positive SCA effect followed by ASKO-1201 x Cross-5 (2.431), Kumuta local x Line-13 (2.258), ASKO-1201 x Line-25 (1.971) and GKD-75 x N-53 (1.650). Majority of the crosses with higher SCA effect were having ASKO-1299, GKD-75 and Kumata local as female parents.

4.3.1.13 Non marketable yield

The tester GKD-45 (0.317) had significant positive GCA effect. While, tester GKD-77 (-0.152) exhibited significant negative effect. Among the lines, Kumata local (0.228) expressed significant positive GCA effect, where as GKD-75 (-0.207) negative GCA effect.

Out of 40 hybrids tested, only one cross ASKO-1299 x Line-13 showed significant positive SCA effect. Seventeen crosses showed positive SCA effect, while other 22 hybrids expressed negative SCA effect.

Table 21. Estimation of GCA effect of parents for 17 characters in onion during *kharif*

Source of variation	Plant height (cm) at 30 DAT	Leaf length (cm) at 30 DAT	No of leaves at 30 DAT	Plant height (cm) at 60 DAT	Leaf length (cm) at 60 DAT	Polar diameter (cm) of bulb	Equatorial diameter (cm) of bulb	P/E ratio	Neck thickness (cm)	TSS °Brix	Market-able yield (t/ha)	Non market-able yield (t/ha)	Average bulb weight (g)	Total yield (t/ha)	Rotten bulbs (t/ha)	Days to maturity
Kumata local	- 2.894**	- 2.464**	0.303**	0.993**	0.964**	0.121**	-0.145**	0.040**	0.019**	- 0.095**	0.945 **	0.228 **	4.338**	0.864**	0.108**	-1.047 **
Bhima Shakti	- 1.813**	- 2.933**	0.090**	- 1.151**	- 0.655**	0.134**	0.118**	- 0.027**	0.020**	- 0.334**	- 0.854**	-0.127**	-1.538**	- 1.017**	- 0.015**	-0.208 **
GKD-75	- 0.194**	- 1.651**	0.027**	- 0.276**	1.008**	-0.224**	0.049**	0.065**	0.075**	0.512**	0.445**	-0.207**	-2.413**	0.251*	- 0.252**	1.582
ASKO-1299	4.975**	4.149 *	- 0.448**	- 0.533**	- 1.136**	-0.106**	0.034 *	- 0.133**	-0.067**	- 0.139**	- 1.064**	0.041	-2.038**	0.029	0.059 *	0.907
S.Em.±	0.3477	0.7552	0.0523	0.1515	0.1429	0.0268	0.0216	0.0261	0.0081	0.1460	0.0882	0.1743	0.4555	0.1916	0.1073	0.7343
C.D. at 5 %	0.7032	1.5276	0.1058	0.3064	0.2890	0.0541	0.0437	0.0528	0.0163	0.2952	0.1784	0.3526	0.9214	0.3876	0.2171	1.4852
C.D. at 1 %	0.9415	2.0451	0.1417	0.4102	0.3869	0.0725	0.0585	0.0707	0.0218	0.3952	0.2388	0.4720	1.2336	0.5189	0.2907	1.9884
Cross-5	- 0.466**	0.659	0.140**	- 0.831**	- 1.675**	0.200**	-0.168**	0.035**	-0.010**	0.668**	0.786 **	-0.123**	2.838 **	0.420 *	0.173 **	3.923 *
GKD-45	1.634**	- 0.561**	0.240**	- 0.691**	- 0.055**	-0.075**	-0.233**	- 0.006**	0.001	- 0.242**	- 1.331**	0.317 *	-0.863**	- 0.836**	- 0.377**	-1.861 **
GKD-77	- 1.726**	- 0.221**	- 0.100**	- 0.331**	- 0.675**	-0.095**	0.122**	0.020**	0.014**	0.108	0.458 **	-0.152**	1.738 *	0.223	0.265 **	0.243
ASKO-1222	- 1.426**	- 1.501**	0.040**	1.599**	- 0.385**	0.037**	-0.107**	- 0.025**	-0.079**	0.218 *	- 1.199**	-0.062**	-6.963**	0.026	- 0.012**	-0.261 **
Arka Kalyan	0.064	- 1.101**	0.020 *	0.099	0.715 **	0.167**	-0.086**	0.012**	0.044 **	- 0.042**	- 0.431**	0.108	-0.363**	- 1.602**	- 0.054**	1.457
N-53	- 0.946**	0.369	- 0.160**	0.799 **	0.785 **	-0.023**	0.019	- 0.059**	-0.003**	- 0.452**	- 0.051**	-0.143**	-0.063**	0.338 *	- 0.055**	0.589
S.Em.±	0.4398	0.9553	0.0662	0.1916	0.1807	0.0339	0.027	0.0330	0.0102	0.1846	0.1115	0.2205	0.5762	0.2424	0.1358	0.9288
C.D. at 5 %	0.8895	1.9323	0.1339	0.3875	0.3655	0.0685	0.0552	0.0668	0.0206	0.3734	0.2256	0.4460	1.1655	0.4903	0.2746	1.8787
C.D. at 1 %	1.1909	2.5869	0.1792	0.5188	0.4893	0.0917	0.0740	0.0895	0.0276	0.4999	0.786**	-0.123**	1.5604	0.6563	0.3677	2.5151

* and ** indicates significant at 5 and 1 % respectively

DAT : Days After Transplanting

TSS : Total Soluble Solids

Table 22. Estimation of SCA effect of crosses for 17 characters in onion during *kharif*

Entries	Plant height (cm) at 30 DAT	Leaf length (cm) at 30 DAT	No of leaves at 30 DAT	Plant height (cm) at 60 DAT	Leaf length (cm) at 60 DAT	No of leaves at 60 DAT	Polar diameter (cm) of bulb	Equatorial diameter (cm) of bulb	Neck thickness (cm)	TSS °Brix	Market-able yield (t/ha)	Non market-able yield (t/ha)	Average bulb weight (g)	Total yield (t/ha)	Rotten bulbs (t/ha)	Days to maturity
Kumata local xGKD-45	0.304	2.124	0.097	0.347	-0.164	0.459	-0.072	-0.224 **	-0.105 **	1.355 **	0.655 *	0.385	-	2.851**	-0.547	2.375
Kumata local xGKD-77	3.414 **	2.084	0.438 **	-1.213 **	-	-0.761	0.199 *	0.045	-0.009	0.355	0.142	-0.406	0.138	-0.183	0.212	0.441
Kumata local xArka Kalyan	-0.626	-0.036	0.118	2.908 **	-0.784	-0.401	-0.393 **	0.015	-0.059 *	-0.995 *	-	-0.036	-7.263 **	-	-0.69**	-1.173
Kumata local xLine-25	-3.906 **	-1.816	-0.063	0.077	-	-0.051	0.304 **	-0.309 **	0.029	0.297	-	0.008	-	-1.061	0.810 *	-1.739
Kumata local xN-53	2.334 *	0.994	0.098	-1.243 **	4.296 **	-0.361	0.189 *	0.112	0.056 *	-	0.125	-0.005	11.663**	-0.418	0.581	1.095
Bhima Shakti x Cross 5	3.223 **	2.173	0.010	-0.369	3.075 **	0.412	-0.250 **	0.326 **	-0.115 **	-	-	0.035	0.038	0.271	-0.183	-0.248
Bhima Shakti x GKD-77	-1.968	3.052	-0.250	-1.019 *	2.325 **	-0.618	-0.124	0.020	-0.038	1.867**	0.887**	0.274	-2.363	-0.828	0.636 *	5.602 *
Bhima Shakti x Line-25	6.363 **	2.452	-0.050	3.671 **	-	0.293	-0.524 **	-0.020	-0.035	1.294 **	-0.069	0.198	-0.663	1.045	0.179	-7.078 **
Bhima Shakti x N-53	-5.998 **	-8.488 **	-0.090	-0.199	-	0.632	0.198 *	-0.394 **	-0.205 **	-0.825	0.863 **	0.198	-3.063 *	-	-0.131	1.086
Bhima Shakti x Line-13	-5.018 **	-1.348	0.030	6.271 **	2.795 **	-1.068 *	0.247 **	-0.076	0.165 **	1.504 **	-	-0.090	-3.263 *	0.407	-0.339	0.608
GKD-75 x Cross 5	-0.696	3.291	-0.228	-0.844	-	-0.363	0.144	0.075	-0.076 **	0.701**	-	-0.075	-1.088	-	-0.136	1.732
GKD-75 x GKD-45	-0.096	-4.589 *	0.172	0.466	2.642 **	1.028 *	-0.316 **	0.191 **	0.101 **	0.189	1.656**	-0.400	-1.388	-1.231*	-0.037	-0.234
GKD-75 x GKD-77	1.364	0.571	0.313 *	1.606 **	-	0.308	0.019	-0.454 **	0.006	-0.602	-0.520 *	-0.246	0.513	-	0.222	-8.488 **
GKD-75 x ASKO-1222	3.064 **	1.551	-0.028	2.576 **	-0.828 *	-0.323	0.182 *	-0.365 **	-0.021	-	-	0.599	12.213 **	1.627**	0.563	0.566

Entries	Plant height (cm) at 30 DAT	Leaf length (cm) at 30 DAT	No of leaves at 30 DAT	Leaf length (cm) at 60 DAT	No of leaves at 60 DAT	Equatorial diameter (cm) of bulb	P/E ratio	TSS °Brix	Market-able yield (t/ha)	Non market-able yield (t/ha)	Average bulb weight (g)	Total yield (t/ha)	Rotten bulbs (t/ha)	Days to maturity
GKD-75 x Arka Kalyan	0.574	0.651	-0.007	-1.178**	-0.233	-0.279 **	0.109	0.899 *	0.645 *	0.074	-0.388	-0.600	0.066	-4.402 *
GKD-75 x Line-25	-1.856	-2.929	0.013	1.653 **	-0.383	0.101	-0.074	0.640	-2.171**	0.063	-6.288 **	2.961**	-0.470	8.962 **
GKD-75 x Line-13	-2.836 **	1.271	-0.208	-0.067	0.358	0.267 **	0.206 **	0.279	4.013 **	0.004	14.050 **	5.037**	0.278	3.068
ASKO-1201 x Cross-5	-1.465	-1.459	-0.027	-3.500**	-0.675	0.166 **	0.181 *	0.945 *	2.431 **	-0.512	9.850 **	1.691**	0.411	4.448 *
ASKO-1201 x GKD-45	-0.665	-2.239	-0.227	0.630	0.415	0.430 **	-0.178 *	0.205	-1.303**	0.403	0.613	0.037	-0.090	1.732
ASKO-1201 x GKD-77	-0.555	-5.979 **	-0.088	-0.650	0.095	-0.078	0.001	-1.095 *	0.259	0.087	9.450 **	1.533**	-0.831**	1.128
ASKO-1201 x Line-25	0.025	3.721	0.012	2.640 **	0.205	0.147 *	-0.104	-0.603	1.971 **	0.241	12.650 **	-3.470**	-0.073	-4.452 *
ASKO-1201 x N-53	3.465 **	5.631 *	0.173	1.590 **	-0.205	0.058	0.080	-0.285	-0.983**	-0.117	-10.250**	-2.037**	-0.312	2.382
ASKO-1201 x Line-13	5.645 **	4.721 *	-0.008	-0.280	0.145	-0.309 **	0.094	-	1.515**	-3.895**	-0.318	-15.950*	0.167	2.384
ASKO-1299 x Cross 5	2.035 *	1.791	0.548 **	0.756	0.506	-0.207 **	-0.056	1.589 **	-1.177**	-0.438	-7.838**	-1.990**	0.503	-3.193
ASKO-1299 x GKD-45	1.135	0.111	0.048	-3.614**	-	-0.308 **	0.105	-1.002 *	0.589 *	-0.228	-2.638 *	-1.469**	0.332	-3.409
ASKO-1299 x GKD-77	-2.255 *	0.271	-	1.106 **	0.976 *	0.464 **	0.064	-0.252	0.876 **	0.291	-7.738**	2.148 **	-0.239	1.317
ASKO-1299 xArka Kalyan	0.005	0.351	-0.233	2.616 **	0.686	-0.229 **	-0.023	0.299	0.839 **	-0.169	2.363	1.148 *	-0.270	4.273 *
ASKO-1299 x Line-25	-0.625	-1.429	0.088	1.346 **	-0.064	0.082	-0.091	0.490	0.058	-0.510	5.963 **	-1.551**	-0.446	4.307 *
ASKO-1299 x N-53	-0.285	1.681	-0.152	-0.504	0.326	-0.225 **	-0.007	-0.242	-0.091	0.232	6.063 **	1.008	0.345	-3.359
ASKO-1299 x Line-13	0.545	-6.229 **	0.668 **	-3.824**	0.126	-0.019	-0.143	-0.022	-1.758**	1.071 *	5.863 **	-0.214	-0.363	-4.257 *
S.Em.±	0.9834	2.1361	0.1480	0.4041	0.4002	0.0611	0.0739	0.4128	0.2494	0.4930	1.2885	0.5420	0.3036	2.0769
C.D. at 5 %	1.9891	4.3207	0.2993	0.8173	0.8095	0.1236	0.1495	0.8350	0.5045	0.9973	2.6062	1.0962	0.6141	4.2009
C.D. at 1 %	2.6629	5.7844	0.4007	1.0942	1.0837	0.1655	0.2001	1.1179	0.6754	1.3351	3.4891	1.4676	0.8222	5.6240

* and ** indicates significant at 5 and 1 % respectively

DAT : Days After Transplanting

TSS : Total Soluble Solids

4.3.1.14 Average bulb weight

Of the 13 parents, only five had significant positive GCA effect. Among lines, it range from - 2.413 (GKD-75) to 4.338 (Kumata local). Among testers, Line-13 (4.638) had highest GCA effect followed by Cross-5 (2.838) and GKD-77 (1.738).

The higher significant positive SCA effect was noticed in the cross GKD-75 x Line-13 (14.050). Out of 40 crosses, 12 had significant positive SCA effect in desirable direction while, 14 crosses had significant negative SCA effect.

4.3.1.15 Total yield

Out of 13 parents, six entries recorded significant positive GCA effect. Among the lines, Kumata local showed higher positive significant GCA effect (0.864). This was followed by GKD-75 (0.251). Two lines Bhima Shakti (-1.017) and ASKO-1201 (-0.127) exhibited significant negative GCA effects which is in undesirable direction. In testers, Line-13 expressed significant positive GCA effect in desirable direction (0.759). Of the eight testers, Arka Kalyan (-1.602) and GKD-45 (-0.836) recorded significant negative GCA effect.

Out of 40 crosses studied, only 13 crosses expressed significant positive SCA effect, while 12 crosses recorded highly significant negative SCA effect in undesirable direction. The cross GKD-75 x Line-13 (5.037) recorded highest significant positive SCA effect followed by Kumata local x Line-13 (3.195).

4.3.1.16 Rotten bulbs

Among the 13 parents, five had the significant positive GCA effect, while seven parents had significant negative GCA effect with highest value in GKD-45 (-0.377).

Out of the total hybrids, only 5 hybrids had significant SCA effect, 3 had positive side and another 2 for negative side and highest negative SCA effect given by the cross ASKO-1201 x GKD-77 (-0.831) which was on par with Kumata local x Arka Kalyan (-0.69).

4.3.1.17 Days to maturity

There were only eight parents which showed significant GCA effects. The higher significant positive GCA effect was observed in cross-5 (3.923) and significant negative GCA was observed in Line-13 (-2.513) which is desirable.

Out of 40 crosses, six expressed significant positive SCA effect, other six crosses expressed significant negative SCA effect, one cross expressed GKD-75 x GKD-77 (-8.488) highly significant negative SCA effect which was at par with other four crosses.

4.4 Analysis of variance in onion F₁ hybrids during *rabi* season

The analysis of variance carried out for 17 characters in onion crosses is presented in table 23. There is a presence of significant difference among treatments for all seventeen characters studied : plant height at 30 and 60 DAT, leaf length at 30 and 60 DAT, number of leaves at 30 and 60 DAT, polar diameter, equatorial diameter, P/E ratio, neck thickness, marketable yield, non-marketable yield, average bulb weight, total soluble solids, rotten bulbs, total yield and days to maturity.

4.5 Performance and Heterosis

4.5.1 Plant height at 30 days after transplanting (Table 24)

Among the lines Kumata local (36.15 cm) was lower in plant height. While, Bhima Shakti (43.90 cm) was the higher. Among the testers, ASKO-1222 (45.10 cm) was the highest, while N-53 (37.60 cm) was the lowest. Among hybrids Bhima Shakti x N-53 (27.20 cm) was the lowest and ASKO-1299 x GKD-77 (45.10 cm) was the highest. The commercial check was found to be 44.9 cm in height, 10 crosses were at par with commercial check (Bhima Shakti).

Significant negative heterosis was observed in hybrids over mid parent, better parent and the standard check. None of the hybrids showed significant positive heterosis over commercial check. The heterosis over mid parent range from -30.76 per cent to 15.47 per cent of which ASKO-1201 x Arka Kalyan (15.47 %) showed significant positive heterosis over mid parent. The heterosis over better parent range from -34.51 per cent to 14.55 per cent of which ASKO-1201 x Arka Kalyan (14.55 %) showed maximum significant positive heterosis.

4.5.2 Leaf length at 30 days after transplanting (Table 25)

The range of variation for this trait among the female parents was from 28.80 cm (Kumata local) to 36.80 cm (Bhima Shakti) and among male parents, it was range from 31.50 cm (GKD-77) to 38.60 cm (ASKO-1222). Among the hybrids, the lower and higher leaf length were recorded by ASKO-1201 x Cross-5 (27.60 cm) and ASKO-1299 x GKD-77 (38.60 cm), respectively.

The range of mid parent heterosis varied from -20.99 (Bhima Shakti x GKD-77) to 14.19 (ASKO-1201 x Arka Kalyan) per cent. Out of 40 hybrids, none of the crosses showed significant positive heterosis over commercial check. Heterosis in F₁s over better parent range from -24.38 (ASKO-1201 x Cross-5) to 10.49 per cent (ASKO-1201 x Arka Kalyan).

4.5.3 Number of leaves at 30 days after transplanting (Table 26)

The higher number of leaves in the female was observed in GKD-75 (6.10) and the lower in ASKO-1201 (5.25). Among the males, range of variation was from 3.50 (GKD-77) to 6.30 (Arka Kalyan). Among the hybrids, ASKO-1299 x GKD-45 and Bhima Shakti x N-53 were observed to have minimum (3.50) and maximum (7.05) number of leaves per plant, respectively.

The range of commercial check heterosis varied from -38.60 per cent (ASKO-1299 x GKD-45) to 23.68 per cent (Bhima Shakti x N-53). Out of 40 hybrids, none of the hybrids showed significant positive heterosis over mid parent and better parent. The maximum heterosis over commercial check was manifested by the only one cross Bhima Shakti x N-53 (23.68 %).

4.5.4 Plant height at 60 days after transplanting (Table 27)

Among the parents, Line-13 (55.80 cm) had recorded higher plant height while lower was recorded by GKD-77 (44.70 cm). In hybrids, the range for plant height varied from 44.00 cm (Bhima Shakti x Arka Kalyan) to 55.60 cm (ASKO-1299 x N-53 and ASKO-1299 x Line-25).

Table 23. Analysis of variance (mean sum of squares) for 17 characters in onion during *rabi*

Source of variation	Df	Plant height (cm) at 30 DAT	Leaf length (cm) at 30 DAT	No of leaves at 30 DAT	Plant height (cm) at 60 DAT	Leaf length (cm) at 60 DAT	No of leaves at 60 DAT	Polar diameter (cm) of bulb	Equatorial diameter (cm) of bulb	P/E ratio	TSS %brix	Market-able yield (t/ha)	Non market-able yield (t/ha)	Average bulb weight (g)	Total yield (t/ha)	Rotten bulbs (t/ha)	Days to maturity
Replications	1	9.34	21.24	0.59	7.04	1.38	0.06	0.02	0.01	0.01	0.57	3.05	0.07	3.33	0.49	0.20	18.60
Treatments	53	52.15*	26.62*	0.64*	22.50*	21.01*	0.45*	0.21*	0.18*	0.02*	4.67*	43.90**	1.27*	141.40**	38.05**	0.40**	22.80**
Error	53	4.10	5.72	0.32	7.77	5.77	0.20	0.01	0.01	0.01	0.35	1.33	0.12	8.32	0.58	0.06	7.75

* and ** indicates significant at 5 and 1 % respectively

Df : Degrees of freedom

DAT : Days After Transplanting

TSS : Total Soluble Solids

Table 24. Per se performance and magnitude of heterosis for plant height at 30 days after transplanting during rabi

Sl. No.	Entries	Plant height at 30 days after transplanting						
		Per se value (cm)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	36.15	38.70	37.43	30.50	-29.89 **	-32.52 **	-31.92 **
2	Kumata local x GKD-45		38.50	37.33	32.30	-22.12 **	-28.54 **	-27.90 **
3	Kumata local x GKD-77		38.35	37.25	31.40	-27.48 **	-30.53 **	-29.91 **
4	Kumata local x ASKO-1222		45.10	40.63	30.70	-29.59 **	-32.08 **	-31.47 **
5	Kumata local x Arka Kalyan		41.50	38.83	38.30	-7.71	-15.27 **	-14.51 **
6	Kumata local x Line-25		41.60	38.88	37.95	-13.85 **	-16.04 **	-15.29 **
7	Kumata local x N-53		37.60	36.88	36.35	-11.07 *	-19.58 **	-18.86 **
8	Kumata local x Line-13		40.40	38.28	29.60	-30.76 **	-34.51 **	-33.93 **
9	Bhima Shakti x Cross 5	43.90	38.70	41.30	33.55	-18.86 **	-19.74 **	-25.11 **
10	Bhima Shakti x GKD-45		38.50	41.20	28.40	-27.78 **	-30.56 **	-36.61 **
11	Bhima Shakti x GKD-77		38.35	41.13	28.90	-29.77 **	-30.19 **	-35.49 **
12	Bhima Shakti x ASKO-1222		45.10	44.50	30.80	-25.69 **	-26.67 **	-31.25 **
13	Bhima Shakti x Arka Kalyan		41.50	42.70	30.43	-22.67 **	-25.60 **	-32.08 **
14	Bhima Shakti x Line-25		41.60	42.75	31.90	-23.87 **	-25.64 **	-28.79 **
15	Bhima Shakti x N-53		37.60	40.75	27.20	-29.76 **	-33.50 **	-39.29 **
16	Bhima Shakti x Line-13		40.40	42.15	31.80	-21.67 **	-22.25 **	-29.02 **
17	GKD-75 x Cross-5	41.10	38.70	39.90	33.15	-18.85 **	-20.69 **	-26.00 **
18	GKD-75 x GKD-45		38.50	39.80	29.90	-22.99 **	-25.06 **	-33.26 **
19	GKD-75 x GKD-77		38.35	39.73	33.90	-16.61 **	-18.12 **	-24.33 **
20	GKD-75 x ASKO-1222		45.10	43.10	30.50	-25.52 **	-27.38 **	-31.92 **
21	GKD-75 x Arka Kalyan		41.50	41.30	41.00	5.53	2.76	-8.48
22	GKD-75 x Line-25		41.60	41.35	34.60	-16.43 **	-19.35 **	-22.77 **
23	GKD-75 x N-53		37.60	39.35	34.80	-8.96	-12.78 *	-22.32 **
24	GKD-75 x Line-13		40.40	40.75	42.70	6.48	5.96	-4.69
25	ASKO-1201 x Cross-5	43.30	38.70	41.00	36.80	-6.84	-11.96 *	-17.86 **
26	ASKO-1201 x GKD-45		38.50	40.90	36.15	-3.54	-4.24	-19.31 **
27	ASKO-1201 x GKD-77		38.35	40.83	43.90	11.70 *	6.04	-2.01
28	ASKO-1201 x ASKO-1222		45.10	44.20	41.10	3.79	-2.14	-8.26
29	ASKO-1201 x Arka Kalyan		41.50	42.40	43.30	15.47 **	14.55 **	-3.35
30	ASKO-1201 x Line-25		41.60	42.45	41.80	4.37	-2.56	-6.70
31	ASKO-1201 x N-53		37.60	40.45	41.50	12.54 *	11.56 *	-7.37
32	ASKO-1201 x Line-13		40.40	41.85	38.70	-0.13	-3.97	-13.62 **
33	ASKO-1299 x Cross-5	41.80	38.70	40.25	38.50	-2.10	-7.89	-14.06 **
34	ASKO-1299 x GKD-45		38.50	40.15	38.35	2.82	1.59	-14.40 **
35	ASKO-1299 x GKD-77		38.35	40.08	45.10	15.27 **	8.94	0.67
36	ASKO-1299 x ASKO-1222		45.10	43.45	41.50	5.26	-1.19	-7.37
37	ASKO-1299 x Arka Kalyan		41.50	41.65	41.60	11.45 *	10.05	-7.14
38	ASKO-1299 x Line-25		41.60	41.70	42.10	5.58	-1.86	-6.03
39	ASKO-1299 x N-53		37.60	39.70	37.60	2.45	2.04	-16.07 **
40	ASKO-1299 x Line-13		40.40	41.10	40.40	4.73	0.25	-9.82 *
	CC (Bhima Shakti)				44.9			
	S.Em. _±				1.43	1.7143	1.9795	1.9795
	C.D. at 5 %				4.06	3.4676	4.0040	4.0040
	C.D. at 1 %				5.42	4.6423	5.3604	5.3604

