HETEROSIS, COMBINING ABILITY AND GENE ACTION INVOLVED FOR YIELD AND QUALITY ATTRIBUTING TRAITS IN TOMATO (*Solanum lycopersicum* L.)

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CERTIFICATE-I

This is to certify that the thesis entitled **"Heterosis, combining ability and gene action involved for yield and quality attributing traits in tomato (*Solanum lycopersicum* L.)"** submitted for the degree of **"Doctor of Philosophy"** in the subject of **Horticulture (Vegetable Science)** to the **Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Ayodhya (U.P.)** is a bonafide research work carried out by **Mr. Pushpendra Kumar**, Id. No. **HFA-4699/09/13/15** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been duly acknowledged.

Narendra Nagar
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CERTIFICATE-II

This is to certify that the thesis entitled **"Heterosis, combining ability and gene action involved for yield and quality attributing traits in tomato (*Solanum lycopersicum* L.)"** submitted by **Mr. Pushpendra Kumar,** Id. No. **HFA-4699/09/13/15** to the Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Ayodhya (U.P.) in partial fulfillment of the requirement for the degree of **"Doctor of Philosophy"** in the subject of **Horticulture (Vegetable Science)** has been evaluated satisfactory by external examiner and approved by student's advisory committee after an oral examination.

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Place: ***Narendra Nagar***
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Chapter-I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.), 2n=2x=24, a member of the family Solanaceae is one of the most popular & extensively cultivated vegetable throughout the world.

It is originated from Peru Ecuador and Bolivia region of Andes of South America **(Rick, 1969)**. India ranks third in terms of production after China and USA. In India, total area under tomato cultivation is 0.808 million hectares with production of 19.69 million tonnes and its productivity is 24.4 tonnes per hectare; In India the leading tomato growing states are, Karnataka, West Bengal, Maharashtra, Uttar Pradesh, Haryana, Punjab, Gujarat and Bihar. **(Anonymous, 2017)**.

It is a day neutral warm season crop and grows under wide range of soil and climatic conditions. Though tomato is a self-pollinated crop, the unusual high heterosis observed in it, has been attributed to the fact that, originally tomato was a highly out crossing genus which has later evolved into a self-pollinated one **(Rick, 1965)** and edible part is botanically known as berry **(Kalloo *et al.,* 2001)**. It is globally cultivated for its fleshy fruits and known as protective food. Under Indian condition, the fruits mainly consumed either as raw or in the preparation of sambar, chatni, pickles etc.

Tomato is also rich in medicinal value. The pulp and juice are digestible, mild aperients, a promoter of gastric secretion and blood purifier. It is reported to have antiseptic properties against intestinal infestations. In the present days, it is gaining more medicinal importance because of the antioxidant property of ascorbic acid and lycopene content. Thus, today it is one of the important raw materials for multimillion food industries. Due to its nutritional values it is also called as “Poor man’s apple”. In many countries it is considered as “poor man’s orange” because of its attractive appearance and nutritive value **(Singh *et al.,* 2004)**. It acts as an antioxidant

and scavenger of free radicals, which is often associated with carcinogenesis. Thus, lycopene has great beneficial effects on human health **(Khachik *et al.*, 1995)**.

Without regular infusion of genetic variability and selection in tomato, through hybridization it is not feasible to make advances in productivity and production. Various breeding techniques advocated considering the breeding behaviour of the crop. Heterosis breeding as a tool for genetic improvement in tomato has been advocated by several workers **(Premalakshme *et al.*, 2005; Fageria *et al.*, 2001; Thakur *et al.*, 2004 and Duhan *et al.*, 2005)**. For obtaining high yield as well as quality fruits which are important for realizing economic gain, the commercial exploitation of hybrid vigour in tomato has received greater importance due to marketable fruit yield and its component traits as well as resistance to biotic and abiotic stresses. That is why large number of commercial hybrids developed in the country in this crop. With increasing popularity of F_1 hybrids in tomato, it is imperative, to obtain such hybrids that have excellent qualities and yield coupled with resistance to diseases. Identification of high yielding and stable varieties and the development of F_1 hybrids will help the farmers to adopt hybrid for successful commercial cultivation of tomatoes. In view of such an importance the tomato crop has gained, increasing the productivity per unit area by even lesser degree assumes greater significance. This increase in production assumes significance because the production of tomato is not sufficient to meet the requirement of fresh market and processing industries.

Pre-requisite for heterosis breeding is to identify the best combiners and knowledge of combining ability and gene action or inheritance pattern of traits will be helpful to formulate appropriate programme for development of hybrids with high yield and quality traits. So a speedy improvement can be brought by assembling the genetical variability locating the best combiners and exploiting heterosis. Combining ability analysis is

one of the powerful tools available that give the estimates of combining ability effects and aids in selecting desirable parents and crosses for further exploitation. The scope of this new dimension in tomato marketing offers some interesting challenges for breeders, post-harvest physiologist and molecular biologist. In the recent past, exploitation of hybrid vigour and selection of parents because of combining ability and gene action have been important breeding approaches in tomato improvement.

The assessment of the parents for their ability to donate desirable genes to their offspring is an important pre-requisite for a systematic vegetable-breeding programme aimed at development of superior strains or varieties. The concept of combining ability analysis has been frequently used in numerous plant species for discriminating the parents for use in hybridization programmes and for understanding the nature and magnitude of gene action governing various characters. In biometrical genetics, two types of combining abilities considered i.e. general combining ability (GCA) and specific combining ability (SCA). General combining ability refers to the average performance of the genotype in a series of hybrid combinations and is a measure of additive gene action whereas; specific combining ability is the performance of a parent in a specific cross in relation to general combining ability. SCA is due to genes showing non-additive effects **(Sprague and Tatum, 1942)**. The importance of combining ability studies lies in the assessment of parental lines and their hybrid combination showing significant additive and non-additive gene effects with respect to certain traits. Gene action refers to the mode of expression of genes in a breeding population. Modes of gene action provide guidelines in the selection of parents for utilization in hybridization programmes as well as choice of breeding procedures for genetic improvement of various quantitative traits of interest. Its main attributes include genetic components of variance that comprises the magnitude of combining ability variances and

their relative effects. Based on genetic variance, gene action is being described in three different forms i.e., additive gene action, dominant and epistatic gene action, respectively. Latter two are collectively termed as non-additive gene action. Different factors affect the mode of gene action, which includes type of genetic material utilized, mode of pollination, pattern of inheritance, sample size, sampling methods, existence of linkages and methods of derivation on gene action. Various biometrical techniques for combining ability analysis such as line × tester, diallel, partial diallel and augmented partial diallel analysis have been developed for accomplishing the twin objectives of understanding the inheritance of characters and identification of genotypically superior parents and crosses.

Breeder can no longer depend upon use of basic stock of the breeding material unless there is a wide genetic diversity for the characters. Hence, selection of parents for hybridization could be more dependable as decided by the appropriate methods for genetic diversity. In tomato, attention should be given to the breeding and inheritance of traits. A judicious choice of parents promotes an improvement process leading to a well-planned hybridization programme in tomato crop. Keeping in view the above facts, the present study on **"Heterosis, combining ability and gene action involved for yield and quality attributing traits in tomato (*Solanum lycopersicum* L.)"** was undertaken with the following objectives:

1. To estimate the general and specific combining ability variances and their effects.
2. to workout gene action involved in inheritance for yield and its attributing traits.
3. to estimate heterosis over better parent and standard varieties.
4. to estimate the heritability in narrow sense and expected genetic advance in per cent of mean.
5. to estimate genetic divergence among the parents and their crosses.

REVIEW OF LITERATURE

Review of literature relevant to the investigation on **"Heterosis and combining ability analysis for growth, yield and quality traits in tomato (*Solanum lycopersicum* L.)"** has been collected and presented (from 1993 to 2018). There has been voluminous literature on transformation aspects in tomato crop. Discretion has been exercised to retain only relevant representative citations and omitting others looking to limitations of quoting here. For improvement of traits in tomato there is a need of having knowledge of genetics of different traits to initiate modifications for our situation specific requirements. Conventional approach of breeding involving utilizing existing genotypes after adequate evaluation to know their performance and expression for desirable traits at particular location is indispensible even with present day complementing breeding tools of tackling insurmountable handicaps in tomato crop more specifically like susceptibility to viral diseases like tomato leaf curl virus and tomato spotted wilt virus. Hence, the investigations in the present study involved hybridization of line with tester to develop F_1's from parents with horticultural traits from diverse background to identify heterotic combinations after subjecting data to statistical analysis to elicit information on heterosis and combining ability variances and their effect, gene action, heritability is narrow sense, genetic advance and genetic divergence among paraents including F_1 to find out heterotic F_1'^{s} for different traits, good general and specific combiners transmissibility of traits in narrow sense improvement over generation as genetic advance and genetic divergence among tomato genotype /F_1 in the present study of tomato. Looking to these outlines of the present investigation, the literature that was reviewed on tomato is presented under following headings:

2.1 Estimates of heterosis

2.2 Combining ability variances and their effects

2.3 Gene action

2.4 Heritability and genetic advance

2.5 Genetic divergence

2.1 Estimates of heterosis

The term heterosis was first coined by **Shull (1914)** for the specific stimulus of heterozygosis upon cell division, growth and other physiological activities of an organism and define heterosis "to cover the real observable phenomenon" when unlike gametes are brought together to form a hybrid. In this sense, heterosis is synonymous with hybrid vigours. **Allard (1960)** considered heterosis as "hybrid vigour such that F_1 hybrid falls outside the range of the parents with respect to some character or characters". Heterosis in common use represents the phenomenon in which the F_1 population obtained by crossing of two genetically dissimilar individuals shows increased vigour over mid-parent value (relative heterosis) or over better parent value (heterobeltiosis). A third type of heterosis expressed as the increased or decreased vigour over the popular or standard check variety called as standard heterosis or economic heterosis has become more valuable.

The first suggestion that heterosis can be exploited in vegetable crops was made by **Hays and Jones (1916)**. Among the vegetables, heterosis was reported first in cabbage by **Pearson (1932)**.

Griffing and Lindstorm (1954) suggested that the expression of heterosis is due to accumulation of desirable genes in hybrid coming from genetically diverse parents. Several workers have propounded that genetic

basis of heterosis for a complex trait like yield can be explained through multiplicative interaction of component traits. **Grafius (1956 and 1959), William and Gilbert (1960), Durate and Adams (1963)** concluded that the heterosis of F_1 is the combined expression of genetical, cytoplasmic and physiological factors and may be attributed to stimulation resulting from the interaction of different heritable factors of the parents in the F_1. Another explanation is the accumulation of the favourable dominant alleles in the F_1, contributed by both male and female parents (**Daskalov, 1963)**. Heterosis breeding has led to a break-through in yield in several crop plants. Heterosis is more pronounced in cross pollinated species **(Hays and Footer, 1976)**. Heterosis is usually manifested in early maturity, high yield, uniformity in size, better resistance to diseases, insect-pests and other traits, better fruit quality, better and wider adaptability to environmental condition, etc **(Swarup, 1991)**.

Dharmatti *et al*. (1997) estimated heterosis for fruit yield and 6 yield components, determined in 50 F_1 hybrids of tomato (*Lycopersicon esculentum* Mill). Derived from line x tester crosses involving 5 female (Alcabassatype) and 10 male parents. A fairly high heterosis observed for all the characters under study. Out the 50 crosses 12, 11 and 8 exhibited significant positive heterosis for fruit yield/plant over mid, better and best parent respectively with respect to yield and number of fruits. The crosses 20/6 Alcobas a x L58, 20/4 Alcobasa x L58 and 20/5 Alcobasa x N229, exhibited positive heterosis, Alcobasa genotypes 20/6, 20/4 and 20/5 could be therefore utilized as female parents in exploiting heterosis when crossed with L58 and N229.

Sharma *et al* .(1997) evaluated 30 hybrids and 13 parental lines for heterosis for plant height, weight and number of fruits per plant, size of

fruits and total soluble solids. Mean performance of hybrids was superior to that of the inbreds for most of the traits.

Subbaramu *et al.* (1998) reported heterosis derived from data on seedling characters and yield in 7 cultivars and their F_1 hybrid P.K.M.1 and Marutham had the greatest 100 seed weight (269 and 277 mg. Respectively) and vigour index based on dry matter accumulation (169 and 159) respectively.

The exploitation of heterosis is considered an outstanding application of the principle of the science of genetics to agriculture. It has become the basis of multi-billion-dollar agro-business in the world **(Phillips, 1999)**. For the exploitation of heterosis, it is imperative to study the magnitude of genetic differences among parents involved in the crosses as well as genetic worth of the crosses. Various theories have been postulated to explain the genetic basis of heterosis. Expression of heterozygosity is one of them. A brief review on various aspect of heterosis in tomato has been presented belows.

Bhatt *et al.* (2004) evaluated twelve divergent line of tomato and their 66 F_1 hybrids to investigate the extent of heterosis and general and specific combining ability effects for five quantitative and three qualitative traits under open and polyhouse environments in mid hill conditions of central Himalyas. The additive as well as non-additive gene effects played significant role in the inheritance of the yield and other traits. Higher proportion of gca x environment interaction variance as compared to sca x environment estimates were recorded.

Joshi and Thakur (2005) reported that line x tester analysis for shelf-life and related traits revealed that line FT-5, 102, Magna and cal-ace were good general combiners for fruits firmness, number of locules per fruits,

pericarp thickness and shelf-life. Among tester, v-16 was good general combiner for all the characters except number of locules per fruits. The ratio of gca/sca variance observed less than unity for all the characters, depicting the predominance of non-additive genetic variance. Among crosse, H-711492 x 101, 260 x V-16 exhibited the maximum heterosis over better parent for whole fruit firmness, pericarp thickness, respectively.

Mahendrakar *et al.* (2005) reported that forty five tomato crosses developed by crossing fifteen lines with three testers, were evaluated along with parents for heterosis and combining ability in a study conducted in Karnataka, India. To identify the maximum heterosis for yield was exhibited by the cross TP8 x Arka Alok.

Premalakshme *et al.* (2005) observed heterosis for earliness (-8.57%), plant height (14.43%) and laterals per plant (13.90%) over the better parent, respectively.

Dharmatti *et al.* (2006) studied heterosis for bacterial wilt and fruit yield of $50F_1$ hybrids of tomato derived from Line x Tester crosses of 5 female and 10 male parents. The per cent heterosis was found significant for most of the characters. It was found that few carried genes for field resistance to bacterial wilt. A few of them like Arka Alok, Sonali and Shakthi could be utilized as female parents in exploiting heterosis for bacterial wilt resistance when crossed with SP-2-2, L-101 and W-9430 (1). The crosses Arka Alok x SP-2-2, Arka Alok x L-101, Sonali x SP-2-2- and Arka Alok x W-9430 (1) had shown negative heterosis over check for bacterial wilt incidence and recorded high fruit yield and these hybrids could be commercially exploited as a bacterial wilt resistant tomato hybrids.

Kumar *et al.* (2006) reported that maximum significant positive heterosis for total soluble solids was obtained in the cross L_3 x T_1 (33.33%, 12.51%).

Singh *et al.* (2006) recorded that magnitude of heterosis percentage of crosses over better parent ranged from 2.28 to 74.91 for plant height, 2.04 to 40.00 for average fruit weight, 3.79 to 17.04 for fruit length, 1.05 to 25.32 for fruit width, 3.12 to 41.38 for pericarp thickness, 0.71 to 49.53 for total soluble solids and 4.44 to 129.43 for fruit yield.

Hannan *et al.* (2007a) found positive and highly singificant heterosis per cent for number of fruits/plant 72.9,75.53 and 20.74, fruit weight /plant 189,172 and 187 over the mid parent, better parent and standard parent respectively.

Seeja *et al.* (2007) observed greatest heterosis for number of fruits per plant (135.62%) followed by fruit yield per plant (99.47%).

Dhadde *et al.* (2009) investigated accumulation of favourable alleles for heterotic purpose in three-way F_1s (TWC F_1s) and isolating segregants for developing improved inbred lines a genotype from three way hybrids in sour segment of tomato. Line x tester mating system was followed to generate material. Ten parents were used in crossing to develop 25 $TWCF_1$ hybrids (from Hy-1 to Hy-25). Five single cross F_1 (SCF_1) hybrids were used as lines (O) in the crossing programme and all these were potentially high yielding entries with different genetic background, where as five OPV were used as testers (O). The high genetic variability resulted into significant heterosis for all the characters except number of primary branches at harvest. In $TWCF_1$s there was heterosis up to 180.11% over commercial check (CC) (SCF_1) for yield per plant, similarly, up to 58.70% for number of fruits per plant and up to 115.91% for fruit weight over CC.

Average yield of $TWCF_1$s was greater than the average for SCF_1s by 13.6 g/plant (2.96 q/ha). The range in yields for three-ways was 669.6 g/plant (145.83 q/ha) more than for singles. There were nine crosses out yielding the average of SCF_1s. The present investigation clearly demonstrate that two $TWCF_1$s have significantly out yielded the best SCF_1s. Three-way crosses out yielding the single crosses indicate, multiple crosses provide an increased opportunity for recombination of favourable genes from many parents in sour segment of tomato. The overall population of TWC hybrids exhibited a very high frequency of 37.00% transgressive segregants and 25.00% economic segregants for yield per plant. The high frequency of transgressive/economic segregants clearly indicates that segregating individuals obtained by involvement of more and more parents would increase the frequency of desirable segregants, than merely just advancing the superior SCF_1s.

Yadav *et al.* (2013) estimated heterosis, by line x tester analysis including 30 F_1 cross combinations using 13 parents after selfing (ten lines and three testers) at Vegetable Research Farm, BHU, Varanasi (India). These 43 genotypes (10 lines and 3 testers and 30 resulting F_1 hybrids) were evaluated for growth, yield and quality (T.S.S and shelf life) contributing traits. The most promising crosses showing significantly standard heterosis for maximum yield were CO-3 x Arka Vikas, CO-3 x NDT-5, NDTVR-60 x NDT-5 and RCMT-1 x NDT-5. These elite hybrids may be tested for yield and other quality traits under different agro-climatic conditions for commercial exploitation of hybrid vigour.

Mali and Patel (2014) conducted diallel analysis in tomato to study the magnitude of heterosis in tomato for fourteen characters including fruit yield and its related components. The experimental material comprising of five genetically diverse parental lines and their twenty hybrids (including

reciprocals). Significant differences among genotypes were obtained for all the traits. In order of merit, the five promising hybrids *viz.*, NTE 2 x NTE 3, NTE 2 x NTE 4, NTE 2 x NTE 1, NTE 1 x NTE 5 and NTE 1 x NTE 2 exhibited standard heterosis with the range of 104.40 to 201.19 and 90.15 to 180.20 over commercial checks, GT2 and JT 3, respectively.

Sherpa *et al.* (2014) undertaken research for hybrid with desirable post harvest traits through line x tester mating design in tomato. All 9 F_1 hybrids had significantly higher number of fruits per cluster and number of fruits per cluster over both mid-and better-parental values, while for the other traits, hybrids expressed average heterosis in both directions. The maximum extent of heterobeltiosis (53.56%) was found in lycopene content of fruit followed by number of fruits per cluster (32.59%) and fruit yield per plant (31.77%).

Figueiredo *et al.* (2015) the objective was to estimate the heterosis in industrial tomato genotypes for the identification of those with good potential for breeding programs. Ten lines of industrial tomato, 45 hybrids derived from a complete diallel and two commercial check cultivars were evaluated. The parent lines RVTD-04, RVTD-10 and RVTD-08 had an exceptionally high presence of favorable alleles for most traits.

Graca *et al.* (2015) heterosis were estimated to ten agronomic and fruit quality traits. The offspring of cross B13LD x "Rio Grande" showed potential for use in dual purpose, considering SCA and heterosis estimates for fruit firmness (FF), total content of soluble solids (TSS), number of fruits per plant (NFP) and yield (YLD). Combinations B13LD x Castone, Massag-72 x "Viradoro", and Massag-72 x "Rio Grande", although having no strength to increase YLD, had positive heterosis for FF, TSS, and NFP.

Samiyoddin *et al.* (2015) ten diverse lines of tomato were crossed with three testers in line x tester mating fashion to study heterosis for number of locules, pericarp thickness, total soluble solids, pH of fruit juice, lycopene and ascorbic acid during *rabi* season of 2013-14 at KRC college of Horticulture Arabhavi, (Karnataka). AR 21 x Arka Vikas, AR 29 x PKM 1, AR 56 x PKM 1, and Podlandt Pink x Arka Alok are good cross combinations for yield per plant. Tommy Toe x Arka Vikas and AR 29 x Arka Vikas are early to flower and the crosses AR 4 x PKM 1 and AR 21 PKM 1 are good hybrids for lycopene whereas AR 56 x PKM 1 and AR 21 x Arka Vikas are good hybrids for Total Soluble Solids. The present study reveals that heterosis breeding is useful for improvement of tomato crop.

Kaushik *et al.* (2015) purpose of this study was to identify heterotic hybrids of tomato resistant to leaf curl virus disease. Eleven parental lines and their 55 one-way F1 crosses produced in a diallel mating design were evaluated for fruit yield, fruit quality, tomato leaf curl virus (TLCV) resistance and other important traits at Research Farm of the Department of Vegetable Science, Punjab Agricultural University, Ludhiana (India) during autumn of 2012. Parent 2-1 showed no TLCV symptoms throughout the growth period under natural epiphytotic conditions. The remaining lines showed mild to very severe disease infection. Seventeen of the crosses were completely free from TLCV symptoms under natural field conditions. Heterosis was worked out over mid-parent, better parent and commercial resistant check NS 524. The hybrids outperforming the best check (NS 524) included 102-13-6-1x2-1 for marketable (66.15%) and total fruit yield (63.12%), Punjab Chhuhara x58-18-1-1 for dry matter content (43.89%), 58-11-1-1x102-13-6-1 for fruit weight (34.14%), 102- 1-6-1x115-1-8-1 for number of locules (-45.15%), 56-14-7-1x58-18-1-1 for lycopene content (61.06%), 102- 1-6-1x58-18-1-1 for TSS content (19.32%), 58-18-1-1x55-

26-1-1 for pericarp thickness (49.56%), 102-1-6- 1x115-1-8-1 for polar diameter (32.07%) and 115-1-8-1x55-26-1-1 for equatorial diameter (19.07%). Based on the overall performance, four crosses *viz.*, 102-8-5-1x7-5-1, 102-13-6-1x55-26-1-1, 58-11-1-1x58-18-1-1 and 102-13-6-1x2-1 were identified as promising. These hybrids recorded fruit yield of 2.22, 2.29, 2.70 and 3.24 kg plant-1, respectively, which was either at par with or significantly better than the resistant check NS 524 (1.95 kg plant-1). The hybrids also had acceptable fruit shape index (0.97-1.20) and fruit size (36.66-96.66 g).

Andrade *et al.* (2015) the objectives of this work were to assess heterosis and its components in F1 hybrids of a diallel cross among lines of scarlet eggplants (*Solanum gilo* Raddi, syn. *S. aeth opicum* L.), and to study the modes of gene action associated with its expression. Six lines (Morro Redondo, Branco Comprido, BGH-1544, Tingua, Iraja, Comprido Verde Claro) and 15 hybrids resulting from a diallel cross among them (reciprocals excluded) were tested in a randomized complete block design with four replications. Traits under study were total yield, mean fruit mass and fruit length/diameter ratio. There was no evidence of epistatic gene action in the expression of any of the traits under study. Heterosis for yield could be explained by overdominance, but higher yields were only weakly associated with larger frequencies of dominant alleles an indication that yields may be markedly influenced by the action of relatively few loci with overdominant gene action. Heterosis for mean fruit mass was associated with incompletely dominant gene action, and larger fruit mass was associated with larger proportions of dominant alleles. For fruit length/diameter ration (L.D-1), heterosis was due to incompletely dominant gene action, and dominant alleles were predominantly associated with lower L.D-1 values.

Aisyah *et al.* (2016) a study was conducted in a 6x6 full diallel cross set of tomato including reciprocals to estimate the heterosis for yield per plant (g) and yield components, namely number of fruits per plant, individual fruit weight (g) fruit length (cm), fruit diameter (cm), locule number, and fruit thickness (cm).The tomato genotype IPB T73 x IPB T3 proved to be the best general combiner for yield and number of fruits per plant. The tomato genotype IPB T3 x IPB T1 proved to exhibit best heterosis for yield per plant and fruit thickness.