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

Table 25. Per se performance and magnitude of heterosis for leaf length at 30 days after transplanting during rabi

Sl. No.	Entries	Leaf length at 30 days after transplanting						
		Per se value (cm)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	28.80	31.70	30.25	30.75	-17.23 **	-18.65 **	-27.65 **
2	Kumata local x GKD-45		31.90	30.35	32.60	-7.52 *	-13.76 **	-23.29 **
3	Kumata local x GKD-77		31.50	30.15	31.00	-17.55 **	-17.99 **	-27.06 **
4	Kumata local x ASKO-1222		38.60	33.70	31.20	-14.87 **	-17.46 **	-26.59 **
5	Kumata local x Arka Kalyan		35.60	32.20	36.70	7.78 *	-2.91	-13.65 **
6	Kumata local x Line-25		35.50	32.15	35.70	-2.99	-5.56	-16.00 **
7	Kumata local x N-53		37.00	32.90	37.60	10.26 **	-0.53	-11.53 **
8	Kumata local x Line-13		37.50	33.15	32.15	-10.13 **	-14.95 **	-24.35 **
9	Bhima Shakti x Cross 5	36.80	31.70	34.25	33.40	-6.57 *	-8.49 *	-21.41 **
10	Bhima Shakti x GKD-45		31.90	34.35	28.10	-16.99 **	-19.71 **	-33.88 **
11	Bhima Shakti x GKD-77		31.50	34.15	28.60	-20.99 **	-23.53 **	-32.71 **
12	Bhima Shakti x ASKO-1222		38.60	37.70	31.50	-10.64 **	-11.27 **	-25.88 **
13	Bhima Shakti x Arka Kalyan		35.60	36.20	29.20	-10.57 **	-16.57 **	-31.29 **
14	Bhima Shakti x Line-25		35.50	36.15	29.40	-16.95 **	-17.88 **	-30.82 **
15	Bhima Shakti x N-53		37.00	36.90	28.60	-12.54 **	-18.29 **	-32.71 **
16	Bhima Shakti x Line-13		37.50	37.15	31.00	-9.82 **	-11.43 **	-27.06 **
17	GKD-75 x Cross-5	34.30	31.70	33.00	33.50	-7.14 *	-8.22 *	-21.18 **
18	GKD-75 x GKD-45		31.90	33.10	30.10	-11.92 **	-15.57 **	-29.18 **
19	GKD-75 x GKD-77		31.50	32.90	34.70	-5.00	-7.22 *	-18.35 **
20	GKD-75 x ASKO-1222		38.60	36.45	31.80	-10.61 **	-10.80 **	-25.18 **
21	GKD-75 x Arka Kalyan		35.60	34.95	33.40	1.29	-6.31	-21.41 **
22	GKD-75 x Line-25		35.50	34.90	28.40	-20.50 **	-20.67 **	-33.18 **
23	GKD-75 x N-53		37.00	35.65	28.80	-12.79 **	-19.21 **	-32.24 **
24	GKD-75 x Line-13		37.50	35.90	34.40	-0.86	-3.51	-19.06 **
25	ASKO-1201 x Cross-5	35.80	31.70	33.75	27.60	-19.88 **	-24.38 **	-35.06 **
26	ASKO-1201 x GKD-45		31.90	33.85	28.80	-11.52 **	-11.93 **	-32.24 **
27	ASKO-1201 x GKD-77		31.50	33.65	36.80	5.44	-1.60	-13.41 **
28	ASKO-1201 x ASKO-1222		38.60	37.20	34.30	1.03	-3.38	-19.29 **
29	ASKO-1201 x Arka Kalyan		35.60	35.70	35.80	14.19 **	10.49 *	-15.76 **
30	ASKO-1201 x Line-25		35.50	35.65	31.90	-6.45	-10.89 **	-24.94 **
31	ASKO-1201 x N-53		37.00	36.40	30.90	-1.59	-4.63	-27.29 **
32	ASKO-1201 x Line-13		37.50	36.65	31.70	-4.16	-6.07	-25.41 **
33	ASKO-1299 x Cross-5	31.90	31.70	31.80	31.90	-16.38 **	-19.85 **	-24.94 **
34	ASKO-1299 x GKD-45		31.90	31.90	31.50	-13.10 **	-20.85 **	-25.88 **
35	ASKO-1299 x GKD-77		31.50	31.70	38.60	0.00	-3.02	-9.18 **
36	ASKO-1299 x ASKO-1222		38.60	35.25	35.60	-5.44	-10.55 **	-16.24 **
37	ASKO-1299 x Arka Kalyan		35.60	33.75	35.50	1.28	-10.80 **	-16.47 **
38	ASKO-1299 x Line-25		35.50	33.70	36.60	-3.17	-8.04 *	-13.88 **
39	ASKO-1299 x N-53		37.00	34.45	37.00	5.41	-7.04 *	-12.94 **
40	ASKO-1299 x Line-13		37.50	34.70	37.50	1.97	-5.78	-11.76 **
	CC (Bhima Shakti)				43.5			
	S.Em.±				1.69	1.1197	1.2929	1.2929
	C.D. at 5 %				4.80	2.2648	2.6152	2.6152
	C.D. at 1 %				6.40	3.0321	3.5011	3.5011

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

Table 26. Per se performance and magnitude of heterosis for number of leaves at 30 days after transplanting during rabi

Sl. No.	Entries	Number of leaves at 30 days after transplanting						
		Per se value				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	5.70	5.85	5.78	6.05	10.00	9.01	6.14
2	Kumata local x GKD-45		5.65	5.68	5.65	-5.04	-12.40	-0.88
3	Kumata local x GKD-77		3.50	4.60	5.25	-8.70	-13.22	-7.89
4	Kumata local x ASKO-1222		5.80	5.75	5.50	-5.98	-12.00	-3.51
5	Kumata local x Arka Kalyan		6.30	6.00	5.40	-1.37	-1.82	-5.26
6	Kumata local x Line-25		5.30	5.50	5.90	-3.67	-13.24	3.51
7	Kumata local x N-53		6.05	5.88	6.15	6.49	0.82	7.89
8	Kumata local x Line-13		5.55	5.63	6.25	11.61	8.70	9.65
9	Bhima Shakti x Cross 5	5.60	5.85	5.73	5.85	-2.90	-10.00	2.63
10	Bhima Shakti x GKD-45		5.65	5.63	5.30	-18.15 *	-18.46 *	-7.02
11	Bhima Shakti x GKD-77		3.50	4.55	5.10	-18.73 *	-21.54 *	-10.53
12	Bhima Shakti x ASKO-1222		5.80	5.70	6.00	-5.88	-7.69	5.26
13	Bhima Shakti x Arka Kalyan		6.30	5.95	5.50	-8.33	-15.38	-3.51
14	Bhima Shakti x Line-25		5.30	5.45	6.75	1.50	-0.74	18.42
15	Bhima Shakti x N-53		6.05	5.83	7.05	11.90	8.46	23.68 *
16	Bhima Shakti x Line-13		5.55	5.58	5.25	-14.29	-19.23 *	-7.89
17	GKD-75 x Cross-5	6.10	5.85	5.98	4.85	-18.14 *	-23.02 *	-14.91
18	GKD-75 x GKD-45		5.65	5.88	5.70	-10.59	-11.63	0.00
19	GKD-75 x GKD-77		3.50	4.80	6.00	-2.83	-4.76	5.26
20	GKD-75 x ASKO-1222		5.80	5.95	5.90	-5.98	-6.35	3.51
21	GKD-75 x Arka Kalyan		6.30	6.20	4.85	-17.80 *	-23.02 *	-14.91
22	GKD-75 x Line-25		5.30	5.70	6.05	-7.63	-11.03	6.14
23	GKD-75 x N-53		6.05	6.08	5.60	-9.68	-11.11	-1.75
24	GKD-75 x Line-13		5.55	5.83	5.45	-9.54	-13.49	-4.39
25	ASKO-1201 x Cross-5	5.25	5.85	5.55	5.55	3.26	0.00	-2.63
26	ASKO-1201 x GKD-45		5.65	5.45	5.70	-2.15	-11.63	0.00
27	ASKO-1201 x GKD-77		3.50	4.38	5.60	-0.44	-7.44	-1.75
28	ASKO-1201 x ASKO-1222		5.80	5.53	6.10	6.55	-2.40	7.02
29	ASKO-1201 x Arka Kalyan		6.30	5.78	5.25	-1.87	-4.55	-7.89
30	ASKO-1201 x Line-25		5.30	5.28	6.05	0.83	-11.03	6.14
31	ASKO-1201 x N-53		6.05	5.65	5.65	0.00	-7.38	-0.88
32	ASKO-1201 x Line-13		5.55	5.40	5.85	6.85	1.74	2.63
33	ASKO-1299 x Cross-5	6.05	5.85	5.95	5.65	-3.00	-7.38	-0.88
34	ASKO-1299 x GKD-45		5.65	5.85	3.50	-44.22 **	-45.74 **	-38.60 **
35	ASKO-1299 x GKD-77		3.50	4.78	5.80	-4.53	-4.92	1.75
36	ASKO-1299 x ASKO-1222		5.80	5.93	6.30	2.02	0.80	10.53
37	ASKO-1299 x Arka Kalyan		6.30	6.18	5.30	-8.62	-13.11	-7.02
38	ASKO-1299 x Line-25		5.30	5.68	5.10	-20.93 **	-25.00 **	-10.53
39	ASKO-1299 x N-53		6.05	6.05	6.05	-0.82	-0.82	6.14
40	ASKO-1299 x Line-13		5.55	5.80	5.55	-6.33	-9.02	-2.63
	CC (Bhima Shakti)				5.75			
	S.Em. _±				0.40	0.4864	0.5617	0.5617
	C.D. at 5 %				1.14	0.9839	1.1361	1.1361
	C.D. at 1 %				1.52	1.3172	1.5210	1.5210

* and ** indicates significant at 5 and 1 % respectively
MP-Mid parent, BP-Better parent, CC-Commercial check

The magnitude of heterosis over mid parent range between -15.36 per cent (Bhima Shakti x ASKO-1222) to 15.47 per cent (ASKO-1201 x Arka Kalyan). The range for heterosis over better parent varied from -21.85 per cent (Bhima Shakti x Arka Kalyan) to 12.20 per cent (ASKO-1201 x Arka Kalyan). None of the hybrids showed significant positive heterosis over commercial check.

4.5.5 Leaf length at 60 days after transplanting (Table 28)

The performance of hybrids for leaf length at 60 DAT point that the entry ASKO-1299 x Arka Kalyan was found to have the higher leaf length (51.40 cm). This was the only hybrid which recorded at par leaf length with the commercial check (Bhima Shakti). Among the lines (female), Kumata local has higher leaf length (47.90 cm). While among testers (male), it was Line-25 (51.40 cm).

The hybrid ASKO-1299 x Arka Kalyan exhibited the highest heterosis over mid parent (25.98 %). Further, the cross combination Kumata local x Arka Kalyan recorded highest significant heterosis over better parent (15.48 %).

The number of hybrids which showed positive heterosis were 22 over mid parent, 13 over better parent. None of the hybrids showed significant positive heterosis over commercial check.

4.5.6 Number of leaves at 60 days after transplanting (Table 29)

The data on number of leaves revealed that range among the parents was between 5.5 (Arka Kalyan) and 7.10 (ASKO-1222). Range among the hybrids was from 5.40 (Kumata local x ASKO-1222) to 7.40 (Bhima Shakti x N-53 and Bhima Shakti x Line-25). Twelve hybrids were at par with Bhima Shakti x N-53.

Out of 40 hybrid crosses, four crosses showed significant negative heterosis and two showed significant positive heterosis over mid parent and highest value was recorded by cross Kumata local x Line-13(15.00 %). The extent of heterosis over better parent was from -19.72 per cent (Kumata local x Line-25) to 15.00 per cent (Kumata local x Line-13). None of the hybrids recorded the significant positive heterosis over commercial check.

4.5.7 Polar diameter (Table 30)

The *per se* value for this trait indicated that the parents varied from 4.53 cm (Kumata local) to 5.39 cm (GKD-77). The value for hybrids was in the range of 4.58 cm (Bhima Shakti x ASKO-1222) to 5.90 cm (ASKO-1299 x GKD-77).

Out of 40 cross combinations, 15 crosses exhibited significant positive heterosis over the mid parent. The range was from -10.13 per cent (ASKO-1299 x ASKO-1222) to 17.39 per cent (ASKO-1201 x N-53). Ten hybrids showed significant positive heterosis over better parent. The range was from -13.70 per cent (ASKO-1299 x ASKO-1222) to 14.45 per cent (ASKO-1201 x N-53). None of the hybrids showed significant negative heterosis over commercial check, highest positive value was showed by ASKO-1299 x GKD-77 (29.92 %).

4.5.8 Equatorial diameter (Table 31)

Among the parents, ASKO-1201 (5.48 cm) recorded the higher equatorial diameter of bulb and lower was by Kumata local (4.78 cm). The values of hybrids was in the range of 4.40 cm (Bhima Shakti x ASKO-1222) to 5.93 cm (GKD-75 x GKD-77).

Table 27. Per se performance and magnitude of heterosis for plant height at 60 days after transplanting

Sl. No.	Entries	Plant height at 60 days after transplanting						
		Per se value (cm)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	54.70	50.70	52.70	52.20	-5.09 **	-7.12 **	-6.45 **
2	Kumata local x GKD-45		51.60	53.15	51.90	-0.67	-7.65 **	-6.99 **
3	Kumata local x GKD-77		44.70	49.70	51.00	-9.25 **	-9.25 **	-8.60 **
4	Kumata local x ASKO-1222		50.70	52.70	49.80	-8.29 **	-11.39 **	-10.75 **
5	Kumata local x Arka Kalyan		49.70	52.20	52.92	6.38 **	-5.83 **	-5.15 *
6	Kumata local x Line-25		55.60	55.15	52.50	1.25	-6.58 **	-5.91 **
7	Kumata local x N-53		51.10	52.90	52.20	2.55	-7.12 **	-6.45 **
8	Kumata local x Line-13		55.80	55.25	51.40	-3.47	-8.54 **	-7.89 **
9	Bhima Shakti x Cross 5	52.70	50.70	51.70	52.10	-5.36 **	-7.46 **	-6.63 **
10	Bhima Shakti x GKD-45		51.60	52.15	50.70	-3.06	-9.95 **	-9.14 **
11	Bhima Shakti x GKD-77		44.70	48.70	47.00	-16.44**	-16.52 **	-15.77 **
12	Bhima Shakti x ASKO-1222		50.70	51.70	46.00	-15.36 **	-18.29 **	-17.56 **
13	Bhima Shakti x Arka Kalyan		49.70	51.20	44.00	-11.65 **	-21.85 **	-21.15 **
14	Bhima Shakti x Line-25		55.60	54.15	52.80	1.73	-6.22 **	-5.38 *
15	Bhima Shakti x N-53		51.10	51.90	50.00	-1.86	-11.19 **	-10.39 **
16	Bhima Shakti x Line-13		55.80	54.25	54.80	2.81	-2.66	-1.79
17	GKD-75 x Cross-5	51.50	50.70	51.10	48.10	-6.87 **	-10.59 **	-13.80 **
18	GKD-75 x GKD-45		51.60	51.55	48.80	-0.20	-1.41	-12.54 **
19	GKD-75 x GKD-77		44.70	48.10	50.10	-5.20 *	-10.85 **	-10.22 **
20	GKD-75 x ASKO-1222		50.70	51.10	53.30	4.61 *	1.72	-4.48 *
21	GKD-75 x Arka Kalyan		49.70	50.60	52.00	12.07 **	5.05 *	-6.81 **
22	GKD-75 x Line-25		55.60	53.55	44.90	-7.42 **	-9.29 **	-19.53 **
23	GKD-75 x N-53		51.10	51.30	46.60	-2.00	-5.86 *	-16.49 **
24	GKD-75 x Line-13		55.80	53.65	51.40	3.01	2.19	-7.89 **
25	ASKO-1201 x Cross-5	49.70	50.70	50.20	50.30	0.90	-6.51 **	-9.86 **
26	ASKO-1201 x GKD-45		51.60	50.65	47.40	0.64	-1.86	-15.05 **
27	ASKO-1201 x GKD-77		44.70	47.20	54.70	7.15 **	-2.67	-1.97
28	ASKO-1201 x ASKO-1222		50.70	50.20	52.70	7.22 **	0.57	-5.56 *
29	ASKO-1201 x Arka Kalyan		49.70	49.70	51.50	15.47 **	12.20 **	-7.71 **
30	ASKO-1201 x Line-25		55.60	52.65	49.70	6.42 **	4.63	-10.93 **
31	ASKO-1201 x N-53		51.10	50.40	49.30	7.76 **	7.41 **	-11.65 **
32	ASKO-1201 x Line-13		55.80	52.75	48.80	1.46	-2.98	-12.54 **
33	ASKO-1299 x Cross-5	48.80	50.70	49.75	50.70	-5.41 **	-5.76 *	-9.14 **
34	ASKO-1299 x GKD-45		51.60	50.20	51.60	1.47	-3.37	-7.53 **
35	ASKO-1299 x GKD-77		44.70	46.75	50.60	18.43**	16.46 **	-9.89 **
36	ASKO-1299 x ASKO-1222		50.70	49.75	50.70	-4.16 *	-5.06 *	-9.14 **
37	ASKO-1299 x Arka Kalyan		49.70	49.25	49.70	2.79	-6.93 **	-10.93 **
38	ASKO-1299 x Line-25		55.60	52.20	55.60	10.21 **	4.12	-0.36
39	ASKO-1299 x N-53		51.10	49.95	55.60	12.32 **	4.12	-0.36
40	ASKO-1299 x Line-13		55.80	52.30	51.10	-1.45	-4.31	-8.42 **
	CC (Bhima Shakti)				56.25			
	S.Em.+				1.97	1.0251	1.1837	1.1837
	C.D. at 5 %				5.60	2.0735	2.3943	2.3943
	C.D. at 1 %				7.46	2.7760	3.2054	3.2054

* and ** indicates significant at 5 and 1 % respectively
MP-Mid parent, BP-Better parent, CC-Commercial check

Table 28. Per se performance and magnitude of heterosis for leaf length at 60 days after transplanting during rabi

Sl. No.	Entries	Leaf length at 60 days transplanting						
		Per se value(cm)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	47.90	44.00	45.95	43.20	-2.15	-6.70 **	-14.96 **
2	Kumata local x GKD-45		44.50	46.20	43.90	7.86 **	4.52	-13.58 **
3	Kumata local x GKD-77		45.60	46.75	44.60	1.36	-3.04	-12.20 **
4	Kumata local x ASKO-1222		45.20	46.55	43.60	0.58	-2.46	-14.17 **
5	Kumata local x Arka Kalyan		43.00	45.45	48.50	22.78 **	15.48 **	-4.53 *
6	Kumata local x Line-25		51.40	49.65	47.60	14.01 **	13.33 **	-6.30 **
7	Kumata local x N-53		44.70	46.30	46.00	14.43 **	9.52 **	-9.45 **
8	Kumata local x Line-13		49.80	48.85	45.30	5.84 *	3.90	-10.83 **
9	Bhima Shakti x Cross 5	46.90	44.00	45.45	46.60	-2.20	-4.90 *	-8.27 **
10	Bhima Shakti x GKD-45		44.50	45.70	44.70	1.13	-8.78 **	-12.01 **
11	Bhima Shakti x GKD-77		45.60	46.25	41.40	-12.84 **	-15.51 **	-18.50 **
12	Bhima Shakti x ASKO-1222		45.20	46.05	41.90	-10.57 **	-14.49 **	-17.52 **
13	Bhima Shakti x Arka Kalyan		43.00	44.95	39.40	-8.37 **	-19.59 **	-22.44 **
14	Bhima Shakti x Line-25		51.40	49.15	46.40	2.54	-5.31 *	-8.66 **
15	Bhima Shakti x N-53		44.70	45.80	42.60	-2.52	-13.06 **	-16.14 **
16	Bhima Shakti x Line-13		49.80	48.35	47.20	1.94	-3.67	-7.09 **
17	GKD-75 x Cross-5	45.40	44.00	44.70	42.80	-3.28	-7.56 **	-15.75 **
18	GKD-75 x GKD-45		44.50	44.95	44.80	9.80 **	6.16 *	-11.81 **
19	GKD-75 x GKD-77		45.60	45.50	47.10	6.80 **	2.39	-7.28 **
20	GKD-75 x ASKO-1222		45.20	45.30	47.10	8.40 **	5.37 *	-7.28 **
21	GKD-75 x Arka Kalyan		43.00	44.20	40.90	3.28	-3.08	-19.49 **
22	GKD-75 x Line-25		51.40	48.40	45.60	8.96 **	8.06 **	-10.24 **
23	GKD-75 x N-53		44.70	45.05	44.20	9.68 **	4.74	-12.99 **
24	GKD-75 x Line-13		49.80	47.60	42.30	-1.40	-2.98	-16.73 **
25	ASKO-1201 x Cross-5	43.50	44.00	43.75	40.70	-3.90	-12.10 **	-19.88 **
26	ASKO-1201 x GKD-45		44.50	44.00	47.90	23.14 **	21.57 **	-5.71 *
27	ASKO-1201 x GKD-77		45.60	44.55	46.90	11.14 **	1.96	-7.68 **
28	ASKO-1201 x ASKO-1222		45.20	44.35	45.40	9.27 **	1.57	-10.63 **
29	ASKO-1201 x Arka Kalyan		43.00	43.25	43.50	15.38 **	13.28 **	-14.37 **
30	ASKO-1201 x Line-25		51.40	47.45	44.00	10.14 **	6.02 *	-13.39 **
31	ASKO-1201 x N-53		44.70	44.10	43.20	12.50 **	12.50 **	-14.96 **
32	ASKO-1201 x Line-13		49.80	46.65	44.00	7.32 **	0.92	-13.39 **
33	ASKO-1299 x Cross-5	44.00	44.00	44.00	44.50	-2.09	-3.89	-12.40 **
34	ASKO-1299 x GKD-45		44.50	44.25	45.60	8.57 **	2.24	-10.24 **
35	ASKO-1299 x GKD-77		45.60	44.80	45.20	-0.22	-1.74	-11.02 **
36	ASKO-1299 x ASKO-1222		45.20	44.60	43.00	-3.70	-3.80	-15.35 **
37	ASKO-1299 x Arka Kalyan		43.00	43.50	51.40	25.98 **	15.25 **	1.18
38	ASKO-1299 x Line-25		51.40	47.70	50.90	18.23 **	14.13 **	0.20
39	ASKO-1299 x N-53		44.70	44.35	44.70	7.71 **	0.22	-12.01 **
40	ASKO-1299 x Line-13		49.80	46.90	49.80	12.93 **	11.66 **	-1.97
	CC (Bhima Shakti)				51.2			
	S.Em. ±				1.70	0.9557	1.1035	1.1035
	C.D. at 5 %				4.82	1.9331	2.2321	2.2321
	C.D. at 1 %				6.43	2.5879	2.9883	2.9883