Sharma and Bhardwaj (2016) magnitude of heterosis revealed that the cross combination BL 312 x EC 191536 was the most consistent for early flowering and harvest. The top best hybrids combinations for marketable yield and yield attributing traits were BWR 5 x EC 191536, BT-18 x BL 312 and BL 312 x EC 191538.

Renuka and Sadashiva (2016) seven diverse genotypes of cherry tomatoes (*Solanum lycopersicum* var. *cerasiforme*) were crossed in a half diallel fashion during *kharif* 2011. The resulting twenty-one hybrids along with 7 parents were tested during *rabi* 2012 for their mean performance and heterosis.

Kumar *et al.* (2016) line x tester analysis was performed by employing nine tomato genotypes (6 lines and 3 testers) to develop 18 hybrids. These hybrids along with parental lines and commercial checks Arka Rakshak and Abhinav were evaluated to know the extent of heterosis exhibited to different nutritional and keeping quality traits along with the yield. Results revealed that the hybrids IIHR 2892 x IIHR 2852 and IIHR 2848 x IIHR 2852 exhibited standard heterosis of 30.67% and 21.24%, respectively over standard check Abhinav for fruit firmness. Standard heterosis of 86.50% has been recorded for total carotenoid in the hybrid

combination IIHR2892 x IIHR2852 over the check Arka Rakshak. IIHR2892 x IIHR2852 have recorded standard heterosis for yield along with important fruit quality traits like acid, total carotenoids, lycopene, fruit firmness and fruit breadth.

Dishri *et al.* (2017) magnitude of heterosis for yield and component traits including some of the important nutritional characters was estimated in 10 hybrids developed using five diverse and indeterminate tomato lines crossed in half-diallel during 2010-11. The study was aimed to develop suitable indeterminate tomato hybrids with good quality attributes which suits to off-season production in the north-western Himalayas. Hybrid UHFT-55 x EC-2798 Showed high significant heterobeltiosis for days to marketable maturity (-7.32%), number of fruits per plant (37.83%) and harvest duration (16.7%). For individual fruit weight (34.74%) and plant height (21.53%) hybrid Solan Vajr x EC-29414, EC-29414 x EC-2798 for ascorbic acid (53.70%) and UHFT-55 x Solan Vajr for pericarp thickness (12.87%) registered higher heterobeltiosis. In the present study, Solan Vajr x Ec-2791 manifested higher heterobeltiosis for yield (55.94%). Similarly UHF-55 x EC-2791 recorded less number of seeds (-35.68%) and locules per fruit (-35.14%).

Rao *et al.* (2017) the magnitude of heterosis in 33 crosses derived from line x tester, indicated pronounced hybrid vigour for total fruit yield and yield attributing traits in bell pepper (*Capsicum annuum* L.). The magnitude of heterosis over the commercial check hybrid was high in the desirable direction for all the 12 characters. The findings revealed that the crosses: Arka Mohini x IIHR-4103, Arka Mohini x IIHR-3341, Arka Mohini x IIHR-4107 and Arka Basant x IIHR-4096 were identified as the best heterotic cross combinations. These four productive hybrids had significantly higher *per se* values than the commercial check (Indra) in

respect of number of primary branches, number of secondary branches, fruit length, fruit width, average fruit weight and number of fruits per plant. These hybrids also possess desirable fruit length and fruit width. The high heterotic response as observed in these hybrids further supported by the predominant role of non-additive gene action in the inheritance of the characters under study. These cross combinations could be exploited in heterosis breeding programme in future.

2.2 Combining ability variances and their effects

The concept of combining ability was first given by **Sprague and Tautum (1942)**. It has been the most important and efficient tool for choosing the desirable parents of high yielding hybrids. This concept enables partioning of total genetic variance into the effect of general and specific combining ability. The term general combining ability (gca) is defined as the average performance of a line involved in hybrid combination and specific combining ability (sca) designate those cases in which certain combinations do relatively better or worse than would be expected on the basis of the average performance of the gca lines involved. Further they concluded that gca was primarily due to additive effects of genes. While, sca was a consequence of intra-allelic interaction (dominance) and their inter-allelic interaction (epistasis). General combining ability is comparatively more important than specific combining ability in previously unselected materials. Specific combining ability on the other hands, assumes a greater importance in material which has been previously selected for general combining ability.

Griffing (1956 a and **1956 b)** emphasized the statistical concept of gca and sca and provided a technique of estimating these. **Jinks (1954)** and **Hayman (1954 a and 1954 b)** provided the genetic basis and analysis of

diallel cross. Hayman's and Griffing's approaches have been extensively used by several workers to estimate combining ability variances.

The general combining ability (gca) included both the additive effects as well as additive x additive interaction **(Griffing, 1956 b** and **Carnham *et. al.*, 1960)**.

Kempthorne (1957) defined the general and specific combining ability variance σ^2gca and σ^2sca, respectively, in terms of half and full sibs. It has been established that a high yielding line may not necessarily be able to transmit its superiority to the hybrids **(Allard, 1960)**. Hence a estimate of gca (worth of parents) and sca (worth of hybrids) effects may be more reliable test rather than *per se* performance. For estimate of the general and specific combining ability, different workers have used several methods. Among them poly cross **(Tysdal *et al.*, 1942)**, line x tester **(Kempthorne, 1957)**, diallel cross **(Griffing, 1956 b)**, partial diallel cross **(Kempthorne** and **Curnow, 1961)** and triallel crosses **(Rawling** and **Cockerham, 1962)** have most commonly used.

A brief review of work done on combining ability variances and their effects in tomato is given as follows:

2.3 Gene action

The first attempt to partition the genotypic variance into its components was made by **Fisher (1918)**. It has subsequently been developed by **Mather (1949)**, **Jinks and Hayman (1953)** and **Hayman (1954b)**. They were able to estimate the genetic parameters, $\hat{D}$, $\hat{H}_1$, $\hat{H}_2$ and $\hat{F}$ (following Mather's notations) and their standard errors from second-degree statistics. $\hat{D}$ variance due to additive genetic effects, $\hat{H}_1$ the dominance variance, $\hat{H}_2$ dominance indicating asymmetry of positive and

negative effects of genes, while $\hat{F}$ gives information on the preponderance of dominant and recessive alleles. Hayman (1958) advocated six parameter model for estimation of various genetic components. The following genetic parameters which are given below:

Additive genetic variance (σ^2A), which arises due to additive effect of genes at all segregating loci. Dominance variance (σ^2D), which results from the intra-allelic interaction of genes at all segregating loci.

(a) Epistatic variance, which arises due to inter-allelic interactions of genes at two or more segregating loci and which is divided into:

i. Additive × additive (σ^2AA),

ii. Additive × dominance (σ^2AD),

iii. Dominance × dominance (σ^2DD), for two locus situation, and

iv. Additive × additive × additive (σ^2AAA), etc. for three or more loci.

(b) Average degree of dominance, ratio of dominance variance to additive genetic variance.

(c) Genotype × environmental interactions, which may be divided into:

i. Additive gene effects × environment,

ii. Non-additive gene effects × environment.

iii. Genotypic correlation among quantitative characters for the particular crop.

The polygenic traits are express under the control of varying proportion of additive and non-additive type of gene action. Simple progeny selection is useful for the genetic improvement of various quantitative traits.

Hence, in sight into the nature of gene action involved in the expression of various quantitative traits is essential to a plant breeder for starting a judicious breeding programme.

The brief review of work done on genetic components analysis and gene action in tomato is given below:

The nature and magnitude of gene action governing the inheritance of certain characters may have vital importance to the plant breeders in formulating an appropriate breeding programme. The brief review on gene action of yield and component characters in respect of present investigation has been presented below.

1. The amount of genetic variability i.e. the magnitude of the difference among different individuals in the base population.

2. The magnitude of masking effect of the environment and the interaction

3. The intensity of selection **(Comstock and Robinson (1952)**.

Govindarasu *et al.* (1982) observed non-additive gene action for yield, whereas, **Swamy and Mathal (1982)** reported that non-additive gene action was predominant for early fruit yield per plant. Non-additive and additive gene action were reported for number of fruits **(Castillo et al. 1986)**.

Sonone *et al.* (1986) reported predominance of additive gene effects for fruit number while non-additive gene effects were important for yield.

Cheema *et al*. (1996) and Sharma *et al*. (1997) concluded that non-additive gene effects were more pronounced for fruit yield. **Wang *et al*. (1998)** observed higher magnitude of variance due to SCA over GCA for fruit yield indicating a major role of non-additive gene effects.

Bhutani and Kalloo (1988) reported non-additive type of gene action for the control of number of fruits and yield per plant as evidence by component and graphical analysis.

Yadav *et al.* (1991) concluded from their experimental finding that thick pericarp thickness was dominant over thin pericarp thickness.

Shrivastava *et al.* (1993) identified the cross Pusa Ruby x Money Maker to be the best combination for earliness. Cheema et al. (1996) identified the cross Rio Grande x UC 8213 exhibiting high sca effect for earliness.

Natrajan (1994) revealed that number of fruits per plant, fruit weight and yield per plant was controlled by both additive and non-additive gene action.

Srivastava *et al.* (1995) found that extent of narrow sense heritability was 45.39% for earliness and 1.77% for yield per plant.

Dod *et al.* (1995) reported the predominance of additive gene effects over the non-additive gene effects for pericarp thickness.

Cheema *et al.* (1996) found that WIR 4339, Neuradora and Castle were good general combiners while 6 crosses exhibited high sca for earliness, one for marketable yield and eight for fruit weight.

Chadha *et al.* (1997) found that non-additive gene action was preponderant for marketable yield per plant, average fruit weight and number of marketable fruits per plant.

Srivastava *et al.* (1998) reported that Pusa Ruby was the best general combiner for T.S.S. and dry matter content. The best specific combiners

were Pusa Ruby x Money Maker for T.S.S. and Sel-18 x marglobe for dry matter.

Susic (1998) found highest specific combining ability (sca) values for fruit length and fruit width in the hybrids obtained by crossing D 150 and No. 10., while, Pandey (1998) observed higher gca values than sca for the various component characters and crosses sowing positive sca affects involved one good and poor or both poor general combiners as parents. The cross combination H-24 x Pant Bahar was the best combiner for yield per plant, showed highest positive sca effects and high degree of heterosis.

Sharma *et al.* (1999) used line x tester analysis and concluded that lines BTL-33 and BTL-11 and tester Roma emerged as good general combiners for yield and its component traits. The best specific cross combinations were (BTN x 46) x Roma, BTL-11 x AC 402 and BTR-49 x Roma. Results from this investigation also revealed that best cross combination did not necessarily involved good general combiner as their parents. Based upon the contribution of lines, testers and their interaction, it was also evident that variability among the crosses was mainly due to the contribution of lines only.

Dharmatti *et al.* (1999) reported that the general combing ability (gca) of the 15 parents (5 female and 10 male) and specific combining ability (sca) of 50 crosses for 7 characters in summer tomato using a line x tester analysis. The female parents were 20/2, 20/4, 20/5, 20/6 and AVRDC Alcobasa, and the male parents were UC-204B, L-15, CA-1, N-229 8 MF 6, 79 B1 390, DWD-2, DWD-1, marikrit, L-58 and LE-79. The results revealed that the GCA: SCA ratio were less than unity for all the characters indicating the pre-dominant role of non-additive gene action. The GCA

effects revealed that the parents 20/2, 20/5 and 20/6 Alcobasa were the best general combiners for fruit yield.

Dhaliwal *et al.* (2000) studied the line x tester analysis among 22 inbreds for several yield attributing traits and found both additive and non additive gene effects governed the inheritance of characters studied, except marketable yield, where non-additive gene action seems to play a pre-dominant role.

Bhatt *et al.* (2001) studied the line x tester analysis and reported pre-dominance of non-additive gene action for plant height, fruits per plant, days to first harvest, number of primary and secondary branches and yield per plant. Punjab Chhuhara showed highly significant desirable gca effect for fruits per plant and yield per plant, while sweet 72 exhibited highly significant negative gca for early maturity. The higher significant sca effects observed for yield per plant as well as for fruits per plant in the cross Punjab Chhuhara x Azad Kranti, while, Punjab Chhuhara was the good general combiner for most of the traits.

Dhaliwal *et al.* (2001) found that additive component of gene effect was significant for total soluble solids, fruit weight and yield per plant and dominance for pericarp thickness and fruit weight.

Makesh *et al.* (2002) conducted experiment with a view to understand the combining ability and nature of gene action for some quality traits and yield in tomato by 6x6 diallel analysis. The traits included in the study were number of locules per fruit, flesh thickness, total soluble solids, acidity, ascorbic acid and yield. The parents according. No. 368893, Accn.No.378642, PKM-1 and Accn.NO.368894 were the best general combiners for most of the traits. The crosses Co-3xAccn.No.368893, PKM-1 x Accn. No.368893, PKM-1 x Accn. No.368894, Shakthi x Accn.

no.378642 and Accn. No. 368893 x Accn. No.368894 were found the best based on their high per se performance and s.c.a. effect. These genotypes can be further exploited in the quality breeding programmes in tomato.

Dhaliwal *et al.* (2003) reported that twenty hybrids of tomato produced in a line x tester fashion at Ludhiana, Punjab India. Among the crosses, 5281 x 5286 and 1979 x 5282 exhibited high estimates of specific combining ability effects for total yield along with significant effects for number of total fruits, fruit weight and days to flowering. C121 x 5282 may also be exploited because this cross involves good x good combining parents.

Joshi and Thakur (2004) study on line x tester analysis for shelf-life and related traits revealed that line FT-5, 102 Magna and Cal-ace were good general combiners among testers V-16 was good general combiner for all the characters except number of locules per fruits. The ratio of generals and specific combining ability (sca) variance were observed less than unity for all the characters, depicting the predominance of non-additive genetic variance.

Devi *et al.* (2005) reported that magnitude of additive gene effects was higher than the dominance effects in most of the crosses for number of fruits per plant. Epistatic gene effects were observed in most of the crosses for fruit weight.

Joshi and Thakur (2005) reported that line x tester analysis for shelf-life and related traits revealed that line FT-5, 102, Magna and cal-ace were good general combiners for fruit firmness, number of locules per fruit, pericarp thickness and shelf-life. Among the testers, V-16 was good general combines for all the cheracters and may be utilized in future tomato breeding programmes. The crosses UHF-11 x EC-401927 and CLN5915-

206D4-2-2-0 x FT-5 exhibited the highest specific combining ability (sca) estimates for total soluble solids and no. of locules, respectively.

Mahendrakar *et al.* (2005) identified TP6, TP5 and TP4 among parents as a good general combiners and TP7 x Megha as good specific cross combination for early and total yield per plant.

Rai *et al.* (2005) observed that dominance components were higher than the estimates of additive components for average fruit weight, fruit length, TSS and yield per plant. The significant effect of the additive and dominance components of genetic variance revealed at both types of gene action were significant for all characters except the number of locules per plant.

Singh *et al.* (2005) found that the additive component played a major role in the expression of all characters, except TSS, which was controlled by non-additive gene effect.

Ahmed *et al.* (2006) reported significance of additive gene effects and the effectiveness of selection for the traits viz., yield per plant, average fruit weight, acidity, number of fruits per plant, fruit length, pericarp thickness, plant height and earliness for the improvement of yield and quality.

Pandey *et al.* (2006) crossed ten diverse lines of tomato with three testers in line x tester mating fashion to study combining ability. The analysis revealed that parents and hybrids differed significantly for gca and sca effects, respectively. The parents, Money maker, NDT-3, Bilahi-2, EC-168282, EC-7343, H-86, H-24 and KS-60 were good general combiners for more than one yield contributing characters. The crosses, Bilahi-2 x H-86, Himlata x H-86, EC-168282 x H-24, EC-6148 x H-86, NDT-3 x H-88 and

KS-60 x H-86 were most promising common combinations in both the environments for yield and its contributing characters.

Singh *et al.* (2006a) studied combining ability for yield and quality traits of tomato and reported the specific combining ability was significant for all traits, but not for plant height. The best general combiners were IIVR Sel-2 for plant height, fruit length, fruit weight and TSS, H-36 number of primary branches, fruit diameter, yield and TSS, ATL13 for fruit length, pericarp thickness, ascorbic acid and TSS and ATL-9744 for number of fruits, ascorbic acid and TSS.

Veer *et al.* (2006) studied yield and yield components in a line x tester analysis of tomato. DTH-7, Pant Bahar, Pusa ruby and Sioux exhibited significant negative general combining ability (gca) effects for number of days to germination and for number of fruits per plant. Among the crosses, Pant Bahar x AC-1153 and Pusa Ruby x AC-1073 showed the greatest positive specific combining ability (sca) effect for number of fruits and fruit length, respectively.

Ganeva (2007) reported the hybrid combinations M21 x F2, M22 x F2 and M7 x F3 showed the highest positive effect of specific combining ability for early ripeness.

Garg *et al.* (2008) evaluated seventy nine genotypes of tomato (15 lines, four testers and their 60 F1 hybrids produced in line x tester fashion) under normal (E1) and late planting (E2) conditions and found that lines were significantly different from testers for most of the characters thereby justifying the choice of testers. Additive gene action was predominant for days to ripening, total yield per plant, marketable yield per plant, number of fruits per plant, average fruit weight, fruit shape index and lycopene in both the environments, whereas non-additive genetic variance

predominated in controlling firmness index, number of locules, pericarp thickness, alcohol insoluble solids (AIS), dry matter, total soluble solids (TSS), titratable acidity, TSS: Acid ratio, pH, ascorbic acid and shelf life, under both normal and late planting conditions. The best general combining ability (gca) effects, among females, in respect of yield per plant were shown by Spectrum in E1 and by LT-42 in E2. Among the testers, the best gca values in both the environments were possessed by nor-RM-1 for total yield per plant, marketable yield per plant, number of fruits per plant, dry matter and TSS; by rin-RM-2 for firmness index, pericarp thickness and alcohol insoluble solids; by alc-IIHR-2050 for average fruit weight, number of locules and shelf life and by alc-IIHR-2052 for lycopene. The gca of ripening mutants had a nice consonance with their *per se* performance for most of the characters indicating that additive gene action was operative in these mutants for majority of the traits.

Prabuddha *et al.* (2008) conducted a study to know combining ability, general combiner for almost all yield attributing traits, tomato leaf curl virus (TOLCV) resistance and whitefly resistance. Among the testers Nandi was found to be a good general combiner for number of branches per plant, number of fruits per cluster, individual fruit weight and whitefly resistance parameters. The cross Sankranti x LA3916 was found to be a good specific combiner for most of the traits. However, the cross Nandi x LA3948 exhibited maximum yield coupled hybrids was carried out to study the combining ability for yield attributes, tomato involving eight lines, three testers and resulting components of gca and scavariances established the predominance of additive gene action for all the characters. Among the linesLA3948 was proved to be the good leaf curl virus resistance and white fly resistance. The estimated with TLCV and whitefly resistance

Saidi *et al.* (2008) undertaken a study to know the combining ability using eleven diverse breeding lines/varieties for yield and its contributing characters, through a line x tester analysis. The results revealed that the variances due to gca effects were found significant for number of fruits per plant and height of plant. Mean of sum of squares due to testers effects were found significant for number of fruits per plant, average weight of fruits and height of plant, while the variances due to line x testers effects, were highly significant for all the characters under study characters except number of locules per fruits.

Mondal *et al.* (2009) crossed nine parental lines in Line x Tester fashion to estimate combining ability in tomato for fruit yield, yield components and fruit quality traits. Involvement of both additive and non additive gene action was operative for the control of fruits per plant, fruit weight, locules per fruit and equatorial diameter of fruit. All the fruit quality characters like, TSS and lycopene contents of the fruit were governed by non additive gene action. Taking into consideration the performance, heterosis and sca effect in the hybrid, H-24 x NF-31 and H-24 x Hissar Arun were the best hybrid.

Janaki *et al*. (2011) found a measure of combining ability and components of genetic variance would be of great value in choice of parents and for effective crosses for crop improvement. Generally, general combining ability is largely associated with additive gene action. While the specific result of line x tester design involving 8 lines and 4 testers were evaluated in RCBD with three replications during 2005-2006 for tomato for yield. Combining ability was the result of dominance epistasis and genotype environment interactions (Spagoe and Tatum, 1942).The analysis of variance for all the characters studied indicated significant differences among hybrids. The line x tester analysis for combining ability revealed the

role of non-additive gene action for all the traits under consideration, except for number of primary branches indicating preponderance of non-additive components of genetic variance.

Katkar *et al.* (2012) evaluvated combining ability of eleven diverse breeding lines/varieties for yield and its contributing characters through a line x tester analysis. The results revealed that variance due to parents, line x tester, crosses and crosses vs. parents were found significant for all characters under study. Mean sum of squares due to female parents were found highly significant for total soluble solids and ascorbic acid content of fruits, while the variance due to male parents were non significant for all characters. The estimate of variance of gca and sca and their ratio indicated preponderance of non-additive gene action for all the traits. Based on mean performance and gca effects, male parents CLN2123E and PT4722A were better for total fruit yield per plant and number of fruits per plant, while female parent Vaibhav was better for total fruit yield per plant.

Srivastava *et al.* (2013) conducted a study with the using thirteen parental lines were crossed in line X tester fashion comprising 10 lines and 3 testers at vegetable farm Banaras Hindu University Varanasi to estimate combining ability in tomato for fruit yield, yield components and fruit quality traits. The study revealed that both additive and non additive gene action was operated for the control of fruits per plant, fruit weight and average fruit weight. All the fruit quality characters like, total soluble solids (TSS) titratable acidity, ascorbic acid and lycopene of the fruit were governed by non additive gene action. In most of the traits, over-dominance was predominant. The analysis of components of genetic variance for yield components showed that the main part of genetic variance was due to additive effect. Estimation of general combining ability (GCA) for yield and earliness showed that Pant T-3 had the highest GCA for increasing yield and

Punjab Upma had the highest GCA for both earliness and average fruit weight. Cross combination CO-3 X Azad T-5 exhibit significant specific combining ability (SCA) for the most of desirable traits among all cross.

Dutta *et al.* (2013) conducted a study to know the gene action for fruit yield and quality characters of tomato analyzing the mean and variances of the six genetic populations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of three cross combinations. Non-additive gene action including non-allelic interactions was important for the genetic control of all the characters which indicated that yield components and fruit quality traits were predominantly under the control of non-fixable gene effects. Presence of complementary type epistasis for fruit yield and lycopene content indicated the possibility of developing hybrids for high fruit yield and high lycopene content in fruits.

Yadav *et al.* (2013) estimated heterosis, and its variances were estimated by line x tester analysis including 30 F_1 cross combinations using 13 parents after selfing (ten lines and three testers) at Vegetable Research Farm, BHU, Varanasi (India). These 43 genotypes (10 lines and 3 testers and 30 resulting F_1 hybrids) were evaluated for grow th, yield and quality (T.S.S and shelf life) contributing traits. Ratio of general combining ability (GCA) and specific combining ability (SCA) variance revealed preponderance of non- additive genetic variances for all studied traits. On the basis of GCA effects across ten traits, Potato Leaf, Pant T-7, IC-177371 and NDTVR-60 were identified as most promising parental lines for inclusion in hybridization programmes. Outstanding crosses based on SCA effect across ten traits were RCMT-2 x VR-20, LCT-6 x VR-20 and Azad T-5 x VR-20.

Sherpa *et al.* (2014) undertaken research for hybrid with desirable post harvest traits through line x tester mating design in tomato. Non-

additive gene action controlled all characters studied. Among parental lines, CLN2777-G' and 'FEB-2' were the best general combiners for yield and processing traits and could be utilized further in tomato breeding programme. Crosses ('CLN2768-A x A.C.AFT' and 'CLN2777-G x FEB-2') showing high specific combining ability and yield involved parents showing high general combining ability for fruit yield per plant and other horticultural traits. The performances of the hybrids illustrated the presence of various degrees of dominance effects i.e., partial to over dominance/or no dominance. We could able to improve processing quality in spite of yield in the cross ('CLN2777-G x FEB-2') which can substantially make a dent for processing industry in the tropics.