* and ** indicates significant at 5 and 1 % respectively
MP-Mid parent, BP-Better parent, CC-Commercial check

Table 29. Per se performance and magnitude of heterosis for number of leaves at 60 days after transplanting during rabi

Sl. No.	Entries	Number of leaves at 60 days after transplanting						
		Per se value				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	5.70	6.80	6.25	6.10	0.00	-1.61	-7.58
2	Kumata local x GKD-45		6.90	6.30	5.80	-4.92	-6.45	-12.12
3	Kumata local x GKD-77		6.00	5.85	6.60	6.45	3.13	0.00
4	Kumata local x ASKO-1222		7.10	6.40	5.40	-14.29 *	-18.18 **	-18.18 **
5	Kumata local x Arka Kalyan		5.50	5.60	6.40	4.92	3.23	-3.03
6	Kumata local x Line-25		7.10	6.40	5.70	-12.98 *	-19.72 **	-13.64 *
7	Kumata local x N-53		6.20	5.95	6.60	3.94	-1.49	0.00
8	Kumata local x Line-13		6.30	6.00	6.90	15.00 *	15.00 *	4.55
9	Bhima Shakti x Cross 5	6.00	6.80	6.40	6.80	1.49	-5.56	3.03
10	Bhima Shakti x GKD-45		6.90	6.45	6.30	-5.97	-12.50 *	-4.55
11	Bhima Shakti x GKD-77		6.00	6.00	6.50	-4.41	-9.72	-1.52
12	Bhima Shakti x ASKO-1222		7.10	6.55	6.00	-13.04 *	-16.67 **	-9.09
13	Bhima Shakti x Arka Kalyan		5.50	5.75	6.10	-8.96	-15.28 *	-7.58
14	Bhima Shakti x Line-25		7.10	6.55	7.40	3.50	2.78	12.12
15	Bhima Shakti x N-53		6.20	6.10	7.40	6.47	2.78	12.12
16	Bhima Shakti x Line-13		6.30	6.15	5.90	-10.61	-18.06 **	-10.61
17	GKD-75 x Cross-5	5.90	6.80	6.35	6.10	-5.43	-8.96	-7.58
18	GKD-75 x GKD-45		6.90	6.40	6.50	0.78	-2.99	-1.52
19	GKD-75 x GKD-77		6.00	5.95	7.10	8.40	5.97	7.58
20	GKD-75 x ASKO-1222		7.10	6.50	6.20	-6.77	-7.46	-6.06
21	GKD-75 x Arka Kalyan		5.50	5.70	6.50	0.78	-2.99	-1.52
22	GKD-75 x Line-25		7.10	6.50	6.30	-8.70	-11.27	-4.55
23	GKD-75 x N-53		6.20	6.05	6.10	-8.96	-8.96	-7.58
24	GKD-75 x Line-13		6.30	6.10	6.90	8.66	2.99	4.55
25	ASKO-1201 x Cross-5	6.20	6.80	6.50	5.90	-5.60	-6.35	-10.61
26	ASKO-1201 x GKD-45		6.90	6.55	5.70	-8.80	-9.52	-13.64 *
27	ASKO-1201 x GKD-77		6.00	6.10	6.00	-5.51	-6.25	-9.09
28	ASKO-1201 x ASKO-1222		7.10	6.65	5.90	-8.53	-10.61	-10.61
29	ASKO-1201 x Arka Kalyan		5.50	5.85	6.20	-0.80	-1.59	-6.06
30	ASKO-1201 x Line-25		7.10	6.65	6.30	-5.97	-11.27	-4.55
31	ASKO-1201 x N-53		6.20	6.20	6.20	-4.62	-7.46	-6.06
32	ASKO-1201 x Line-13		6.30	6.25	6.80	10.57	7.94	3.03
33	ASKO-1299 x Cross-5	6.30	6.80	6.55	6.90	10.40	9.52	4.55
34	ASKO-1299 x GKD-45		6.90	6.60	6.00	-4.00	-4.76	-9.09
35	ASKO-1299 x GKD-77		6.00	6.15	7.10	11.81	10.94	7.58
36	ASKO-1299 x ASKO-1222		7.10	6.70	5.50	-14.73 *	-16.67 *	-16.67 *
37	ASKO-1299 x Arka Kalyan		5.50	5.90	7.10	13.60 *	12.70	7.58
38	ASKO-1299 x Line-25		7.10	6.70	7.10	5.97	0.00	7.58
39	ASKO-1299 x N-53		6.20	6.25	6.20	-4.62	-7.46	-6.06
40	ASKO-1299 x Line-13		6.30	6.30	6.30	2.44	0.00	-4.55
	CC (Bhima Shakti)				6.65			
	S.Em.+				0.31	0.3724	0.4300	0.4300
	C.D. at 5 %				0.89	0.7532	0.8698	0.8698
	C.D. at 1 %				1.19	1.0084	1.1644	1.1644

* and ** indicates significant at 5 and 1 % respectively
MP-Mid parent, BP-Better parent, CC-Commercial check

Heterosis over mid parent exhibited by the hybrids for equatorial diameter was in the range of -14.45 per cent (Bhima Shakti x ASKO-1222) to 11.96 per cent (Kumata local x GKD-45). GKD-75 x GKD-77 cross showed significant positive heterosis over better parent (10.63 %) and over commercial check (18.30 %).

4.5.9 P/E ratio (Table 32)

Parents displayed variation for this trait, which dispersed between 0.88 in line GKD-75 to 1.10 in tester ASKO-1222. Among hybrids, the range was between 0.88 in GKD-75 x GKD-77 to 1.21 in cross Bhima Shakti x Arka Kalyan and Bhima Shakti x ASKO-1222.

Out of 40 hybrid crosses, one cross showed significant positive heterosis over mid parent viz., Kumata local x N-53 (29.14 %). Seven crosses showed significant positive heterosis over commercial check, the highest heterosis over commercial check was given by the crosses Bhima Shakti x ASKO-1222 and Bhima Shakti x Arka Kalyan (39.08 %), and none of the hybrids towards negative direction. None of the hybrids showed significant positive heterosis over better parent.

4.5.10 Neck thickness (Table 33)

ASKO-1299 female parent has a lower neck thickness of 1.03 cm. Bhima Shakti showed higher neck thickness of 1.17 cm among lines. Whereas, among testers values dispersed from 0.60 cm (Cross-5) to 1.22 cm (N-53). In hybrids, cross ASKO-1299 x GKD-77 showed lower neck thickness of 0.97 cm and higher neck thickness of 1.32 cm was given by Kumata local x Line-25 and Kumata local x Cross-5.

The heterosis over mid parent range between -17.35 per cent (ASKO-1201 x Line-13) to 23.63 per cent (Kumata local x Cross-5). The range for heterosis over better parent varied from -18.74 per cent (ASKO-1201 x Line-25) to 19.33 per cent (Kumata local x Cross-5). The range for heterosis over commercial check varied from -20.08 per cent (ASKO-1299 x GKD-77) to 8.81 per cent (Kumata local x Cross-5). The cross Kumata local x Cross-5 showed significant positive heterosis over mid parent, better parent and commercial check followed by Kumata local x Line-25.

4.5.11 Total soluble solids (Table 34)

The TSS among the parents range between 8.50 °Brix (GKD-45) to 12.35 °Brix (ASKO-1299), while in hybrids it was found between 7.75 °Brix (Kumata local x Line-13) to 12.50 °Brix (ASKO-1201 x Cross-5).

The manifestation of heterosis range from -36.17 per cent (Bhima Shakti x GKD-45) to 26.48 per cent (GKD-75 x N-53) over mid parent. Among the 40 hybrids, five crosses showed significant positive heterosis, while 19 cross had significant negative heterosis over mid parent.

With respect to heterosis over better parent, the variation was from -46.27 per cent (Bhima Shakti x GKD-45) to 17.14 per cent (GKD-75 x N-53). Among the total hybrids, none of the hybrids showed significant positive heterosis over commercial check.

Table 30. Per se performance and magnitude of heterosis for polar diameter during rabi

Sl. No.	Entries	Polar diameter						
		Per se value(cm)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	4.53	4.83	4.68	4.65	-0.75	-3.83	2.37
2	Kumata local x GKD-45		4.98	4.76	5.30	11.43 **	6.37 **	16.80 **
3	Kumata local x GKD-77		5.39	4.96	5.09	2.67	-5.52 **	12.23 **
4	Kumata local x ASKO-1222		4.92	4.73	4.98	5.40 **	1.22	9.75 **
5	Kumata local x Arka Kalyan		5.18	4.86	4.81	-0.93	-7.14 **	6.01 **
6	Kumata local x Line-25		5.33	4.93	5.33	8.22 **	0.12	17.55 **
7	Kumata local x N-53		4.88	4.71	5.28	12.21 **	8.19 **	16.35 **
8	Kumata local x Line-13		5.24	4.89	5.50	12.63 **	5.00 **	21.26 **
9	Bhima Shakti x Cross 5	5.01	4.83	4.92	5.07	3.05	1.20	11.74 **
10	Bhima Shakti x GKD-45		4.98	5.00	5.30	5.98 **	5.69 **	16.69 **
11	Bhima Shakti x GKD-77		5.39	5.20	5.19	-0.24	-3.76 *	14.33 **
12	Bhima Shakti x ASKO-1222		4.92	4.97	4.58	-7.85 **	-8.68 **	0.83
13	Bhima Shakti x Arka Kalyan		5.18	5.10	5.52	13.64 **	11.78 **	27.60 **
14	Bhima Shakti x Line-25		5.33	5.17	5.26	1.81	-1.22	15.98 **
15	Bhima Shakti x N-53		4.88	4.95	4.69	-5.16 **	-6.39 **	3.36
16	Bhima Shakti x Line-13		5.24	5.13	5.88	10.83 **	10.40 **	29.45 **
17	GKD-75 x Cross-5	5.19	4.83	5.01	5.40	11.63 **	7.81 **	22.20 **
18	GKD-75 x GKD-45		4.98	5.09	5.31	4.40 **	2.36	16.97 **
19	GKD-75 x GKD-77		5.39	5.29	5.22	-1.28	-3.15	15.04 **
20	GKD-75 x ASKO-1222		4.92	5.06	5.19	2.72	0.10	14.38 **
21	GKD-75 x Arka Kalyan		5.18	5.19	5.35	3.25 *	3.20	17.93 **
22	GKD-75 x Line-25		5.33	5.26	4.87	-7.40 **	-8.63 **	7.27 **
23	GKD-75 x N-53		4.88	5.04	4.63	-8.10 **	-10.80 **	1.93
24	GKD-75 x Line-13		5.24	5.22	5.03	-3.50 *	-4.01 *	10.85 **
25	ASKO-1201 x Cross-5	5.14	4.83	4.99	4.66	-6.45 **	-9.25 **	2.75
26	ASKO-1201 x GKD-45		4.98	5.06	5.02	-0.79	-2.29	10.63 **
27	ASKO-1201 x GKD-77		5.39	5.27	5.65	6.78**	7.8**	28.94 **
28	ASKO-1201 x ASKO-1222		4.92	5.03	5.16	2.61	0.44	13.72 **
29	ASKO-1201 x Arka Kalyan		5.18	5.16	5.09	-1.34	-1.75	12.17 **
30	ASKO-1201 x Line-25		5.33	5.24	4.93	-5.78 **	-7.46 **	8.65 **
31	ASKO-1201 x N-53		4.88	5.01	5.35	17.39 **	14.45 **	19.59 **
32	ASKO-1201 x Line-13		5.24	5.19	5.78	13.61 **	12.50 **	29.18 **
33	ASKO-1299 x Cross-5	5.35	4.83	5.09	4.99	-1.97	-6.69 **	9.92 **
34	ASKO-1299 x GKD-45		4.98	5.17	4.81	-6.95 **	-10.10 **	5.90 **
35	ASKO-1299 x GKD-77		5.39	5.37	5.90	9.91**	10.48**	29.92 **
36	ASKO-1299 x ASKO-1222		4.92	5.14	4.61	-10.13 **	-13.70 **	1.65
37	ASKO-1299 x Arka Kalyan		5.18	5.27	4.86	-7.65 **	-9.07 **	7.11 **
38	ASKO-1299 x Line-25		5.33	5.34	4.98	-6.68 **	-6.83 **	9.75 **
39	ASKO-1299 x N-53		4.88	5.12	5.15	0.73	-3.65 *	13.50 **
40	ASKO-1299 x Line-13		5.24	5.30	4.93	-6.90 **	-7.81 **	8.60 **
	CC (Bhima Shakti)				4.66			
	S.Em.±				0.07	0.080	0.092	0.092
	C.D. at 5 %				0.19	0.161	0.186	0.186
	C.D. at 1 %				0.25	0.216	0.250	0.250

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

Table 31. Per se performance and magnitude of heterosis equatorial diameter during *rabi*

Sl. No.	Entries	Equatorial diameter						
		Per se value(cm)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	4.78	4.98	4.88	4.70	-3.76 **	-5.72 **	-6.28 **
2	Kumata local x GKD-45		5.16	4.97	5.57	11.96 **	7.84 **	11.01 **
3	Kumata local x GKD-77		5.36	5.07	5.14	1.38	-4.10 **	2.54
4	Kumata local x ASKO-1222		5.11	4.95	4.53	-8.39 **	-11.35 **	-9.63 **
5	Kumata local x Arka Kalyan		5.24	5.01	5.03	0.40	-4.01 **	0.35
6	Kumata local x Line-25		5.27	5.03	4.96	-1.29	-5.88 **	-1.05
7	Kumata local x N-53		5.24	5.01	4.86	-2.99 *	-7.25 **	-3.04 *
8	Kumata local x Line-13	5.17	5.25	5.02	5.00	-0.38	-4.84 **	-0.33
9	Bhima Shakti x Cross 5		4.98	5.08	4.87	-4.06 **	-5.80 **	-2.84
10	Bhima Shakti x GKD-45		5.16	5.17	4.83	-6.55 **	-6.64 **	-3.71 *
11	Bhima Shakti x GKD-77		5.36	5.27	4.95	-5.94 **	-7.60 **	-1.20
12	Bhima Shakti x ASKO-1222		5.11	5.14	4.40	-14.45 **	-14.94 **	-12.27 **
13	Bhima Shakti x Arka Kalyan		5.24	5.21	5.28	1.45	0.77	5.35 **
14	Bhima Shakti x Line-25		5.27	5.22	4.66	-10.73 **	-11.57 **	-7.03 **
15	Bhima Shakti x N-53	5.33	5.24	5.21	5.39	3.55 **	2.86 *	7.53 **
16	Bhima Shakti x Line-13		5.25	5.21	5.11	-1.92	-2.67	1.95
17	GKD-75 x Cross-5		4.98	5.16	5.23	1.41	-1.92	4.34 **
18	GKD-75 x GKD-45		5.16	5.25	5.18	-1.26	-2.86 *	3.34 *
19	GKD-75 x GKD-77		5.36	5.35	5.93	10.92 **	10.63 **	18.30 **
20	GKD-75 x ASKO-1222		5.11	5.22	5.63	7.83 **	5.58 **	12.32 **
21	GKD-75 x Arka Kalyan		5.24	5.29	4.98	-5.84 **	-6.66 **	-0.70
22	GKD-75 x Line-25	5.48	5.27	5.30	5.65	6.63 **	6.00 **	12.77 **
23	GKD-75 x N-53		5.24	5.29	4.84	-8.49 **	-9.28 **	-3.49 *
24	GKD-75 x Line-13		5.25	5.29	5.17	-2.32	-3.08 *	3.11 *
25	ASKO-1201 x Cross-5		4.98	5.23	5.02	-4.06 **	-8.44 **	0.15
26	ASKO-1201 x GKD-45		5.16	5.32	5.81	9.18 **	5.97 **	15.91 **
27	ASKO-1201 x GKD-77		5.36	5.42	5.73	5.70 **	4.51 **	14.31 **
28	ASKO-1201 x ASKO-1222		5.11	5.30	4.82	-8.99 **	-12.08 **	-3.84 **
29	ASKO-1201 x Arka Kalyan	5.20	5.24	5.36	5.13	-4.31 **	-6.43 **	2.34
30	ASKO-1201 x Line-25		5.27	5.38	5.10	-5.14 **	-6.98 **	1.75
31	ASKO-1201 x N-53		5.24	5.36	4.88	-8.98 **	-10.99 **	-2.64
32	ASKO-1201 x Line-13		5.25	5.37	5.30	-1.19	-3.28 *	5.79 **
33	ASKO-1299 x Cross-5		4.98	5.09	5.30	4.17 **	2.02	5.79 **
34	ASKO-1299 x GKD-45		5.16	5.18	5.31	2.49 *	2.12	5.89 **
35	ASKO-1299 x GKD-77		5.36	5.28	5.04	-4.48 **	-5.92 **	0.60
36	ASKO-1299 x ASKO-1222	5.11	5.16	4.91	4.91	-4.73 **	-5.53 **	-2.04
37	ASKO-1299 x Arka Kalyan		5.24	5.22	5.15	-1.32	-1.72	2.74
38	ASKO-1299 x Line-25		5.27	5.24	4.86	-7.14 **	-7.78 **	-3.04 *
39	ASKO-1299 x N-53		5.24	5.22	5.23	0.22	-0.19	4.34 **
40	ASKO-1299 x Line-13	5.25	5.23	5.18	5.18	-0.84	-1.33	3.34 *
	CC (Bhima Shakti)							
	S.Em.+				0.05	0.061	0.071	0.166
	C.D. at 5 %				0.14	0.124	0.143	0.143
	C.D. at 1 %				0.19	0.166	0.192	0.192

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

Table 32. Per se performance and magnitude of heterosis for P/E Ratio during rabi

Sl. No.	Entries	P/E Ratio						
		Per se value				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	0.99	0.91	0.95	0.99	9.09	4.76	13.79
2	Kumata local x GKD-45		0.95	0.97	0.98	13.70	3.17	12.07
3	Kumata local x GKD-77		0.90	0.95	1.05	17.75	10.58	20.11
4	Kumata local x ASKO-1222		1.10	1.05	1.16	18.97	15.42	33.33 *
5	Kumata local x Arka Kalyan		1.02	1.01	1.14	13.72	7.55	31.03 *
6	Kumata local x Line-25		0.92	0.96	0.99	5.63	4.23	13.22
7	Kumata local x N-53		1.08	1.04	1.13	29.14 *	19.58	29.89 *
8	Kumata local x Line-13		0.85	0.92	1.11	18.50	16.93	27.01
9	Bhima Shakti x Cross 5	1.00	0.91	0.96	0.99	3.39	-5.26	13.79
10	Bhima Shakti x GKD-45		0.95	0.98	1.10	21.21	5.26	26.44
11	Bhima Shakti x GKD-77		0.90	0.95	1.08	15.20	3.35	24.14
12	Bhima Shakti x ASKO-1222		1.10	1.05	1.21	18.05	15.79	39.08 **
13	Bhima Shakti x Arka Kalyan		1.02	1.01	1.21	14.96	14.15	39.08 **
14	Bhima Shakti x Line-25		0.92	0.96	1.10	11.96	5.26	26.44
15	Bhima Shakti x N-53		1.08	1.04	1.06	14.05	0.96	21.26
16	Bhima Shakti x Line-13		0.85	0.93	1.11	18.50	16.93	27.01
17	GKD-75 x Cross-5	0.88	0.91	0.90	1.00	-1.23	-13.42	14.94
18	GKD-75 x GKD-45		0.95	0.92	0.98	1.82	-15.15	12.64
19	GKD-75 x GKD-77		0.90	0.89	0.88	-11.34	-23.81 *	1.15
20	GKD-75 x ASKO-1222		1.10	0.99	0.90	-17.13	-22.51 *	2.87
21	GKD-75 x Arka Kalyan		1.02	0.95	0.96	-13.32	-16.88	10.34
22	GKD-75 x Line-25		0.92	0.90	0.99	-4.58	-14.29	13.79
23	GKD-75 x N-53		1.08	0.98	1.01	3.06	-12.55	16.09
24	GKD-75 x Line-13		0.85	0.87	1.04	0.24	-9.96	19.54
25	ASKO-1201 x Cross-5	1.00	0.91	0.96	1.00	9.59	4.71	14.94
26	ASKO-1201 x GKD-45		0.95	0.98	1.00	15.36	4.19	14.37
27	ASKO-1201 x GKD-77		0.90	0.95	1.13	5.32	-1.57	29.89*
28	ASKO-1201 x ASKO-1222		1.10	1.05	0.94	-4.08	-6.47	8.05
29	ASKO-1201 x Arka Kalyan		1.02	1.01	1.03	2.23	-2.83	18.39
30	ASKO-1201 x Line-25		0.92	0.96	0.99	5.60	3.66	13.79
31	ASKO-1201 x N-53		1.08	1.04	1.03	17.05	7.85	18.39
32	ASKO-1201 x Line-13		0.85	0.93	1.13	8.80	9.62	29.89*
33	ASKO-1299 x Cross-5	1.06	0.91	0.99	0.92	5.75	5.75	5.75
34	ASKO-1299 x GKD-45		0.95	1.01	1.00	21.95	14.94	14.94
35	ASKO-1299 x GKD-77		0.90	0.98	1.03	25.29	22.41	22.41
36	ASKO-1299 x ASKO-1222		1.10	1.08	0.97	3.47	-3.48	11.49
37	ASKO-1299 x Arka Kalyan		1.02	1.04	1.00	3.63	-5.66	14.94
38	ASKO-1299 x Line-25		0.92	0.99	0.95	6.15	3.26	9.20
39	ASKO-1299 x N-53		1.08	1.07	0.97	15.22	10.92	10.92
40	ASKO-1299 x Line-13		0.85	0.96	0.93	3.35	0.54	6.32
	CC (Bhima Shakti)				0.91			
	S.Em.±				0.07	0.1042	0.1204	0.1204
	C.D. at 5 %				0.20	0.2109	0.2435	0.2435
	C.D. at 1 %				0.27	0.2823	0.3260	0.3260

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

Table 33. Per se performance and magnitude of heterosis for neck thickness during rabi