Hussan *et al.* (2014) used line x tester analysis to identify the potential parents and their hybrids from a set of 12 crosses derived from three lines (LA-2661, LA-2662 and 017899) and four testers (BL-1078, BL-1079, CLN-2413 and CLN-2418-A). Results showed that parents and F_1 hybrids differed significantly for general combining ability and specific combining ability effects, respectively. The values of general combining ability (GCA) and specific combining ability (SCA) variances depicted non-additive and additive gene action with predominance of non-additive gene action in the genetic determination of all characters except fruit yield per plant. Parent lines LA-2662 and CLN-2418-A provided the best general combining ability in more than one yield contributing traits. Specific combining ability effects was recorded in two crosses viz. "LA-2662 x CLN-2418-A" and "LA-2662x BL-1078". F_1 hybrid "LA-2662x CLN-2418-A" proved to be the best cross in overall performance and should be further exploited in breeding plans for hybrid vigour and commercial utilization.

Pujer *et al.* (2014) studied that the diallel analysis was done in eight lines of cherry tomato to study the combining ability effects for growth, yield and quality traits. The lines found to be good general combiners were L 00427 for plant height DAT; L 00398 for number of fruits per cluster, number fruits per plant, fruit yield per plant and lycopene content; L 04780 for ascorbic acid; L 01696 for total soluble solids and reducing sugar. The best specific combiners for plant height L 04780 x L 03686, the L 00427 x Arka Vikas is for number of fruits per cluster, number of fruits per plant and total soluble solids and the hybrids L 00427 x L 03686, L 01696 x L 03686 for ascorbic acid and lycopene content respectively.

Singh *et al.* (2014) conducted a trial with the using ten lines of tomato were crossed with three testers in line x tester mating fashion to study combinig ability effects for yield and yield traits. The analysis of variance revealed the predominance of non-additive gene action for all the traits. In respect of both gca and sca effects, the parents and hybrids differed significantly. Among the parents, Potato Leaf, Pant T-7, IC-177371 and NOTVR-60 were the best general combiners for improving plant height, yield per plant and other characters under study and these may be used as valuable donors in the hybridization programme for producing promising combinations. Among the crosses, RCMT-2 x VR-20, LCT-6 x VR-20 and Azad-T-5 x VR-20 were the most valuable specific combiners for yield per plant and other characters under study.

Figueiredo *et al.* (2015) the objective was to estimate the combining ability of lines in industrial tomato genotypes for the identification of those with good potential for breeding programs. Ten lines of industrial tomato, 45 hybrids derived from a complete diallel and two commercial check cultivars were evaluated. The combining ability of tomato lines of hybrid combinations for fruit-quality related traits were estimated. The parent lines

RVTD-04, RVTD-10 and RVTD-08 had an exceptionally high presence of favorable alleles for most traits. The above lines can be used in breeding programs to develop tomato hybrids with high performance for characteristics related to industrial processing.

Adarsh and Kumari (2015) the combining ability analysis is the basic, most important and efficient tool in selecting the desirable parents for breeding programme. It is based on first degree statistics which is statistically robust. It helps in estimation of inbreds in terms of their genetic value and in the selection of best parents for hybridization in chilli. Therefore combining ability have been the most important and efficient tool in selecting the desirable parents for a hybridization, selection of breeding procedure and estimation of genetic parameters. This review will be more helpful in understanding the opportunities offered by combining ability and gene action studies in chilli.

Zengin *et al.* (2015) this research was carried out to investigate the genetic structure of the 30 F1 hybrid tomato combinations established from 15 female lines and two male testers, and to determine parents showing superior general combining ability (GCA). The 47 genotypes (30 F1 and 17 parents) were planted in a randomized complete block design with three replications in a greenhouse at the Bat Akdeniz Agricultural Research Institute, Antalya, during the spring growing season. General combining ability was investigated for eight traits. The highest effect on GCA among lines had BH-135 for yield per plant and days to first flowering; BH-28 for early yield per plant and pH of fruit juice; BH-93 for days to first fruit ripening; G-8 for plant height and plant stem diameter at 60 days after transplantation and fruit weight. Non-additive genetic variance was predominant in controlling eight characters. Based on GCA, lines BH-4,

BH-28, BH-37, BH-135, BH-53, BH- 102, G-8 and Tester 2 can be recommended as potential lines for further hybrid breeding studies.

Basavaraj *et al.* (2015) a population improvement approach in the form of recurrent selection or simple selection could be used for exploitation of additive and non-additive gene actions for these traits.

Aisyah *et al.* (2016) a study was conducted in a 6x6 full diallel cross set of tomato including reciprocals to estimate the general combining ability, specific combining ability for yield per plant (g) and yield components, namely number of fruits per plant, individual fruit weight (g) fruit length (cm), fruit diameter (cm), locule number, and fruit thickness (cm). The experiment was conducted from March to August 2013 at Bogor Agricultural University Experiment Field, Bogor - Indonesia. Randomized Complete Block Design was used with three replications. Data from Fl-generation and parents were analyzed using the Griffing Method. Significant differences among genotypes were obtained for all the traits. The variances for general combining ability (GCA) and specific combining ability (SCA) were highly significant indicating the presence of additive as well as non-additive gene effects except the fruit thickness. The tomato genotype IPB 78 is parental with the best general combining ability for yield per plant, individual fruit weight, fruit length, and fruit thickness. The tomato genotype IPB T73 x IPB T3 proved to be the best general combiner for yield and number of fruits per plant. The tomato genotype IPB T3 x IPB T1 proved to exhibit best heterosis for yield per plant and fruit thickness.

Yadav *et al.* (2016) the estimate of indicated preponderance of non-additive gene action for most of the traits. Based on the mean performance and *gca* effects, male parents H-86 and NDT-4 were found as good general combiner for fruit yield per plant and number of fruits per plant, while

female parents Arka Ahuti, Arka Abha and Azad T-6 were better for fruit yield per plant.

Kumar *et al.* (2017) nine tomato genotypes were crossed in Line x Tester fashion to develop 18 hybrids, which, along with their parents and checks were evaluated for early blight resistance, fruit yield and quality of tomato (*Solanum lyco-persicum*) to know extent of combining ability for the same. IIHR1816 was found to be the best general combiner with significant highest GCA (General Combining Ability) in desirable direction for per cent disease index (-15.71), carotenoids (3.46), lycopene (2.43) and yield (13.13); while, for plant height (3.94), average fruit weight (25.93), fruit length (0.54), fruit breadth (0.63) and pericarp thickness (1.71), the line IIHR2848 was best general combiner. The tester IIHR2852 was a best general combiner for traits like days to 50% flowering (-0.83) and fruit firmness (0.51). The crosses *viz*., IIHR2891 x IIHR2853 (11.61), IIHR2850 x IIHR2852 (11.40) and IIHR2892 x IIHR2890 (11.19) were found to be superior specific combiners for yield. IIHR2892 x IIHR2852 was a superior specific combin-er for fruit quality traits like fruit firmness (0.98), total carotenoids (6.95) and lycopene (4.52). Best specific combiners for early blight resistance were IIHR2850 x IIHR2852 (-9.58), IIHR2891 x IIHR2890 (-9.58) and IIHR2892 x IIH-R2890 (-6.82). The experiment helped in identifying these superior general combiners and specific combiners for early blight resistance, coupled with good yield and quality of the crop, which can be used in further breeding under-takings.

Reddy *et al.* (2017) the investigation was conducted to study the possibility of improving tomato quality traits through combining ability studies for them. In this respect, during *rabi* of 2014-15 a line x tester analysis was made in tomato (*Solanum lycopersicum* L.) with ten lines four testers and forty hybrids to determine the combining ability effects for some

quality characters. The magnitude of variance due to general and specific combining abilities were highly significant indicating the importance of the additive (sigma 2 A) and non-additive (sigma 2 D) gene actions. However, the ratios of sigma 2 GCA/ sigma 2 SCA (<1) and sigma 2 A/ sigma 2 D (<1) revealed the preponderance of non-additive variance in the inheritance of all the studied traits except TSS and carotene. The estimated average degree of dominance (0.68 and 0.77) revealed partial and complete dominance for TSS% content and carotene, respectively, while revealed over-dominance (>1) for the remaining traits. Kashi Sharad, Pant T-3, T-Local, EC-521087 and H-24 were found to be good general combiners for quality parameters. The crosses T-Local x H-86, GT-20 x H-24 and Kashi Sharad x Sel-7 showed significant positive sca effect for pericarp thickness, shelf life and TSS. The results also suggested the possibility of improvement of these tomato traits through recurrent selection and hybrid breeding programs.

Sharma and Singh (2017) a study was conducted in tomato using a line x tester mating design evolved thirty crosses with 10 genotypes as female parents (lines) and 3 genotypes as male parents (testers). The most promising general combiners were PT-2009-02 for fruit yield per hectare, fruit yield per plant, average fruit weight, S- 816 for plant height PT-1 exhibited the highest General Combining Ability (GCA) for days to first harvest and days to last harvest. Most promising hybrids exhibiting significant Specific Combining Ability (SCA) effects were PT-19 x Punjab Chhuhara for fruit yield per hectare, fruit yield per plant and average fruit weight, PT-41 x Punjab Chhuhara for dwarfness, PT-41 x Roma tallness and PT-11 x PT-3 for earliness. The combining ability analysis indicated the importance of both additive and non-additive gene action for different growth, yield and fruit quality characters.

Kumar *et al.* (2017) the combining ability analysis involving 8 lines and three testers was carried out for 13 characters for yield and its related traits in 1 x t design. The variance due to GCA and SCA showed that additive gene action was predominant for yield and its related traits, though the non additive component was also significant for some characters. Among the parents Bony Best, Black Prince and UK Local-2 were good general combiners for yield and its related traits. The crosses Podlandt Pink x Sioux and Tommy Toe UK Local-2 were good specific combiners for yield and its related traits.

Pramila *et al.* (2018) study on genetic component of variance revealed that additive and non-additive system operating in inheritance of yield and yield components. Gene effect with respect to the nature and magnitude for yield and its contributing traits were studied by involving 30 crosses made by using 10 lines and 3 testers. Crosses were evaluated in two subsequent year i.e. 2013-14 and 2014-15 and pooled analysis was carried out. For earliness, plant height, fruit length and fruit diameter σ2 gca (average) was reported higher than σ2 sca. σ2gca (line) was found higher than σ2 gca (tester) for most of the characters. Rest of the characters shows high σ 2 sca than σ2 gca.For most of the characters except earliness, fruit length and fruit diameter σ 2 D was higher than σ 2 A. For total yield/plant line× tester interaction were reported57.04%, 53.76% and38.35% respectively in year 2013-14, 2014-15 and in pooled analysis.σ2 gca/ σ2 sca ratio was less than unity for mast of the characters except earliness, fruit length and fruit diameter. In majority of characters there were preponderance of nonadditive gene action; therefore these characters could be exploited through heterosis breeding.

2.4 Heretability and genetic advance

Lush (1947) defined heritability in broad as well as in narrow In broad sense, heritability is the ratio of total genetic variation to total phenotypic variance, while narrow sense heritability is the ratio of only additive genetic variance to total phenotypic variance. Heritability estimates provide the assessment of amount of transmissible genetic variance to total variation and determine genetic improvement or response to selection. The estimates of genetic advance in per cent of mean provides more reliable information regarding the effectiveness of selection in improving a trait because its estimate is derived by involving heritability, phenotypic standard deviation and selection intensity. Thus the estimate of heritability and genetic advance are of great significance to plant breeders for developing suitable selection strategy.

Shahu and Mishra (1993) observed that the yield per plant, number of fruits per plant and fruit weight showed high degree of variation with high values for heritability and genetic advance.

Rai *et al.* (1994) reported higher heritability for acidity in F_1 and F_2 in both populations. However **Natarajan (1994)** observed high heritability for days to flowering, mean fruit weight and yield showing partial dominance.

Kurion and Peter (1995) reported that insoluble solids had high heritability coupled with high genetic advance, while **Pujari *et al.* (1995)** observed high heritability coupled with high genetic advance for no. of fruits per plant, plant height and average fruit weight, which indicated role of additive gene action. Beside this high genotypic and phenotypic coefficient of variation were also recorded for above traits. The range of broad sense heritability recorded from 86.8% for fruit length to 98.8% for number of leaves between first and second truss, reported by **Hegazi *et al.* (1995).**

Singh and Singh (1999) recorded high genotypic coefficient of variation and high heritability for fruit yield and ascorbic acid content, while Indrajyothi (2001) also observed high estimate of PCV and heritability value in addition to high genetic advance for all the characters under study.

Kumar *et al.* (2004) reported the analysis of variance for the fourteen characters which showed that mean squares due to genotypes were highly significant for all the character. The genotypic and phenotypic coefficient of variation (96.50%) along with high genetic advance (108.91%) indicated that it was less affected by the environment. The average fruit weight and lycopene showed high heritability that ranged from 89.10 to 96.50%.

Kumari *et al.* (2007) observed the highest genotypic coefficient of variation for plant height followed by early yield, lycopene content, number of fruit bearing branches and titrable acidity. The estimates of heritability were high for all the traits. Genetic advance was high for plant height, moderate for total number of fruit bearing branches, weight per fruit and days to maturity, while the remaining characters had low value of genetic advance.

Rani *et al.* (2011) evaluated eighteen genotypes of tomato were evaluated for yield and various yield attributing characters at Vegetable Breeding Station, Agricultural Research Institute, Rajendra nagar, Hyderabad, India during *Rabi* 2006 and 2007. The data were utilized to estimate the genetic variability in terms of mean, genotypic and phenotypic coefficients of variation, heritability, expected genetic advance and expected genetic advance as per cent mean. The present investigation showed that phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all traits showing the influence of environmental effect. GCV estimates were high for average fruit weight,

number of fruits per plant and yield per plant. Heritability estimates were high for average fruit weight, plant height, number of branches per plant and number of fruits per plant. In spite of high heritability values for most of the characters exhibited high expected genetic advance as per cent of mean.

Singh *et al.* (2011) carried out a field experiment of 10x10 diallel cross (excluding reciprocals) during 2004 and 2005 to study the heritability and expected genetic advance of different traits in tomato (*Lycopersicon esculentum* Mill). High heritability was recorded for fruits per plant and plant height while for other characters, moderate to low heritability estimates were observed in both F_1s and F_2 generations. In F_1s highest genetic advance was observed for fruit yield, primary branches, biological yield and fruit length for other characters, moderate to low genetic gain were recorded. In F_2 highest genetic advance was observed for fruit yield, biological yield and fruit length, while other characters showed moderate to low genetic gain.

Islam *et al.* (2012) evaluated traits of 11 cherry tomato ((*Solanum lycopersicum* L.) var. *cerasiforme* (Dunal) A. Gray) in inbred lines exhibited a wide range of genetic variability. High geno- and phenotypic coefficients of variation were obtained for individual fruit weight (68.16 and 74.23%, respectively) followed by number of fruits/plant (58.8 and 68.34%, respectively). High estimates of heretibility, genetic advance and genotypic coefficient of variation for the traits of individual fruit weight, number of fruits and clusters/plant were controlled by additive gene action indicating the possibility of selection to improve these characters. Fruit yield/plant showed low heritability along with low genetic advance and did not show significant and positive correlation with the remaining characters. It indicates that improvement of high yield through selection is difficult rather hybridization can be effective for improving the fruit yield/plant. Among the

lines, CH154 produced the highest number of fruits/plant (291) and highest fruit yield (1.89 kg/plant and 63.4 t/ha) and can be selected for cultivation under Bangladesh condition.

Reddy *et al.* (2013) studied the genetic parameters to elucidate the genetic variability, heritability and genetic advance in tomato (*Solanum lycopersicum* L.). The genotypes exhibited a wide range of variability for all the characters studied. Phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all the characters studied. High heritability combined with high genetic advance was observed for the characters like plant height, number of clusters per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, fruit length, fruit weight, fruit yield per plant, ascorbic acid, acidity, shelf life and TSS. High heritability combined with high genetic advance indicates that additive gene action plays a major role in governing these traits and these traits can be improved by simple selection.

Patel *et al.* (2013) evalueated thirteen tomato genotypes to estimate variability, heritability and genetic advance in yield and yield contributing characters at AICRP on vegetable crop, M.P.K.V., Rahuri. A high degree of significant variation was observed for all the characters studied except pericarp thickness and number of locules. Highest GCV was observed for fruit yield per plant and PCV for fruit yield per plant and number of locules while lowest GCV was noticed for days to first harvest, days to 50 per cent flowering and pericarp thickness and PCV for days to first harvest and days to 50 per cent flowering. High heritability with high genetic advance as per cent of mean was observed for fruit yield per plant and average fruit weight which could be improved by simple selection.

Shalaby (2013) the studied determine the heterosis and the type of gene action controlling some economical traits of tomato. Six populations of the cross CastleRock x CLN 2498E (P_1, P_2, F_1,F_2, BC_1 and BC_2) were used to study the genetic parameters of tomato traits. Means of the six populations were widely differed for most of the studied traits. One or more of the three scaling tests (*A*, *B* and *C*) were significant for some studied traits indicating that additive dominance model was inadequate to know the role of the type of gene action in the inheritance of these traits. Additive gene effects were found to be important in the inheritance of average fruit weight. Dominance and dominance x dominance gene effects were important in the inheritance of plant height, number of branches per plant, fruit firmness and early yield. Heterosis relative to better parent was present for number of branches per plant, early yield, total yield and fruit firmness. The heritability estimates in broad sense were high for early yield, total yield, average fruit weight, fruit firmness and TSS content. However, heritability estimates in narrow sense were high for early yield and average fruit weight and moderate for TSS content. The estimated dovainance ratio (*P*) was larger than one for all studied traits except for average fruit weight and TSS content.

Akhtar and Hazra (2013) determined nature of gene action for three important fruit quality characters of tomato viz., total soluble solids (TSS), beta -carotene and lycopene contents by analyzing one 7x7 half diallel population and six genetic populations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of two cross combinations. The nature of gene action determined from two biometrical methods matched well and it appeared that the fruit quality characters were under the control of both fixable and non-fixable gene effects, with the non-fixable gene effects with gene interactions being more important. Diallel analysis revealed moderate narrow

sense heritability estimates and 6-parameter model suggested duplicate epistasis as well as significant additive x additive type non-allelic interaction with negative sign for the characters, which will hinder the pace of progress through simple selection. Single seed descent method with progeny row testing and deferred selection will be the best breeding method to develop line bred varieties with good fruit quality character.

Ahirwar *et al.* (2013) studied genetic advance for different yield contributing characters in 19 genotypes of tomato. Significant differences were observed among the genotypes for all the traits. Genetic advance as per cent of mean at 5 per cent was noticed high for all the traits except days to flower initiation and days to first harvest.

Meena *et al.* (2014) carried out investigation at Vegetable Research Farm, Department of Horticulture, SHIATS, Allahabad during 2012-13. The experiment was laid out in Randomized Block Design with three replications having thirty germplasm. Analysis of variance revealed significant differences among germplasm for all the traits studies, suggesting sufficient variability for yield and quality characters. The overall values of PCV were higher than those of GCV. Higher magnitude of GCV and PCV, respectively were recorded for leaf curl incidence per cent (35.45 and 35.46), followed by plant height, ascorbic acid and TSS degrees Brix. High values of GCV are an indication of high genetic variability among the germplasm and thus the scope for improvement of these characters through simple selection would be better. In present study, all the characters showed high heritability the magnitude of heritability ranged from 92% to 100% indicating that these traits are controlled by additive gene action which is very useful in standard selection. The traits like plant height, leaf curl incidence per cent, TSS degrees Brix and ascorbic acid with high GCV, PCV, heritability and genetic advance as percentage of mean, indicating that

these characters are under additive gene effects and more reliable for effective selection.

Genetic divergence

D^2 statistics developed by **Mahalanobis (1936)** provides a measure of magnitude of divergence between biological populations and relative contribution of each component character to the total divergence.

Genetic diversity is an essential requirement for increasing crop productivity through breeding. Selection of diverse parent in breeding programmes help in isolation of superior recombinant using cluster analysis, such as D^2 analysis, principal component analysis and metroglyph analysis which have shown to be useful in selecting genetically distant parent. Genetic diversity determines the inherent potential of a cross for heterosis and frequency of desirable recombinants in advance generation.

D^2 analysis is useful in identification of divergent parent for use in the hybridization programme. The D^2 analysis is only possible by replicated data. In D^2 analysis the genetic diversity is depicted by the cluster representing number of groups in which a population can be classified on the basis of D^2 statistics.

Suinaga *et al.* (2004) the objective of worked out with to determine the genetic differences among eight Brazilian populations of the tomato leafminer *Tuta absoluta* (Lepidoptera: Gelechiidae), from the Brazilian states of Espirito, Santo (Santa Tereza), Goias (Goianapolis), Minas Gerais (Uberlandia and Vicosa), Pernambuco (Camocim de Sao Felix), Rio de Janeiro (Sao Joao da Barra) and Sao Paulo (Paulinia and Sumare), using the amplified fragment length polymorphism (AFLP) technique. Fifteen combinations of EcoRI and MseI primers were used to assess divergence among populations. The data were analysed using

unweighted pair-group method, based on arithmetic averages (UPGMA) bootstrap analysis and principal coordinate analysis. Using a multilocus approach, these populations were divided in two groups, based on genetic fingerprints. Populations from Goianapolis, Santa Tereza, and Vicosa formed one group. Populations from Camocim de Sao Felix, Paulinia, Sao Joao da Barra, Sumare, and Uberlandia fitted in the second group. These results were congruent with differences in susceptibility of this insect to insecticides, previously identified by other authors.

Mahesha *et al.* (2006) studied thirty genetically diverse genotypes of tomato for genetic diversity. The genotypes were grouped into nine clusters irrespective of geographic divergence, indicating no parallelism between genetic diversity and geographical divergence. The maximum number of genotypes included in cluster II was 11. The cluster mean indicated that days to 50% flowering, plant height, number of branches per plant, number of clusters per plant, number of fruits per cluster, fruit weight, fruit length, fruit diameter, number of locules per fruit, number of seeds per fruit, fruit set percentage, fruits per plant and fruit yield per plant were important characters towards the maximum genetic divergence. The maximum genetic distance was observed between clusters VI and IX (8132.17), whereas it was minimum between clusters I and IV (405.05). However, no close correspondence was evident between geographical distribution and genetic divergence as estimated by D^2 statistics.

Jogi *et al.* (2008) studied divergence was studied using 28 tomato genotypes, which were grouped into five clusters irrespective of geographical diversity indicating no parallelism between geographic and genetic diversity. Cluster V. topped having maximum eight genotypes, while cluster II having minimum number of genotypes. The maximum inter-cluster distance was noticed between cluster II and V.

Mehta and Asati (2008) carried out genetic divergence analysis using Mahalonabis D^2 statistic in twenty two tomato determinate genotypes. These genotypes were grouped into six clusters based on sixteen important fruit characteristics. The cluster-I was the largest containing seven genotypes followed by cluster-III with six genotypes. The diversity among the cultivars was measured by inter-cluster distance. The higher order of divergence was recorded between cluster II and V which was adequate for improvement of tomato by hybridization and selection. The genotypes included from the diverse duster can be used as promising parents for hybridization, programme to obtain high heterotic response and thus better segregants in tomato for industrial purpose.

Prashanth *et al.* (2008) assessed sixty-seven tomato genotypes from different geographical origin to determine the value and magnitude of genetic divergence using Mahalanobis D^2 statistics. A wide genetic diversity was observed among the genotypes which were grouped into seven clusters. The clustering pattern indicated that the geographic diversity need not necessarily be related to genetic diversity. The maximum intercluster distance was observed between cluster V and VI closely followed by cluster III and V, cluster IV and V, cluster IV and VII, cluster VI and VII, and cluster V and VII. Cluster II revealed the least distance relationship with cluster III. The selection of divergent parents based on the obtained cluster distance is recommended to obtain good hybrids or segregants in tomato.

Rana and Singh (2010) carried out investigation with 33 genotypes of tomato. All thirty three genotypes could be grouped into eight clusters. Cluster I was the largest with 22 genotypes followed by clusters II and III with three genotypes in each whereas clusters IV to VIII had single genotype in each. Highest value of genetic distance was observed between cluster IV with single genotype ARTH-210 and cluster VIII with NTH-242

(5.63). Cluster III had highest values for number of primary branches, leaf area, number of fruits per plant, number of seeds per fruit and fruit yield per plant. Based on divergence studies, crosses *viz*., NTH-242 x ARTH-210, NTH-242 x NTH-255, NTH-242 x Pant Bahar are recommended for future breeding programs.

Shashikanth *et al.* (2010) conducted genetic divergence study in 30 tomato genotypes. Mahalanobis D2 statistics helped in grouping the 30 genotypes into 10 diverse clusters. The composition of clusters of heterogenous geographic origin indicated that the strains were distributed among the different clusters randomly irrespective of their geographical origin. This indicated that there was no parallelism between genetic diversity and geographical divergence in tomato. A high diversity among the genotypes suggested that those belonging to cluster VII (genotype NDTTNR-76) and X (genotype ATL-02-39) can be selected in hybridization programmes to obtain good seggregants.

Naralia and Reddy (2012) studied in fifty-five genotypes of tomato for their genetic divergence using Mahalanobis D^2statistics at Hyderabad. Based on D^2 values of 13 characters, genotypes were grouped into 12 highly divergent clusters. Some of genotypes were so divergent in all the characters; hence, each single genotype formed a separate cluster. Thus, eight clusters viz., III, VI, VII, VIII, IX, X, XI and XII were solitary with one genotype in each cluster. The remaining four clusters were having maximum number of genotypes. Cluster II was biggest with 20 genotypes followed by cluster I (14 genotypes), while the other two clusters IV and V comprised six and seven genotypes, respectively. The maximum genetic divergence was observed between clusters IX and XII followed by between clusters V and IX. The maximum intra-cluster distance was shown by cluster V. Hence, the crosses of genotypes from clusters IX with cluster XII

will result in the development of high acidity and early maturity variety. The characters viz., acidity content followed by shelf life, plant height, TSS, ascorbic acid content, average fruit weight and number of fruits per plant contributed greatly towards diversity.

Reddy *et al.* (2013) studied on genetic divergence analysis following Mahalanobis D^2 statistics revealed the considerable genetic diversity among 59 genotypes of tomato for all the eighteen quantitative characters which was pertaining to the growth, earliness, yield and quality. Fifty nine genotypes were grouped into 7 distinct clusters depending upon the similarities of their D^2 values following Tocher's method. Appreciable diversity within and between 7 clusters was observed. The characters fruit weight, number of fruits per plant and plant height were the potent factors in differentiating the germplasm of tomato under study. The use of diverse genotypes from the clusters with high intercluster distance (cluster VI and VII, V and VII and V and VI) in hybridization is expected to result in high heterosis and throw desirable transgressive segregants.

Dutta *et al.* (2013) conducted a study to know the heritability in narrow sense for growth and yield. Study revealed that Narrow sense heritability estimates in all the characters were low to moderate additive genes indicating that environment will have much influence on such traits.

Thapa *et al.* (2014) carried out present investigation to study the genetic divergence in 30 tomato genotypes using Mahalonabis D^2statistics. These genotypes were grouped into five clusters based on nineteen characters. Maximum divergence was recorded between clusters III and IV followed by cluster IV and V. Genotype MT-4 (Oval big) of cluster III was found to be best for yield and related traits, like number of primary

branches, fruit length, diameter, weight and yield per plant. Similarly, BT-10 of cluster IV was suitable for quality traits, like TSS, ascorbic acid, juice, beta -carotene and lycopene content. Genotypes of cluster III and IV can be used for the development of hybrid/varieties having higher yield and quality.

Chapter-III

MATERIALS AND METHODS

The present investigation entitled **"Heterosis, combining ability and gene action involved for yield and quality attributing traits in tomato (*Solanum lycopersicum* L.)"** was carried out at the Main Vegetable Research Station, Division of Vegetable Science and in the laboratory of the College of Horticulture and Forestry, Narendra Deva University of Agriculture and Technology Narendra Nagar (Kumarganj), Ayodhya, India, during 2016- 17 and 2017-18. The experimental designs adapted, statistical procedures followed and methodology adopted is described here under.

3.1 Experimental site

Experiments were conducted on sandy loam soil, at the Main Experiment Station, Department of Vegetable Science, Narendra Deva University of Agriculture and Technology, Narendra Nagar, Kumarganj, Ayodhya (U.P.). Geographically, Kumarganj falls under humid sub-tropical climate and is located in between 24.47^0 and 26.56^0 N latitude and 82.12^0 and 83.98^0 E longitude at an altitude of 113 m Gangetic Alluvial Plains of Eastern Uttar Pradesh. The physical and chemical properties of the soil are good and average fertility level and pH in the range of 7.5 to 8.5.

3.2 Environmental conditions

This area falls under subtropical climatic zone and the farm receives an annual rainfall of about 1200 mm. The monsoon starts in the month of June and remains active up to September. Sometimes, continuous cloudy weather with heavy rains for longer period drastically affect the agricultural production. Occasional showers are also very common in winter season. The hot period of summer season generally start somewhere from middle of April and continuous till the middle of June. The weather data recorded at

meteorological observatory of the university for the period during which experiments were conducted, have been given in Table 3.1.

Table-3.1 Meteorological data (weekly average) during the investigation period (2016-17 and 2017-18)

Months	SMW	Temperature (ºC)				Average Relative Humidity (%)		Sunshine (hrs)		Rainfall (mm)	
		Minimum		Maximum							
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Sep.	36	26.5	26.0	34.4	34.0	75.6	80.1	7.5	6.5	2.2	49.4
	37	26.0	26.7	32.2	34.7	84.7	78.7	1.2	7.3	9.2	00.0
	38	25.7	25.8	32.8	32.7	80.6	84.7	1.5	5.2	00.0	88.2
	39	24.2	25.2	30.5	33.1	80.4	82.4	1.0	5.3	76.2	20.6
Oct.	40	25.7	24.8	34.0	33.8	76.6	79.9	5.1	6.8	9.8	00.0
	41	21.8	21.4	32.7	33.7	74.5	71.7	5.1	7.6	25.3	00.0
	42	18.0	17.0	32.8	29.9	68.1	75.2	5.9	5.8	00.0	00.0
	43	16.3	15.3	32.4	29.2	64.9	73.6	3.5	4.3	00.0	00.0
	44	14.1	13.9	31.0	29.3	65.4	66.7	2.6	4.5	00.0	00.0
Nov.	45	12.7	11.9	29.7	26.8	67.2	66.0	1.5	5.6	00.0	00.0
	46	11.8	08.1	29.0	25.9	67.4	63.0	1.8	5.6	00.0	00.0
	47	11.1	09.8	27.3	26.1	67.4	66.7	2.4	5.7	00.0	00.0
	48	12.2	10.1	25.8	25.1	79.9	71.2	1.0	5.5	00.0	00.0
Dec.	49	11.7	09.8	19.2	26.1	86.6	66.7	1.7	5.7	00.0	00.0
	50	9.0	10.1	19.5	25.5	86.9	71.2	1.5	5.5	00.0	00.0
	51	7.5	08.1	23.2	23.3	74.0	78.2	2.1	3.9	00.0	00.0
	52	10.6	08.4	20.2	19.4	84.1	85.6	2.0	4.3	00.0	00.0
	1	10.2	04.7	18.0	15.1	88.2	84.3	1.0	0.6	00.0	00.0
Jan	2	4.9	05.2	20.1	13.8	66.3	87.8	2.2	0.5	00.0	00.0
	3	5.9	04.8	22.4	21.8	68.0	74.1	2.5	4.1	00.0	00.0
	4	9.1	05.9	23.7	21.3	76.0	74.8	2.0	4.1	10.8	01.0
	5	8.2	07.2	21.9	24.3	80.2	70.0	2.7	4.7	03.0	00.0
Feb.	6	8.4	08.1	21.0	24.3	75.3	60.7	5.2	4.6	00.0	00.0
	7	9.9	10.7	25.7	24.7	70.3	72.2	5.5	3.5	00.0	00.0
	8	11.1	11.8	27.9	28.7	63.9	66.3	5.3	6.5	00.0	00.0
	9	11.5	14.1	28.8	30.1	57.8	67.3	6.4	6.6	00.0	00.0
Mar.	10	12.3	12.3	27.8	31.1	62.4	64.7	4.4	6.6	00.0	00.0
	11	10.0	13.7	29.4	32.8	56.8	58.2	7.9	7.1	0.70	00.0
	12	15.5	14.2	33.4	34.2	50.9	54.5	8.4	7.1	00.0	00.0
	13	15.0	15.5	32.8	35.2	52.2	54.4	9.5	7.3	00.0	00.0
Apr.	14	16.5	18.7	34.5	35.3	55.1	58.0	8.3	7.4	00.0	00.0
	15	18.5	18.3	39.2	35.4	48.0	53.2	6.8	7.1	00.0	00.0
	16	19.0	20.5	35.2	39.2	47.5	41.9	6.5	7.9	00.0	00.0

Source: Department of Agro-meteorology, NDUA&T, Kumarganj, Ayodhya (U.P.) India

3.3 Experimental materials

The experimental plant material for present investigation was comprised of 40 F_1's developed by crossing 10 lines (NDT-1, NDT-2, NDT-3, NDT-4, NDT-5, NDT-6, NDT-7, NDT-8, Azad T-6, Arka Saurabh) with 4 testers (Pusa Ruby, Punjab Chhuhara, Arka Vikash and Arka Meghali) during *Rabi* season 2015-16.

Table 3.2: Details of parental lines/genotypes of tomato included in the study.

S. N.	Name of genotype	Source	Description of main features
1	NDT-1	N.D.U.A.T., Ayodhya	Indeterminate, fruit round, medium size
2	NDT-2	N.D.U.A.T., Ayodhya	Determinate, round and small size fruits
3	NDT-3	N.D.U.A.T., Ayodhya	Determinate, round and small size fruits are slightly grooved
4	NDT-4	N.D.U.A.T., Ayodhya	Indeterminate, fruit round and medium size
5	NDT-5	N.D.U.A.T., Ayodhya	Indeterminate in nature, fruits are round in shape, medium in size
6	NDT-6	N.D.U.A.T., Ayodhya	Determinate, fruit round and medium size
7	NDT-7	N.D.U.A.T., Ayodhya	Determinate, fruit round and medium size
8	NDT-8	N.D.U.A.T., Ayodhya	Determinate, round and small size fruits
9	Azad T-6	C.S.A.U.&T, Kanpur	Indeterminate fruits, small in size and round.
10	Arka Saurabh	I.I.H.R. Bengalore	Semi-determinate in nature, fruits are medium-large size and firm round
11	Pusa Ruby	I.A.R.I., New Delhi	Indeterminate in nature, fruits are flat round.
12	Punjab Chhuhara	P.A.U, Ludhiana	Determinate, pear shaped and small size fruits
13	Arka Vikash	I.I.H.R. Bengalore	Semi-determinate in nature, fruits are medium size
14	Arka Meghali	I.I.H.R. Bengalore	Semi-determinate in nature, fruits oblong, superior in size

These 40 F_1's along with their parents were evaluated for the study of heterosis, combining ability, gene action, heritability, genetic advance and genetic divergence involving fifteen characters i.e. fruit yield and yield attributes and quality traits. Distinguishing features of the lines and testers are given in Table 3.2

3.4 CULTURAL PRACTICES

3.4.1 Raising of seedlings

The seedlings of all the aforesaid genotypes and developed F_1's along with parents were brought up in raised nursery beds. Recommended cultural and plant protection measures were taken up before and after sowing of the seeds.

3.4.2 Field preparation and layout of the experiment

The experimental fields was ploughed and brought to fine tilth. FYM @ 25 tonnes per ha and 115:100:60 kg NPK per ha were applied in the recommended manner. The experiment was laid out during *Rabi* 2016-17, and *Rabi* 2017-18 in Randomized Block Design including 10 lines, 4 testers and 40 $F_1^{S.}$

3.4.3 Transplanting and after care

Thirty days old seedlings were transplanted to the main field. Top dressing was done with 50 per cent nitrogen after one month of planting. Timely irrigation was given and recommended package of practices followed. The dates of nursery sowing and transplanting of genotypes/hybrids done in different seasons are as below:

3.5 Experimental design

The experiments were conducted in RBD with three replications to assess the performance of 40 F_1 hybrids and 14 parents (10 lines and 4 testers). The treatments were planted in rows spaced at 0.6 meters apart with a plant to plant spacing of 0.5 meter. The experiments were sown on 11th September, 2016 and 08th October, 2017. All the recommended agronomic package of practices and protection measures were followed to raise good crop.

3.6 Development of F_1 hybrids and their evaluation

Inbred lines of 14 divergent parents were selected from the evaluated genotypes and crossed in line x tester mating design as suggested by

Kempthorne (1957) to produce 40 hybrids in ***Rabi*** **2016-17** and evaluated during ***Rabi*** **2017-18**. This involves 10 females (lines) and 4 male parents.

3.7 Hybridization programme

The seeds of the above said parents were sown in nursery and transplanted in separate crossing block. Healthy flower buds in a cyme preferably of the first flush of the female parents, which were expected to open next day were emasculated before their opening, between 3 to 6 pm and bagged to prevent out crossing. Pollination was done next morning using pollen grains from desired freshly opened male parent flowers. Crossed flower buds were covered with butter paper bags or cotton till fruits were set and labelled. Simultaneously, flower buds of parents were selfed and it was ensured by bagging the flower buds. Seeds were extracted from red ripe fruits by fermentation method.



Fig. 3.1- Nursery beds of tomato in 2015-16



Fig. 3.2- Cottoning of tomato in 2015-16



Fig. 3.3- Field view of tomato experimental block *Rabi* season 2016-17



Fig. 3.4- Field view of tomato experimental block *Rabi* season 2017-18

3.6.3 Evaluation of Parents and F_1

The evaluation of 40 F_1 hybrids along with their parents and commercial check (Arka Vikash) for various traits was taken up in *Rabi* 2016-17. The details of experiment are as under,

Treatments : 40 hybrids + 14 parents including commercial check (Arka Vikash)

Replication : Three

Design : Randomized Block Design (RBD)

Spacing : 60 cm x 50 cm

Plot size : 1.2 m x 3.0 m

Population : 10 plants per plot

3.7 OBSERVATIONS RECORDED

Observations on all the quantitative characters, except length of edible fruit and fruit circumference were recorded on all the five plants of each genotype in each replication. The observations recorded on the five plants

were averaged to get mean value. The observation for fruit length, circumference and quality traits were taken as specified below and the procedure is described under the respective sub-heads:

3.7.1 Plant growth parameters

3.7.1.1 Days to 50 per cent flowering

Number of days from transplanting to first flower appearance in 50 per cent of the plants in each plot was recorded and the average was computed.

3.7.1.2 Days to first fruit set

Number of days to first fruit set was counted from date of transplanting of seedling to the date when first flower became pea size fruit.

3.7.1.3 Days to first fruit harvest

Number of days to first fruit harvest was counted from date of transplanting of seedling to the date of first fruit harvesting.

3.7.1.4 Plant height (cm)

Height of the plants from the base to the tip of the plant at end of crop was measured in five plants and expressed in centimetre and the average was used for computation.

3.7.1.5 Number of primary branches per plant

Number of primary branches per plant was counted in five plants in each genotype and the average was calculated.

3.7.1.6 Number of fruits per cluster

Before first picking, three fruit bunches were chosen at random in each of labelled plant to calculate the average number of fruits per cluster.

3.7.2 Fruit quality parameters

3.7.2.1 Total soluble solids (per cent)

The fruits utilized for recording pericarp thickness were used for total soluble solids determination. Percentage was determined with the help of (Earma, Japan) hand refractometer (0-32 range).

3.7.2.2. Ascorbic acid content (mg/100g)

Ascorbic acid content was estimated by crushing 10 g fresh fruit with three per cent metaphosphoric acid buffer. The extract was filtered and 100 ml volume was made with three per cent HPO_3. 10 ml aliquot was titrated against, 2, 6-dichlorophenol-indophenol dye solution till the light pink colour appeared. The results were expressed as mg/100g of fresh fruit **(A.O.A.C., 1970)**.

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titrated value (ml)} \times \text{Dye factor x Vol. made up (ml)}}{\text{Aliquot of extract taken (ml)} \times \text{Weight of sample taken for estimation (g)}} \times 100$$

3.7.3 Fruits physical parameters

Fully grown mature representative fruits of each genotype/hybrid were selected to measure fruit parameters. Five fruits were used for recording these traits and average was taken from them.

3.7.3.1 Fruit length (cm)

Fruit length was measured on five randomly selected fruits in centimeters at fifth picking with the help of Vernier calipers. The average fruit length was derived by summing of the length of all five fruits and dividing it by five.

3.7.3.2 Fruit girth (cm)

The same fruit, which were used for measuring length of fruit were also taken for measuring the girth (cm). The girth of fruit was measured and the average fruit girth was calculated as it was done in case of fruit length.

3.7.3.3 Pericarp thickness (mm)

The five fruits were taken randomly for the measurement of pericarp thickness. The thickness of pericarp was measured with the help of Vernier calipers and averaged.

3.7.3.4 Number of locules per fruit

Number of locules was counted by cutting the fruit transversely in the middle and the average was calculated.

3.7.4 Yield parameters

3.7.4.1 Number of fruits per plant

Total number of fruits harvested from all the pickings was pooled and the average number of fruits was calculated.

3.7.4.2 Average fruit weight (g)

Total fruit yield (kg) of a plot was divided by total number of fruits of that plot to the average fruit weight and converted in gram.

3.7.4.3 Total fruit yield per plant (kg)

The total yield per plant, over all the picking was recorded in kilograms from each plot and divided by the total number of yielding plants to obtain the total fruit yield per plant (kg).

3.8 Statistical and genetical analysis

The experimental data were compiled by taking the mean value of the 14 parents (10 lines and 4 testers) and 40 F_1's for all the 16 quantitative traits including fruit quality traits for all the three replications for both the experiments. Then it was subjected to the following statistical and biometrical analysis:

3.8.1 Analysis of variance for the design of experiment

The analysis of variance for the design of experiment was carried out according to the procedure outlined by **Panse and Sukhatme (1967)**. The significance of difference among treatment means was tested by 'F' test. To test the hypothesis H_0: $t_1 = t_2 =$ ---------- $= t_v$, the fixed effect model for the analysis of variance for Randomized Block Design is given below:

$$Y_{ij} = \mu + t_i + b_j + e_{ij}$$

Where,

Y_{ij} = Yield of i^{th} entry in the j^{th} replication

μ = General mean

t_i = Effect of the i^{th} entry (i = 1, 2, ---------, v.)

b_j = Effect of the j^{th} replicate (j = 1, 2, ---------, r.)

e_{ij} = Environmental effect

The details of the ANOVA for parents and crosses are:

Source of variation	**d.f.**	**SS**	**MS**	**F ratio**
Replications	(r-1)	SSR	MSR	MSR/MSE
Treatments	(t-1)	SST	MST	MST/MSE
Parents	(P-1)	SSP	MSP	MSP/MSE
Crosses	(C-1)	SSC	MSC	MSC/ MSE
Parents *vs* crosses	1	SSP *vs* SSC	MSP *vs* MSC	MSP *vs* MSC/ MSE
Error	(r-1) (t-1)	SSE	MSE	

Where,

r = Number of replications

t = Number of treatments

P = Number of parents

C = Number of crosses

The standard error, critical difference and coefficient of variation were calculated as follows:

$$\text{S.E. (d) mean} = \sqrt{\frac{2\text{MSE}}{\text{r}}}$$

$$\text{Critical difference} = \text{SE} \times \text{t value}$$

Where,

Table value of t distribution at error d.f. and $P \leq 0.05$

$$\text{Coefficient of variation (C.V.)} = \frac{\sqrt{\text{MSE}}}{\text{Gm}} \times 100$$

3.8.2 Nature and magnitude of heterosis for yield and its components

The nature and magnitude of heterosis was worked out using information on various quantitative characters studied. Heterosis expressed as per cent increase or decrease of hybrids (F_1's) over better parent (heterobeltiosis) and standard variety (standard heterosis).

Heterobeltiosis

$$\text{Heterobeltiosis}(\%) = \frac{\bar{F}1 - \overline{BP}}{\overline{BP}} \times 100$$

Where,

$\overline{BP}$ = Mean value of the better parent

S.E(d) for $\bar{F}_1 - \overline{BP} = \sqrt{\frac{2MSE}{r}}$

C.D. = S.E(d) × t (at error d.f.)

Standard heterosis

The must be a hybrid of tomato involved in crosses was used as standard variety to calculate standard heterosis.

$$\text{Standard heterosis (\%)} = \frac{\bar{F}_1 - \overline{SC}}{\overline{SC}} \text{ x } 100$$

Where,

$\overline{SV}$ = Mean value of the standard variety.

$$\text{S.E (d) for} = \bar{F}_1 - SC = \sqrt{\frac{2MSE}{r}}$$

C.D. = S.E (d) x t (at error d.f.)

Testing of significance of both types of heterosis was done on the basis of absolute difference between the value of F_1 and the value of better parent/standard variety.

3.8.3 Combining ability analysis

The combining ability analysis was carried out following line × tester mating design outlined by **Kempthorne (1957)** and further elaborated by

Arunachalam (1974). Line × tester analysis was used to estimate general combining ability (gca) and specific combining ability (sca) variances and their effects using the observations taken on F_1 generation of the line × tester sets of crosses. In this mating system, a random sample of 'l' lines is taken and each line is mated to each of the 't' testers **(Singh and Chaudhary, 1977)**.

(i) The model underlying this analysis is as follows:

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

Where,

μ = General mean

g_i = gca effect of the i^{th} male (tester), i = 1,2,…m.

g_j = gca effect of j^{th} female (line), j = 1,2,…f.

s_{ij} = sca effect of the i^{th} tester and j^{th} line cross combination.

e_{ijk} = Error associated with ijk^{th} observation, k = 1,2,…r.

(ii) The individual effects were estimated as follows:

(a) $$\mu = \frac{X...}{mfr}$$

Where,

X... = Total of all hybrid combinations.

(b) $$g_i = \frac{X_{i..}}{fr} - \frac{X...}{mfr}$$

Where,

$X_{i..}$ = Total of i^{th} male over all the females and replications.

(c) $$g_j = \frac{X_{.j.}}{mr} - \frac{X...}{mfr}$$

Where,

$X_{.j.}$ = total of j^{th} female over all males and replications.

(d) $$s_{ij} = \frac{X_{ij.}}{r} - \frac{X_{i..}}{fr} - \frac{X_{.j.}}{mr} + \frac{X...}{mfr}$$

Where,

$X_{ij.}$ = Total of ij^{th} combination over all replications.

(iii) Standard errors for combining ability estimates were calculated as given below:

SE (gca for line) = $(Me/rm)^{1/2}$

SE (gca for tester) = $(Me/rf)^{1/2}$

SE (sca effect) = $(Me/r)^{1/2}$

SE (g_i-g_j) line = $(2Me/rm)^{1/2}$

SE (g_i-g_j) tester = $(2Me/rf)^{1/2}$

SE $(S_{ij}-S_{kl})$ = $(2Me/r)^{1/2}$

Where,

Me = Error MS

Critical differences (CD) were calculated as:

CD = SEd × t at 5% and 1% probability levels at error d.f.