Sl. No.	Entries	Neck thickness						
		Per se value (cm)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	1.14	0.60	0.87	1.32	23.63 **	19.33 **	8.81 *
2	Kumata local x GKD-45		1.06	1.16	1.16	7.91	4.27	-4.92
3	Kumata local x GKD-77		1.16	1.15	1.28	18.07 **	15.28 **	5.12
4	Kumata local x ASKO-1222		0.97	1.05	1.13	5.34	2.02	-6.97
5	Kumata local x Arka Kalyan		1.08	1.11	1.26	18.59 **	13.26 **	3.28
6	Kumata local x Line-25		0.99	1.06	1.32	18.21 **	17.56 **	8.40 *
7	Kumata local x N-53		1.22	1.18	1.19	1.79	-3.35	-1.97
8	Kumata local x Line-13		1.06	1.10	1.12	-5.97	-11.96 **	-7.99
9	Bhima Shakti x Cross 5	1.17	0.60	0.88	1.13	6.60	4.15	-7.38
10	Bhima Shakti x GKD-45		1.06	1.11	1.28	20.85 **	18.20 **	5.12
11	Bhima Shakti x GKD-77		1.16	1.16	1.17	9.56 *	8.29	-3.69
12	Bhima Shakti x ASKO-1222		0.97	1.07	1.15	8.11	5.99	-5.74
13	Bhima Shakti x Arka Kalyan		1.08	1.12	1.29	23.24 **	19.12 **	5.94
14	Bhima Shakti x Line-25		0.99	1.08	1.22	10.86 **	8.89	0.41
15	Bhima Shakti x N-53		1.22	1.19	1.05	-9.15 *	-14.75 **	-13.52 **
16	Bhima Shakti x Line-13		1.06	1.11	1.25	5.93	-1.96	2.46
17	GKD-75 x Cross-5	1.14	0.60	0.87	1.17	2.74	-6.01	-3.89
18	GKD-75 x GKD-45		1.06	1.09	1.28	12.04 **	2.61	4.92
19	GKD-75 x GKD-77		1.16	1.15	1.24	8.13 *	0.00	2.25
20	GKD-75 x ASKO-1222		0.97	1.05	1.25	9.17 *	0.20	2.46
21	GKD-75 x Arka Kalyan		1.08	1.11	1.19	5.97	-4.01	-1.84
22	GKD-75 x Line-25		0.99	1.06	1.25	5.58	0.40	2.66
23	GKD-75 x N-53		1.22	1.18	1.05	-15.09 **	-15.43 **	-13.52 **
24	GKD-75 x Line-13		1.06	1.10	1.21	-3.87	-4.90	-0.61
25	ASKO-1201 x Cross-5	1.15	0.60	0.87	1.15	-0.56	-10.02 *	-5.74
26	ASKO-1201 x GKD-45		1.06	1.10	1.14	-1.53	-10.80 **	-6.56
27	ASKO-1201 x GKD-77		1.16	1.15	1.16	-0.38	-8.88 *	-4.55
28	ASKO-1201 x ASKO-1222		0.97	1.06	1.13	-1.96	-10.99 **	-6.76
29	ASKO-1201 x Arka Kalyan		1.08	1.11	1.15	0.41	-10.02 *	-5.74
30	ASKO-1201 x Line-25		0.99	1.07	1.03	-13.57 **	-18.74 **	-14.88 **
31	ASKO-1201 x N-53		1.22	1.18	1.05	-16.12 **	-17.45 **	-13.52 **
32	ASKO-1201 x Line-13		1.06	1.10	1.05	-17.35 **	-17.45 **	-13.52 **
33	ASKO-1299 x Cross-5	1.03	0.60	0.82	1.06	-1.28	-4.72	-13.11 **
34	ASKO-1299 x GKD-45		1.06	1.05	1.16	8.37 *	4.72	-4.51
35	ASKO-1299 x GKD-77		1.16	1.10	0.97	-10.24 *	-12.36 **	-20.08 **
36	ASKO-1299 x ASKO-1222		0.97	1.01	1.08	0.51	-2.65	-11.23 **
37	ASKO-1299 x Arka Kalyan		1.08	1.06	0.99	-6.12	-10.34 *	-18.24 **
38	ASKO-1299 x Line-25		0.99	1.01	1.11	-0.56	-1.11	-8.81 *
39	ASKO-1299 x N-53		1.22	1.13	1.22	4.26	-1.01	0.41
40	ASKO-1299 x Line-13		1.06	1.05	1.06	-10.79 **	-16.47 **	-12.70 **
	CC (Bhima Shakti)				1.25			
	S.Em. _±				0.08	0.0432	0.0499	0.0499
	C.D. at 5 %				0.22	0.0873	0.1018	0.1018
	C.D. at 1 %				0.29	0.1169	0.1350	0.1350

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

Table 34. Per se performance and magnitude of heterosis total soluble solids during rabi

Sl. No.	Entries	Total soluble solids						
		Per se value (° brix)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	9.50	9.20	9.35	11.82	4.19	-7.62	3.96
2	Kumata local x GKD-45		8.50	9.00	10.70	-19.70 **	-36.12 **	-5.93
3	Kumata local x GKD-77		11.90	10.70	12.42	20.05 **	15.05 *	9.23
4	Kumata local x ASKO-1222		9.10	9.30	10.45	-3.91	-11.81 *	-8.13
5	Kumata local x Arka Kalyan		10.35	9.93	11.10	0.45	-9.02	-2.42
6	Kumata local x Line-25		10.10	9.80	8.60	-24.56 **	-33.33 **	-24.40 **
7	Kumata local x N-53		10.25	9.88	9.45	-7.35	-10.00	-16.92 **
8	Kumata local x Line-13		11.15	10.33	7.75	-20.92 **	-21.72 **	-31.87 **
9	Bhima Shakti x Cross 5	9.75	9.20	9.48	10.88	-10.31 *	-15.04 **	-4.40
10	Bhima Shakti x GKD-45		8.50	9.13	9.00	-36.17 **	-46.27 **	-20.88 **
11	Bhima Shakti x GKD-77		11.90	10.83	10.00	-10.11 *	-12.66 *	-12.09 *
12	Bhima Shakti x ASKO-1222		9.10	9.43	10.65	-8.58	-10.13	-6.37
13	Bhima Shakti x Arka Kalyan		10.35	10.05	9.75	-17.55 **	-20.08 **	-14.29 *
14	Bhima Shakti x Line-25		10.10	9.93	8.78	-27.89 **	-31.94 **	-22.81 **
15	Bhima Shakti x N-53		10.25	10.00	11.10	1.14	-3.06	-2.42
16	Bhima Shakti x Line-13		11.15	10.45	10.18	-3.78	-11.14 *	-10.55
17	GKD-75 x Cross-5	12.03	9.20	10.62	11.50	5.75	-10.16 *	1.10
18	GKD-75 x GKD-45		8.50	10.27	9.95	-22.57 **	-40.60 **	-12.53 *
19	GKD-75 x GKD-77		11.90	11.97	11.20	13.42 *	3.70	-1.54
20	GKD-75 x ASKO-1222		9.10	10.57	9.45	-9.13	-20.25 **	-16.92 **
21	GKD-75 x Arka Kalyan		10.35	11.19	11.70	10.64 *	-4.10	2.86
22	GKD-75 x Line-25		10.10	11.07	11.50	5.26	-10.85 *	1.10
23	GKD-75 x N-53		10.25	11.14	12.30	26.48 **	17.14 **	8.13
24	GKD-75 x Line-13		11.15	11.59	11.32	21.45 **	16.75 *	-0.44
25	ASKO-1201 x Cross-5	11.85	9.20	10.53	12.50	-1.96	-2.34	9.89
26	ASKO-1201 x GKD-45		8.50	10.18	9.50	-35.48 **	-43.28 **	-16.48 **
27	ASKO-1201 x GKD-77		11.90	11.88	9.75	-17.02 **	-23.23 **	-14.29 *
28	ASKO-1201 x ASKO-1222		9.10	10.48	12.03	-2.04	-5.31	5.71
29	ASKO-1201 x Arka Kalyan		10.35	11.10	11.85	-4.82	-6.69	4.18
30	ASKO-1201 x Line-25		10.10	10.98	12.35	-3.52	-4.26	8.57
31	ASKO-1201 x N-53		10.25	11.05	11.30	-2.59	-11.02 *	-0.66
32	ASKO-1201 x Line-13		11.15	11.50	9.20	-17.86 **	-27.56 **	-19.12 **
33	ASKO-1299 x Cross-5	12.35	9.20	10.78	8.50	-32.67 **	-33.59 **	-25.27 **
34	ASKO-1299 x GKD-45		8.50	10.43	11.90	-18.49 **	-28.96 **	4.62
35	ASKO-1299 x GKD-77		11.90	12.13	9.10	-21.72 **	-26.91 **	-20.00 **
36	ASKO-1299 x ASKO-1222		9.10	10.73	10.35	-14.81 **	-16.87 **	-9.01
37	ASKO-1299 x Arka Kalyan		10.35	11.35	10.10	-18.05 **	-18.88 **	-11.21 *
38	ASKO-1299 x Line-25		10.10	11.23	9.50	-25.05 **	-26.36 **	-16.48 **
39	ASKO-1299 x N-53		10.25	11.30	10.25	-10.68 *	-17.67 **	-9.89
40	ASKO-1299 x Line-13		11.15	11.75	11.15	0.68	-10.44 *	-1.98
	CC (Bhima Shakti)				11.76			
	S.Em.+				0.43	0.5262	0.6076	0.6076
	C.D. at 5 %				1.22	1.0644	1.2291	1.2291
	C.D. at 1 %				1.63	1.4250	1.6454	

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

4.5.12 Marketable yield (Table 35)

A wide range of variation was observed among parents for marketable yield from 16.10 t/ha (Arka Kalyan) to 26.80 t/ha (ASKO-1222). Among the hybrids, the highest yield of 26.80 t/ha was recorded in ASKO-1299 x GKD-77 which was at par with 6 crosses viz., Kumata local x Cross-5, Kumata local x GKD-45, Bhima Shakti x Cross 5, Bhima Shakti x Line-13, ASKO-1201 x GKD-77, ASKO-1201 x Line-13 and commercial check (Bhima Shakti). More number of hybrids exhibiting significantly higher yield but at par with commercial check was observed with Bhima Shakti, Kumata local and ASKO-1201 as female parent.

Heterosis over mid parent for marketable yield range between -49.95 per cent (Bhima Shakti x Arka Kalyan) to 64.69 per cent (ASKO-1201 x GKD-77). There were eight crosses showing significant positive heterosis over mid parent. With respect to heterosis over better parent, the range was from -51.18 per cent (Bhima Shakti x Arka Kalyan) to 43.42 per cent (ASKO-1201 x Line-13). Only six crosses were showing the significant positive heterosis over commercial check. The higher per cent heterosis towards positive direction over commercial check was given by the crosses ASKO-1299 x GKD-77 (13.08 %) followed by ASKO-1201 x Line-13 (10.76 %) and ASKO-1201 x GKD-77 (10.55 %).

4.5.13 Non-marketable yield (Table 36)

Among the parents, lowest non-marketable yield was exhibited by the Cross-5 (0.78 t/ha) and highest was by Arka Kalyan (1.38 t/ha) and among hybrids the cross ASKO-1299 x N-53 (1.60 t/ha) showed highest non marketable yield whereas, lowest was by the cross Kumata local x ASKO-1222 (0.04 t/ha).

The variation in the magnitude of heterosis percentage over the mid parent was from -97.14 (Kumata local x ASKO-1222) to 106.2 per cent (GKD-75 x GKD-77). Heterosis over better parent range from -97.33 per cent (Kumata local x ASKO-1222) to 104.62 per cent (GKD-75 x GKD-77). Over commercial check, none of the hybrids showed significant negative heterosis. Highest significant negative heterosis over mid parent and better parent was showed by cross Kumata local x ASKO-1222 (-97.14 per cent and -97.33 per cent, respectively).

4.5.14 Average bulb weight (Table 37)

The magnitude of variation among the parents with respect to bulb weight was 47.40 g (ASKO-1299) to 69.20 g (Bhima Shakti). The cross combination of ASKO-1299 x GKD-77 recorded highest bulb weight (69.20 g) which was at par with ASKO-1201 x Line-13 (67.00 g), Bhima Shakti x Line-13 (66.50 g), ASKO-1201 x ASKO-1222 (65.10 g), ASKO-1201 x GKD-77 (66.50 g), GKD-75 x Line-25 (66.25 g) and GKD-75 x ASKO-1222 (64.20 g).

Heterosis over mid parent exhibited by the F₁s for bulb weight varied from -37.74 per cent (Bhima Shakti x ASKO-1222) to 39.24 per cent (Kumata local x N-53). Totally, 18 crosses showed significant positive heterosis over mid parent, the highest was by Kumata local x N-53. With respect to better parent, 12 crosses showed positive significant heterosis. The highest was recorded by ASKO-1201 x Line-13 (28.26 %). With respect to heterosis over commercial check, only seven crosses showed significant positive heterosis, and the highest was again recorded by ASKO-1299 x GKD-77 (12.52 %).

Table 35. Per se performance and magnitude of heterosis for marketable yield during rabi

Sl. No.	Entries	Marketable yield						
		Per se value(t/ha)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	24.30	26.25	25.28	25.05	-5.51 **	-7.80 **	5.70 *
2	Kumata local x GKD-45		18.65	21.48	25.25	45.77 **	7.07 **	6.54 *
3	Kumata local x GKD-77		20.47	22.39	17.45	-39.01 **	-41.93 **	-26.37 **
4	Kumata local x ASKO-1222		26.80	25.55	14.80	-41.87 **	-45.53 **	-37.55 **
5	Kumata local x Arka Kalyan		16.10	20.20	17.20	-32.97 **	-36.69 **	-27.43 **
6	Kumata local x Line-25		23.10	23.70	19.15	-18.28 **	-29.52 **	-19.20 **
7	Kumata local x N-53		18.40	21.35	21.15	8.55 **	-22.16 **	-10.76 **
8	Kumata local x Line-13		21.25	22.78	17.05	-34.51 **	-37.25 **	-28.06 **
9	Bhima Shakti x Cross 5	26.20	26.25	26.23	24.65	-3.80	-4.64 *	4.01
10	Bhima Shakti x GKD-45		18.65	22.43	15.50	1.14	-38.98 **	-34.60 **
11	Bhima Shakti x GKD-77		20.47	23.34	16.58	-40.20 **	-44.83 **	-30.04 **
12	Bhima Shakti x ASKO-1222		26.80	26.50	21.85	-11.09 **	-13.98 **	-7.81 **
13	Bhima Shakti x Arka Kalyan		16.10	21.15	12.40	-49.95 **	-51.18 **	-47.68 **
14	Bhima Shakti x Line-25		23.10	24.65	20.33	-9.84 **	-19.96 **	-14.22 **
15	Bhima Shakti x N-53		18.40	22.30	19.30	-3.76 **	-24.02 **	-18.57 **
16	Bhima Shakti x Line-13		21.25	23.73	26.25	4.37 **	3.35	10.76 **
17	GKD-75 x Cross-5		26.25	26.23	24.45	-12.54 **	-5.42 *	3.16
18	GKD-75 x GKD-45	18.10	18.65	18.38	18.80	4.55	6.82	-20.68 **
19	GKD-75 x GKD-77		20.47	19.29	19.80	6.89	-34.11 **	-16.46 **
20	GKD-75 x ASKO-1222		26.80	22.45	22.60	9.31	-14.84 **	-4.64
21	GKD-75 x Arka Kalyan		16.10	17.10	20.85	10.23	-13.66 **	-12.03 **
22	GKD-75 x Line-25		23.10	20.60	18.52	-7.70 **	-15.99 *	-21.86 **
23	GKD-75 x N-53		18.40	18.25	16.25	-10.54 **	-7.67 *	-31.43 **
24	GKD-75 x Line-13		21.25	19.68	15.25	-28.24 **	-38.76 **	-35.65 **
25	ASKO-1201 x Cross-5	19.85	26.25	23.05	18.05	-9.64 **	-30.17 **	-23.84 **
26	ASKO-1201 x GKD-45		18.65	19.25	24.30	51.16**	32.34 **	2.53
27	ASKO-1201 x GKD-77		20.47	20.16	26.20	64.69 **	42.81 **	10.55 **
28	ASKO-1201 x ASKO-1222		26.80	23.33	18.10	-4.36 **	-23.79 **	-23.63 **
29	ASKO-1201 x Arka Kalyan		16.10	17.98	19.85	3.79 **	11.6	-16.24 **
30	ASKO-1201 x Line-25		23.10	21.48	18.88	11.72 **	-9.16 **	-20.34 **
31	ASKO-1201 x N-53		18.40	19.13	21.50	60.02 **	32.48 **	-9.28 **
32	ASKO-1201 x Line-13		21.25	20.55	26.25	34.62 **	43.42 **	10.76 **
33	ASKO-1299 x Cross-5	18.88	26.25	22.57	18.65	-21.49 **	-27.85 **	-21.31 **
34	ASKO-1299 x GKD-45		18.65	18.77	20.47	52.14 **	5.49 **	-13.63 **
35	ASKO-1299 x GKD-77		20.47	19.68	26.80	43.66**	40.82 **	13.08 **
36	ASKO-1299 x ASKO-1222		26.80	22.84	16.10	-29.09 **	-32.21 **	-32.07 **
37	ASKO-1299 x Arka Kalyan		16.10	17.49	23.10	-16.85 **	24.35 **	-2.53
38	ASKO-1299 x Line-25		23.10	20.99	18.40	-11.03 **	-15.05 **	-22.36 **
39	ASKO-1299 x N-53		18.40	18.64	18.40	9.98	-15.05 **	-22.36 **
40	ASKO-1299 x Line-13		21.25	20.07	21.25	-8.72 **	14.6	-10.34 **
	CC (Bhima Shakti)				24.6			
	S.Em.+				0.82	0.4989	0.5761	0.5761
	C.D. at 5 %				2.32	1.0091	1.1652	1.1652
	C.D. at 1 %				3.09	1.3509	1.5599	1.5599

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

Table 36. Per se performance and magnitude of heterosis non marketable yield during rabi

Sl. No.	Entries	Non marketable yield						
		Per se value (t/ha)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	1.15	0.78	0.97	0.78	-25.84	-40.38	0.00
2	Kumata local x GKD-45		0.88	1.02	0.41	-89.09 **	-93.39 **	-47.74
3	Kumata local x GKD-77		1.25	1.20	0.15	-84.02 **	-88.08 **	-80.00
4	Kumata local x ASKO-1222		0.83	0.99	0.04	-97.14 **	-97.33 **	-94.84
5	Kumata local x Arka Kalyan		1.38	1.27	0.04	-96.74 **	-96.92 **	-94.19
6	Kumata local x Line-25		1.23	1.19	0.28	-72.68 *	-78.46 **	-63.87
7	Kumata local x N-53		1.60	1.38	0.60	-55.72 *	-57.45 *	-22.58
8	Kumata local x Line-13		0.88	1.02	0.44	-58.59 *	-66.15 *	-43.23
9	Bhima Shakti x Cross 5	0.95	0.78	0.87	0.67	-22.41	-28.95	-12.90
10	Bhima Shakti x GKD-45		0.88	0.92	0.60	-83.04 **	-90.20 **	-22.58
11	Bhima Shakti x GKD-77		1.25	1.10	0.77	-2.52	-18.42	0.00
12	Bhima Shakti x ASKO-1222		0.83	0.89	0.35	-71.43 **	-76.67 **	-54.84
13	Bhima Shakti x Arka Kalyan		1.38	1.17	1.40	16.18	-4.11	80.65
14	Bhima Shakti x Line-25		1.23	1.09	0.63	-26.47	-34.21	-19.35
15	Bhima Shakti x N-53		1.60	1.28	1.40	18.64	-0.71	80.65
16	Bhima Shakti x Line-13		0.88	0.92	0.93	4.23	-2.63	19.35
17	GKD-75 x Cross-5	1.30	0.78	1.04	0.93	28.47	17.09	19.35
18	GKD-75 x GKD-45		0.88	1.09	1.25	-63.10 **	-79.59 **	61.29
19	GKD-75 x GKD-77		1.25	1.28	1.33	106.20 *	104.62	71.61
20	GKD-75 x ASKO-1222		0.83	1.07	1.05	-2.33	-30.00	35.48
21	GKD-75 x Arka Kalyan		1.38	1.34	0.82	-21.80	-43.49	6.45
22	GKD-75 x Line-25		1.23	1.27	0.89	26.43	18.00	14.19
23	GKD-75 x N-53		1.60	1.45	0.90	-12.62	-36.17	16.13
24	GKD-75 x Line-13		0.88	1.09	0.93	25.42	12.12	19.35
25	ASKO-1201 x Cross-5	0.95	0.78	0.87	1.10	58.27	39.24	41.94
26	ASKO-1201 x GKD-45		0.88	0.92	1.15	-65.80 **	-81.22 **	48.39
27	ASKO-1201 x GKD-77		1.25	1.10	0.95	53.23	48.44	22.58
28	ASKO-1201 x ASKO-1222		0.83	0.89	1.30	23.81	-13.33	67.74
29	ASKO-1201 x Arka Kalyan		1.38	1.17	0.95	-7.77	-34.93	22.58
30	ASKO-1201 x Line-25		1.23	1.09	0.98	44.44	30.00	25.81
31	ASKO-1201 x N-53		1.60	1.28	0.60	-40.30	-57.45 *	-22.58
32	ASKO-1201 x Line-13		0.88	0.92	0.77	8.77	-6.06	0.00
33	ASKO-1299 x Cross-5	0.98	0.78	0.88	0.88	-12.06	-27.08	12.90
34	ASKO-1299 x GKD-45		0.88	0.93	1.25	-65.87 **	-79.59 **	61.29
35	ASKO-1299 x GKD-77		1.25	1.12	0.82	-10.33	-31.25	6.45
36	ASKO-1299 x ASKO-1222		0.83	0.91	1.37	1.85	-8.33	77.42
37	ASKO-1299 x Arka Kalyan		1.38	1.18	1.23	-7.52	-15.75	58.71
38	ASKO-1299 x Line-25		1.23	1.11	0.98	0.00	-18.75	25.81
39	ASKO-1299 x N-53		1.60	1.29	1.60	22.61	13.48	106.45
40	ASKO-1299 x Line-13		0.88	0.93	0.88	-13.58	-27.08	12.90
	CC (Bhima Shakti)				0.7			
	S.Em.±				0.24	0.2924	0.3376	0.3376
	C.D. at 5 %				0.68	0.5914	0.6828	0.6828
	C.D. at 1 %				0.91	0.7917	0.9142	0.9142

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

4.5.15 Total yield (Table 38)

The performance of parents and hybrids for total yield range from 17.48 t/ha (Arka Kalyan) to 27.63 t/ha (ASKO-1222) and 13.80 t/ha (Bhima Shakti x Arka Kalyan) to 27.62 t/ha (ASKO-1299 x GKD-77) respectively. Out of 40 hybrids, significant positive heterosis was exhibited by 13 over mid parent, nine over better parent and nine over commercial check.

The variation noticed in magnitude of heterosis over mid parent was from -48.52 per cent (Kumata local x ASKO-1222) to 35.66 per cent (ASKO-1201 x GKD-77); -50.81 per cent (Kumata local x ASKO-1222) to 36.61 per cent (ASKO-1201 x Line-13) over better parent and; -56.42 per cent (Bhima Shakti x Arka Kalyan) to 35.02 per cent (ASKO-1299 x GKD-77) over commercial check.

4.5.16 Rotten bulbs (Table 39)

The performance of parents and hybrids for rotten bulbs range from 0.15 t/ha (Line-13) to 1.05 t/ha (Line-25) and 0.05 t/ha (Kumata local x ASKO-1222) to 1.75 t/ha Kumata local x Line-13), respectively. Among 40 hybrids, 14 and 23 hybrids showed significant negative heterosis over mid parent and better parent, respectively. None of the hybrid showed significant negative heterosis over commercial check.

4.5.17 Days to maturity (Table 40)

Among the parents, earliest to maturity was shown by the N-53 and GKD-75 (108.0 days) and farthest was by GKD-77 (116.4 days). Among the hybrids the cross ASKO-1201 x ASKO-1222 (104.3 days) exhibited earliest to maturity whereas farthest to maturity by the cross ASKO-1299 x ASKO-1222 and GKD-75 x Line-25 (119.8 days).

The variation in the magnitude of heterosis percentage over the mid parent was from -7.02 (ASKO-1201 x ASKO-1222) to 8.18 per cent (GKD-75 x N-53). Magnitude of heterosis over better parent range from -8.21 per cent (ASKO-1201 x ASKO-1222) to 8.18 (GKD-75 x N-53). Magnitude of heterosis over commercial check range from -12.69 per cent (ASKO-1201 x ASKO-1222) to 0.28 per cent (ASKO-1299 x ASKO-1222 and GKD-75 x Line-25). Highest significant negative heterosis over mid parent, better parent and commercial check was showed the by cross (ASKO-1201 x ASKO-1222) -7.02 per cent, -8.21 per cent and -12.69 per cent, respectively.

4.6 Combining ability

4.6.1 Combining ability effects

Analysis of variance carried out for randomized block design for the seventeen characters under the study are summarized in table 41. Variation due to female parents (lines) showed significant variation for only 4 characters. While, the male parents (testers) recorded significant variation for only one character (neck thickness). Lines vs. testers exhibited significant variation for 14 characters except three characters *viz.*, number of leaves at 30 days after transplanting, P/E ratio, and non marketable yield. The hybrids also exhibited significant variation for 15 characters except two characters *viz.*, number of leaves at 30 days after transplanting and P/E ratio. There was no significant variation in any of the sources for the character number of leaves at 30 days after transplanting.

Table 37. Per se performance and magnitude of heterosis average bulb weight during rabi

Sl. No.	Entries ^z	Average bulb weight						
		Per se value (g)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	59.25	67.00	63.13	59.00	-12.76 **	-9.77 **	-4.07 *
2	Kumata local x GKD-45		53.98	56.62	59.30	18.01 **	16.50 **	-3.58
3	Kumata local x GKD-77		62.35	60.80	53.25	-9.13 **	-19.68 **	-13.41 **
4	Kumata local x ASKO-1222		62.15	60.70	46.00	-14.70 **	-21.23 **	-25.20 **
5	Kumata local x Arka Kalyan		55.75	57.50	54.30	0.28	-5.40 **	-11.71 **
6	Kumata local x Line-25		58.00	58.63	48.25	-9.30 **	-19.06 **	-21.54 **
7	Kumata local x N-53		52.05	55.65	60.50	39.24 **	18.86 **	-1.63
8	Kumata local x Line-13		57.00	58.13	51.88	-11.51 **	-21.82 **	-15.65 **
9	Bhima Shakti x Cross 5	69.20	67.00	68.10	59.00	18.30 **	-27.62 **	-4.07 *
10	Bhima Shakti x GKD-45		53.98	61.59	42.75	-10.56 **	-13.81 **	-30.49 **
11	Bhima Shakti x GKD-77		62.35	65.78	48.25	-14.07 **	-27.22 **	-21.54 **
12	Bhima Shakti x ASKO-1222		62.15	65.68	32.05	-37.74 **	-43.72 **	-47.89 **
13	Bhima Shakti x Arka Kalyan		55.75	62.48	40.50	-21.66 **	-29.44 **	-34.15 **
14	Bhima Shakti x Line-25		58.00	63.60	52.20	2.86	-5.95 **	-15.12 **
15	Bhima Shakti x N-53		52.05	60.63	48.00	-17.07 **	4.35	-21.95 **
16	Bhima Shakti x Line-13		57.00	63.10	66.50	18.38 **	-12.56**	8.13 **
17	GKD-75 x Cross-5	65.10	67.00	66.05	57.75	-9.22 **	-17.44 **	-6.10 **
18	GKD-75 x GKD-45		53.98	59.54	54.10	-16.50 **	-14.04 **	-12.03 **
19	GKD-75 x GKD-77		62.35	63.73	45.65	-22.82 **	-31.15 **	-25.77 **
20	GKD-75 x ASKO-1222		62.15	63.63	64.20	26.21 **	20.29 **	10.65 **
21	GKD-75 x Arka Kalyan		55.75	60.43	49.50	-9.51 **	-23.76 **	-19.51 **
22	GKD-75 x Line-25		58.00	61.55	66.25	24.00 **	20.09	8.37 **
23	GKD-75 x N-53		52.05	58.58	51.00	-15.91 **	-14.92 **	-17.07 **
24	GKD-75 x Line-13		57.00	61.05	49.50	-16.35 **	-25.40 **	-19.51 **
25	ASKO-1201 x Cross-5	49.50	67.00	58.25	52.50	-22.72 **	-29.33 **	-14.63 **
26	ASKO-1201 x GKD-45		53.98	51.74	59.25	18.38 **	17.33 **	-3.66
27	ASKO-1201 x GKD-77		62.35	55.93	66.50	18.38 **	7.44 **	8.13 **
28	ASKO-1201 x ASKO-1222		62.15	55.83	65.10	21.17 **	14.31 **	5.85 **
29	ASKO-1201 x Arka Kalyan		55.75	52.63	49.50	-14.25 **	-13.76 **	-19.51 **
30	ASKO-1201 x Line-25		58.00	53.75	47.40	-16.57 **	-14.59 **	-22.93 **
31	ASKO-1201 x N-53		52.05	50.78	56.00	25.48 **	10.89 **	-8.94 **
32	ASKO-1201 x Line-13		57.00	53.25	67.00	14.68 **	28.26**	8.94 **
33	ASKO-1299 x Cross-5	47.40	67.00	57.20	53.98	-2.09 **	-4.47 *	-12.24 **
34	ASKO-1299 x GKD-45		53.98	50.69	62.35	17.53 **	10.35 **	1.38
35	ASKO-1299 x GKD-77		62.35	54.88	69.20	18.49 **	14.37 *	12.52 **
36	ASKO-1299 x ASKO-1222		62.15	54.78	55.75	11.72 **	2.11 *	-9.35 **
37	ASKO-1299 x Arka Kalyan		55.75	51.58	58.00	13.84 **	8.05 **	-5.69 **
38	ASKO-1299 x Line-25		58.00	52.70	55.75	18.45 **	-1.33 **	-9.35 **
39	ASKO-1299 x N-53		52.05	49.73	52.05	12.54 **	0.1	-15.37 **
40	ASKO-1299 x Line-13		57.00	52.20	57.00	22.20 **	0	-7.32 **
	CC (Bhima Shakti)				62.75			
	S.Em. _±				2.04	0.9764	1.1275	1.1275
	C.D. at 5 %				5.79	1.9750	2.2805	2.2805
	C.D. at 1 %				7.72	2.6441	3.0531	3.0531

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

Table 38. Per se performance and magnitude of heterosis for total yield during rabi

Sl. No.	Entries	Total yield						
		Per se value (t/ha)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	25.45	27.03	26.24	25.83	-6.79 **	-8.92 **	25.47 **
2	Kumata local x GKD-45		19.53	22.49	25.66	29.96 **	7.12	23.92 **
3	Kumata local x GKD-77		21.72	23.59	17.60	-43.57 **	-44.88 **	-21.63 **
4	Kumata local x ASKO-1222		27.63	26.54	14.84	-48.52 **	-50.81 **	-33.32 **
5	Kumata local x Arka Kalyan		17.48	21.47	17.24	-36.95 **	-40.88 **	-19.86 **
6	Kumata local x Line-25		24.33	24.89	19.43	-20.62 **	-32.69 **	-8.74 *
7	Kumata local x N-53		20	22.73	21.75	4.22	-24.03 **	-12.99*
8	Kumata local x Line-13		22.13	23.79	17.49	-41.18 **	-43.67 **	-23.64 **
9	Bhima Shakti x Cross 5	27.15	27.03	27.09	25.32	-4.28 **	-4.65	3.35 **
10	Bhima Shakti x GKD-45		19.53	23.34	16.10	-43.89 **	-38.15 **	-20.60 **
11	Bhima Shakti x GKD-77		21.72	24.44	17.35	-46.76 **	-5.58 *	-34.25 **
12	Bhima Shakti x ASKO-1222		27.63	27.39	22.20	-17.83 **	-19.40 **	-13.47*
13	Bhima Shakti x Arka Kalyan		17.48	22.32	13.80	-43.67 **	-45.80 **	-56.42 **
14	Bhima Shakti x Line-25		24.33	25.74	20.96	-10.65 **	-22.48 **	-5.48**
15	Bhima Shakti x N-53		20	23.58	20.70	-15.11 **	-25.00 **	-6.15**
16	Bhima Shakti x Line-13		22.13	24.64	27.18	4.84 **	3.08	32.34 **
17	GKD-75 x Cross-5	19.4	27.03	23.22	25.38	11.14 **	-7.24 *	4.10 **
18	GKD-75 x GKD-45		19.53	19.47	20.05	8.69 **	9.27 *	-5.39**
19	GKD-75 x GKD-77		21.72	20.56	21.13	14.73 **	-6.40 **	-2.47**
20	GKD-75 x ASKO-1222		27.63	23.52	23.65	10.60	-5.92 **	-16.17 *
21	GKD-75 x Arka Kalyan		17.48	18.44	21.67	-9.62 **	-14.92 **	-0.96*
22	GKD-75 x Line-25		24.33	21.87	19.41	-3.85	-16.43 **	-6.04**
23	GKD-75 x N-53		20	19.70	17.15	-4.85 **	-13.42 **	-25.03 **
24	GKD-75 x Line-13		22.13	20.77	16.18	-10.29 **	-23.84 **	-5.51**
25	ASKO-1201 x Cross-5	20.8	27.03	23.92	19.15	-14.27 **	-10.02 **	-16.41 **
26	ASKO-1201 x GKD-45		19.53	20.17	25.45	34.42 **	19.81 **	4.90 **
27	ASKO-1201 x GKD-77		21.72	21.26	27.15	35.66**	27.48 **	32.11**
28	ASKO-1201 x ASKO-1222		27.63	24.22	19.40	-7.51 *	-25.90 **	-8.50 *
29	ASKO-1201 x Arka Kalyan		17.48	19.14	20.80	16.00 **	10.62 **	-24.26 **
30	ASKO-1201 x Line-25		24.33	22.57	19.86	-12.42 **	-10.51**	-25.15**
31	ASKO-1201 x N-53		20	20.40	22.10	16.94 **	26.32 **	-20.72 **
32	ASKO-1201 x Line-13		22.13	21.47	27.02	28.03 *	36.61 **	33.19**
33	ASKO-1299 x Cross-5	19.86	27.03	23.45	19.53	-3.76 **	-16.36 **	-28.92 **
34	ASKO-1299 x GKD-45		19.53	19.70	21.72	6.47 **	12.64 **	-23.80 **
35	ASKO-1299 x GKD-77		21.72	20.79	27.62	15.24 **	19.37**	35.02 **
36	ASKO-1299 x ASKO-1222		27.63	23.75	17.47	-19.68 **	-25.70 **	-34.26 *
37	ASKO-1299 x Arka Kalyan		17.48	18.67	24.33	17.03 *	18.39 **	-3.95*
38	ASKO-1299 x Line-25		24.33	22.10	19.38	-7.07 *	-21.67	-14.71**
39	ASKO-1299 x N-53		20	19.93	20.00	7.83	2.3	-9.94 *
40	ASKO-1299 x Line-13		22.13	21.00	22.13	1.65	6.18	-20.41 **
	CC (Bhima Shakti)				25.3			
	S.Em.+				0.54	0.6638	0.7665	0.7665
	C.D. at 5 %				1.53	1.3426	1.5503	1.5503
	C.D. at 1 %				2.04	1.7975	2.0755	2.0755

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

Table 39. Per se performance and magnitude of heterosis for rotten bulbs during rabi

Sl. No.	Entries	Rotten bulbs						
		Per se value (t/ha)				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	0.45	0.28	0.37	0.53	-50.12 *	-66.13 **	23.53
2	Kumata local x GKD-45		0.25	0.35	0.47	27.52	-14.41	11.76
3	Kumata local x GKD-77		0.60	0.53	0.06	-95.56 **	-97.21 **	-85.88
4	Kumata local x ASKO-1222		0.38	0.42	0.05	-90.95 *	-90.99 *	-88.24
5	Kumata local x Arka Kalyan		0.87	0.66	0.08	-82.46	-86.49	-82.35
6	Kumata local x Line-25		1.05	0.75	0.10	-72.60	-81.98	-76.47
7	Kumata local x N-53		0.50	0.48	0.60	-4.38	-14.29	41.18
8	Kumata local x Line-13		0.15	0.30	1.75	88.68 **	34.62	311.76**
9	Bhima Shakti x Cross 5	0.35	0.28	0.32	0.48	-68.28 **	-69.35 **	11.76
10	Bhima Shakti x GKD-45		0.25	0.30	0.40	-51.07	-72.32 **	-5.88
11	Bhima Shakti x GKD-77		0.60	0.48	0.70	-61.06 **	-67.44 **	64.71
12	Bhima Shakti x ASKO-1222		0.38	0.37	0.72	-27.32	-49.83 **	70.59
13	Bhima Shakti x Arka Kalyan		0.87	0.61	0.83	-5.44	-42.91 *	94.12
14	Bhima Shakti x Line-25		1.05	0.70	1.20	48.15	-16.96	182.35**
15	Bhima Shakti x N-53		0.50	0.43	0.25	-76.69 **	-82.70 **	-41.18
16	Bhima Shakti x Line-13		0.15	0.25	0.08	-93.81 **	-94.12 **	-80.00
17	GKD-75 x Cross-5	0.25	0.28	0.27	0.90	-26.53	-41.94 *	111.76
18	GKD-75 x GKD-45		0.25	0.25	0.55	0.92	-38.89	29.41
19	GKD-75 x GKD-77		0.60	0.43	0.22	-85.57 **	-89.77 **	-48.24
20	GKD-75 x ASKO-1222		0.38	0.32	0.63	-13.79	-30.56	47.06
21	GKD-75 x Arka Kalyan		0.87	0.56	0.40	-33.33	-55.56 *	-5.88
22	GKD-75 x Line-25		1.05	0.65	0.50	-6.98	-44.44	17.65
23	GKD-75 x N-53		0.50	0.38	0.65	-18.75	-27.78	52.94
24	GKD-75 x Line-13		0.15	0.20	0.70	-36.36	-46.15 *	64.71
25	ASKO-1201 x Cross-5	0.43	0.28	0.36	0.85	-30.61	-45.16 **	100.00
26	ASKO-1201 x GKD-45		0.25	0.34	0.45	-17.43	-50.00	5.88
27	ASKO-1201 x GKD-77		0.60	0.52	0.35	-77.05 **	-83.72 **	-17.65
28	ASKO-1201 x ASKO-1222		0.38	0.41	0.25	-65.52 *	-72.22 *	-41.18
29	ASKO-1201 x Arka Kalyan		0.87	0.65	0.43	-29.17	-52.78	0.00
30	ASKO-1201 x Line-25		1.05	0.74	0.40	-25.58	-55.56 *	-5.88
31	ASKO-1201 x N-53		0.50	0.47	0.40	-50.00	-55.56 *	-5.88
32	ASKO-1201 x Line-13		0.15	0.29	0.28	-75.00 **	-78.85 **	-35.29
33	ASKO-1299 x Cross-5	0.40	0.28	0.34	0.25	-78.72 **	-83.87 **	-41.18
34	ASKO-1299 x GKD-45		0.25	0.33	0.60	21.21	-25.00	41.18
35	ASKO-1299 x GKD-77		0.60	0.50	0.38	-74.24 **	-82.33 **	-10.59
36	ASKO-1299 x ASKO-1222		0.38	0.39	0.87	28.89	8.75	104.71
37	ASKO-1299 x Arka Kalyan		0.87	0.64	1.05	90.91 *	31.25	147.06 *
38	ASKO-1299 x Line-25		1.05	0.73	0.75	53.85	-6.25	76.47
39	ASKO-1299 x N-53		0.50	0.45	0.50	-33.33	-37.50	17.65
40	ASKO-1299 x Line-13		0.15	0.28	0.15	-85.71 **	-88.46 **	-64.71
	CC (Bhima Shakti)				0.325			
	S.Em. _t				0.17	0.2080	0.2402	0.2402
	C.D. at 5 %				0.48	0.4207	0.4858	0.4858
	C.D. at 1 %				0.64	0.5632	0.6504	0.6504

* and ** indicates significant at 5 and 1 % respectively
 MP-Mid parent, BP-Better parent, CC-Commercial check

Table 40. Per se performance and magnitude of heterosis for days to maturity during rabi

Sl. No.	Entries	Days to maturity						
		Per se value				Heterosis percentage over		
		Line	Tester	Mean	F ₁ s	MP	BP	CC
1	Kumata local x Cross-5	111.0	114.0	115.0	111.0	-1.32	-2.61	-7.11 **
2	Kumata local x GKD-45		111.2	112.1	112.3	1.10	0.99	-6.00 **
3	Kumata local x GKD-77		116.4	117.7	115.5	1.58	-0.79	-3.35
4	Kumata local x ASKO-1222		113.7	114.6	113.6	1.13	-0.06	-4.94 *
5	Kumata local x Arka Kalyan		115.0	115.5	114.1	0.97	-0.78	-4.52 *
6	Kumata local x Line-25		114.0	114.9	107.0	-4.89 **	-6.14 **	-10.46 **
7	Kumata local x N-53		108.0	112.1	110.5	0.91	-0.45	-7.53 **
8	Kumata local x Line-13		110.8	111.1	107.0	-3.49	-3.60	-10.46 **
9	Bhima Shakti x Cross 5	114.0	114.0	115.9	115.3	1.18	1.17	-3.49
10	Bhima Shakti x GKD-45		111.2	113.0	110.8	-1.58	-2.78	-7.26 **
11	Bhima Shakti x GKD-77		116.4	118.6	115.5	0.25	-0.79	-3.35
12	Bhima Shakti x ASKO-1222		113.7	115.5	108.5	-4.68 **	-4.82 *	-9.21 **
13	Bhima Shakti x Arka Kalyan		115.0	116.4	116.5	1.75	1.30	-2.51
14	Bhima Shakti x Line-25		114.0	115.8	106.5	-6.58 **	-6.58 **	-10.88 **
15	Bhima Shakti x N-53		108.0	113.0	113.3	2.10	-0.59	-5.16 **
16	Bhima Shakti x Line-13		110.8	112.0	112.8	0.33	-1.10	-5.65 **
17	GKD-75 x Cross-5	108.0	114.0	114.3	116.1	4.61 *	1.86	-2.85
18	GKD-75 x GKD-45		111.2	111.5	112.4	2.50	1.01	-5.98 **
19	GKD-75 x GKD-77		116.4	117.1	109.2	-2.68	-6.20 **	-8.62 **
20	GKD-75 x ASKO-1222		113.7	113.9	113.3	2.18	-0.37	-5.23 **
21	GKD-75 x Arka Kalyan		115.0	114.9	113.5	1.79	-1.30	-5.02 *
22	GKD-75 x Line-25		114.0	114.2	119.8	7.95 **	5.11 *	0.28
23	GKD-75 x N-53		108.0	111.5	116.8	8.18 **	8.18 **	-2.23
24	GKD-75 x Line-13		110.8	110.5	117.0	6.97 **	5.64 **	-2.09
25	ASKO-1201 x Cross-5	110.7	114.0	111.6	119.0	5.91 **	4.41 *	-0.42
26	ASKO-1201 x GKD-45		111.2	108.7	113.5	2.26	2.05	-5.02 *
27	ASKO-1201 x GKD-77		116.4	114.3	109.0	-4.03 *	-6.37 **	-8.79 **
28	ASKO-1201 x ASKO-1222		113.7	111.2	104.3	-7.02 **	-8.21 **	-12.69 **
29	ASKO-1201 x Arka Kalyan		115.0	112.1	111.0	-1.66	-3.48	-7.11 **
30	ASKO-1201 x Line-25		114.0	111.5	106.1	-5.58 **	-6.93 **	-11.21 **
31	ASKO-1201 x N-53		108.0	108.7	111.6	2.03	0.77	-6.61 **
32	ASKO-1201 x Line-13		110.8	107.7	109.5	-1.13	-1.13	-8.37 **
33	ASKO-1299 x Cross-5	109.5	114.0	110.7	114.5	2.45	0.46	-4.18 *
34	ASKO-1299 x GKD-45		111.2	107.9	111.0	0.56	-0.20	-7.11 **
35	ASKO-1299 x GKD-77		116.4	113.5	114.3	1.20	-1.79	-4.33 *
36	ASKO-1299 x ASKO-1222		113.7	110.3	119.8	7.37 **	5.42 **	0.28
37	ASKO-1299 x Arka Kalyan		115.0	111.3	115.5	2.88	0.43	-3.35
38	ASKO-1299 x Line-25		114.0	110.6	114.5	2.44	0.44	-4.18 *
39	ASKO-1299 x N-53		108.0	107.9	111.0	2.05	1.33	-7.11 **
40	ASKO-1299 x Line-13		110.8	106.9	110.0	-0.13	-0.68	-7.95 **
	CC (Bhima Shakti)				119.0			
	S.Em.+				1.86	1.9416	2.2420	2.2420
	C.D. at 5 %				5.86	3.9273	4.5349	4.5349
	C.D. at 1 %				7.26	5.2578	6.0712	6.0712

Table 41. Analysis of variance (mean sum of squares) for combining ability for 17 characters in onion during *rabi*

Source of variation	Df	Plant height (cm) at 30 DAT	Leaf length (cm) at 30 DAT	No of leaves at 30 DAT	Plant height (cm) at 60 DAT	Leaf length (cm) at 60 DAT	No of leaves at 60 DAT	Polar diameter (cm) of bulb	P/E ratio	Neck thickness (cm)	TSS °brix	Market - able yield (t/ha)	Non market -able yield (t/ha)	Average bulb weight (g)	Total yield (t/ha)	Rotten bulbs (t/ha)	Days to maturity
Replicates	1	22.324*	5.304	0.153	0.167	0.648	0.072	0.013	0.012	0.002	0.293	0.036	0.037	0.276	0.075	0.305 *	0.200
Crosses	39	51.776*	19.229**	0.663	16.045**	14.167**	0.515**	0.235**	0.013	0.208*	3.030**	26.295**	0.288**	138.858**	30.439**	0.233*	28.007**
Line Effect	4	321.351**	67.349**	0.511	15.755	23.577	0.633	0.152	0.053**	0.166	4.400	12.727	1.499**	228.469	22.552	0.088	48.378
Tester Effect	7	35.317	16.884	1.138	4.072	11.118	0.861	0.232	0.008	0.400*	1.636	19.097	0.076	55.466	43.507	0.074	21.378
Line * Tester Eff.	28	17.380*	12.941**	0.566	19.079**	13.585**	0.412*	0.248**	0.008	0.165*	3.182*	30.033**	0.168	146.905**	28.298**	0.294*	26.753**
Error	39	1.359	1.868	0.406	1.429	1.165	0.183	0.008	0.014	0.008	0.354	0.425	0.099	1.271	0.626	0.050	4.097
Total	79	26.514	10.482	0.530	8.628	7.577	0.345	0.120	0.013	0.106	1.674	13.191	0.191	69.181	15.337	0.144	15.851
σ^2_{gca}		13.417*	3.111*	0.039*	0.655	1.241*	0.043*	0.014	0.001*	0.021*	0.204	1.198	0.052**	10.823	2.496*	0.002	2.296*
σ^2_{sca}		6.731**	5.635*	0.125*	8.839**	6.184**	0.113*	0.12**	-0.003	0.079*	1.406*	14.851**	0.027	72.817**	13.855**	0.118*	10.863**
$\sigma^2_{gca}/\sigma^2_{sca}$		1.993	0.552	0.313	0.074	0.201	0.381	0.12	-0.386	0.269	0.145	0.081	1.919	0.149	0.18	0.015	0.211

* and ** indicates significant at 5 and 1 % respectively Df : Degrees of freedom DAT : Days After Transplanting

TSS : Total Soluble Solids

The estimation of general combining ability and specific combining ability effects for the traits in 5 line x 8 tester mating design are presented in the table 42 and 43 and the results are highlighted below.