(iv) The analysis of variance for combining ability is as follows:

Source of variation	**d.f.**	**S.S.**	**M.S.**	**Expected MS**
Replications	(r-1)	-	-	-
Lines (females)	(l-1)	SS (l)	MS (l)	σ^2e + r (Cov. F.S.-2 Cov. H.S.) + rt Cov. H.S.
Testers (males)	(t-1)	SS (t)	MS (t)	σ^2e + r (Cov. F.S.-2 Cov. H.S.) + rl Cov. H.S.
Lines × Testers	(l-1) (t-1)	SS (l × t)	MS (l × t)	σ^2e + r (Cov. F.S.-2 Cov. H.S.)
Error	(rlt-1)	SS (e)	MS (e)	σ^2e

Where,

r = Number of replications

l = Number of lines

t = Number of testers

$\sigma^2 e$ = Variance due to error

(v) Proportional contribution of lines, testers and their interactions:

$$\text{Contribution of lines (\%)} = \frac{\text{S.S.(lines)}}{\text{S.S.(crosses)}} \times 100$$

$$\text{Contribution of testers (\%)} = \frac{\text{S.S.(testers)}}{\text{S.S.(crosses)}} \times 100$$

$$\text{Contribution of lines} \times \text{testers} = \frac{\text{S.S. (lines} \times \text{testers)}}{\text{S.S. (crosses)}} \times 100$$

3.8.4 Genetic components

$$\text{Cov. Half sib (line)} = \frac{M_f - M_{fm}}{rm}$$

$$\text{Cov.Half sib (tester)} = \frac{M_m - M_{fm}}{rf}$$

$$\text{Cov.Half sib (average)} = \frac{1}{r(2fm - f - m)}\left[\frac{(f-1)M_f + (m-1)M_m}{f+m-2} - M_{fm}\right]$$

$$\text{Cov.F.S. (average)} = \frac{(M_f - M_e) + (M_m - M_e) + (M_{fm} - M_e)}{3r} +$$

$$\frac{6r\,\text{Cov.H.S. (average)} - r\,(f+m)\,\text{Cov.H.S. (average)}}{3r}$$

Where,

M_f = Mean squares due to lines (females)

M_m = Mean squares due to testers (males)

M_{fm} = Mean squares due to line × tester interactions

M_e = Mean squares due to error

r = Number of replications

f = Number of lines

m = Number of testers

gca variance (σ^2gca) = Cov. H.S. (average) = $\left[\frac{1+F}{4}\right]$ σ^2A

Therefore,

Additive genetic variance (σ^2A) = 2 Cov. H.S. (average), if F = 1 and (σ^2A) = 4 Cov. H.S. (average), If F = 0

$$\text{sca variance } (\sigma^2\text{sca}) = \frac{(M_{fm} - M_e)}{r}$$

$$\sigma^2\text{sca} = \left[\frac{1+F}{2}\right]^2 \sigma^2\text{D}$$

Therefore,

Dominance variance (σ^2D) = σ^2 sca with F = 1, and

$$\sigma^2\text{D} = 4\sigma^2\text{sca, if F = 0}$$

Where,

F = Inbreeding coefficient

(i) Average degree of dominance

It was calculated using formula given by **Kempthorne and Curnow (1961)**.

$$\text{Average degree of dominance} = \sqrt{(\sigma^2\text{sca})/(2\,\sigma^2\text{gca})} \text{ or } \sqrt{(\sigma^2\text{D})/(\sigma^2\text{A})}$$

Where, σ^2sca = Estimated variance due to sca.

σ^2gca = Estimated variance due to gca

(ii) Predictability ratio

It was suggested by Baker (1978) and was calculated as follows:

$$\text{Predictability ratio} = \frac{2\sigma^2 g}{2\sigma^2 g + \sigma^2 s}$$

3.8.5 Heritability in narrow sense and genetic advance in per cent of mean

(i) Heritability in narrow sense

Heritability in narrow sense (h^2ns) was calculated as suggested by **Kempthorne (1957)**.

$$h^2n\,(\%) = \frac{2\sigma^2 g}{2\sigma^2 g + \sigma^2 s + \sigma^2 e} \times 100$$

Where,

$\sigma^2 g$ = Variance due to gca
$\sigma^2 s$ = Variance due to sca
$\sigma^2 e$ = Variance due to error

(ii) Genetic advance in per cent of mean

Expected genetic advance ($\overline{G}$) was estimated by the formula suggested by Johnson *et al*. (1955).

$$G.A. = \frac{\sigma^2 g \times K\sigma p}{\sigma^2 p}$$

$$= K\,\sigma p\, h^2$$

Where,

$\sigma^2 g$ = genotypic variance

$\sigma^2 p$ = phenotypic variance

σp = phenotypic standard deviation

K = selection different at 5% selection intensity (2.06), genetic advance as per cent of mean (G.A. %)

$$G.A.(\%) = \frac{\text{Geneticadvance}}{\overline{X}} \times 100$$

Where,

$\overline{X}$ = grand mean of the character

3.8.6 Genetic divergence analysis

The genetic divergence of 54 genotypes of tomato was worked out using **Mahalanobis** (1928) D^2 statistics. The fifteen quantitative characters in tomato were included for these analyses. The calculation of D^2 the values involved following steps:

(i) A set of uncorrelated linear combinations (Y's) was obtained by the pivotal condensation of the common dispersion matrix **(Rao, 1952)** of a set of correlated variables (X's).

(ii) Using the relationship between Y's and X's, the mean values of different genotypes for different characters (X_1 to X_{18}) were transformed in to the mean values of a set of uncorrelated linear combinations (Y_1 to Y_{18}).

(iii) The D^2 between i^{th} and j^{th} genotypes for K characters was calculated as:

$$D^2_{ij} = \sum_{t=1}^{K} (Y_{it}-Y_{jt})^2$$

The K components were calculated separately and added to get D^2_{ij}

(iv) The K components of D^2_{ij} for each combination were ranked in descending order of magnitude.

(v) Group constellation: The D^2 values were arranged in an increasing order of magnitude. The grouping of the strains into different clusters was done using Tocher's methods **(Rao, 1952)**. The two most closely associated groups were chosen and third group was found which had the smaller average D^2 value from the first two. Similarly the fourth was chosen to have the smallest average D^2 from the first three and so on. The D^2 value that did not fit with the former group and was, therefore, taken as another cluster.

(vi) Intra and inter-cluster distance: The intra-cluster D^2 was calculated as the sum of n (n-1)/2 genotypes within a cluster divided by total number of combinations. All possible D^2 values between the groups of two clusters were added and then divided by n1×n2 for computing inter-cluster distance.

Where,

n1 and n2 = the number of genotypes in two clusters

(vii) Cluster mean: The cluster mean for the particular character is the summation of mean values of the strains included in a cluster divided by number of strains in the cluster.

(viii) These ranks were added up for each component over all the combinations of i and j and the rank totals were obtained.

(ix) Testing D^2_{ij} as the generalized statistical distance between i^{th} and j^{th} populations, the populations were grouped into number of clusters on the basis of D^2 values. Any two genotypes belonging to the same cluster had the smallest possible intra-cluster distance. On an average, intra-cluster distance was less than the inter-cluster distance (Tocher's method).

(x) Per cent contribution of each character towards genetic divergence was calculated as below:

Percentage contribution of character X = $\frac{N}{C} \times 100$

Where,

N= Number of genotype combinations which was ranked first for character X

C= All possible combinations of genotypes involved in D^2 analysis

EXPERIMENTAL FINDINGS

The experimental findings of the present investigation have been set out in the following sub-heads:

4.1 Analysis of variance

4.2 Mean and range for different characters

4.3 Estimates of heterosis

4.4 Combining ability variances and their effects

4.4.1 Analysis of variance for combining ability

4.4.2 Estimates of general combining ability effects

4.4.3 Estimates of specific combining ability effects

4.5 Proportional contribution of lines, testers and lines × testers

4.6 Components of variation

4.7 Heritability and genetic advance

4.8 Estimation of genetic divergence

4.1 Analysis of variance

Analysis of variance for line × tester mating design for both the years (Y_1 and Y_2) had been presented in Table 4.1.1. Analysis of variance revealed that the differences among treatments were highly significant for all the characters studied in both the years. Further partitioning of treatment variances into parents, crosses, lines and testers revealed highly significant differences among parents as well as crosses for all the fifteen characters. Variances due to parents was highly significant for all the characters in both the years and significant for days to 50 % flowering in second year except days to 50 % flowering in first year while, for days to first fruit set, days to first fruit harvest, number of primary branches per plant and number of locules per fruit in both the years. Variances due to parents *vs.* crosses were highly significant for days to 50 % flowering, days to first fruit set, days to

first fruit harvest, plant height, number of fruits per plant, average fruit weight (g), pericarp thickness (mm) and total fruit yield per plant (kg) in both the years and ascorbic acid in scound year while, significant for number of fruits per cluster and fruit length (cm) in both the years. Variances due to lines *vs*. testers were highly significant for the characters like plant height, number of fruits per plant, average fruit weight (g) and fruit girth (cm) while, significant for number of primary branches per plant and number of locules per fruit in both the years.

The pooled analysis of variance given in Table 4.1.2 also divided the source of variance into environments found highly significant for all the traits under study. Variances due to treatments and parents were found highly significant for all the traits under study as well as crosses for all the fifteen characters. Variances due to parent vs crosses were found highly significant for all the traits under study, except for number of locules per fruit and total soluble solids, while significant for fruit girth (cm) and ascorbic acid. Variances due to line vs testers were found highly significant for the characters like plant height, number of primary branches per plant, number of fruits per plant, average fruit weight (g), fruit girth (cm), number of locules per fruit, while significant for fruit length (cm) and total fruit yield per plant (kg).

4.2 *Per se* performance of parents and hybrids

Per se performance of parents and hybrids for all the fifteen traits has been given in Table 4.2. The range of mean values of parents and hybrids, average of mean values over parents and hybrids and grand mean over parents and hybrids over two years and pooled has been presented in Table 4.3. These results are described under the following heads:

4.2.1 Days to 50 % flowering

In Y_1, days to 50 % flowering ranged from 26.79 to 30.45 days for parents and 24.45 to 32.16 days for hybrids. Parent Pusa Ruby (26.79 days) showed earliest days to 50 % flowering among the parents which was followed by NDT-4 (27.77 days), NDT-5 (27.79 days), NDT-2 (27.97 days) and Azad T-6 (27.99 days). The best F_1 hybrid regarding days to 50 % flowering was NDT-4 × Arka Meghali (24.45 days) followed by Azad T-6 × Arka Vikas (26.99 days), NDT-1 × Arka Meghali (27.06 days), NDT-6 × Punjab Chhuhara (27.53 days) and NDT-5 × Pb. Chhuhara (27.91 days). Average over the parental mean (28.91 days) and average over the F_1 hybrid mean (29.82 days) were more or less of the same order.

In Y_2, days to 50 % flowering ranged from 30.00 to 34.32 days for parents and 28.33 to 35.37 days for hybrids. Parent Pusa Ruby (30.00 days) showed earliest days to 50 % flowering among the parents which was followed by NDT-4 (30.32 days), NDT-5 (31.00 days), NDT-2 (31.18 days) and Azad T-6 (31.20 days). The best F_1 hybrid regarding days to 50 % flowering was NDT-4 × Arka Meghali (28.33 days) followed by NDT-1 × Arka Meghali (30.27 days), NDT-6 × Punjab Chhuhara (30.40 days), NDT-7 × Arka Vikas (30.69 days) and NDT-5 × Pb. Chhuhara (31.12 days). Average over the parental mean (32.21 days) and average over the F_1 hybrid mean (33.03 days) were more or less of the same order.

In pooled, days to 50 % flowering ranged from 28.40 to 32.39 days for parents and 26.39 to 33.77 days for hybrids. Parent Pusa Ruby (28.40 days) showed earliest days to 50 % flowering among the parents which was followed by NDT-4 (29.05 days), NDT-5 (29.40 days), NDT-2 (29.58 days) and Azad T-6 (29.59 days). The best F_1 hybrid regarding days to 50 % flowering was NDT-4 × Arka Meghali (26.39 days) followed by NDT-1 × Arka Meghali (28.67 days), NDT-6 × Punjab Chhuhara (28.97 days),

Table- 4.1.1 Analysis of variance (Mean sum of squire) for 15 characters of line × tester set of crosses and their parents in tomato (Y_1=2016-17 and Y_2=2017-18)

Sources of variation	Years	*df*	Days to 50 % flowering	Days to first fruit set	Days to first fruit harvest	Plant height (cm)	Number of primary branches per plant	Number of fruits per cluster	Number of fruits per plant
Replications	Y_1	2	1.97	5.85	1.93	7.44	0.79*	0.11	0.19
	Y_2	2	0.27	5.85	1.93	17.78	0.72	0.10	0.19
Treatments	Y_1	53	7.55**	6.93**	6.74**	1997.65**	0.50**	0.81**	215.86**
	Y_2	53	7.26**	6.93**	6.74**	2002.92**	0.50**	0.80**	215.86**
Parents	Y_1	13	4.56	5.04	4.44	1162.58**	0.36	0.82**	390.43**
	Y_2	13	5.28*	5.04	4.44	1150.87**	0.36	0.82**	390.43**
Parents (Line)	Y_1	9	3.92	4.26	3.94	1497.28**	0.32	1.04**	510.02**
	Y_2	9	4.35	4.26	3.94	1480.81**	0.32	1.04**	510.02**
Parents (Testers)	Y_1	3	6.87	7.63	6.49	501.95**	0.10	0.29	72.78**
	Y_2	3	9.84*	7.63	6.49	491.49**	0.10	0.29	72.78**
Lines *vs* Testers	Y_1	1	3.31	4.21	2.84	132.17**	1.48*	0.45	267.00**
	Y_2	1	0.02	4.21	2.84	159.62**	1.48*	0.45	267.00**
Parents *vs* Crosses	Y_1	1	26.22**	34.60**	34.24**	2727.06**	0.96	1.72*	2687.98**
	Y_2	1	20.93**	34.60**	34.24**	3303.22**	0.96	1.49*	2687.98**
Crosses	Y_1	39	8.06**	6.86**	6.80**	2189.35**	0.53**	0.79**	94.28**
	Y_2	39	7.57**	6.86**	6.80**	2253.60**	0.53**	0.77**	94.28**
Error	Y_1	106	2.64	3.31	3.49	11.42	0.25	0.30	2..27
	Y_2	106	2.65	3.31	3.49	12.05	0.25	0.31	2..27

Contd….

Table-4.1.1 contd…

Sources of variation	Years	*Df*	Average fruit weight (g)	Fruit length (cm)	Fruit girth (cm)	Number of locules per fruit	Pericarp thickness (mm)	Total soluble solid (TSS)	Ascorbic acid (mg/100 g fresh fruit)	Total fruit yield per plant (kg)
Replications	Y_1	2	0.09	0.03	3.19	0.10	0.53	0.25	0.49	0.20
	Y_2	2	0.13	0.03	3.14	0.10	046	0.25	15.76	0.16
Treatments	Y_1	53	231.86**	0.98**	3.30**	1.06**	0.49**	0.84**	262.37**	0.46**
	Y_2	53	232.13**	0.98**	3.38**	1.06**	0.49**	0.84**	264.10**	0.43**
Parents	Y_1	13	386.23**	1.53**	5.17**	0.57	0.69**	0.84**	128.74**	0.44**
	Y_2	13	386.23**	1.53**	5.17**	0.57	0.69**	0.84**	117.56**	0.42**
Parents (Line)	Y_1	9	354.49**	1.53**	5.21**	0.46	0.86**	1.02**	178.11**	0.20*
	Y_2	9	354.49**	1.53**	5.21**	0.46	0.86**	1.02**	161.15**	0.16
Parents (Testers)	Y_1	3	495.69**	1.73**	2.66	0.49	0.40	0.54	22.52*	1.28**
	Y_2	3	495.69**	1.73**	2.66	0.49	0.40	0.54	22.52*	1.28**
Lines *vs* Testers	Y_1	1	343.50**	0.95	12.38**	1.74*	0.04	0.07	3.08	0.12
	Y_2	1	343.50**	0.95	12.38**	1.74*	0.04	0.07	10.36	0.26
Parents *vs* Crosses	Y_1	1	328.71**	1.40*	3.42	0.00	2.20**	0.17	10.54	3.75**
	Y_2	1	332.09**	1.40*	3.78	0.00	2.20**	0.17	47.32**	3.00**
Crosses	Y_1	39	177.92**	0.79**	2.68**	1.26**	0.37*	0.86**	313.37**	0.38**
	Y_2	39	178.20**	0.79**	2.77**	1.26**	0.37*	0.86**	318.51**	0.37**
Error	Y_1	106	3.60	0.32	1.45	0.36	0.24	0.29	5.86	0.08
	Y_2	106	3.65	0.32	1.46	0.36	0.24	0.29	6.84	0.09

*,** Significant at 5% and 1% probability levels, respectively.

Table- 4.1.2 Pooled ANOVA for 15 characters of line × tester set of crosses and their parents in tomato

Sources of variation	*df*	Days to 50 % flowering	Days to first fruit set	Days to first fruit harvest	Plant height (cm)	Number of primary branches per plant	Number of fruits per cluster	Number of fruits per plant
Replicates	2	1.53	11.71*	3.86	6.02	1.51**	0.20	0.38
Environments	1	847.39**	126.56**	128.60**	262.21**	17.89**	20.06**	128.60**
Rep × Env.	2	0.71	0.00	0.00	19.21	0.00	0.00	0.00
Treatments	53	14.54**	13.86**	13.48**	3943.70**	0.99**	1.60**	431.71**
Parents	13	9.51**	10.07**	8.88**	2313.23**	0.71**	1.64**	780.85**
Parents (Line)	9	8.17**	8.52**	7.88*	2977.99**	0.64**	2.07**	1020.04**
Parents(Testers)	3	16.07**	15.27**	12.97*	992.97**	0.19	0.58	145.55**
Parents (L vs T)	1	1.93	8.42	5.68	291.14**	2.96**	0.91	533.99**
Parent vs Crosses	1	47.00**	69.19**	68.48**	6016.48**	1.92**	3.20**	5375.97**
Crosses	39	15.38**	13.71**	13.60**	4434.04**	1.06**	1.55**	188.56**
Error	212	2.65	3.30	3.49	11.73	0.25	0.30	2.27

Contd….

Sources of variation	*df*	Average fruit weight (g)	Fruit length (cm)	Fruit girth (cm)	Number of locules per fruit	Pericarp thickness (mm)	Total soluble solid (TSS)	Ascorbic acid (mg/100 g fresh fruit)	Total fruit yield per plant (kg)
Replicates	2	0.20	0.06	6.32*	0.21	0.98*	0.50	10.31	0.36*
Environments	1	126.09**	23.62**	116.18**	10.50**	13.62**	12.32**	343.61**	10.36**
Rep × Env.	2	0.01	0.00	0.01	0.00	0.00	0.00	5.95	0.00
Treatments	53	463.98**	1.96**	6.67**	2.12**	0.97**	1.69**	514.58**	0.89**
Parents	13	772.46**	3.06**	10.35**	1.13**	1.39**	1.67**	239.99**	0.85**
Parents (Line)	9	708.99**	3.06**	10.42**	0.93**	1.73**	2.04**	330.26**	0.34**
Parents(Testers)	3	991.38**	3.47**	5.31*	0.97*	0.80*	1.08*	45.04**	2.55**
Parents (L vs T)	1	687.00**	1.89*	24.77**	3.49**	0.08	0.15	12.37	0.36*
Parent vs Crosses	1	660.79**	2.79**	7.19*	0.00	4.41**	0.33	51.27*	6.73**
Crosses	39	356.11**	1.58**	5.44**	2.51**	0.74**	1.72**	617.99**	0.75**
Error	212	3.63	0.32	1.46	0.36	0.24	0.29	6.35	0.08

*,** Significant at 5% and 1% probability levels, respectively.

Table-4.2 Mean performance, general mean, range, coefficient of variation, critical difference and standard error for 15 characters of line × tester set of 40 F_1's and their 14 parents (Y_1=2016-17 and Y_2=2017-18) and pooled

Genotypes	Days to 50 % flowering			Days to first fruit set			Days to first fruit harvest			Plant height (cm)		
Crosses	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1 × Pusa Ruby	28.79	31.38	30.09	36.25	37.50	36.88	60.15	61.41	60.78	130.90	132.16	131.53
NDT-1 × Pb. Chhuhara	28.12	31.33	29.73	35.80	37.05	36.42	59.27	60.53	59.90	94.03	95.29	94.66
NDT-1 × Arka Vikas	30.97	33.85	32.41	38.20	39.45	38.83	61.55	62.81	62.18	101.35	102.61	101.98
NDT-1 × Arka Meghali	27.06	30.27	28.67	34.64	35.89	35.26	58.16	59.42	58.79	104.80	116.06	110.43
NDT-2 × Pusa Ruby	31.08	33.96	32.52	37.10	38.35	37.72	60.98	62.24	61.61	108.03	109.29	108.66
NDT-2 × Pb. Chhuhara	28.96	32.17	30.56	36.33	37.58	36.96	60.35	61.61	60.98	67.07	68.33	67.70
NDT-2 × Arka Vikas	31.12	34.33	32.72	38.56	39.81	39.19	62.22	63.48	62.85	76.37	77.63	77.00
NDT-2 × Arka Meghali	30.78	34.66	32.72	39.53	40.78	40.15	62.52	63.78	63.15	82.70	83.96	83.33
NDT-3 × Pusa Ruby	31.44	34.65	33.05	39.24	40.49	39.86	63.18	64.44	63.81	107.69	118.95	113.32
NDT-3 × Pb. Chhuhara	32.12	35.33	33.72	39.49	40.74	40.11	63.11	64.37	63.74	82.03	83.29	82.66
NDT-3 × Arka Vikas	31.89	35.10	33.49	37.91	39.16	38.53	63.11	64.37	63.74	84.53	85.79	85.16
NDT-3 × Arka Meghali	29.00	33.21	31.11	36.19	37.44	36.81	60.13	61.39	60.76	76.32	77.58	76.95
NDT-4 × Pusa Ruby	28.45	31.66	30.06	35.85	37.10	36.48	59.42	60.68	60.05	148.16	149.42	148.79
NDT-4 × Pb. Chhuhara	29.45	31.99	30.72	36.21	37.46	36.84	59.99	61.25	60.62	128.03	130.95	129.49
NDT-4 × Arka Vikas	31.01	34.22	32.61	38.09	39.34	38.72	62.02	63.28	62.65	125.91	127.17	126.54
NDT-4 × Arka Meghali	24.45	28.33	26.39	32.60	33.85	33.22	56.38	57.64	57.01	113.66	114.92	114.29
NDT-5 × Pusa Ruby	29.93	33.14	31.53	37.18	38.43	37.81	61.10	62.36	61.73	150.41	155.00	152.70
NDT-5 × Pb. Chhuhara	27.91	31.12	29.51	35.59	36.84	36.22	59.24	60.50	59.87	138.10	139.36	138.73
NDT-5 × Arka Vikas	30.98	34.19	32.58	38.60	39.85	39.23	62.13	63.39	62.76	134.10	135.36	134.73
NDT-5 × Arka Meghali	30.10	32.31	31.20	36.60	37.85	37.22	60.27	61.53	60.90	131.80	133.06	132.43
NDT-6 × Pusa Ruby	31.45	34.66	33.06	38.88	40.13	39.50	62.56	63.82	63.19	115.43	116.69	116.06
NDT-6 × Pb. Chhuhara	27.53	30.40	28.97	35.66	36.91	36.28	59.54	60.80	60.17	79.44	85.70	82.57
NDT-6 × Arka Vikas	29.79	33.30	31.54	36.93	38.18	37.55	61.15	62.41	61.78	78.37	79.63	79.00
NDT-6 × Arka Meghali	32.16	35.37	33.77	39.53	40.78	40.15	63.18	64.44	63.81	86.72	87.98	87.35
NDT-7 × Pusa Ruby	30.60	33.81	32.20	37.24	38.49	37.87	61.15	62.41	61.78	135.30	136.56	135.93
NDT-7 × Pb. Chhuhara	29.38	32.59	30.99	37.04	38.29	37.66	60.47	61.73	61.10	78.03	79.29	78.66
NDT-7 × Arka Vikas	28.14	30.69	29.41	35.31	36.56	35.94	59.19	60.45	59.82	84.97	84.23	84.60
NDT-7 × Arka Meghali	31.56	34.11	32.83	37.98	39.23	38.60	62.20	63.46	62.83	85.70	85.96	85.83
NDT-8 × Pusa Ruby	30.76	33.97	32.37	38.10	39.35	38.72	62.27	63.53	62.90	123.83	125.09	124.46

Contd....

Genotypes		Days to 50 % flowering			Days to first fruit set			Days to first fruit harvest			Plant height (cm)		
		Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-8 × Pb. Chhuhara		28.99	32.20	30.59	36.03	37.28	36.65	60.48	61.74	61.11	68.17	69.43	68.80
NDT-8 × Arka Vikas		29.79	33.10	31.44	37.28	38.53	37.90	61.36	62.62	61.99	69.83	71.09	70.46
NDT-8 × Arka Meghali		31.45	34.33	32.89	39.07	40.32	39.70	62.19	63.45	62.82	74.63	75.89	75.26
Azad T-6 × Pusa Ruby		30.19	33.40	31.80	38.05	39.30	38.67	61.92	63.18	62.55	157.76	160.02	158.89
Azad T-6 × Pb. Chhuhara		31.45	34.99	33.22	38.87	40.12	39.50	62.51	63.77	63.14	125.30	126.56	125.93
Azad T-6 × Arka Vikas		26.99	31.20	29.10	35.28	36.53	35.91	59.07	60.33	59.70	126.13	127.39	126.76
Azad T-6 × Arka Meghali		29.32	32.93	31.13	37.09	38.34	37.72	60.31	61.57	60.94	131.53	132.79	132.16
Arka Saurabh × Pusa Ruby		29.30	32.97	31.14	37.78	39.03	38.41	61.34	62.60	61.97	127.15	131.75	129.45
Arka Saurabh × Pb. Chhuhara		30.24	33.45	31.84	38.12	39.37	38.75	61.31	62.57	61.94	73.58	74.84	74.21
Arka Saurabh × Arka Vikas		29.45	32.66	31.06	36.98	38.23	37.60	60.47	61.73	61.10	84.37	85.63	85.00
Arka Saurabh × Arka Meghali		30.79	34.00	32.40	38.24	39.49	38.86	62.12	63.38	62.75	70.70	71.96	71.33
Lines													
NDT-1		28.62	32.17	30.40	36.14	37.39	36.77	60.09	61.35	60.72	120.85	122.04	121.44
NDT-2		27.97	31.18	29.58	35.24	36.49	35.87	58.90	60.16	59.53	86.04	87.30	86.67
NDT-3		30.05	33.26	31.66	37.63	38.88	38.26	61.23	62.49	61.86	95.03	96.29	95.66
NDT-4		27.77	30.32	29.05	34.62	35.87	35.24	58.27	59.53	58.90	125.40	126.66	126.03
NDT-5		27.79	31.00	29.40	35.20	36.45	35.83	59.43	60.69	60.06	121.67	122.67	122.17
NDT-6		30.01	33.22	31.61	37.46	38.71	38.08	61.30	62.56	61.93	68.14	69.40	68.77
NDT-7		30.45	33.66	32.06	37.86	39.11	38.49	61.49	62.75	62.12	66.37	67.63	67.00
NDT-8		29.91	33.12	31.52	37.43	38.68	38.05	61.01	62.27	61.64	79.03	80.75	79.89
Azad T-6		27.99	31.20	29.59	35.49	36.74	36.12	59.08	60.34	59.71	110.16	110.82	110.49
Arka Saurabh		30.26	33.14	31.70	36.74	37.99	37.37	60.37	61.63	61.00	85.62	86.88	86.25
Testers													
Pusa Ruby		26.79	30.00	28.40	34.09	35.34	34.72	58.06	59.32	58.69	111.01	111.69	111.35
Punjab Chhuhara		28.12	32.69	30.41	35.68	36.93	36.31	59.31	60.57	59.94	87.20	87.30	87.25
Arka Vikas		28.49	31.70	30.09	35.09	36.34	35.71	59.22	60.48	59.85	82.37	83.63	83.00
Arka Meghali		30.45	34.32	32.39	37.86	39.11	38.49	61.57	62.83	62.20	87.03	88.29	87.66
Mean		**29.59**	**32.82**	**31.20**	**36.96**	**38.21**	**37.59**	**60.73**	**61.99**	**61.36**	**101.64**	**103.44**	**102.54**
C.V.		5.49	4.96	4.72	4.92	4.76	4.33	3.08	3.01	2.72	3.32	3.36	3.20
S.E. m ±		0.94	0.94	0.60	1.05	1.05	0.66	1.08	1.08	0.68	1.95	2.00	1.34
C.D. 5%		2.63	2.64	1.67	2.94	2.94	1.85	3.02	3.02	1.90	5.47	5.62	3.73
Range	**Lowest**	24.45	28.33	26.39	32.60	33.85	33.22	56.38	57.64	57.01	66.37	67.63	67.00
	Highest	32.16	35.37	33.77	39.53	40.78	40.15	63.18	64.44	63.81	157.76	160.02	158.89

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Genotypes	Number of primary branches per plant			Number of fruits per cluster			Number of fruits per plant			Average fruit weight (g)		
Crosses	**Y_1**	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**
NDT-1 × Pusa Ruby	3.65	4.12	3.89	5.23	5.74	5.49	41.48	42.74	42.11	30.06	31.32	30.69
NDT-1 × Pb. Chhuhara	3.99	4.46	4.23	6.16	6.67	6.42	43.55	44.81	44.18	37.10	38.36	37.73
NDT-1 × Arka Vikas	3.49	3.96	3.73	6.10	6.61	6.36	40.39	41.65	41.02	50.38	51.64	51.01
NDT-1 × Arka Meghali	3.02	3.49	3.26	5.33	5.84	5.59	43.89	45.15	44.52	56.08	57.34	56.71
NDT-2 × Pusa Ruby	3.75	4.22	3.99	6.16	6.67	6.42	41.86	43.12	42.49	43.78	45.04	44.41
NDT-2 × Pb. Chhuhara	3.35	3.82	3.59	5.60	6.11	5.86	37.23	38.49	37.86	45.75	47.01	46.38
NDT-2 × Arka Vikas	3.29	3.76	3.53	5.40	5.91	5.66	46.88	48.14	47.51	34.93	36.19	35.56
NDT-2 × Arka Meghali	3.29	3.76	3.53	5.56	6.07	5.82	41.87	43.13	42.50	27.42	28.68	28.05
NDT-3 × Pusa Ruby	3.52	3.99	3.76	5.63	6.14	5.89	45.82	47.08	46.45	30.21	31.47	30.84
NDT-3 × Pb. Chhuhara	3.32	3.79	3.56	4.60	5.11	4.86	44.88	46.14	45.51	34.99	36.25	35.62
NDT-3 × Arka Vikas	3.25	3.72	3.49	4.63	5.14	4.89	44.80	46.06	45.43	39.78	41.04	40.41
NDT-3 × Arka Meghali	2.92	3.39	3.16	4.70	5.21	4.96	44.23	45.49	44.86	27.00	28.26	27.63
NDT-4 × Pusa Ruby	2.95	3.42	3.19	5.40	5.91	5.66	38.56	39.82	39.19	26.32	27.58	26.95
NDT-4 × Pb. Chhuhara	2.95	3.42	3.19	5.40	5.91	5.66	37.58	38.84	38.21	28.68	29.94	29.31
NDT-4 × Arka Vikas	3.89	4.36	4.13	6.10	6.61	6.36	34.38	35.64	35.01	30.33	31.59	30.96
NDT-4 × Arka Meghali	3.09	3.56	3.33	5.60	6.11	5.86	36.53	37.79	37.16	31.20	32.46	31.83
NDT-5 × Pusa Ruby	3.25	3.72	3.49	5.33	5.84	5.59	39.31	40.57	39.94	27.33	28.59	27.96
NDT-5 × Pb. Chhuhara	3.89	4.36	4.13	5.66	6.17	5.92	37.61	38.87	38.24	27.92	29.18	28.55
NDT-5 × Arka Vikas	3.49	3.96	3.73	5.53	6.04	5.79	37.39	38.65	38.02	28.28	29.54	28.91
NDT-5 × Arka Meghali	3.19	3.66	3.43	4.66	5.17	4.92	38.56	39.82	39.19	28.37	29.63	29.00
NDT-6 × Pusa Ruby	3.49	3.96	3.73	5.66	6.17	5.92	31.49	32.75	32.12	31.30	32.56	31.93
NDT-6 × Pb. Chhuhara	3.29	3.76	3.53	4.56	5.07	4.82	36.89	38.15	37.52	30.23	31.49	30.86
NDT-6 × Arka Vikas	3.79	4.26	4.03	5.63	6.14	5.89	27.50	28.76	28.13	33.65	34.24	33.95
NDT-6 × Arka Meghali	3.99	4.46	4.22	4.80	5.31	5.06	29.95	31.21	30.58	34.22	35.48	34.85
NDT-7 × Pusa Ruby	3.19	3.66	3.43	4.66	5.17	4.92	36.85	38.11	37.48	33.89	35.15	34.52
NDT-7 × Pb. Chhuhara	3.69	4.16	3.93	5.23	5.74	5.49	35.10	36.36	35.73	36.31	37.57	36.94
NDT-7 × Arka Vikas	3.49	3.96	3.73	6.03	6.54	6.29	28.72	29.98	29.35	40.75	42.01	41.38
NDT-7 × Arka Meghali	3.89	4.36	4.13	5.10	5.28	5.19	40.86	42.12	41.49	45.37	46.63	46.00
NDT-8 × Pusa Ruby	3.62	4.09	3.86	6.16	6.67	6.42	33.56	34.82	34.19	34.07	35.33	34.70

Contd....

Genotypes		Number of primary branches per plant			Number of fruits per cluster			Number of fruits per plant			Average fruit weight (g)		
		Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-8 × Pb. Chhuhara		3.75	4.22	3.99	5.94	6.45	6.19	34.55	35.81	35.18	36.32	37.58	36.95
NDT-8 × Arka Vikas		3.82	4.29	4.06	6.38	6.56	6.47	34.29	35.55	34.92	34.06	35.32	34.69
NDT-8 × Arka Meghali		3.19	3.66	3.42	5.60	6.11	5.86	28.59	29.85	29.22	42.63	43.89	43.26
Azad T-6 × Pusa Ruby		3.99	4.46	4.23	5.53	6.04	5.79	27.77	29.03	28.40	39.33	40.59	39.96
Azad T-6 × Pb. Chhuhara		3.79	4.26	4.03	4.56	5.07	4.82	29.58	30.84	30.21	37.83	39.09	38.46
Azad T-6 × Arka Vikas		4.02	4.49	4.26	5.05	5.56	5.31	27.73	28.99	28.36	39.55	40.81	40.18
Azad T-6 × Arka Meghali		4.49	4.96	4.73	5.83	6.34	6.09	32.23	33.49	32.86	48.03	49.29	48.66
Arka Saurabh × Pusa Ruby		2.69	3.16	2.93	5.93	6.44	6.19	36.13	37.39	36.76	56.68	57.94	57.31
Arka Saurabh × Pb. Chhuhara		3.25	3.72	3.49	5.10	5.61	5.36	38.78	40.04	39.41	36.01	37.27	36.64
Arka Saurabh × Arka Vikas		2.49	2.96	2.73	5.66	6.17	5.92	40.89	42.15	41.52	33.47	34.73	34.10
Arka Saurabh × Arka Meghali		2.89	3.36	3.13	5.60	6.11	5.86	45.41	46.67	46.04	33.00	34.26	33.63
Lines													
NDT-1		3.69	4.16	3.93	6.10	6.61	6.36	33.36	34.62	33.99	50.68	51.94	51.31
NDT-2		4.15	4.62	4.39	5.36	5.87	5.62	37.37	38.63	38.00	59.32	60.58	59.95
NDT-3		3.52	3.99	3.76	4.43	4.94	4.69	35.24	36.50	35.87	36.37	37.63	37.00
NDT-4		3.95	4.42	4.19	4.20	4.71	4.46	45.26	46.52	45.89	30.03	31.29	30.66
NDT-5		4.19	4.66	4.43	5.70	6.21	5.96	45.23	46.49	45.86	31.08	32.34	31.71
NDT-6		3.45	3.92	3.69	5.40	5.91	5.66	73.56	74.82	74.19	25.35	26.61	25.98
NDT-7		3.42	3.89	3.66	5.63	6.14	5.89	66.61	67.87	67.24	25.07	26.33	25.70
NDT-8		3.39	3.86	3.63	5.70	6.21	5.96	51.23	52.49	51.86	37.23	38.49	37.86
Azad T-6		3.62	4.09	3.86	5.13	5.64	5.39	44.58	45.84	45.21	39.26	40.52	39.89
Arka Saurabh		4.15	4.62	4.39	5.10	5.61	5.36	49.88	51.14	50.51	40.69	41.95	41.32
Testers													
Pusa Ruby		3.49	3.96	3.73	4.83	5.34	5.09	37.96	39.22	38.59	36.33	37.59	36.96
Punjab Chhuhara		3.15	3.62	3.39	4.73	5.24	4.99	40.88	42.14	41.51	29.67	30.93	30.30
Arka Vikas		3.49	3.96	3.73	5.26	5.77	5.52	42.23	43.49	42.86	56.01	57.27	56.64
Arka Meghali		3.22	3.69	3.46	5.36	5.87	5.62	49.54	50.80	50.17	53.35	54.61	53.98
Mean		**3.51**	**3.98**	**3.74**	**5.39**	**5.88**	**5.64**	**39.75**	**41.01**	**40.38**	**36.91**	**38.16**	**37.53**
C.V.		14.23	12.58	11.95	10.18	9.45	8.78	3.79	3.67	3.34	5.14	5.01	4.54
S.E. m ±		0.29	0.29	0.18	0.32	0.32	0.20	0.87	0.87	0.55	1.10	1.10	0.70
C.D. 5%		0.81	0.81	0.51	0.89	0.90	0.56	2.44	2.44	1.53	3.07	3.09	1.94
Range	**Lowest**	2.49	2.96	2.73	4.20	4.71	4.46	27.50	28.76	25.07	25.07	26.33	25.70
	Highest	4.49	4.96	4.73	6.38	6.67	6.47	73.56	74.82	59.32	59.32	60.58	59.95

Table 4.2 Contd…

Genotypes / Crosses	Fruit length (cm)			Fruit girth (cm)			Number of locules per fruit			Pericarp thickness (mm)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1 × Pusa Ruby	6.16	6.70	6.43	11.72	12.93	12.33	4.30	4.66	4.48	3.90	4.31	4.11
NDT-1 × Pb. Chhuhara	7.22	7.76	7.49	13.20	14.41	13.81	4.47	4.83	4.65	4.25	4.66	4.46
NDT-1 × Arka Vikas	7.12	7.66	7.39	12.93	14.14	13.54	4.50	4.86	4.68	4.04	4.45	4.25
NDT-1 × Arka Meghali	7.14	7.68	7.41	13.08	14.29	13.68	4.77	5.13	4.95	3.93	4.34	4.14
NDT-2 × Pusa Ruby	6.84	7.38	7.11	11.64	12.85	12.25	4.63	4.99	4.81	4.58	4.99	4.79
NDT-2 × Pb. Chhuhara	6.84	7.38	7.11	13.08	14.29	13.69	4.10	4.46	4.28	4.79	5.20	5.00
NDT-2 × Arka Vikas	5.97	6.51	6.24	12.01	13.22	12.62	5.13	5.49	5.31	5.07	5.48	5.28
NDT-2 × Arka Meghali	6.81	7.35	7.08	12.24	13.45	12.85	4.37	4.73	4.55	4.61	5.02	4.82
NDT-3 × Pusa Ruby	6.25	6.79	6.52	11.96	13.17	12.57	1.90	2.26	2.08	4.58	4.99	4.79
NDT-3 × Pb. Chhuhara	7.12	7.66	7.39	12.01	13.22	12.62	3.60	3.96	3.78	4.35	4.76	4.56
NDT-3 × Arka Vikas	6.59	7.13	6.86	12.36	13.57	12.97	3.33	3.69	3.51	4.55	4.96	4.76
NDT-3 × Arka Meghali	6.17	6.71	6.44	12.70	13.91	13.31	4.47	4.83	4.65	4.09	4.50	4.30
NDT-4 × Pusa Ruby	7.60	8.14	7.87	14.21	15.42	14.82	4.83	5.19	5.01	3.98	4.39	4.19
NDT-4 × Pb. Chhuhara	7.03	7.57	7.30	14.14	15.35	14.75	4.97	5.33	5.15	3.98	4.39	4.19
NDT-4 × Arka Vikas	7.06	7.60	7.33	12.57	13.78	13.18	4.07	4.43	4.25	4.91	5.32	5.12
NDT-4 × Arka Meghali	6.14	6.68	6.41	11.92	13.13	12.53	4.13	4.49	4.31	4.35	4.76	4.56
NDT-5 × Pusa Ruby	5.48	6.02	5.75	10.56	11.77	11.17	3.80	4.16	3.98	4.47	4.88	4.68
NDT-5 × Pb. Chhuhara	5.91	6.45	6.18	11.54	12.75	12.15	3.97	4.33	4.15	4.53	4.94	4.74
NDT-5 × Arka Vikas	6.29	6.83	6.56	13.27	14.48	13.88	3.60	3.96	3.78	4.69	5.10	4.90
NDT-5 × Arka Meghali	7.00	7.54	7.27	14.41	15.62	15.02	4.23	4.59	4.41	4.69	5.10	4.90
NDT-6 × Pusa Ruby	6.03	6.57	6.30	11.96	13.17	12.57	5.70	6.06	5.88	4.22	4.63	4.43
NDT-6 × Pb. Chhuhara	6.44	6.98	6.71	12.14	13.02	12.58	5.17	5.53	5.35	4.73	5.14	4.93
NDT-6 × Arka Vikas	7.54	8.08	7.81	12.24	13.45	12.85	3.90	4.26	4.08	4.42	4.83	4.63
NDT-6 × Arka Meghali	6.47	7.01	6.74	11.87	12.75	12.31	3.93	4.29	4.11	5.12	5.53	5.33
NDT-7 × Pusa Ruby	6.42	6.96	6.69	13.54	14.75	14.15	4.00	4.36	4.18	4.29	4.70	4.49
NDT-7 × Pb. Chhuhara	7.76	8.30	8.03	13.13	14.34	13.74	4.33	4.69	4.51	4.42	4.83	4.63
NDT-7 × Arka Vikas	6.72	7.26	6.99	12.86	14.07	13.47	3.83	4.19	4.01	4.85	5.26	5.06
NDT-7 × Arka Meghali	6.56	7.10	6.83	13.28	14.49	13.89	4.87	5.23	5.05	4.33	4.74	4.54
NDT-8 × Pusa Ruby	7.19	7.73	7.46	12.96	14.17	13.57	3.97	4.33	4.15	4.15	4.56	4.36

Contd....

Genotypes		Fruit length (cm)			Fruit girth (cm)			Number of locules per fruit			Pericarp thickness (mm)		
		Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-8 × Pb. Chhuhara		6.19	6.73	6.46	13.06	14.27	13.67	3.83	4.19	4.01	5.34	5.75	5.55
NDT-8 × Arka Vikas		6.66	7.20	6.93	13.01	14.22	13.62	3.90	4.26	4.08	5.00	5.41	5.21
NDT-8 × Arka Meghali		6.64	7.18	6.91	13.20	14.41	13.81	5.13	5.49	5.31	4.90	5.31	5.11
Azad T-6 × Pusa Ruby		6.82	7.36	7.09	12.80	14.01	13.41	5.00	5.36	5.18	4.69	5.10	4.90
Azad T-6 × Pb. Chhuhara		6.71	7.25	6.98	11.84	13.05	12.45	4.37	4.73	4.55	4.34	4.75	4.55
Azad T-6 × Arka Vikas		6.89	7.43	7.16	12.09	13.30	12.70	4.87	5.23	5.05	4.59	5.00	4.80
Azad T-6 × Arka Meghali		6.89	7.43	7.16	13.07	14.28	13.68	4.57	4.93	4.75	4.52	4.93	4.72
Arka Saurabh × Pusa Ruby		7.18	7.72	7.45	13.01	14.22	13.62	4.30	4.66	4.48	4.29	4.70	4.50
Arka Saurabh × Pb. Chhuhara		6.48	7.02	6.75	14.80	16.01	15.41	4.87	5.23	5.05	4.65	5.06	4.86
Arka Saurabh × Arka Vikas		7.66	8.20	7.93	15.28	16.49	15.89	4.77	5.13	4.95	3.95	4.36	4.16
Arka Saurabh × Arka Meghali		6.56	7.10	6.83	12.20	13.41	12.81	4.13	4.49	4.31	4.29	4.70	4.50
Lines													
NDT-1		7.09	7.63	7.36	13.56	14.77	14.17	4.77	5.13	4.95	5.52	5.93	5.73
NDT-2		7.70	8.24	7.97	13.36	14.57	13.97	5.17	5.53	5.35	4.92	5.33	5.13
NDT-3		6.53	7.07	6.80	14.50	15.71	15.11	4.67	5.03	4.85	4.89	5.30	5.10
NDT-4		7.93	8.47	8.20	15.47	16.68	16.08	4.50	4.86	4.68	4.22	4.63	4.43
NDT-5		6.53	7.07	6.80	12.49	13.70	13.09	4.37	4.73	4.55	4.45	4.86	4.66
NDT-6		6.29	6.83	6.56	12.46	13.67	13.07	4.23	4.59	4.41	4.29	4.70	4.50
NDT-7		6.41	6.95	6.68	11.50	12.71	12.11	4.40	4.76	4.58	4.29	4.70	4.50
NDT-8		6.50	7.04	6.77	12.16	13.37	12.77	3.77	4.13	3.95	4.49	4.90	4.70
Azad T-6		6.93	7.47	7.20	13.53	14.74	14.14	4.60	4.96	4.78	5.79	6.20	6.00
Arka Saurabh		8.30	8.84	8.57	15.20	16.41	15.81	4.03	4.39	4.21	4.85	5.26	5.06
Testers													
Pusa Ruby		6.40	6.94	6.67	12.30	13.51	12.91	3.90	4.26	4.08	4.39	4.80	4.60
Punjab Chhuhara		5.90	6.44	6.17	11.06	12.27	11.67	3.53	3.89	3.71	4.85	5.26	5.06
Arka Vikas		7.70	8.24	7.97	13.36	14.57	13.97	4.07	4.43	4.25	5.15	5.56	5.36
Arka Meghali		6.76	7.30	7.03	12.16	13.37	12.77	4.50	4.86	4.68	4.42	4.83	4.63
Mean		**6.77**	**7.31**	**7.04**	**12.84**	**14.03**	**13.44**	**4.32**	**4.68**	**4.50**	**4.56**	**4.97**	**4.76**
C.V.		8.36	7.74	7.19	9.37	8.62	8.03	13.93	12.85	11.96	10.67	9.81	9.15
S.E. m ±		0.33	0.33	0.21	0.69	0.70	0.44	0.35	0.35	0.22	0.28	0.28	0.18
C.D. 5%		0.92	0.92	0.58	1.95	1.96	1.23	0.97	0.97	0.61	0.79	0.79	0.50
Range	**Lowest**	5.48	6.02	5.75	10.56	11.77	11.17	1.90	2.26	2.08	3.90	4.31	4.11
	Highest	8.30	8.84	8.57	15.47	16.68	16.08	5.70	6.06	5.88	5.79	6.20	6.00

Taable 4.2 Contd…

Genotypes / Crosses	Total soluble solid (TSS)			Ascorbic acid (mg/100 g fresh fruit)			Total fruit yield per plant (kg)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1 × Pusa Ruby	5.08	5.47	5.28	33.33	34.22	33.77	2.66	3.03	2.85
NDT-1 × Pb. Chhuhara	5.00	5.39	5.20	25.53	32.35	28.94	2.78	2.99	2.88
NDT-1 × Arka Vikas	5.84	6.23	6.04	26.53	26.75	26.64	2.67	3.04	2.86
NDT-1 × Arka Meghali	4.98	5.37	5.18	36.09	48.64	42.37	2.64	3.01	2.83
NDT-2 × Pusa Ruby	5.97	6.36	6.17	43.22	44.11	43.66	2.88	3.25	3.07
NDT-2 × Pb. Chhuhara	5.40	5.79	5.60	34.93	36.82	35.87	2.60	2.97	2.79
NDT-2 × Arka Vikas	6.18	6.57	6.38	31.55	33.43	32.49	2.99	3.36	3.17
NDT-2 × Arka Meghali	6.12	6.51	6.32	32.77	33.99	33.38	3.04	3.41	3.22
NDT-3 × Pusa Ruby	5.92	6.31	6.12	32.09	33.31	32.70	2.67	3.04	2.86
NDT-3 × Pb. Chhuhara	5.34	5.73	5.54	35.09	36.31	35.70	2.85	3.22	3.04
NDT-3 × Arka Vikas	5.76	6.15	5.96	39.08	40.20	39.64	3.17	3.54	3.36
NDT-3 × Arka Meghali	5.96	6.35	6.16	37.27	39.20	38.24	2.60	2.97	2.79
NDT-4 × Pusa Ruby	5.22	5.61	5.42	40.49	41.53	41.01	2.44	2.81	2.63
NDT-4 × Pb. Chhuhara	5.22	5.61	5.42	42.00	43.20	42.60	2.44	2.81	2.63
NDT-4 × Arka Vikas	5.52	5.91	5.72	44.07	45.29	44.68	2.94	3.31	3.13
NDT-4 × Arka Meghali	5.12	5.51	5.32	43.03	44.25	43.64	2.32	2.69	2.51
NDT-5 × Pusa Ruby	4.50	4.89	4.70	46.87	55.75	51.31	1.74	2.11	1.92
NDT-5 × Pb. Chhuhara	6.00	6.39	6.20	61.09	61.31	61.20	2.35	2.72	2.54
NDT-5 × Arka Vikas	4.96	5.35	5.16	58.70	58.92	58.81	1.74	2.11	1.92
NDT-5 × Arka Meghali	5.72	6.11	5.92	60.31	61.53	60.92	2.30	2.67	2.49
NDT-6 × Pusa Ruby	4.99	5.38	5.19	32.86	34.08	33.47	2.66	3.03	2.85
NDT-6 × Pb. Chhuhara	5.74	6.13	5.94	32.53	33.75	33.14	1.57	1.94	1.75
NDT-6 × Arka Vikas	5.84	6.23	6.03	30.87	32.09	31.48	2.40	2.77	2.59
NDT-6 × Arka Meghali	4.68	5.07	4.88	32.53	33.75	33.14	2.30	2.67	2.49
NDT-7 × Pusa Ruby	5.04	5.43	5.24	28.75	34.64	31.70	1.94	2.31	2.13
NDT-7 × Pb. Chhuhara	6.40	6.79	6.60	27.20	28.42	27.81	1.84	2.21	2.03
NDT-7 × Arka Vikas	5.01	5.40	5.21	28.75	29.97	29.36	2.35	2.72	2.54
NDT-7 × Arka Meghali	4.85	5.24	5.05	28.42	29.64	29.03	2.44	2.70	2.57
NDT-8 × Pusa Ruby	5.62	6.01	5.82	29.09	30.31	29.70	2.60	2.97	2.79

Contd....