4.6.1.1 Plant height at 30 days after transplanting

Out of 13 parents, four exhibited significant positive GCA effect and one parent ASKO-1299 had highly significant GCA effect. Line ASKO-1299 (4.688) showed highly significant positive GCA effect which is in desirable direction. Whereas, tester GKD-45 (-2.956) exhibited highly significant negative GCA effects. Among the testers (male), Arka Kalyan (2.950) exhibited significant positive GCA effects for plant height.

The highest significant negative SCA effect was observed in Kumata local x Line-13 (-4.452). The higher significant positive SCA effect was observed in GKD-75 x Line-13 (6.967) and involved parental combination of non significant negative x non significant positive general combiners. This was followed by Bhima Shakti x Cross-5 (4.653) and ASKO-1299 x GKD-77 (3.792).

4.6.1.2 Leaf length at 30 days after transplanting

Among the 13 parents, four recorded significant positive GCA effect. Two lines namely ASKO-1299 (2.910) and Kumata local (0.848) recorded significant positive GCA effect. Among the lines, Bhima Shakti was significant general combiner in negative direction. While, among the testers, Arka Kalyan (1.505) had significant GCA effect in positive direction.

Out of 40 hybrids, six crosses Kumata local x Line-25, Kumata local x N-53, Bhima Shakti x Cross-5, GKD-75 x Cross-5, ASKO-1201 x GKD-77, and ASKO-1201 x Arka Kalyan expressed highly significant positive SCA effect. The highest SCA effect was recorded in Bhima Shakti x Cross-5 (4.610).

4.6.1.3 Number of leaves at 30 days after transplanting

Only one parent N-53 showed significant positive GCA effect (0.441). None of the F₁ hybrids showed significant positive SCA effect.

4.6.1.4 Plant height at 60 days after transplanting

It was evident from the table 42 that, two out of five lines and only one out of eight testers recorded significant positive GCA effect. Among lines (female), Kumata local had highly significant in desirable positive direction (1.225). The tester, Line-13 was highly significant in desirable positive direction (0.984). Whereas, GKD-75 (-1.116) recorded highest significant negative GCA effect in non-desirable direction among 13 parents.

Out of 40 hybrids, 10 crosses showed significant positive SCA effect, out of these ASKO-1201 x GKD-77 (5.166) recorded highest SCA effect followed by ASKO-1299 x N-53 (4.163) and Bhima Shakti x Line-13 (4.141).

4.6.1.5 Leaf length at 60 days after transplanting

Of the 13 parents, only eight had significant GCA effect, three in positive direction and five in negative direction. Among lines, ASKO-1299 expressed highly significant positive GCA effect (1.928). In case of testers, Line-25 recorded highly significant positive GCA effect (1.940).

The highest significant positive SCA effect was noticed in the cross ASKO-1299 x Arka Kalyan (4.733) followed by Bhima Shakti x Cross-5 (4.225) and GKD-75 x ASKO-1222 (3.510). Out of 40 crosses, 11 had significant positive SCA effect in desirable direction.

4.6.1.6 Number of leaves at 60 days after transplanting

Four out of 13 parents, had significant GCA effect. Only one parent GKD-77 had significant positive GCA effect (0.290) in desired direction and the other three (ASKO-1201 , GKD-45 and ASKO-1222) in non-desired direction.

Out of 40 crosses, significant SCA effects were observed for four crosses of which two crosses were positive and other two crosses were in negative direction. Among them, highest significant positive and negative SCA effect were observed in Bhima Shakti x N-53 (0.720) and Bhima Shakti x Line-13 (-0.840), respectively.

4.6.1.7 Polar diameter

Among the 13 parents, significant GCA effects were observed for all parents, of which seven were positive and other six were in negative direction. The highest significant positive and negative GCA were observed in Line-13 (0.275) and ASKO-1222 (-0.228), respectively.

Out of 40 hybrids, 15 hybrids had significant positive SCA effect of which highest was showed by cross ASKO-1299 x GKD-77 (0.661).

4.6.1.8 Equatorial diameter

Six parents had significant positive GCA value in positive and seven parents showed significant GCA on negative direction, the parent GKD-77 (0.243) showed highest positive significant value for GCA effect.

For the SCA effect, 11 of the crosses had significant effect in positive direction and highest significant positive SCA effect was showed by the cross GKD-75 x ASKO-1222 (5.629).

4.6.1.9 P/E ratio

Among 13 parents, only one parent showed significant positive GCA effect Bhima Shakti (0.075). With respect to SCA effect none of the hybrids showed SCA effect significantly in positive direction.

4.6.1.10 Neck thickness

There were only seven parents which showed significant negative GCA effect. The highest significant positive GCA effect was observed in Line-13 (0.423) and negative GCA was observed in GKD-45 (-0.233).

Out of 40 crosses, eight expressed significant negative SCA effect. Highest was observed in GKD-75 x N-53 (-1.005). Further, ASKO-1299 x N-53 (0.188) showed highly significant positive SCA effect.

4.6.1.11 TSS (total soluble solids)

Among the parents, three parents had significant positive GCA effect and three showed significant negative GCA effect. The parents GKD-75 and Line-13 had highest positive (0.594) and negative (-0.602) GCA effect respectively.

For SCA effect, seven crosses showed significant positive effect and the highest was exhibited by cross Kumata local x GKD-77 (2.165) followed by ASKO-1299 x GKD-45 (2.106), ASKO-1201 x Line-25 (1.667) and ASKO-1299 x Line-13 (1.646).

4.6.1.12 Marketable yield

Five out of 13 parents showed significant positive GCA effect and highest was observed in Cross-5 (2.00) followed by ASKO-1201 (1.472), GKD-77 (1.197), Line-13 (1.041) and GKD-45 (0.695). Seven of parents recorded significant negative GCA effect.

Fifteen of the crosses exhibited significant positive SCA effect. Highest was recorded by ASKO-1299 x GKD-77 (5.602) followed by Bhima Shakti x Line-13 (5.207), Kumata local x GKD-45 (4.918), GKD-75 x ASKO-1222 (4.515) and ASKO-1299 x Arka Kalyan (4.193). Two of the crosses having higher SCA effect had ASKO-1299 as female parent. This is having good TSS value, more P/E ratio and higher leaf length. Next cross GKD-75 x ASKO-1222 also having the good average bulb weight, GKD-75 found to be a good general combiner for TSS and rotten bulbs.

4.6.1.13 Non-marketable yield

Among the lines, Kumata local exhibited highest significant negative GCA effect (-0.517). The line ASKO-1299 (0.266) had significant positive GCA effect. None of the testers exhibited significant negative GCA effect.

Out of 40 hybrids tested, only one cross ASKO-1201 x N-53 showed significant negative SCA effect (-0.535), which is desirable.

4.6.1.14 Average bulb weight

Of the 13 parents only seven had significant positive GCA effect. Among lines, it range from -6.170 (Bhima Shakti) to 3.418 (ASKO-1201). Among testers, Line-13 (3.549) had higher positive significant GCA effect followed by Cross-5 (1.619) and GKD-77 (0.874).

The higher significant positive SCA effect was noticed in the cross ASKO-1299 x GKD-77 (18.363) followed by Bhima Shakti x Line-13 (14.295). Out of 40 crosses, 15 had significant positive SCA effect in desirable direction while, 18 crosses had significant negative SCA effect.

4.6.1.15 Total yield

Six parents had significant positive GCA effect and seven had significant negative effect, values varying from -1.817 (Kumata local) to 4.550 (Cross-5).

For SCA effect, 14 crosses had significant positive value, highest value was showed by cross ASKO-1299 x GKD-77 (8.470) towards positive direction, followed by the crosses ASKO-1201 x Line-13 (6.089), Bhima Shakti x Line-13 (5.224) and cross ASKO-1201 x GKD-77 (5.197).

4.6.1.16 Rotten bulbs

Among the 13 parents, only one parent GKD-77 (-0.178) had the significant negative GCA effect.

Out of 40 hybrids, only 10 hybrids had significant SCA effect, four were on positive side and six were on negative side. Highest negative SCA effect was recorded by the cross Bhima Shakti x Line-13 was -0.570, which is desirable.

4.6.1.17 Days to maturity

Seven parents out of 13 showed significant negative GCA effect. The line ASKO-1201 (-2.072) had significant negative GCA effect. Six of the parents exhibited significant positive effect. Among them, Cross-5 exhibited highest significant positive GCA effect (2.611).

Out of 40 hybrids tested, only four crosses showed significant negative SCA effect, highest was showed by GKD-75 x GKD-77 (-5.688) followed by ASKO-1201 x ASKO-1222 (-5.500) which was desirable.

Table 42. Estimation of GCA effect of parents for 17 characters in onion during *rabi*

Source of variation	Leaf length at 30 DAT (cm)	No of leaves at 30 DAT	Ht of plant 60 DAT (cm)	Leaf length at 60 DAT (cm)	No of leaves at 60 DAT	Polar diameter (cm)	Equatorial diameter (cm)	P/E ratio	TSS	Marketable yield (t/ha)	Avg bulb wt (g)	Total yield (t/ha)	Bulbs rotten (t/ha)	Days to maturity
Kumata local	0.848 *	0.110	1.225 **	0.378	-0.183	-0.015	-0.144**	0.050	-0.235	-0.532**	-0.767**	-1.817**	-0.065	-1.197**
Bhima Shakti	-2.640 **	0.191	-0.841**	-1.185 **	0.180	0.062	-0.181**	0.075 *	-0.481**	-0.562**	-6.170**	0.609 **	0.063	-0.170 **
GKD-75	-0.728 *	-0.109	-1.116**	-0.610 *	0.093	0.016	0.210 **	-0.047	0.594 **	-0.604**	1.218 **	-0.578**	0.048	2.182 *
ASKO-1201	-0.390	0.060	0.034	-0.510	-0.245 *	0.094	0.108 **	-0.035	0.537 **	1.472 **	3.418 **	1.025 **	-0.095	-2.072 **
ASKO-1299	2.910 **	-0.253	0.697 *	1.928 **	0.155	-0.157	0.007 **	-0.042	-0.416**	0.227	2.302 **	0.761 **	0.049	1.257
S.Em. ₊	0.3232	0.1404	0.2959	0.2759	0.1075	0.0230	0.0177	0.0301	0.1519	0.1440	0.2819	0.1916	0.0600	0.5605
C.D. at 5 %	0.6538	0.2840	0.5986	0.5580	0.2174	0.0466	0.0368	0.0609	0.3073	0.2913	0.5701	0.3876	0.1214	1.1337
C.D. at 1 %	0.8753	0.3802	0.8014	0.7471	0.2911	0.0624	0.0489	0.0815	0.4114	0.3900	0.7633	0.5189	0.1626	1.5178
Cross 5	-1.185 **	-0.069	0.164	-1.400 **	-0.010	-0.140	-0.092**	-0.037	0.518 *	2.000 **	1.619**	4.550 **	0.080	2.611 *
GKD-45	-2.395 **	-0.489**	-0.436	0.420	-0.310 *	0.014	0.221 **	-0.007	-0.312	0.695 **	0.724 *	-1.630**	-0.025	-0.573 **
GKD-77	1.325 **	-0.109	-1.016**	0.080	0.290 *	0.097	0.243 **	-0.015	-0.027	1.197 **	0.874 *	0.957 **	-0.178*	0.130
ASKO-1222	0.265	0.301	-0.016	-0.760 *	-0.570**	-0.228	-0.259**	0.018	0.063	-1.480**	-0.206	-1.658**	-0.016	-0.673 **
Arka Kalyan	1.505 **	-0.399 *	-0.491	-0.220	0.090	0.049	-0.003**	0.051	0.378	-1.490**	-4.466**	-0.976**	0.035	1.545
Line-25	-0.215	0.311	0.584	1.940 **	0.190	-0.057	-0.070**	-0.014	-0.376	-1.114**	-0.776 *	-0.959**	0.070	-1.790 **
N-53	-0.035	0.441 *	0.224	-0.820 *	0.130	-0.007	-0.077**	0.021	0.358	-0.850**	-1.316**	-1.012**	-0.040	0.077
Line-13	0.735	0.011	0.984 *	0.760 *	0.190	0.275	0.036 **	-0.020	-0.602**	1.041 **	3.549 **	0.731 **	0.072	-1.326 **
S.Em. ₊	0.4089	0.1776	0.3743	0.3490	0.1360	0.0291	0.0224	0.0381	0.1922	0.1822	0.3565	0.2424	0.0759	0.7090
C.D. at 5 %	0.8270	0.3593	0.7571	0.7059	0.2750	0.0589	0.0452	0.0770	0.3887	0.3685	0.7212	0.4903	0.1536	1.4341
C.D. at 1 %	1.1072	0.4810	1.0137	0.9450	0.3682	0.0789	0.0605	0.1031	0.5203	0.4933	0.9655	0.6563	0.2057	1.9199

* and ** indicates significant at 5 and 1 % respectively

DAT : Days After Transplanting

TSS : Total Soluble Solids

Table 43. Estimation of SCA effect of crosses for 17 characters in onion during *rabi*

Entries	Ht of plant 30 DAT (cm)	Leaf length at 30 DAT (cm)	No of leaves at 30 DAT	Ht of plant 60 DAT (cm)	Leaf length at 60 DAT (cm)	No of leaves at 60 DAT	Polar diameter (cm)	P/E ratio	Neck thickness	TSS	Marketable yield (t/ha)	xTotal yield (t/ha)	Days to maturity
Kumata local x Cross-5	-1.412	-1.528	0.350	0.295	-0.738	-0.077	-0.332 **	-0.040	0.099 **	1.020 *	3.412 **	1.780 **	-2.989
Kumata local xGKD-45	1.868	1.533	0.370	0.595	-1.858 *	-0.078	0.169 *	-0.085	-0.106 **	0.724	4.918 **	1.845 **	1.525
Kumata local xGKD-77	-2.652	-3.788	-0.410	0.275	-0.817	0.123	-0.121	-0.007	0.053	2.165 **	-3.384 **	-4.042**	3.991 *
Kumata local xASKO-	-1.632	-2.528	-0.570	-1.925	-0.978	-0.218	0.090	0.075	-0.077 *	0.099	-3.358 **	-3.867 **	2.895
Kumata local xArka	1.962	1.732	0.030	1.675	3.383 **	0.122	-0.356 **	0.022	0.020	0.435	-0.948 *	-1.739**	1.177
Kumata local xLine-25	2.868 *	2.453 *	-0.180	0.175	0.323	-0.678	0.273 **	-0.068	0.072 *	-1.312**	0.626	0.564	-2.589
Kumata local xN-53	3.448 *	4.173 **	-0.060	0.235	1.483	0.283	0.168 *	0.042	0.020	-1.196**	2.362 **	3.067 **	-0.955
Kumata local xLine-13	-4.452	-2.048 *	0.470	-1.325	-0.797	0.523	0.109	0.058	-0.080 *	-1.936**	-3.628 **	-4.236**	-3.053
Bhima Shakti x Cross	4.653	4.610 **	0.069	2.261	4.225 **	0.260	0.017	-0.065	-0.068	0.316	3.042 **	-0.671	0.315
Bhima Shakti x GKD-	0.983	0.520	-0.061	1.461	0.505	0.060	0.087	0.015	0.050	-0.729	-4.802**	-3.666**	-1.001
Bhima GKD-77	-2.137	-2.700**	-0.641	-1.659	-2.455**	-0.340	-0.102	0.003	-0.023	-0.014	-4.224**	-1.719**	2.965
Bhima Shakti x ASKO-	1.483	1.260	-0.151	-3.659 **	-1.115	0.020	-0.390**	0.100	-0.031	0.546	3.722**	1.387*	-3.232 *
Bhima Shakti xArka	-2.893 *	-2.280 *	0.049	-5.184 **	-4.155**	-0.540	0.212 **	0.067	0.083 *	-0.669	-5.718 **	-6.371**	2.551
Bhima Shakti x Line-25	-0.167	-0.360	0.589	2.541 **	0.685	0.660 *	0.125	0.022	0.005	-0.885 *	1.836 **	-0.138	-4.116 *
Bhima Shakti x N-53	-2.687	-1.340	0.759	0.101	-0.355	0.720 *	-0.496**	-0.058	-0.092 *	0.701	0.542	-0.759	0.849
Bhima Shakti x Line-13	0.763	0.290	-0.611	4.141 **	2.665 **	-	0.583 **	0.087	0.079 *	0.736	5.207 **	5.224 **	1.670
GKD-75 x Cross 5	-0.443	2.798 **	-0.631	-1.464	-0.150	-0.352	-0.152 *	0.067	-0.039	-0.134	2.885 **	-0.184	-1.268
GKD-75 x GKD-45	-2.213	0.607	0.639	-0.164	0.030	0.348	0.146 *	0.017	0.031	-0.854	-1.460 **	0.696	-1.834
GKD-75 x GKD-77	-1.833	1.487	0.559	1.716 *	2.670 **	0.348	-0.002	-0.075	0.035	0.111	-0.962 *	-1.281 *	-5.688 **
GKD-75 x ASKO-1222	-3.513 *	-0.353	0.049	3.916 **	3.510 **	0.308	0.270 **	-0.093	0.056	-1.729**	4.515 **	5.023 **	-0.834

* and ** indicates significant at 5 and 1 % respectively

DAT : Days After Transplanting

TSS : Total Soluble Solids

Conted...

Entries	Ht of plant 30 DAT (cm)	Leaf length at 30 DAT (cm)	No of leaves at 30 DAT	Ht of plant 60 DAT (cm)	Leaf length at 60 DAT (cm)	No of leaves at 60 DAT	Polar diameter (cm)	Neck thickness	TSS	Marketable yield (t/ha)	Non maketable yield(t/ha)	Bulbs rotten (t/ha)	Days to maturity
GKD-75 x Arka Kalyan	2.981	0.007	-0.301	3.091	-3.230**	-0.053	0.155 *	-0.025	0.206	2.775 **	-0.217	-0.203	-2.802
GKD-75 x Line-25	-2.163	-3.273	0.189	-5.084	-0.690	-0.353	-0.223 **	0.020	0.760	0.069	-0.015	-0.138	6.862 **
GKD-75 x N-53	0.217	-3.053	-0.391	-3.024	0.670	-0.493	-0.515 **	-1.005 **	0.826	-2.466 **	-0.272	0.122	1.996
GKD-75 x Line-13	6.967	1.778	-0.111	1.016	-2.810**	0.247	-0.402 **	0.0282	0.811	-5.356 **	-0.015	0.060	3.568 *
ASKO-1201 x Cross 5	-2.131	-3.440 **	-0.100	-0.414	-2.350**	-0.215	-0.042 **	0.036	0.923 *	-5.592 **	0.115	0.345 *	5.886 **
ASKO-1201 x GKD-45	-1.301	-1.030	0.470	-2.714	3.030 **	-0.115	-0.220 **	-0.012	-1.247**	1.964 **	0.104	0.050	3.570 *
ASKO-1201 x GKD-77	2.830	3.250 **	-0.010	5.166	2.370 **	-0.415	0.394 **	0.049	-1.282**	3.362 **	0.028	0.103	-1.634
ASKO-1201 x ASKO-1222	1.750	1.810	0.080	2.166	1.710 *	0.345	0.162 *	0.040	0.903 *	-2.062 **	0.362	-0.159	-5.500 **
ASKO-1201 xArka Kalyan	-0.057	2.070 *	-0.070	1.441	-0.730	-0.015	-0.185 **	0.024	0.413	-0.302	-0.055	-0.035	-1.048
ASKO-1201 x Line-25	-0.301	-0.110	0.020	-1.434	-2.390**	-0.015	-0.238 **	-0.097 **	1.667 **	-1.648 **	0.112	-0.095	-2.614
ASKO-1201 x	1.580	-1.290	-0.510	-1.474	-0.430	-0.055	0.245 **	-0.008	-0.117	0.708	-0.535*	0.015	1.020
ASKO-1201 x Line-13	-2.370	-1.260	0.120	-2.734	-1.210	0.485	0.543 **	-0.032	-1.257**	3.568 **	-0.128	-0.222	0.322
ASKO-1299 x Cross 5	-0.668	-2.440 *	0.313	-0.677	-0.987	0.385	0.154 *	-0.030	-2.124**	-3.747 **	-0.261	-0.399 *	-1.943
ASKO-1299 x GKD-45	0.662	-1.630	1.418**	0.823	-1.708	-0.215	-0.182 **	0.040	2.106 **	-0.621	0.053	0.056	-2.259
ASKO-1299 x GKD-77	3.792 **	1.750	0.502	-5.497	-1.768	0.285	0.661 **	-0.114 **	-0.979 *	5.602 **	-0.248	-0.011	0.367
ASKO-1299 x ASKO-1222	1.912	-0.190	0.593	-0.497	-3.128**	-0.455	-0.132 *	0.011	0.181	-2.817 **	0.286	0.317	6.671 **
ASKO-1299 xArka Kalyan	-1.994	-1.530	0.293	-1.022	4.733 **	0.485	-0.162 *	-0.102 **	-0.384	4.193 **	0.074	0.446 *	0.123
ASKO-1299 x Line-25	-0.238	1.290	-0.618	3.803 **	2.073 *	0.385	0.063	0.002	-0.230	-0.883 *	-0.039	0.111	2.457
ASKO-1299 x N-53	-2.558	1.510	0.203	4.163	-1.368	-0.455	0.183 **	0.188 **	-0.214	-1.147 **	0.314	-0.029	-2.909
ASKO-1299 x Line-13	-0.908	1.240	0.133	-1.097	2.153	-0.415	-0.322 **	0.003	1.646 **	-0.187	-0.179	-0.491 **	-2.507
S.Em.±	1.3998	0.9142	0.3972	0.8370	0.7803	0.3041	0.0652	0.0352	0.4297	0.4073	0.2387	0.1698	1.585
C.D. at 5 %	2.8313	1.8492	0.8033	1.6930	1.5783	0.6150	0.1390	0.0713	0.8691	0.8239	0.4828	0.3435	3.206
C.D. at 1 %	3.7904	2.4757	1.0755	2.2666	2.1130	0.8234	0.1765	0.0955	1.1635	1.1030	0.6464	0.4599	4.2930

* and ** indicates significant at 5 and 1 % respectively

DAT : Days After Transplanting

TSS : Total Soluble Solids

5. DISCUSSION

Producing more vegetables to meet food and nutritional security of the increasing population from limited land, less water and without eroding the ecological foundation will be a difficult task. Therefore, increasing the productivity is an obvious choice. Achieving this through genetic means is eco friendly and a remunerative one. The main aim of any plant breeding programme is to develop high yielding hybrids or variety. To accomplish this, the breeding programme can efficiently be planned with prior knowledge of the genetic make up of complex quantitative characters like yield and its attributes. The information so obtained in the experiment helps to know about gene action and form the basis for developing precise breeding programme.

Exploitation of hybrid vigour holds a key for genetic improvement of onion crop. The concept of pooling of favourable alleles into a single variety or hybrid is difficult to achieve. Efforts have been made by several researchers, developing double crosses and multiple crosses with the aim of accumulating maximum number of favourable alleles.

For exploitation of heterosis, choice of suitable parents is an important pre-requisite. The parental genotypes are selected on the basis of not only their *per se* performance but also their combining ability. Genetic constitution of the parents involved in hybridization governs the nature of gene action in that hybrid. 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 abilities which are due to additive and non-additive gene effects, respectively.

The recent trend in onion breeding has been towards development of hybrids to meet the specific uses (*viz.*, average bulb weight, bulb shape, uniformity in size, higher total soluble solids, days to maturity *etc.*) coupled with high yield. It may be difficult to develop a hybrid having all the characters. However, it is reasonable to search one which can have maximum number of useful characters keeping yield as primary motto. The parents for the present investigation were selected on the basis of their performance with a view to develop productive hybrids. The superiority of the hybrids in crosses was estimated over mid parent, better parent and commercial check for all the 17 characters studied separately for *kharif* as well as *rabi* season.

The study was conducted with an intention to identify high yielding hybrids and to identify good combiners for, its components traits and to performance of hybrids. Hence, the present investigation was undertaken with the following objectives: heterosis for growth parameters, yield and yield components; performance of hybrids; general combining ability and specific combining ability.

5.1 During *kharif*

5.1.1 Heterosis and performance of hybrids in onion

The impulse of progress in crop improvement through plant breeding was propelled by a better understanding and an appropriate exploitation of heterosis.

In the present investigation 54 entries have been evaluated (13 parents : 40 hybrids : 1 commercial check). Performance of hybrids like GKD-75 x Line-13 (11.83 t/ha), Kumata local x Line-13 (10.57 t/ha), ASKO-1201 x Cross-5 (9.60 t/ha), Kumata local x cross-5 (8.88 t/ha), ASKO-1201 x Line-25 (8.61 t/ha) and GKD-75 x N-53 (7.90 t/ha) for the marketable yield was better than commercial check – Bhima Shakti (6.55 t/ha). These kind of results were observed by Suciú and Tempelman (1979), Mahanthesh *et al.*, (2008), Ambresh *et al.* (2013) and Dwivedi *et al.* (2012). In terms of heterosis, eight hybrids had significant positive heterosis over commercial check for marketable yield, which is the ultimate and most important trait, out of which GKD-75 x Line-13 [11.83 t/ha (Plate 4a)] recorded highest marketable yield 80.61 % more than the commercial check. This was followed by Kumata local x Line-13 [10.57 t/ha, 61.37 % more yield than commercial check (Plate 4b)] and ASKO-1201 x Cross-5 [9.60 t/ha, 46.56 % more yield than commercial check (Plate 4c)]. The higher yield in these entries amounts to demonstration of accumulation of maximum number of favourable alleles in hybrids for yield trait. The yield level achieved through the crop improvement programme in *kharif* is welcome as the yield levels are almost equivalent to *rabi* season crop. These kind of differential performance of hybrids has been demonstrated by workers like Doruchowsk (1986), Veere Gowda (1988), Vinutha (2000), Divakar (2001), Mallikarjun (2006), Noor *et al.* (2012), Ambresh and Veere Gowda (2013), Veere Gowda and Ambresh (2014), Quartiero *et al.* (2014). These entries should be further tested for their performance in *kharif* in other years also. If the performance is consistent in *kharif* over number of years then these are the entries which could be commercialized. The higher yields so obtained could overwhelmingly justify the extra cost involved in hybrid seed production programmes. Since, the Karnataka state has significant area under onion in *kharif* season this kind of increase in yield is note worthy.

The higher yield in GKD-75 x Line-13 is attributed to higher average bulb weight of 80.00 g. This can be viewed by its significant positive heterosis over commercial check by 16.15 %. This was followed by Kumata local x Line-13 having average bulb weight of 78.00 g. This can viewed by its significant positive heterosis over commercial check by 14.71 %. Followed by ASKO-1201 x Cross-5 with average bulb weight of 74.00 g having 8.82 % significant positive heterosis over commercial check. The higher bulb weight accounts to higher polar diameter and equatorial diameter in the top yielding crosses GKD-75 x Line-13 (5.3 cm and 4.3 cm), Kumata local x Line-13 (5.21 cm and 4.3 cm) and ASKO-1201 x Cross-5 (5.28 cm and 4.4 cm). These entries (GKD-75 x Line-13, Kumata local x Line-13 and ASKO-1201 x Cross-5) having P/E ratio >1 (torpedo shape). The top yielding crosses had moderate vegetative growth. This indicates these entries did not put up luxuriant growth. Hence, more photosynthates were diverted to the economic parts. Entries like ASKO-1299 x Line-25 and ASKO-1299 x N-53 had higher vegetative growth and this at expense of yield. These results were in confirmation with Vadivel *et al.* (1982), Madalageri (1983), Aghora (1985), Pal *et al.* (1988), Vinutha (2000), Mallikarjun (2006), Evoor *et al.* (2007), Abubakar and Ado (2008), Ambresh and Veere Gowda (2013), Veere Gowda and Ambresh (2014) and Quartiero *et al.* (2014).



GKD-75

Plate 4a : Top performing *kharif* hybrids



GKD-75 X Line- 13

Plate 4a : Top performing *kharif* hybrids



Line- 13

Plate 4a : Top performing *kharif* hybrids

Plate 4a: Top performing *kharif* hybrids



Kumata local

Plate 4b : Top performing *kharif* hybrids



Kumata local X Line- 13

Plate 4b : Top performing *kharif* hybrids



Line- 13

Plate 4b : Top performing *kharif* hybrids

Plate 4b: Top performing *kharif* hybrids



ASKO-1201

Plate 4c : Top performing *kharif* hybrids



ASKO-1201 X Cross- 5

Plate 4c : Top performing *kharif* hybrids



Cross- 5

Plate 4c : Top performing *kharif* hybrids

Plate 4c: Top performaing *kharif* hybrids

Total soluble solids is one of the most important quality parameter. In the present investigation GKD-75 x Line-13, Kumata local x Line-13 and ASKO-1201 x Cross-5 had heterosis in negative direction over commercial check (Bhima Super). Normally, TSS is negatively correlated with yield. Therefore, breeding for higher yield is at the expense of TSS. However, in the present investigation higher yielding entries like GKD-75 x Line-13, Kumata local x Line-13, ASKO-1201 x Cross-5 and ASKO-1201 x GKD-77 had higher yield along with acceptable TSS (11.35 °Brix, 10.90 °Brix and 12.30 °Brix respectively). These results were in confirmations with McCollum (1968), Padda *et al.* (1973), Madalageri (1983), Veere Gowda (1988), Hays and Randle (1996), Divakar (2001) and Evoor *et al.* (2007) findings.

For the characters like neck thickness, significant negative heterosis is desirable, normally lower neck thickness gives the advantage of higher shelf life. Majority of the crosses showed significant negative heterosis for this trait. Among them, top yielding superior hybrids GKD-75 x Line-13 (1.22 cm), Kumata local x Line-13 (1.11 cm) and ASKO-1201 x Cross-5 (1.21 cm) exhibited -6.97 %, -15.83 % and -7.95 % heterosis over commercial check respectively. These results were in confirmation with Veere Gowda (1988), Divakar (2001), Evoor *et al.* (2007) and Veere Gowda and Ambresh (2014).

Early maturity with higher yield is desirable. This means one has to look for negative heterosis over commercial check. Kumata local x Line-13 had significant negative heterosis over commercial check. GKD-75 x Line-13 and ASKO-1201 x Cross-5 got matured in 114.5 days and 119.5 days, respectively. These kind of results were observed by Sayed *et al.* (1999) and Veere Gowda and Ambresh (2014).

The top yielding crosses GKD-75 x Line-13 (1.15 t/ha), Kumata local x Line-13 (1.20 t/ha) and ASKO-1201 x Cross-5 (0.75 t/ha) were with less non marketable yield as indicated by non significant negative heterosis value of -12.55 %, -8.75 % and -42.97 % over commercial check, respectively. They were having less amount of rotten bulbs *i.e.*, 2.08 t/ha (Kumata local x Line-13), 1.58 t/ha (GKD-75 x Line-13), 2.25 t/ha (ASKO-1201 x Cross-5). Heterosis for this character was observed by Divakar (2001). These three hybrids should be tried further on a large scale during *kharif* and if found stable in expression, then they can be released for commercial cultivation.

The top yielding crosses GKD-75 x Line-13 had medium red to light red bulbs, Kumata local x Line-13 and ASKO-1201 x Cross-5 had medium red colour bulbs. (Appendix III).

Any deviation in our findings with others are due to the differences in population size, genotypes used in the genetic study, diversity of the material, cropping season, environmental condition under which they were grown and the method of analysis employed. The estimates vary among populations because of the different alleles that are present and the frequency of the occurrence of these alleles.

5.1.2 Combining ability

The combining ability concept was first proposed by Sprague and Tatum (1942) in corn. According to them, the general combining ability (*gca*) is the comparative ability of the mean performance of all the cross involving a parent from over all mean. Specific combining ability (*sca*) was defined as the deviation in the performance of specific cross from the performance expected on

the basis of general combining ability effects of parents involved in the crosses. A positive general combining ability (*gca*) indicates a parent that produced above average progeny, whereas parent with negative *gca* produces progeny that performs below average of the population. Specific combining ability (*sca*) can be either negative or positive and *sca* always refers to specific cross and never to particular parent by itself.

The Line-13 (1.517) exhibited highest positive GCA effect significantly for marketable yield followed by Kumata local (0.945), Cross-5 (0.786) and ASKO-1201 (0.528). The line ASKO-1201 and the tester Cross-5 showed good GCA effect for the trait average bulb weight. The top yielding entries [GKD-75 x Line-13 (4.013), ASKO-1201 x Cross-5 (2.431) and Kumata local x Line-13 (2.258)] involved positive (significant) x positive (significant) general combiner. This indicates that if parents with positive significant general combiners are included in the crossing programme, there are every chances of getting entry with high yield for *kharif* season. Variance due to GCA and SCA was significant for the yield trait, indicating the involvement of both additive and non additive gene action, however, the estimates of SCA were higher than GCA variances indicating predominance of non-additive gene action in controlling the inheritance of this trait. Non additive gene action inheriting this character was also observed by Vadivel *et al.* (1982) and Sundari *et al.* (2003).

The cross having highest SCA value for average bulb weight was Kumata local x Line-13 (12.738) which involved positive (significant) x positive (significant) general combiners. This was followed by ASKO-1201 x Cross-5 (9.850) which involved positive (significant) x positive (significant) general combiners and GKD-75 x Line-13 (14.050) which involved positive (significant) x negative (significant) general combiners. Variance due to SCA was significant, where as variance due to GCA was non significant indicating the involvement non additive gene action. Non additive gene action inheriting this character was also observed by Vadivel *et al.* (1982) and Sundari *et al.* (2003).

Following parents were good general combiners for various traits: Line Kumata local (0.945) and tester Line-13 (1.517) for marketable yield; line Kumata local (4.338) and tester Line-13 (4.638) for average bulb weight; line Bhima Shakti (0.134) and tester Cross-5 (0.200) for polar diameter; line Bhima Shakti (0.118) and tester Line-13 (0.423) for equatorial diameter; line GKD-75 (0.512) and tester Cross-5 (0.668) for TSS; line ASKO-1299 (-0.067) and tester ASKO-1222 (-0.079) for neck thickness; line GKD-75 (0.065) and tester Cross-5 (0.035) for P/E ratio; line Kumata local (0.864) and tester Line-13 (0.759) for total yield. Similar results were expressed by Hosfield *et al.* (1977b), Vadivel *et al.* (1982), Madalageri (1983), Sayed *et al.* (1999), Divakar (2001) and Sundari *et al.* (2003).

For total yield, positive significant SCA effect was exhibited by GKD-75 x Line-13 which involved positive (significant) x positive (significant) general combiner. This was followed by Kumata local x Line-13 which involved positive (significant) x positive (significant) general combiner and ASKO-1201 x Cross-5 involved negative (significant) x positive (significant) general combiner. Variance due to SCA was significant indicating the involvement of non additive gene action. Non additive gene action inheriting this character was also observed by Vadivel *et al.* (1982) and Sundari *et al.* (2003).

Table 44. The best hybrids for important characters during *kharif*

Sl. No.	Characters	Cross combinations
1	Average bulb weight (g) > 70 g	GKD-75 x Line-13 ASKO-1201 x GKD-45 Kumata local x Line-13 ASKO-1201 x Cross-5
2	Total soluble solids (°B) > 12	ASKO-1299 x Cross-5 ASKO-1201 x ASKO-1222 ASKO-1201 x Cross-5 GKD-75 x Cross-5 GKD-75 x Arka Kalyan
3	Marketable yield (t/ha) > 8	GKD-75 x Line-13 Kumata local x Line-13 ASKO-1201 x Cross-5 Kumata local x Cross-5 ASKO-1201 x Line-25
4	Neck thickness (cm) < 1	ASKO-1299 x ASKO-1222 Bhima Shakti x N-53 ASKO-1201 x Line-13

Out of above three crosses (GKD-75 x Line-13, ASKO-1201 x Cross-5 and Kumata local x Line-13), ASKO-1201 x Cross-5 (0.945) involved positive (non significant) x positive (significant) general combiners having significant positive SCA effect for TSS. Variance due to GCA and SCA were significant indicating the involvement of both additive and non additive gene action. However, the estimates of SCA were higher than GCA variances in controlling the inheritance of this trait indicating predominance of non additive genetic variance. Similar findings were observed by Vadivel *et al.* (1982) Madalageri (1983), and Sundari *et al.* (2003).

For polar diameter, higher positive significant SCA effect was observed in cross GKD-75 x Line-13 (0.608). This was followed by Kumata local x Line-13 (0.565) and ASKO-1201 x Cross-5 (0.480). Variances due to GCA and SCA were significant indicating the importance of both additive and non additive genetic variances in the inheritance of these traits. However, the SCA variance is higher than GCA variance indicating predominance of non additive genetic variance. Madalageri (1983), Divakar (2001) and Sundari *et al.* (2003) also observed the significant variances due to GCA and SCA effects.

For equatorial diameter, among hybrids, significant positive SCA effect were recorded by GKD-75 x Line-13 (0.267) and Kumata local x Line-13 (0.137). Variances due to SCA were significant indicating predominance of non additive genetic variance. Madalageri (1983), Divakar (2001) and Sundari *et al.* (2003) also observed the significant variances due to GCA and SCA effects.

For P/E ratio, GKD-75 x Line-13 (0.206) was found to have significant positive SCA effect which was at par with other two superior hybrids (Kumata local x Line-13 and ASKO-1201 x Cross-5). Even though the variance for gca and sca were low it was significant, indicating involvement of both additive and non-additive gene action in controlling the inheritance of P/E ratio (shape index). The non-additive gene action in controlling the inheritance of P/E ratio (shape index) was also observed by Madalageri (1983), Sayed *et al.* (1999), Divakar (2001) and Sundari *et al.* (2003).

For all the vegetative parameters like plant height, leaf length and number of leaves (except plant height and leaf length at 60DAT where, variance due to GCA were not significant indicating predominance of non additive gene action) variance due to GCA and SCA were significant indicating the involvement of both additive and non additive gene action, however the estimates of SCA were higher than GCA variances in controlling the inheritance of these traits indicating predominance of non additive gene action. Non additive gene action inheriting these characters was also observed by Vadivel *et al.* (1982), Sayed *et al.* (1999) and Sundari *et al.* (2003).

For days to maturity, in case of parents significant negative GCA effect was exhibited by Line-13 (-2.513). This was followed by ASKO-1201 (-1.234). SCA variances was significant for days to maturity indicating non additive gene action was controlling. Similar study was done by Hosfield *et al.* (1977b), Vadivel *et al.* (1982), Sayed *et al.* (1999) and Sundari *et al.* (2003).

Any deviation in our findings with others are due to the differences in population size, genotypes used in the genetic study, diversity of the material, cropping season, environmental condition under which they were grown and the method of analysis employed.

5.2 During *rabi*

5.2.1 Heterosis and performance of hybrids in onion

The impulse of progress in crop improvement through plant breeding was propelled by a better understanding and an appropriate exploitation of heterosis.

Marketable yield is the ultimate and most important trait. The performance of hybrids for marketable yield point to entries like ASKO-1299 x GKD-77 (26.80 t/ha), ASKO-1201 x Line-13 (26.25 t/ha), Bhima Shakti x Line-13 (26.25 t/ha), ASKO-1201 x GKD-77 (26.20 t/ha), Bhima Shakti x cross-5 (24.65 t/ha), Kumata local x GKD-45 (25.25 t/ha) and Kumata local x Cross-5 (25.05 t/ha) are statistically at par with commercial check [Bhima Shakti (24.6 t/ha)]. These kind of results were observed by Suci and Tempelman (1979), Mahanthesh *et al.* (2008), Ambresh *et al.* (2013) and Dwivedi *et al.* (2012). In terms of heterosis, six hybrids had significant positive heterosis over commercial check for marketable yield. Out of which, ASKO-1299 x GKD-77 [26.80 t/ha (Plate 5a)] has significant positive heterosis over commercial check by 13.08 per cent. This was followed by ASKO-1201 x Line-13 [26.25 t/ha (Plate 5b)] and Bhima Shakti x Line-13 [26.25 t/ha (Plate 5c)]. They were also having significant positive heterosis over better parent and mid parent. These results are in line with Doruchowsk (1986), Veere Gowda (1988), Vinutha (2000), Divakar (2001), Mallikarjun (2006), Noor *et al.* (2012), Ambresh and Veere Gowda (2013), Veere Gowda and Ambresh (2014), Quartiero *et al.* (2014). These 40 hybrids in the present investigation were also tested in *kharif* season. Unlike, *kharif* season where there were three hybrids superior over commercial check in terms of *per se* performance, none of the hybrids were found superior over commercial check in *rabi*. This indicates the role of environment on the expression of character being different. The present study in *rabi* points that the diversity of the parents included for *rabi* is having less genetic diversity for the expression of the characters. Since, none of the hybrids were superior over commercial check, there is a necessity to include more diversified parents for developing hybrids suited for *rabi*.

One of the major contributing character for marketable yield is the bulb weight. For recording the marketable yield the entire plot yield was taken into consideration, where as for arriving average bulb weight, only five bulbs were chosen. This has resulted into some of the entries promising better than commercial check in the present investigation, as far as the average bulb weight character is taken into consideration.

Per se performance for average bulb weight indicate ASKO-1299 x GKD-77 cross had significantly higher bulb weight than commercial check. There were six entries (Bhima Shakti x Line-13, GKD-75 x ASKO-1222, GKD-75 x Line-25, ASKO-1201 x GKD-77, ASKO-1201 x Line-13 and ASKO-1299 x GKD-77) which had expressed higher heterosis over commercial check. The higher bulb weight is accounted by higher polar diameter and equatorial diameter in top yielding crosses ASKO-1299 x GKD-77 (5.90 cm and 5.04 cm), Bhima Shakti x Line-13 (5.88 cm and 5.11 cm) and ASKO-1201 x Line-13 (5.78 cm and 5.30 cm). These entries (ASKO-1299 x GKD-77, Bhima Shakti x Line-13 and ASKO-1201 x Line-13) had P/E ratio >1 (torpedo shape). The top yielding crosses which were at par with commercial check for marketable yield had more or less vegetative growth at par with commercial check. These results were in confirmation with the findings of Madalageri (1983), Vadivel *et al.* (1982), Aghora (1985), Pal *et al.* (1988), Vinutha (2000), Mallikarjun (2006), Evoor *et al.* (2007), Abubakar and Ado (2008), Ambresh and Veere Gowda (2013), Veere Gowda and Ambresh (2014) and Quartiero *et al.* (2014).

Table 45. The best general combiners for important characters during *kharif*

Sl. No.	Characters	Cross combinations
1	Average bulb weight (g) > 75 g	Kumata local Bhima Shakti ASKO-1299 Line-25
2	Total soluble solids (°B) > 10.5	GKD-45 GKD-75 ASKO-1201 Line-25
3	Marketable yield (t/ha) > 6.5	ASKO-1299 Bhima Shakti ASKO-1201
4	Neck thickness (cm) < 1	Arka Kalyan Cross-5



ASKO-1299

Plate 5a : Top performing *rabi* hybrids

X



ASKO-1299 X GKD-77

Plate 5a : Top performing *rabi* hybrids



GKD-77

Plate 5a : Top performing *rabi* hybrids

Plate 5a : Top performing *rabi* hybrids



ASKO-1201

Plate 5b : Top performing *rabi* hybrids



ASKO-1201 X Line-13

Plate 5b : Top performing *rabi* hybrids



Line-13

Plate 5b : Top performing *rabi* hybrids

Plate 5b : Top performing *rabi* hybrids



Bhima Shakti

Plate 5c : Top performing *rabi* hybrids



Bhima Shakti X Line-13

Plate 5c : Top performing *rabi* hybrids



Line-13

Plate 5c : Top performing *rabi* hybrids

Plate 5c : Top performing *rabi* hybrids

Total soluble solids is one of the most important quality parameter. In the present investigation ASKO-1299 x GKD-77, Bhima Shakti x Line-13 and ASKO-1201 x Line-13 had heterosis in negative direction over commercial check (Bhima Shakti). Normally, TSS is negatively correlated with yield. Therefore, breeding for higher yield is at the expense of TSS. However, in the present investigation higher yielding entries like ASKO-1299 x GKD-77, Bhima Shakti x Line-13 and ASKO-1201 x Line-13 had higher yield along with acceptable TSS (9.10 °Brix, 10.18 °Brix and 9.20 °Brix, respectively). These results are in line with McCollum (1968), Padda *et al.* (1973), Madalageri (1983), Veere Gowda (1988), Hays and Randle (1996), Divakar (2001) and Evoor *et al.* (2007).

For the characters like neck thickness significant negative heterosis is desirable, normally lower neck thickness gives the advantage of higher shelf life. Majority of the crosses showed significant negative heterosis for this trait, among them top yielding superior hybrids ASKO-1299 x GKD-77 (0.97 cm) and ASKO-1201 x Line-13 (1.05 cm) had significant negative heterosis of -20.88 % and -13.52 %, respectively. While other cross (Bhima Shakti x Line-13) did not show significant negative heterosis over commercial check. These results were in confirmation with Veere Gowda (1988), Divakar (2001), Evoor *et al.* (2007) and Veere Gowda and Ambresh (2014).

Early maturity along with higher yield is desirable. This means one has to look for negative heterosis over commercial check. ASKO-1299 x GKD-77, Bhima Shakti x Line-13 and ASKO-1201 x Line-13 had significant negative heterosis over commercial check. ASKO-1299 x GKD-77, Bhima Shakti x Line-13 and ASKO-1201 x Line-13 got matured in 114.3 days, 112.8 days and 109.5 days, respectively. These kind of results were observed by Sayed *et al.* (1999) and Veere Gowda and Ambresh (2014).

With respect to rotten bulbs none of the hybrid showed negative significant heterosis over commercial check. Bhima Shakti x Line-13 (0.08 t/ha), ASKO-1201 x Line-13 (0.29 t/ha) and ASKO-1299 x GKD-77 (0.50 t/ha) performed good for this character and are at par with commercial check (Bhima Shakti). These results are in line with Divakar (2001).

The top yielding crosses Bhima Shakti x Line, ASKO-1201 x Line-13 and ASKO-1299 x GKD-77 are having bulbs with colour medium red to light red colour (Appendix III).

Any deviation in our findings with others are due to the differences in population size, genotypes used in the genetic study, diversity of the material, cropping season, environmental condition under which they were grown and the method of analysis employed. The estimates vary among populations because of the different alleles that are present and the frequency of the occurrence of these alleles.

5.2.2 Combining ability

From the analysis of combining ability estimates, it was observed that both additive and non-additive gene actions were operating for all the characters under study because variance due to general combining ability (*gca*) and specific combining ability (*sca*) were highly significant. Further it was observed that variance due to *sca* were higher in magnitude than *gca* for 14 traits except plant height at 30 DAT, P/E ratio and non marketable yield. Thus, it supports the predominance of non-additive gene action over additive gene action on governing the expressions of these characters.

For marketable yield, significant positive SCA effect for this trait was exhibited by cross ASKO-1299 x GKD-77 (5.602) which involved positive (non significant) x positive (significant) general combiner. This was followed by Bhima Shakti x Line-13 (5.207) which involved negative (significant) x positive (significant) general combiner and ASKO-1201 x Line-13 (3.568) which involved positive (significant) x positive (significant) general combiner. Variance due to SCA was significant indicating the involvement of non additive gene action. Non additive gene action controlling this character was also observed by Vadivel *et al.* (1982) and Sundari *et al.* (2003).