Genotypes		Total soluble solid (TSS)			Ascorbic acid (mg/100 g fresh fruit)			Total fruit yield per plant (kg)		
		Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-8 × Pb. Chhuhara		4.43	4.82	4.63	38.61	35.49	37.05	2.62	2.93	2.78
NDT-8 × Arka Vikas		5.69	6.08	5.88	42.28	45.16	43.72	2.61	2.98	2.80
NDT-8 × Arka Meghali		5.06	5.45	5.26	48.72	50.94	49.83	2.29	2.85	2.57
Azad T-6 × Pusa Ruby		5.26	5.65	5.46	49.39	51.61	50.50	2.60	2.94	2.77
Azad T-6 × Pb. Chhuhara		5.72	6.11	5.92	54.12	57.67	55.89	2.36	2.68	2.52
Azad T-6 × Arka Vikas		5.49	5.88	5.69	55.45	58.00	56.72	2.59	2.96	2.78
Azad T-6 × Arka Meghali		5.90	6.29	6.10	57.57	58.79	58.18	2.31	2.68	2.49
Arka Saurabh × Pusa Ruby		5.92	6.31	6.12	28.47	40.69	34.58	2.85	3.22	3.04
Arka Saurabh × Pb. Chhuhara		5.34	5.73	5.54	31.42	32.64	32.03	2.63	3.00	2.82
Arka Saurabh × Arka Vikas		4.92	5.31	5.12	33.31	32.53	32.92	2.51	2.88	2.69
Arka Saurabh × Arka Meghali		6.92	7.31	7.12	31.48	33.70	32.59	2.44	2.91	2.68
Lines										
NDT-1		5.92	6.31	6.12	40.78	42.00	41.39	2.76	3.13	2.94
NDT-2		5.42	5.81	5.62	31.87	40.09	35.98	3.28	3.65	3.46
NDT-3		4.92	5.31	5.12	27.24	28.46	27.85	2.63	3.00	2.82
NDT-4		4.45	4.84	4.65	28.78	30.00	29.39	2.46	2.83	2.64
NDT-5		6.42	6.81	6.62	32.76	33.98	33.37	2.51	2.88	2.69
NDT-6		5.72	6.11	5.92	39.31	41.20	40.26	2.76	3.13	2.94
NDT-7		5.38	5.77	5.58	43.40	44.62	44.01	2.76	3.03	2.89
NDT-8		6.12	6.51	6.32	47.13	48.35	47.74	2.98	3.12	3.05
Azad T-6		5.92	6.31	6.12	49.62	50.84	50.23	2.82	3.19	3.01
Arka Saurabh		5.38	5.77	5.58	41.46	40.02	40.74	3.11	3.26	3.18
Testers										
Pusa Ruby		4.95	5.34	5.15	34.14	35.36	34.75	2.47	2.84	2.65
Punjab Chhuhara		5.55	5.94	5.75	37.55	38.77	38.16	2.26	2.63	2.44
Arka Vikas		5.98	6.37	6.18	38.03	39.25	38.64	3.44	3.81	3.63
Arka Meghali		5.41	5.80	5.61	40.82	42.04	41.43	3.53	3.90	3.71
Mean		**5.49**	**5.88**	**5.68**	**38.50**	**40.55**	**39.53**	**2.58**	**2.94**	**2.76**
C.V.		9.73	9.09	8.41	6.29	6.45	6.91	10.85	10.05	9.41
S.E. m ±		0.31	0.31	0.19	1.40	1.51	1.11	0.16	0.17	0.11
C.D. 5%		0.86	0.86	0.54	3.92	4.23	3.10	0.45	0.48	0.30
Range	**Lowest**	4.43	4.82	4.63	25.53	26.75	26.64	1.57	1.94	1.75
	highest	6.92	7.31	7.12	61.09	61.53	61.20	3.53	3.90	3.71

Table 4.3 Range of variation in mean values and grand means of various traits Y_1=2016-17 and Y_2=2017-18 and pooled

Characters	Range of mean values						Mean over						Grand mean		
	Parents			Crosses			Parents			Crosses					
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
Days to 50 % flowering	26.79-30.45	30.00-34.32	28.40-32.39	24.45-32.16	28.33-35.37	26.39-33.77	28.91	32.21	30.56	29.82	33.03	31.43	29.59	32.82	31.20
Days to first fruit set	34.09-37.86	35.34-39.11	34.72-38.49	32.60-39.53	33.85-40.78	33.22-40.15	36.18	37.43	36.81	37.24	38.49	37.86	36.96	38.21	37.59
Days to first fruit harvest	58.06-61.57	59.32-62.83	58.69-62.20	56.38-63.18	57.64-64.44	57.01-63.81	59.95	61.21	60.58	61.00	62.26	61.63	60.73	61.99	61.36
Plant height (cm)	66.37-125.40	67.63-126.66	67.00-126.03	67.07-157.76	68.33-160.02	67.70-158.89	94.71	95.81	95.26	104.07	106.11	105.09	101.64	103.44	102.54
Number of primary branches per plant	3.15-4.19	3.62-4.66	3.39-4.43	2.49-4.49	2.96-4.96	2.73-4.73	3.64	4.11	3.87	3.46	3.93	3.70	3.51	3.98	3.74
Number of fruits per cluster	4.20-6.10	4.71-6.61	4.46-6.36	4.56-6.38	5.07-6.67	4.82-6.47	5.21	5.72	5.47	5.45	5.94	5.69	5.39	5.88	5.64
Number of fruits per plant	33.36-73.56	34.62-74.82	33.99-74.19	27.50-46.88	28.76-48.14	28.13-47.51	46.64	47.90	47.27	37.34	38.60	37.97	39.75	41.01	40.38
Average fruit weight (g)	25.07-59.32	26.33-60.58	25.70-59.95	26.32-56.68	27.58-57.94	26.95-57.31	39.32	40.58	39.95	36.07	37.31	36.69	36.91	38.16	37.53
Fruit length (cm)	5.90-8.30	6.44-8.84	6.17-8.57	5.48-7.76	6.02-8.30	5.75-8.03	6.92	7.46	7.19	6.71	7.25	6.98	6.77	7.31	7.04
Fruit girth (cm)	11.06-15.47	12.27-16.68	11.67-16.08	10.56-15.28	11.77-16.49	11.17-15.89	13.08	14.29	13.69	12.75	13.94	13.35	12.84	14.03	13.44
Number of locules per fruit	3.53-5.17	3.89-5.53	3.71-5.35	1.90-5.70	2.26-6.06	2.08-5.88	4.32	4.68	4.50	4.32	4.68	4.50	4.32	4.68	4.50
Pericarp thickness (mm)	4.22-5.79	4.63-6.20	4.43-6.00	3.90-5.34	4.31-5.75	4.11-5.55	4.75	5.16	4.96	4.49	4.90	4.69	4.56	4.97	4.76
Total soluble solid (TSS)	4.45-6.42	4.84-6.81	4.65-6.62	4.43-6.92	4.82-7.31	4.63-7.12	5.54	5.93	5.74	5.47	5.86	5.66	5.49	5.88	5.68
Ascorbic acid (mg/100 g fresh fruit)	27.24-49.62	28.46-50.84	27.85-50.23	25.53-61.09	26.75-61.53	26.64-61.20	38.06	39.64	38.85	38.65	40.87	39.76	38.50	40.55	39.53
Total fruit yield per plant (kg)	2.26-3.53	2.63-3.90	2.44-3.71	1.57-3.17	1.94-3.54	1.75-3.36	2.84	3.17	3.01	2.49	2.86	2.68	2.58	2.94	2.76

Azad T-6 × Arka Vikas (29.10 days) and NDT-7 × Arka Vikas (29.41 days). Average over the parental mean (30.56 days) and average over the F_1 hybrid mean (31.43 days) were more or less of the same order.

4.2.2 Days to first fruit set

In Y_1, days to first fruit set ranged from 34.09 to 37.86 days for parents and 32.60 to 39.53 days for hybrids. Parent Pusa Ruby (34.09 days) showed earliest days to first fruit set among the parents which was followed by NDT-4 (34.62 days), Arka Vikas (35.09 days), NDT-5 (35.20 days) and NDT-2 (35.34 days). The best F_1 hybrid regarding days to first fruit set was NDT-4 × Arka Meghali (32.60 days) followed by NDT-1 × Arka Meghali (34.64 days), Azad T-6 × Arka Vikas (35.28 days), NDT-7 × Arka Vikas (35.31 days) and NDT-5 × Pb. Chhuhara (35.59 days). Average over the parental mean (36.18 days) and average over the F_1 hybrid mean (37.24 days) were more or less of the same order.

In Y_2, days to first fruit set ranged from 35.34 to 39.11 days for parents and 33.85 to 40.78 days for hybrids. Parent Pusa Ruby (35.34 days) showed earliest days to first fruit set among the parents which was followed by NDT-4 (35.87 days), Arka Vikas (36.34 days), NDT-5 (36.45 days) and NDT-2 (36.49 days). The best F_1 hybrid regarding days to first fruit set was NDT-4 × Arka Meghali (33.85 days) followed by NDT-1 × Arka Meghali (35.89 days), Azad T-6 × Arka Vikas (36.53 days), NDT-7 × Arka Vikas (36.56 days) and NDT-5 × Pb. Chhuhara (36.84 days). Average over the parental mean (37.43 days) and average over the F_1 hybrid mean (38.49 days) were more or less of the same order.

In pooled, days to first fruit set ranged from 34.72 to 38.49 days for parents and 33.22 to 40.15 days for hybrids. Parent Pusa Ruby (34.72 days) showed earliest days to first fruit set among the parents which was followed by NDT-4 (35.24 days), Arka Vikas (35.71 days), NDT-5 (35.83 days) and

NDT-2 (35.87 days). The best F_1 hybrid regarding days to first fruit set was NDT-4 × Arka Meghali (33.22 days) followed by NDT-1 × Arka Meghali (35.26 days), Azad T-6 × Arka Vikas (35.91 days), NDT-7 × Arka Vikas (35.94 days) and NDT-5 × Pb. Chhuhara (36.22 days). Average over the parental mean (36.81 days) and average over the F_1 hybrid mean (37.86 days) were more or less of the same order.

4.2.3 Days to first fruit harvest

In Y_1, days to first fruit harvest ranged from 58.06 to 61.57 days for parents and 56.38 to 63.18 days for hybrids. Parent Pusa Ruby (58.06 days) showed earliest days to first fruit harvest among the parents which was followed by NDT-4 (58.27 days), NDT-2 (58.90 days), Azad T-6 (59.08 days) and Arka Vikas (59.22 days). The best F_1 hybrid regarding days to first fruit harvest was NDT-4 × Arka Meghali (56.38 days) followed by NDT-1 × Arka Meghali (58.16 days), Azad T-6 × Arka Vikas (59.07 days), NDT-7 × Arka Vikas (59.19 days) and NDT-5 × Pb. Chhuhara (59.24 days). Average over the parental mean (59.95 days) and average over the F_1 hybrid mean (61.00 days) were more or less of the same order.

In Y_2, days to first fruit harvest ranged from 59.32.34 to 62.83 days for parents and 57.64 to 64.44 days for hybrids. Parent Pusa Ruby (59.32 days) showed earliest days to first fruit harvest among the parents which was followed by NDT-4 (59.53 days), NDT-2 (60.16 days), Azad T-6 (60.34 days) and Arka Vikas (60.48 days). The best F_1 hybrid regarding days to first fruit harvest was NDT-4 × Arka Meghali (57.64 days) followed by NDT-1 × Arka Meghali (59.42 days), Azad T-6 × Arka Vikas (60.33 days), NDT-7 × Arka Vikas (60.45 days) and NDT-5 × Pb. Chhuhara (60.50 days). Average over the parental mean (61.21 days) and average over the F_1 hybrid mean (62.26 days) were more or less of the same order.

In pooled, days to first fruit harvest ranged from 58.69 to 62.20 days

for parents and 57.01 to 63.81 days for hybrids. Parent Pusa Ruby (58.69 days) showed earliest days to first fruit harvest among the parents which was followed by NDT-4 (58.90 days), NDT-2 (59.53 days), Azad T-6 (59.71 days) and Arka Vikas (59.85 days). The best F_1 hybrid regarding days to first fruit harvest was NDT-4 × Arka Meghali (57.01 days) followed by NDT-1 × Arka Meghali (58.79 days), Azad T-6 × Arka Vikas (59.70 days), NDT-7 × Arka Vikas (59.82 days) and NDT-5 × Pb. Chhuhara (59.87 days). Average over the parental mean (60.58 days) and average over the F_1 hybrid mean (61.63 days) were more or less of the same order.

4.2.4 Plant height (cm)

The mean value in Y_1 over the parental lines regarding plant hieght was 94.71 cm with a range of 66.37 to 125.40 cm. Among the parents maximum plant hieght (cm) was recorded in NDT-4 (125.40 cm) followed by NDT-5 (121.67 cm), NDT-1 (120.85 cm), Pusa Ruby (111.01 cm) and Azad T-6 (110.16 cm). The mean value over the F_1 hybrids for plant hieght was 104.07 cm with a range of 67.07 to 157.76 cm. The F_1 hybrid Azad T-6 × Pusa Ruby (157.76 cm) was the tallest with respect to this trait followed by NDT-5 × Pusa Ruby (150.41 cm), NDT-4 × Pusa Ruby (148.16 cm), NDT-5 × Pb. Chhuhara (138.10 cm) and NDT-7 × Pusa Ruby (135.30 cm).

In Y_2, the mean value over the parental lines regarding plant hieght was 95.81 cm with a range of 67.63 to 126.66 cm. Among the parents Maximum hieght (cm) was recorded in NDT-4 (126.66 cm) followed by NDT-5 (122.67 cm), NDT-1 (122.04 cm), Pusa Ruby (111.69 cm) and Azad T-6 (110.82 cm). The mean value over the F_1 hybrids for plant hieght was 106.11 cm with a range of 68.33 to 160.02 cm. The F_1 hybrid Azad T-6 × Pusa Ruby (160.02 cm) was the tallest with respect to this trait followed by NDT-5 × Pusa Ruby (155.00 cm), NDT-4 × Pusa Ruby (149.42 cm), NDT-5 × Pb. Chhuhara (139.36 cm) and NDT-7 × Pusa Ruby (136.56 cm).

In pooled, the mean value over the parental lines regarding plant hieght was 95.26 cm with a range of 67.00 to 126.03 cm. Among the parents Maximum hieght (cm) was recorded in NDT-4 (126.03 cm) followed by NDT-5 (122.17 cm), NDT-1 (121.44 cm), Pusa Ruby (111.35 cm) and Azad T-6 (110.49 cm). The mean value over the F_1 hybrids for plant hieght was 105.09 cm with a range of 67.70 to 158.89 cm. The F_1 hybrid Azad T-6 × Pusa Ruby (158.89 cm) was the tallest with respect to this trait followed by NDT-5 × Pusa Ruby (152.70 cm), NDT-4 × Pusa Ruby (148.79 cm), NDT-5 × Pb. Chhuhara (138.73 cm) and NDT-7 × Pusa Ruby (135.93 cm).

4.2.5 Number of primary branches per plant

In Y_1, number of primary branches per plant ranged from 3.15 to 4.19 for parental lines and 2.49 to 4.49 for F_1 hybrids. The mean values over the parental lines and F_1 hybrids were 3.64 and 3.46, respectively. The parental line NDT-5 (4.19) had maximum number of primary branches per plant, which was followed by NDT-2 and Arka Saurabh (4.15), NDT-4 (3.95), NDT-1 (3.69) and Azad T-6 (3.62). Among the F_1 hybrids Azad T-6 × Arka Meghali (4.49) had maximum number of primary branches per plant followed by Azad T-6 × Arka Vikas (4.02), NDT-1 × Pb. Chhuhara, NDT-6 × Arka Meghali and Azad T-6 × Pusa Ruby (3.99), NDT-7 × Arka Meghali (3.89) and NDT-8 × Arka Vikas (3.82).

In Y_2, number of primary branches per plant ranged from 3.62 to 4.66 for parental lines and 2.96 to 4.96 for F_1 hybrids. The mean values over the parental lines and F_1 hybrids were 4.11 and 3.93, respectively. The parental line NDT-5 (4.66) had maximum number of primary branches per plant, which was followed by NDT-2 and Arka Saurabh (4.62), NDT-4 (4.42), NDT-1 (4.16) and Azad T-6 (4.09). Among the F_1 hybrids Azad T-6 × Arka Meghali (4.96) had maximum number of primary branches per plant followed by Azad T-6 × Arka Vikas (4.49), NDT-1 × Pb. Chhuhara, NDT-6 × Arka

Meghali and Azad T-6 × Pusa Ruby (4.46), NDT-4 × Arka Vikas, NDT-5 × Pb. Chhuhara and NDT-7 × Arka Meghali (4.36) and NDT-8 × Arka Vikas (4.29).

In pooled, number of primary branches per plant ranged from 3.39 to 4.43 for parental lines and 2.73 to 4.73 for F_1 hybrids. The mean values over the parental lines and F_1 hybrids were 3.87 and 3.70, respectively. The parental line NDT-5 (4.43) had maximum number of primary branches per plant, which was followed by NDT-2 and Arka Saurabh (4.39), NDT-4 (4.19), NDT-1 (3.93) and Azad T-6 (3.86). Among the F_1 hybrids Azad T-6 × Arka Meghali (4.73) had maximum number of primary branches per plant followed by Azad T-6 × Arka Vikas (4.26), NDT-1 × Pb. Chhuhara and Azad T-6 × Pusa Ruby (4.23), NDT-6 × Arka Meghali (4.22) and NDT-4 × Arka Vikas, NDT-5 × Pb. Chhuhara and NDT-7 × Arka Meghali (4.13).

4.2.6 Number of fruits per cluster

In Y_1, number of fruits per cluster varied from 4.20 to 6.10 in parental lines and 4.56 to 6.38 in F_1 hybrids with a mean value of 5.21 over the parents and 5.45 over the hybrids. Highest number of fruits per cluster was recorded in parent NDT-1 (6.10) followed by NDT-5 and NDT-8 (5.70), NDT-7 (5.63), NDT-6 (5.40) and NDT-2 and Arka Meghali (5.36). Among the hybrids, the highest number of fruits per cluster was observed in NDT-8 × Arka Vikas (6.38) which was followed by NDT-1 × Pb. Chhuhara, NDT-2 × Pusa Ruby and NDT-8 × Pusa Ruby (6.16), NDT-1 × Arka Vikas and NDT-4 × Arka Vikas (6.10), NDT-7 × Arka Vikas (6.03) and NDT-8 × Pb. Chhuhara (5.94).

In Y_2, number of fruits per cluster varied from 4.71 to 6.61 in parental lines and 5.07 to 6.67 in F_1 hybrids with a mean value of 5.72 over the parents and 5.94 over the hybrids. Highest number of fruits per cluster was recorded in parent NDT-1 (6.61) followed by NDT-5 and NDT-8 (6.21), NDT-7 (6.14), NDT-6 (5.91) and NDT-2 and Arka Meghali (5.87). Among the hybrids, the highest number of fruits per cluster was observed in NDT-1 × Pb. Chhuhara,

NDT-2 × Pusa Ruby and NDT-8 × Pusa Ruby (6.67) which was followed by NDT-1 × Arka Vikas and NDT-4 × Arka Vikas (6.61), NDT-8 × Arka Vikas (6.56), NDT-7 × Arka Vikas (6.54) and Arka Saurabh × Pusa Ruby (6.44).

In pooled, number of fruits per cluster varied from 4.46 to 6.36 in parental lines and 4.82 to 6.47 in F_1 hybrids with a mean value of 5.47 over the parents and 5.69 over the hybrids. Highest number of fruits per cluster was recorded in parent NDT-1 (6.36) followed by NDT-5 and NDT-8 (5.96), NDT-7 (5.89), NDT-6 (5.66) and NDT-2 and Arka Meghali (5.62). Among the hybrids, the highest number of fruits per cluster was observed in NDT-8 × Arka Vikas (6.47) which was followed by NDT-1 × Pb. Chhuhara, NDT-2 × Pusa Ruby and NDT-8 × Pusa Ruby (6.42), NDT-1 × Arka Vikas and NDT-4 × Arka Vikas (6.36), NDT-7 × Arka Vikas (6.29) and NDT-8 × Pb. Chhuhara (6.19).

4.2.7 Number of fruits per plant

In Y_1, number of fruits per plant varied from 33.36 to 73.56 in parental lines and 27.50 to 46.88 in F_1 hybrids with a mean value of 46.64 over the parents and 37.34 over the hybrids. Highest number of fruits per plant was recorded in parent NDT-6 (73.56) followed by NDT-7 (66.61), NDT-8 (51.23), Arka Saurabh (49.88) and Arka Meghali (49.54). Among the hybrids, the highest number of fruits per plant was observed in NDT-2 × Arka Vikas (46.88) which was followed by NDT-3 × Pusa Ruby (45.82), Arka Saurabh × Arka Meghali (45.41), NDT-3 × Pb. Chhuhara (44.88) and NDT-3 × Arka Vikas (44.80).

In Y_2, number of fruits per plant varied from 34.62 to 74.82 in parental lines and 28.76 to 48.14 in F_1 hybrids with a mean value of 47.90 over the parents and 38.60 over the hybrids. Highest number of fruits per plant was recorded in parent NDT-6 (74.82) followed by NDT-7 (67.87), NDT-8 (52.49), Arka Saurabh (51.14) and Arka Meghali (50.80). Among the hybrids, the

highest number of fruits per plant was observed in NDT-2 × Arka Vikas (48.14) which was followed by NDT-3 × Pusa Ruby (47.08), Arka Saurabh × Arka Meghali (46.67), NDT-3 × Pb. Chhuhara (46.14) and NDT-3 × Arka Vikas (46.06).

In pooled, number of fruits per plant varied from 33.99 to 74.19 in parental lines and 28.13 to 47.51 in F_1 hybrids with a mean value of 47.27 over the parents and 37.47 over the hybrids. Highest number of fruits per plant was recorded in parent NDT-6 (74.19) followed by NDT-7 (67.24), NDT-8 (51.86), Arka Saurabh (50.51) and Arka Meghali (50.17). Among the hybrids, the highest number of fruits per plant was observed in NDT-2 × Arka Vikas (47.51) which was followed by NDT-3 × Pusa Ruby (46.45), Arka Saurabh × Arka Meghali (46.04), NDT-3 × Pb. Chhuhara (45.51) and NDT-3 × Arka Vikas (45.43).