Following parents were good general combiners for various traits: Line ASKO-1201 (1.472) and tester Cross-5 (2.00) for marketable yield; line ASKO-1201 (3.418) and tester Line-13 (3.549) for average bulb weight; line ASKO-1201 (0.094) and tester Line-13 (0.275) for polar diameter; line GKD-75 (0.210) and tester GKD-77 (0.290) for equatorial diameter; line GKD-75 (0.594) and tester Cross-5 (0.518) for TSS; line Kumata local (-0.143) and tester GKD-45 (-0.233) for neck thickness; line Bhima Shakti (0.075) for P/E ratio; line ASKO-1201 (1.025) and tester Cross-5 (4.550) for total yield. Similar results were expressed by, Hosfield *et al.* (1977b), Vadivel *et al.* (1982), Madalageri (1983), Sayed *et al.* (1999), Divakar (2001), Sundari *et al.* (2003), Mallikarjun (2006), Ara *et al.* (2011) and Noor Farid *et al.* (2012).

For the important yield attributing character *i.e.*, average bulb weight, Cross ASKO-1299 x GKD-77 (18.363) involved positive (significant) x positive (significant) general combiner. This was followed by Bhima Shakti x Line-13 (14.295) which involved negative (significant) x positive (significant) general combiner and ASKO-1201 x Line-13 (5.208) which involved positive (significant) x positive (significant) general combiner. These were the crosses which demonstrated significant positive SCA effect. Variance due to SCA was significant, where as variance due to GCA was non significant indicating the involvement non additive gene action. Non additive gene action controlling this character was also observed by Vadivel *et al.* (1982) and Sundari *et al.* (2003).

For total yield, positive significant SCA effect exhibited by top three crosses [ASKO-1299 x GKD-77 (8.470), ASKO-1201 x Line-13 (6.089) and Bhima Shakti x Line-13 (5.224)] involved positive (significant) x positive (significant) general combiners. Variance due to GCA and SCA was significant for this trait, indicating the involvement of both additive and non additive gene action. However, the estimates of SCA were higher than GCA variances indicating predominance of non additive gene action in controlling the inheritance of this trait. Non additive gene action controlling this character was also observed by Vadivel *et al.* (1982) and Sundari *et al.* (2003).

For TSS, none of the top performing hybrids had significant positive SCA effect. Variance due to SCA was significant, where as variance due to GCA was non significant indicating the involvement non additive gene action. Similar findings were observed by Vadivel *et al.* (1982) Madalageri (1983) and Sundari *et al.* (2003).

For polar diameter, cross ASKO-1299 x GKD-77 (0.661) found to have highest positive significant SCA effect followed by Bhima Shakti x Line-13 (0.583) and ASKO-1201 x Line-13 (0.543). Variance due to SCA was significant, where as variance due to GCA was non significant indicating the involvement non additive gene action. For equatorial diameter, significant positive SCA effect showed the by cross Bhima Shakti x Line-13 (0.140) among superior yielding crosses. Variances due

to GCA and SCA were significant indicating the importance of both additive and non additive genetic variances in the inheritance of this trait indicating predominance of non additive genetic variance. Madalageri (1983), Divakar (2001) and Sundari *et al.* (2003) also observed non additive genetic variances in the inheritance of these traits.

For P/E ratio, none of the hybrids showed SCA significantly in positive direction. Variance due to GCA was significant for this character indicating the involvement of additive gene action. Additive gene action inheriting this trait was observed by Hosfield *et al.* (1976), Hosfield *et al.* (1977b) and Sayed *et al.* (1999).

For all the vegetative parameters like plant height, leaf length and number of leaves (except for plant height at 60DAT, where, variance due to SCA was significant indicating role of non additive gene action) variance due to GCA and SCA was significant indicating the involvement of both additive and non additive gene action in the expression of characters. Non additive gene action controlling these characters was also observed by Vadivel *et al.* (1982), Sayed *et al.* (1999) and Sundari *et al.* (2003).

For plant height at 30DAT, variance due to GCA and SCA was significant indicating the involvement of both additive and non additive gene action. However, the estimates of GCA were higher than SCA variances in controlling the inheritance of this trait indicating additive gene action. Additive gene action controlling this character was also observed by Madalageri (1983) and Divakar (2001).

Any deviation in our findings with others are due to the differences in population size, genotypes used in the genetic study, diversity of the material, cropping season, environmental condition under which they were grown and the method of analysis employed.

Future line of work

Based on the present investigation following suggestions are made:

1. Identified superior hybrids for *kharif* should be tested under different locations and seasons for their stability analysis.
2. Identified lines with good *gca* for various traits can be used in multiple cross combination to develop superior segregants for yield improvement.

Practical utility of the investigation

1. The superior hybrids GKD-75 x Line-13, ASKO-1201 x Cross-5 and Kumata local x Line-13 should be evaluated in the farmer's field on larger scale for getting higher yield as compared to the locally used varieties in *kharif*.

Table 46. The best hybrids for important characters during *rabi*

Sl. No.	Characters	Cross combinations
1	Average bulb weight (g) > 65	ASKO-1299 x GKD-77 ASKO-1201 x Line-13 Bhima Shakti x Line-13 ASKO-1201 x GKD-77 GKD-75 x Line-25
2	Total soluble solids (°B) > 12	ASKO-1201 x Cross-5 Kumata local x GKD-77 ASKO-1201 x Line-25 GKD-75 x N-53 ASKO-1201 x ASKO-1222
3	Marketable yield (t/ha) > 26	ASKO-1299 x GKD-77 Bhima Shakti x Line-13 ASKO-1201 x Line-13 ASKO-1201 x GKD-77
4	Neck thickness (cm) < 1	ASKO-1299 x GKD-77 ASKO-1299 x Arka Kalyan

Table 47. The best general combiners for important characters during *rabi*

Sl. No.	Characters	Cross combinations
1	Average bulb weight (g) > 60	Bhima Shakti Cross-5 GKD-75 GKD-77 ASKO-1222
2	Total soluble solids (°B) > 11.5	ASKO-1299 GKD-75 GKD-77 ASKO-1201
3	Marketable yield (t/ha) > 24	ASKO-1222 Cross-5 Bhima Shakti Kumata local
4	Neck thickness (cm) < 1	Cross-5 ASKO-1222 Line-25

6. SUMMARY AND CONCLUSIONS

Studies on "Heterosis and combining ability studies in onion" was undertaken during 2014-16 at network project on onion and garlic site, Department of Horticulture, Main Agricultural Research Station, Dharwad. The study was mainly contemplated to develop best hybrids and also to find the best general and specific combiner for higher yield and other yield attributing characters.

In order to generate hybrids, 5 lines were used as female parents to cross with the 8 testers as males. F₁s were generated using line x tester design and they were harvested in the month of April 2015. F₁ were evaluated separately for *kharif* and as well as *rabi* season.

Genotypes *viz.*, Kumata local, Bhima Shakti, GKD-75, ASKO-1201 and ASKO-1299 were used as lines. Cross-5, GKD-45, GKD-77, ASKO-1222, Arka Kalyan, Line-25, N-53 and Line-13 were used as testers and 40 hybrids were generated. Forty hybrids were evaluated along with 13 parents and one commercial check during 2015-16 for estimation of heterosis and combining ability.

During *kharif* season

Among 40 hybrids, three crosses GKD-75 x Line-13, Kumata local x Line-13 and ASKO-1201 x Cross-5 expressed positive significant heterosis over commercial check. These hybrids GKD-75 x Line-13, Kumata local x Line-13 and ASKO-1201 x Cross-5 performed better than commercial check for marketable yield. Out of which, GKD-75 x Line-13 (11.83 t/ha) recorded highest marketable yield of 80.61 per cent more than the commercial check. Above three hybrids had higher bulb weight of 80.00 g, 78.00 g and 74.00 g, respectively. Eight hybrids had significant positive heterosis over commercial check for marketable yield. ASKO-1299 was better yielding among 13 parents (8.61 t/ha).

Heterosis of a complex character such as yield was regulated by hybrid vigour expressed by its component characters such as polar diameter and P/E ratio. GKD-75 x Line-13, Kumata local x Line-13 and ASKO-1201 x Cross-5 manifested significant positive heterosis over mid parent, better parent commercial check in desirable direction for polar diameter. Kumata local x Line-13 and ASKO-1201 x Cross-5 manifested significant positive heterosis for P/E ratio in desirable direction over mid parent and better parent. These hybrids GKD-75 x Line-13, Kumata local x Line-13 and ASKO-1201 x Cross-5 should be tried on large scale, if found stable in expression, they can be released for commercial cultivation.

Analysis of variance for combining ability reveals the presence of both additive and non additive gene action in nine characters out of seventeen [plant height (30 DAT), leaf length (30 DAT), number of leaves (30 DAT), number of leaves (60 DAT), equatorial diameter of bulb, P/E ratio, neck thickness, TSS and marketable yield]. Of these nine characters which showed both additive and non additive gene effect, the estimates of SCA variance were higher than GCA variance indicating predominance of non additive gene action. For seven characters namely plant height (60 DAT), leaf length (60 DAT), polar diameter, average bulb weight, total yield, rotten bulbs and days to maturity had only SCA variance as significant, where as GCA variance was non significant indicating the role of non additive gene action.

The GCA effects indicated that none of the parent was a good general combiner for all the characters. However, the following are good general combiners for various traits. Line Kumata local (0.945) and tester Line-13 (1.517) for marketable yield; line Kumata local (4.338) and tester Line-13 (4.638) for average bulb weight; line Bhima Shakti (0.134) and tester Cross-5 (0.200) for polar diameter; line Bhima Shakti (0.118) and tester Line-13 (0.423) for equatorial diameter; line GKD-75 (0.512) and tester Cross-5 (0.668) for TSS; line ASKO-1299 (-0.067) and tester ASKO-1222 (-0.079) for neck thickness; line GKD-75 (0.065) and tester Cross-5 (0.035) for P/E ratio; line Kumata local (0.864) and tester Line-13 (0.759) for total yield; line ASKO-1299 and tester Line-13 for plant height at 30 DAT; line ASKO-1299 for leaf length at 30 DAT; line Kumata local and tester GKD-45 for number of leaves at 30 DAT; line Kumata local and tester ASKO-1222 for plant height at 60 DAT; line GKD-75 and N-53 for leaf length at 60 DAT; line ASKO-1201 and tester N-53 for number of leaves at 60 DAT.

The hybrid combinations with maximum significant SCA effect for different traits were GKD-75 x Line-13, ASKO-1201 x Cross-5, Kumata local x Line-13 and ASKO-1201 x Line-25 exhibited high SCA effects for marketable yield; GKD-75 x Line-13, and Kumata local x Line-13 exhibited significant SCA effect for average bulb weight; GKD-75 x Line-13, Kumata local x Line-13 and ASKO-1201 x Cross-5 for polar diameter; ASKO-1299 x GKD-77, ASKO-1201 x GKD-45 and GKD-75 x N-53 for equatorial diameter; GKD-75 x Line-13, Kumata local x Line-13 and ASKO-1201 x GKD-45 for P/E ratio; ASKO-1201 x ASKO-1222, ASKO-1299 x Cross-5 and Bhima Shakti x N-53 for TSS; ASKO-1299 x ASKO-1222 and Bhima Shakti x N-53 for neck thickness; GKD-75 x Line-13 and Kumata local x Line-13 for total yield. Kumata local parent having highest and significant GCA effect demonstrated its value as good general combiner for the total yield. Bhima Shakti x Line-25 and ASKO-1201 x Line-13 for plant height at 30 DAT; ASKO-1201 x N-53 and ASKO-1201 x Line-13 for leaf length at 30 DAT; ASKO-1299 x Line-13 and ASKO-1299 x Cross-5 for number of leaves at 30 DAT; ASKO-1299 x N-53 and Bhima Shakti x Line-13 for plant height at 60 DAT; Kumata local x N-53 and Bhima Shakti x Cross-5 for leaf length at 60 DAT; GKD-75 x GKD-45 and ASKO-1299 x GKD-77 for number of leaves at 60 DAT.

During *rabi* season

Among 40 hybrids, five entries like ASKO-1299 x GKD-77 (26.80 t/ha), ASKO-1201 x Line-13 (26.25 t/ha), Bhima Shakti x Line-13 (26.25 t/ha), ASKO-1201 x GKD-77 (26.20 t/ha) and Bhima Shakti x cross-5 (24.65 t/ha) performed at par with commercial check [Bhima Shakti (24.6 t/ha)]. In terms of heterosis, six hybrids had significant positive heterosis over commercial check for marketable yield. Out of which, ASKO-1299 x GKD-77, ASKO-1201 x Line-13 and Bhima Shakti x Line-13 expressed positive significant heterosis over commercial check. These three hybrids had higher bulb weight of 69.20 g, 67.00 g and 66.50 g, respectively. Seven hybrids had significant positive heterosis over commercial check for average bulb weight. ASKO-1222 had better marketable yield among 13 parents (26.80 t/ha).

Heterosis of a complex character such as yield was regulated by hybrid vigour expressed by its component characters such as polar diameter and P/E ratio. ASKO-1299 x GKD-77, ASKO-1201 x Line-13 and Bhima Shakti x Line-13 manifested significant positive heterosis over mid parent, better parent and commercial check in desirable direction for polar diameter. None of the above hybrids manifested significant positive heterosis for P/E ratio in desirable direction over commercial check.

Analysis of variance for combining ability reveals the presence of both additive and non additive gene action in nine characters out of seventeen [Plant height (30 DAT), leaf length (30 DAT), number of leaves (30 DAT), leaf length (60 DAT), number of leaves (60 DAT), equatorial diameter of bulb, neck thickness, total yield and days to maturity]. Of these nine characters which showed both additive and non additive gene effect, the estimates of SCA variance were higher than GCA variance indicating predominance of non additive gene action. For seven characters namely plant height (60 DAT), polar diameter of bulb, TSS, marketable yield, non marketable yield, average bulb weight and rotten bulbs had only SCA variance as significant, where as GCA variance was non significant indicating the role of non additive gene action. For the character P/E ratio, variance due to GCA were significant, where as variance due to SCA were non significant indicating predominance of additive gene action.

The GCA effects indicated that none of the parent was a good general combiner for all the characters. However, the following are good general combiners for various traits. Line ASKO-1201 (1.472) and tester Cross-5 (2.00) for marketable yield; line ASKO-1201 (3.418) and tester Line-13 (3.549) for average bulb weight; line ASKO-1201 (0.094) and tester Line-13 (0.275) for polar diameter; line GKD-75 (0.210) and tester GKD-77 (0.290) for equatorial diameter; line GKD-75 (0.594) and tester Cross-5 (0.518) for TSS; line Kumata local (-0.143) and tester GKD-45 (-0.233) for neck thickness; line Bhima Shakti (0.075) for P/E ratio; line ASKO-1201 (1.025) and tester Cross-5 (4.550) for total yield; line ASKO-1299 and tester Arka Kalyan for plant height at 30 DAT; line ASKO-1299 and tester Arka Kalyan for leaf length at 30 DAT; tester N-53 for number of leaves at 30 DAT; line Kumata local and tester Line-13 for plant height at 60 DAT; line ASKO-1299 and Line-25 for leaf length at 60 DAT; tester GKD-77 for number of leaves at 60 DAT.

The hybrid combinations with maximum significant SCA effect for different traits were ASKO-1299 x GKD-77, Kumata local x GKD-45, Kumata local x GKD-45 and GKD-75 x ASKO-1222 exhibited high SCA effects for marketable yield; GKD-75 x ASKO-1222 and Bhima Shakti x Line-13 exhibited significant SCA effect average bulb weight; ASKO-1299 x GKD-77, Bhima Shakti x Line-13 and ASKO-1201 x Line-13 for polar diameter; GKD-75 x ASKO-1222 and Bhima Shakti x N-53 for equatorial diameter; Kumata local x GKD-77, ASKO-1299 x GKD-45 and ASKO-1201 x Line-25 for TSS; GKD-75 x N-53 and ASKO-1299 x GKD-77 for neck thickness; ASKO-1299 x GKD-77 and ASKO-1201 x Line-13 for total yield; GKD-75 x Line-13 and Bhima Shakti x Cross-5 for plant height at 30 DAT; Bhima Shakti x Cross-5 and Kumata local x N-53 for leaf length at 30 DAT; ASKO-1201 x GKD-77 and ASKO-1299 x N-53 for plant height at 60 DAT; ASKO-1299 x Arka Kalyan and Bhima Shakti x Cross-5 for leaf length at 60 DAT; Bhima Shakti x N-53 and Bhima Shakti x Line-25 for number of leaves at 60 DAT.

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Appendix I: Physical and chemical properties of the experimental site

Sl. No.	Particulars	Values	Method adopted
A. Physical properties			
1.	Particle size analysis		International pipette method (Piper, 1966)
	a. Sand (%)	19	
	b. Silt (%)	28	
	c. Clay (%)	53	
	d. Textural class	Clay	
B. Chemical properties			
	1. Organic carbon (%)	0.53	Walkley and Black wet oxidation method Sparks (1996)
	2. pH (1:1.25 soil: water suspension)	7.39	Buckman's pH meter Sparks (1996)
	3. EC (1:1.25 soil: water suspension) (dS/m)	0.31	Conductivity bridge Sparks (1996)
	4. Available nitrogen (kg ha ⁻¹)	147.5	Alkaline permanganate method Sharawat and Burford (1982)
	5. Available P ₂ O ₅ (kg ha ⁻¹)	43.51	Olsen's method Sparks (1996)
	6. Available K ₂ O (kg ha ⁻¹)	296.5	Flame photometer method Sparks (1996)

Appendix II: Monthly meteorological data for the experimental year (2014 – 2016) of Main Agricultural Research Station, University of Agricultural sciences, Dharwad.

Year 2014-15						
Month	Maximum temperature (°C)	Minimum temperature (°C)	Maximum Relative Humidity (%)	Minimum Relative Humidity (%)	Rain fall (mm)	Rainy days
January	29.5	14.7	66.6	38.1	0.0	0
February	31.1	16.1	55.8	32.1	0.0	0
March	34.5	18.5	56.4	25.4	11.4	1
April	36.4	21.1	65.3	36.7	44.9	3
May	33.7	21.1	75.5	51.3	197.2	7
June	31.0	21.5	84.6	63.4	29.2	4
July	27.1	20.8	90.0	82.0	242.2	17
August	26.8	20.5	91.3	82.7	158.4	19
September	28.0	20.3	87.4	75.4	100.2	8
October	29.7	19.7	82.3	69.7	103.4	7
November	29.0	15.5	72.5	49.0	48.8	2
December	27.9	14.6	76.9	52.6	26.2	1
Year 2015-16						
January	28.6	13.3	63.6	40.7	0.2	0
February	31.8	14.6	52.6	24.2	0.0	0
March	33.2	19.2	73.1	34.8	105.2	3
April	35.1	20.3	68.3	35.6	13.2	1
May	34.7	21.9	78.8	53.2	129.4	7
June	28.8	21.2	85.0	74.3	160.2	11
July	28.7	21.2	87.1	72.5	42.8	6
August	28.7	20.6	87.9	75.5	34.4	5
September	30.9	20.6	91.6	80.0	22.4	3
October	31.2	19.6	77.3	60.2	179.8	5
November	30.0	18.4	81.4	63.5	28.6	2
December	30.6	15.7	73.4	42.9	0.0	0
Year 2016-17						
January	30.1	14.0	62.6	44.0	0.4	0
February	33.6	17.9	51.6	46.0	0.2	0
March	36.1	20.6	70.1	41.0	2.4	0
April	38.0	21.6	62.3	50.0	20.4	3

Appendix III: Bulbs colour of F₁ during *kharif* and *rabi* season evaluation

1	Kumata local x Cross-5	Medium red
2	Kumata local x GKD-45	Deep to medium red
3	Kumata local x GKD-77	Medium red
4	Kumata local x ASKO-1222	Light red
5	Kumata local x Arka Kalyan	Light red
6	Kumata local x Line-25	Deep to medium red
7	Kumata local x N-53	Medium red
8	Kumata local x Line-13	Medium red
9	Bhima Shakti x Cross 5	Light red
10	Bhima Shakti x GKD-45	Medium red
11	Bhima Shakti x GKD-77	Light red
12	Bhima Shakti x ASKO-1222	Deep to medium red
13	Bhima Shakti x Arka Kalyan	Light red
14	Bhima Shakti x Line-25	Medium red
15	Bhima Shakti x N-53	Light red
16	Bhima Shakti x Line-13	Medium red to light red
17	GKD-75 x Cross-5	Deep to medium red
18	GKD-75 x GKD-45	Medium red
19	GKD-75 x GKD-77	Medium red
20	GKD-75 x ASKO-1222	Light red
21	GKD-75 x Arka Kalyan	Red
22	GKD-75 x Line-25	Light red
23	GKD-75 x N-53	Medium red
24	GKD-75 x Line-13	Medium red to light red
25	ASKO-1201 x Cross-5	Medium red
26	ASKO-1201 x GKD-45	Light red
27	ASKO-1201 x GKD-77	Medium red colour
28	ASKO-1201 x ASKO-1222	Medium red colour
29	ASKO-1201 x Arka Kalyan	Red
30	ASKO-1201 x Line-25	Red
31	ASKO-1201 x N-53	Light red
32	ASKO-1201 x Line-13	Medium red to light red
33	ASKO-1299 x Cross-5	Medium red
34	ASKO-1299 x GKD-45	Medium red
35	ASKO-1299 x GKD-77	Medium red to light red
36	ASKO-1299 x ASKO-1222	Medium red to light red
37	ASKO-1299 x Arka Kalyan	Light red
38	ASKO-1299 x Line-25	Medium red
39	ASKO-1299 x N-53	Medium red
40	ASKO-1299 x Line-13	Light red
42	CC during <i>kharif</i> (Bhima super)	Red colour
43	CC during <i>rabi</i> (Bhima Shakti)	Red colour

HETEROSIS AND COMBINING ABILITY STUDIES IN ONION (*Allium cepa* L.)

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ABSTRACT

An investigation was conducted in the Department of Horticulture, College of Agriculture, Dharwad to study the heterosis and combining ability studies in onion (*Allium cepa* L.) with the objectives of identifying good general combiners and to assess the magnitude of heterosis for seventeen characters and to know the performance of hybrids. In the present investigation 54 entries have been evaluated (13 parents : 40 hybrids : 1 commercial check). Performance of hybrids like GKD-75 x Line-13 (11.83 t/ha), Kumata local x Line-13 (10.57 t/ha), ASKO-1201 x Cross-5 (9.60 t/ha) and Kumata local x cross-5 (8.88 t/ha) for the marketable yield was better than commercial check – Bhima Shakti (6.55 t/ha). These expressed considerable magnitude of heterosis over commercial check for yield. The top yielding entries [GKD-75 x Line-13 (4.013), ASKO-1201 x Cross-5 (2.431) and Kumata local x Line-13 (2.258)] involved positive (significant) x positive (significant) general combiner. Variance due to GCA and SCA was significant for the yield trait, indicating the involvement of both additive and non additive gene action. However, the estimates of SCA were higher than GCA variances indicating predominance of non-additive gene action in controlling the inheritance of this trait during *kharif* season.

Marketable yield is the ultimate and most important trait. The performance of hybrids for marketable yield point to entries like ASKO-1299 x GKD-77 (26.80 t/ha), ASKO-1201 x Line-13 (26.25 t/ha), Bhima Shakti x Line-13 (26.25 t/ha), ASKO-1201 x GKD-77 (26.20 t/ha) and Bhima Shakti x cross-5 (24.65 t/ha) are statistically at par with commercial check [Bhima Shakti (24.6 t/ha)]. Expressed considerable magnitude of heterosis over commercial check for yield. For marketable yield, significant positive SCA effect for this trait was exhibited by cross ASKO-1299 x GKD-77 (5.602) which involved positive (non significant) x positive (significant) general combiner. This was followed by Bhima Shakti x Line-13 (5.207) which involved negative (significant) x positive (significant) general combiner. Variance due to SCA was significant indicating the involvement of non additive gene action during *rabi* season.