4.2.8 Average fruit weight (g)

In Y_1, the average fruit weight at picking stage varied from 25.07 to 59.32 g for parents and 26.32 to 56.68 g for F_1 hybrids. The mean values over the parental lines and F_1 hybrids were 39.32 and 36.07 g, respectively. The parent NDT-2 (59.32 g) produced heaviest fruit followed by Arka Vikas (56.01 g), Arka Meghali (53.35 g), NDT-1 (50.68 g) and Arka Saurabh (40.69 g). Among the hybrids, the highest fruit weight was exhibited by the Arka Saurabh × Pusa Ruby (56.68 g) followed by NDT-1 × Arka Meghali (56.08 g), NDT-1 × Arka Vikas (50.38 g), Azad T-6 × Arka Meghali (48.03 g) and NDT-2 × Pb. Chhuhara (45.75 g) in descending order.

In year Y_2, the average fruit weight at picking stage varied from 26.33 to 60.58 g for parents and 27.58 to 57.94 g for F_1 hybrids. The mean values over the parental lines and F_1 hybrids were 40.58 and 37.31 g, respectively. The parent NDT-2 (60.58 g) produced heaviest fruit followed by Arka Vikas (57.27 g), Arka Meghali (54.61 g), NDT-1 (51.94 g) and Arka Saurabh (41.95

g). Among the hybrids, the highest fruit weight was exhibited by the Arka Saurabh × Pusa Ruby (57.94 g) followed by NDT-1 × Arka Meghali (57.34 g), NDT-1 × Arka Vikas (51.64 g), Azad T-6 × Arka Meghali (49.29 g) and NDT-2 × Pb. Chhuhara (47.01 g) in descending order.

In pooled, the average fruit weight at picking stage varied from 25.70 to 59.95 g for parents and 26.95 to 57.31 g for F_1 hybrids. The mean values over the parental lines and F_1 hybrids were 39.95 and 36.69 g, respectively. The parent NDT-2 (59.95 g) produced heaviest fruit followed by Arka Vikas (56.64 g), Arka Meghali (53.98 g), NDT-1 (51.31 g) and Arka Saurabh (41.32 g). Among the hybrids, the highest fruit weight was exhibited by the Arka Saurabh × Pusa Ruby (57.31 g) followed by NDT-1 × Arka Meghali (56.71 g), NDT-1 × Arka Vikas (51.01 g), Azad T-6 × Arka Meghali (48.66 g) and NDT-2 × Pb. Chhuhara (46.38 g) in descending order.

4.2.9 Fruit length (cm)

In Y_1, fruit length of parental lines at edible stage ranged from 5.90 to 8.30 cm with a mean value of 6.92 cm over the parents. Largest fruits were recorded in parent Arka Saurabh (8.30 cm) followed by NDT-4 (7.93 cm), NDT-2 and Arka Vikas (7.70 cm), NDT-1 (7.09 cm) and Arka Meghali (6.76 cm). The length of fruits in F_1 hybrids ranged from 5.48 to 7.76 cm with a mean over crosses of 6.71 cm. Among the hybrids NDT-7 × Pb. Chhuhara (7.76 cm) displayed maximum fruit length followed by Arka Saurabh × Arka Vikas (7.66 cm), NDT-4 × Pusa Ruby (7.60 cm) and NDT-6 × Arka Vikas (7.54 cm) and NDT-1 × Pb. Chhuhara (7.22 cm).

In Y_2, fruit length of parental lines at edible stage ranged from 6.44 to 8.84 cm with a mean value of 7.46 cm over the parents. Largest fruits were recorded in parent Arka Saurabh (8.84 cm) followed by NDT-4 (8.47 cm), NDT-2 and Arka Vikas (8.24 cm), NDT-1 (7.63 cm) and Azad T-6 (7.47 cm). The length of fruits in F_1 hybrids ranged from 6.02 to 8.30 cm with a mean

over crosses of 7.25 cm. Among the hybrids NDT-7 × Pb. Chhuhara (8.30 cm) displayed maximum fruit length followed by Arka Saurabh × Arka Vikas (8.20 cm), NDT-4 × Pusa Ruby (8.14 cm) and NDT-6 × Arka Vikas (8.08 cm) and NDT-1 × Pb. Chhuhara (7.76 cm).

In pooled, fruit length of parental lines at edible stage ranged from 6.17 to 8.57 cm with a mean value of 7.19 cm over the parents. Largest fruits were recorded in parent Arka Saurabh (8.57 cm) followed by NDT-4 (8.20 cm), NDT-2 and Arka Vikas (7.97 cm), NDT-1 (7.36 cm) and Azad T-6 (7.20 cm). The length of fruits in F_1 hybrids ranged from 5.75 to 8.03 cm with a mean over crosses of 6.98 cm. Among the hybrids NDT-7 × Pb. Chhuhara (8.03 cm) displayed maximum fruit length followed by Arka Saurabh × Arka Vikas (7.93 cm), NDT-4 × Pusa Ruby (7.87 cm) and NDT-6 × Arka Vikas (7.81 cm) and NDT-1 × Pb. Chhuhara (7.49 cm).

4.2.10 Fruit girth (cm)

In Y_1, fruit girth which is a measure of fruit thickness, varied from 11.06 to 15.47 cm for parental lines and 10.56 to 15.28 cm for F_1 hybrids. The mean values over the parental lines and F_1 hybrids were 13.08 and 12.75 cm, respectively. The parental line NDT-4 (15.47 cm) had maximum fruit girth followed by Arka Saurabh (15.20 cm), NDT-3 (14.50 cm), NDT-1 (13.56 cm) and Azad T-6 (13.53 cm). Among the hybrids Arka Saurabh × Arka Vikas (15.28 cm) bore the maximum fruit girth followed by Arka Saurabh × Pb.Chhuhara (14.80 cm), NDT-5 × Arka Meghali (14.41 cm), NDT-4 × Pusa Ruby (14.21 cm) and NDT-4 × Pb. Chhuhara (14.14 cm).

In Y_2, fruit girth which is a measure of fruit thickness, varied from 12.27 to 16.68 cm for parental lines and 11.77 to 16.49 cm for F_1 hybrids. The mean values over the parental lines and F_1 hybrids were 14.29 and 13.94 cm, respectively. The parental line NDT-4 (16.68 cm) had maximum fruit girth followed by Arka Saurabh (16.41 cm), NDT-3 (15.71 cm), NDT-1 (14.77 cm)

and Azad T-6 (14.74 cm). Among the hybrids Arka Saurabh × Arka Vikas (16.49 cm) bore the maximum fruit girth followed by Arka Saurabh × Pb.Chhuhara (16.01 cm), NDT-5 × Arka Meghali (15.62 cm), NDT-4 × Pusa Ruby (15.42 cm) and NDT-4 × Pb. Chhuhara (15.35 cm).

In pooled, fruit girth which is a measure of fruit thickness, varied from 11.67 to 16.08 cm for parental lines and 11.17 to 15.89 cm for F_1 hybrids. The mean values over the parental lines and F_1 hybrids were 13.69 and 13.35 cm, respectively. The parental line NDT-4 (16.08 cm) had maximum fruit girth followed by Arka Saurabh (15.81 cm), NDT-3 (15.11 cm), NDT-1 (14.17 cm) and Azad T-6 (14.14 cm). Among the hybrids Arka Saurabh × Arka Vikas (15.89 cm) bore the maximum fruit girth followed by Arka Saurabh × Pb.Chhuhara (15.41 cm), NDT-5 × Arka Meghali (15.02 cm), NDT-4 × Pusa Ruby (14.82 cm) and NDT-4 × Pb. Chhuhara (14.75 cm).

4.2.11 Number of locules per fruit

In Y_1, the parental lines for number of locules per fruit varied from 3.53 to 5.17 with a mean value of 4.32 over parents. Among the parents, NDT-2 (5.17) recorded maximum number of locules per fruit followed by NDT-1 (4.77), NDT-3 (4.67), Azad T-6 (4.60) and NDT-4 and Arka Meghali (4.50). Among the F_1 hybrids, the mean value for number of locules per fruit over the crosses was 4.32 with a range of 1.90 to 5.70. The hybrid NDT-6 × Pusa Ruby (5.70) had maximum number of locules per fruit followed by NDT-6 × Pb. Chhuhara (5.15), NDT-2 × Arka Vikas and NDT-8 × Arka Meghali (5.13), Azad T-6 × Pusa Ruby (5.00) and NDT-4 × Pb. Chhuhara (4.97) among hybrids.

In Y_2, the parental lines for number of locules per fruit varied from 3.89 to 5.53 with a mean value of 4.68 over parents. Among the parents, NDT-2 (5.53) recorded maximum number of locules per fruit followed by NDT-1 (5.13), NDT-3 (5.03), Azad T-6 (4.96) and NDT-4 and Arka Meghali (4.86).

Among the F_1 hybrids, the mean value for number of locules per fruit over the crosses was 4.68 with a range of 2.26 to 6.06. The hybrid NDT-6 × Pusa Ruby (6.06) had maximum number of locules per fruit followed by NDT-6 × Pb. Chhuhara (5.53), NDT-2 × Arka Vikas and NDT-8 × Arka Meghali (5.49), Azad T-6 × Pusa Ruby (5.36) and NDT-4 × Pb. Chhuhara (5.33) among hybrids.

In pooled, the parental lines for number of locules per fruit varied from 3.71 to 5.35 with a mean value of 4.50 over parents. Among the parents, NDT-2 (5.35) recorded maximum number of locules per fruit followed by NDT-1 (4.95), NDT-3 (4.85), Azad T-6 (4.78) and NDT-4 and Arka Meghali (4.68). Among the F_1 hybrids, the mean value for number of locules per fruit over the crosses was 5.50 with a range of 2.08 to 5.88. The hybrid NDT-6 × Pusa Ruby (5.88) had maximum number of locules per fruit followed by NDT-6 × Pb. Chhuhara (5.35), NDT-2 × Arka Vikas and NDT-8 × Arka Meghali (5.31), Azad T-6 × Pusa Ruby (5.18) and NDT-4 × Pb. Chhuhara (5.15) among hybrids.

4.2.12 Pericarp thickness (mm)

In Y_1, the parental lines for pericarp thickness varied from 4.22 to 5.79 mm with a mean value of 4.75 mm over parents. Among the parents, Azad T-6 (5.79 mm) recorded maximum pericarp thickness followed by NDT-1 (5.52 mm), Arka Vikas (5.15 mm), NDT-2 (4.92 mm) and NDT-3 (4.89 mm). Among the F_1 hybrids, the mean value for pericarp thickness over the crosses was 4.49 mm with a range of 3.90 to 5.34 mm. The hybrid NDT-8 × Pb. Chhuhara (5.34 mm) had maximum pericarp thickness followed by NDT-6 × Arka Meghali (5.12 mm), NDT-2 × Arka Vikas (5.07 mm), NDT-8 × Arka Vikas (5.00 mm) and NDT-4 × Arka Vikas (4.91 mm) among hybrids.

In Y_2, the parental lines for pericarp thickness varied from 4.63 to 6.20 mm with a mean value of 5.16 mm over parents. Among the parents,

Azad T-6 (6.20 mm) recorded maximum pericarp thickness followed by NDT-1 (5.93 mm), Arka Vikas (5.56 mm), NDT-2 (5.33 mm) and NDT-3 (5.30 mm). Among the F_1 hybrids, the mean value for pericarp thickness over the crosses was 4.90 mm with a range of 4.31 to 5.75 mm. The hybrid NDT-8 × Pb. Chhuhara (5.75 mm) had maximum pericarp thickness followed by NDT-6 × Arka Meghali (5.53 mm), NDT-2 × Arka Vikas (5.58 mm), NDT-8 × Arka Vikas (5.41 mm) and NDT-4 × Arka Vikas (5.32 mm) among hybrids.

In pooled, the parental lines for pericarp thickness varied from 4.43 to 6.00 mm with a mean value of 4.96 mm over parents. Among the parents, Azad T-6 (6.00 mm) recorded maximum pericarp thickness followed by NDT-1 (5.73 mm), Arka Vikas (5.36 mm), NDT-2 (5.13 mm) and NDT-3 (5.10 mm). Among the F_1 hybrids, the mean value for pericarp thickness over the crosses was 4.69 mm with a range of 4.11 to 5.55 mm. The hybrid NDT-8 × Pb. Chhuhara (5.55 mm) had maximum pericarp thickness followed by NDT-6 × Arka Meghali (5.33 mm), NDT-2 × Arka Vikas (5.28 mm), NDT-8 × Arka Vikas (5.21 mm) and NDT-4 × Arka Vikas (5.12 mm) among hybrids.

4.2.13 Total soluble solids (°B)

In Y_1, total soluble solids varied from 4.45 to 6.42 °B for parental lines and 4.43 to 6.92 °B for F_1 hybrids. The mean values over the parental lines and F_1 hybrids were 5.54 and 5.47 °B, respectively. The parental line NDT-5 (6.42 °B) had maximum total soluble solids which were followed by NDT-8 (6.12 °B), Arka Vikas (5.98 °B), NDT-1 and Azad T-6 (5.92 °B) and NDT-6 (5.72 °B). Among the hybrids, Arka Saurabh × Arka Meghali (6.92 °B) showed highest total soluble solids followed by NDT-7 × Pb. Chhuhara (6.40 °B), NDT-2 × Arka Vikas (6.18 °B), NDT-2 × Arka Meghali (6.12 °B) and NDT-5 × Pb. Chhuhara (6.00 °B).

In Y_2, total soluble solids varied from 4.84 to 6.81 °B for parental lines and 4.82 to 7.31 °B for F_1 hybrids. The mean values over the parental

lines and F_1 hybrids were 5.93 and 5.86 °B, respectively. The parental line NDT-5 (6.81 °B) had maximum total soluble solids which were followed by NDT-8 (6.51 °B), Arka Vikas (6.37 °B), NDT-1 and Azad T-6 (6.31 °B) and NDT-6 (6.11 °B). Among the hybrids, Arka Saurabh × Arka Meghali (7.31 °B) showed highest total soluble solids followed by NDT-7 × Pb. Chhuhara (6.79 °B), NDT-2 × Arka Vikas (6.57 °B), NDT-2 × Arka Meghali (6.51 °B) and NDT-5 × Pb. Chhuhara (6.39 °B).

In pooled, total soluble solids varied from 4.65 to 6.62 °B for parental lines and 4.63 to 7.12 °B for F_1 hybrids. The mean values over the parental lines and F_1 hybrids were 5.74 and 5.66 °B, respectively. The parental line NDT-5 (6.62 °B) had maximum total soluble solids which were followed by NDT-8 (6.32 °B), Arka Vikas (6.18 °B), NDT-1 and Azad T-6 (6.12 °B) and NDT-6 (5.92 °B). Among the hybrids, Arka Saurabh × Arka Meghali (7.12 °B) showed highest total soluble solids followed by NDT-7 × Pb. Chhuhara (6.60 °B), NDT-2 × Arka Vikas (6.38 °B), NDT-2 × Arka Meghali (6.32 °B) and NDT-5 × Pb. Chhuhara (6.20 °B).

4.2.14 Ascorbic acid (mg/100 g fruit)

In Y_1, the ascorbic acid for parental lines varied from 27.24 to 49.62 mg with a mean value of 38.06 mg. Among the parents, Azad T-6 (49.62 mg) recorded maximum ascorbic acid followed by NDT-8 (47.13 mg), NDT-7 (43.40 mg), Arka Saurabh (41.46 mg) and Arka Meghali (40.82 mg). Among the F_1 hybrids, the mean value for ascorbic acid over the crosses was 38.65 mg with a range of 25.53 to 61.09 mg. The hybrid NDT-5 × Pb. Chhuhara (61.09 mg) had maximum ascorbic acid followed by NDT-5 × Arka Meghali (60.31 mg), NDT-5 × Arka Vikas (58.70 mg), Azad T-6 × Arka Meghali (57.57 mg) and Azad T-6 × Arka Vikas (55.45 mg).

In Y_2, the ascorbic acid for parental lines varied from 28.46 to 50.84 mg with a mean value of 39.64 mg. Among the parents, Azad T-6 (50.84 mg)

recorded maximum ascorbic acid followed by NDT-8 (48.35 mg), NDT-7 (44.62 mg), Arka Meghali (42.04 mg) and NDT-1 (42.00 mg). Among the F_1 hybrids, the mean value for ascorbic acid over the crosses was 40.87 mg with a range of 26.75 to 61.53 mg. The hybrid NDT-5 × Arka Meghali (61.53 mg) had maximum ascorbic acid followed by NDT-5 × Pb. Chhuhara (61.31 mg), NDT-5 × Arka Vikas (58.92 mg), Azad T-6 × Arka Meghali (58.79 mg) and Azad T-6 × Arka Vikas (58.00 mg).

In pooled, the ascorbic acid for parental lines varied from 27.85 to 50.23 mg with a mean value of 38.85 mg. Among the parents, Azad T-6 (50.23 mg) recorded maximum ascorbic acid followed by NDT-8 (47.74 mg), NDT-7 (44.01 mg), Arka Meghali (41.43 mg) and NDT-1 (41.39 mg). Among the F_1 hybrids, the mean value for ascorbic acid over the crosses was 39.76 mg with a range of 26.64 to 61.20 mg. The hybrid NDT-5 × Pb. Chhuhara (61.20 mg) had maximum ascorbic acid followed by NDT-5 × Arka Meghali (60.92 mg), NDT-5 × Arka Vikas (58.81 mg), Azad T-6 × Arka Meghali (58.18 mg) and Azad T-6 × Arka Vikas (56.72 mg).

4.2.15 Total fruit yield per plant (kg)

In Y_1, the mean value for total fruit yield per plant ranged from 2.26 to 3.53 kg for parental lines and 1.57 to 3.17 kg for F_1 hybrids. The mean values over the parental lines and F_1 hybrids were 2.84 and 2.49 kg, respectively. Among the parental lines, the highest total fruit yield per plant was recorded with Arka Meghali (3.53 kg) followed by Arka Vikas (3.44 kg), NDT-2 (3.28 kg), Arka Saurabh (3.11 kg) and NDT-8 (2.98 kg). The highest yielding hybrid was NDT-3 × Arka Vikas (3.17 kg) followed by NDT-2 × Arka Meghali (3.04 kg), NDT-2 × Arka Vikas (2.99 kg), NDT-4 × Arka Vikas (2.94 kg) and NDT-2 × Pusa Ruby (2.88 kg).

In Y_2, the mean value for total fruit yield per plant ranged from 2.63 to 3.90 kg for parental lines and 1.94 to 3.54 kg for F_1 hybrids. The mean values

over the parental lines and F_1 hybrids were 3.17 and 2.86 kg, respectively. Among the parental lines, the highest total fruit yield per plant was recorded with Arka Meghali (3.90 kg) followed by Arka Vikas (3.81 kg), NDT-2 (3.65 kg), Arka Saurabh (3.26 kg) and Azad T-6 (3.19 kg). The highest yielding hybrid was NDT-3 × Arka Vikas (3.54 kg) followed by NDT-2 × Arka Meghali (3.41 kg), NDT-2 × Arka Vikas (3.36 kg), NDT-4 × Arka Vikas (3.31 kg) and NDT-2 × Pusa Ruby (3.25 kg).

In pooled, the mean value for total fruit yield per plant ranged from 2.44 to 3.71 kg for parental lines and 1.75 to 3.36 kg for F_1 hybrids. The mean values over the parental lines and F_1 hybrids were 3.01 and 2.68 kg, respectively. Among the parental lines, the highest total fruit yield per plant was recorded with Arka Meghali (3.71 kg) followed by Arka Vikas (3.63 kg), NDT-2 (3.46 kg), Arka Saurabh (3.18 kg) and NDT-8 (3.05 kg). The highest yielding hybrid was NDT-3 × Arka Vikas (3.36 kg) followed by NDT-2 × Arka Meghali (3.22 kg), NDT-2 × Arka Vikas (3.17 kg), NDT-4 × Arka Vikas (3.13 kg) and NDT-2 × Pusa Ruby (3.07 kg).

Table-4.4: Visual observations on fruit characteristics of the fourteen parents (10 lines and 4 testers) and their crosses in tomato

Genotypes	Fruit shape	Fruit colour	Plant habit (determinate/ indeterminate)
Parental lines	**1**	**2**	**3**
NDT-1	Round	Pink	Indeterminate
NDT-2	Round	Red	Determinate
NDT-3	Oval	Orange	Determinate
NDT-4	Round	Orange	Indeterminate
NDT-5	Round	Red	Indeterminate
NDT-6	Round	Red	Determinate
NDT-7	Round	Pink	Determinate
NDT-8	Round	Red	Determinate
Azad T-6	Round	Red	Indeterminate
Arka Saurabh	Round	Red	Semi-determinate
Pusa Ruby	Round	Red	Indeterminate
Punjab Chhuhara	Cylindrical	Red	Determinate
Arka Vikas	Oval	Red	Semi-determinate
Arka Meghali	Oval	Red	Semi-determinate
F_1 hybrids			
NDT-1 × Pusa Ruby	Round	Red	Indeterminate
NDT-1 × Pb. Chhuhara	Round	Red	Semi-determinate
NDT-1 × Arka Vikas	Round	Red	Indeterminate
NDT-1 × Arka Meghali	Round	Red	Indeterminate
NDT-2 × Pusa Ruby	Round	Red	Semi-determinate
NDT-2 × Pb. Chhuhara	Cylindrical	Red	Determinate
NDT-2 × Arka Vikas	Round	Red	Determinate
NDT-2 × Arka Meghali	Round	Red	Determinate
NDT-3 × Pusa Ruby	Round	Orange	Determinate
NDT-3 × Pb. Chhuhara	Oval	Orange	Determinate
NDT-3 × Arka Vikas	Oval	Orange	Determinate
NDT-3 × Arka Meghali	Oval	Orange	Determinate
NDT-4 × Pusa Ruby	Round	Red	Indeterminate
NDT-4 × Pb. Chhuhara	Round	Orange	Indeterminate

Contd.....

	1	2	3
NDT-4 × Arka Vikas	Round	Red	Indeterminate
NDT-4 × Arka Meghali	Round	Orange	Indeterminate
NDT-5 × Pusa Ruby	Round	Red	Indeterminate
NDT-5 × Pb. Chhuhara	Round	Red	Indeterminate
NDT-5 × Arka Vikas	Round	Pink	Indeterminate
NDT-5 × Arka Meghali	Round	Red	Indeterminate
NDT-6 × Pusa Ruby	Round	Red	Determinate
NDT-6 × Pb. Chhuhara	Round	Red	Determinate
NDT-6 × Arka Vikas	Round	Red	Determinate
NDT-6 × Arka Meghali	Oval	Orange	Determinate
NDT-7 × Pusa Ruby	Round	Red	Determinate
NDT-7 × Pb. Chhuhara	Round	Red	Determinate
NDT-7 × Arka Vikas	Round	Red	Determinate
NDT-7 × Arka Meghali	Round	Red	Determinate
NDT-8 × Pusa Ruby	Round	Pink	Semi-determinate
NDT-8 × Pb. Chhuhara	Round	Red	Determinate
NDT-8 × Arka Vikas	Oval	Red	Determinate
NDT-8 × Arka Meghali	Round	Red	Determinate
Azad T-6 × Pusa Ruby	Round	Pink	Indeterminate
Azad T-6 × Pb. Chhuhara	Cylindrical	Red	Indeterminate
Azad T-6 × Arka Vikas	Round	Red	Indeterminate
Azad T-6 × Arka Meghali	Round	Orange	Indeterminate
Arka Saurabh × Pusa Ruby	Round	Red	Indeterminate
Arka Saurabh × Pb. Chhuhara	Round	Red	Semi-determinate
Arka Saurabh × Arka Vikas	Round	Red	Semi-determinate
Arka Saurabh × Arka Meghali	Round	Red	Semi-determinate



Fig. 4.1 (A) NDT-1



Fig. 4.1 (B) NDT-4



Fig. 4.1 (C) Azad T-6



Fig. 4.1 (D) Arka Saurabh

Fig.-4.1 (A-D) Fruit shape of parents (lines)



Fig. 4.2 (A) Arka Vikas



Fig. 4.2 (B) Arka Meghali

Fig.-4.2 (A-B) Fruit shape of parents (testers)



Fig.-4.3 (A) NDT-1 × Pb. Chhuhara



Fig.-4.3 (B) NDT-4 × Pusa Rubi



Fig.-4.3 (C) NDT-5 × Arka Meghali



Fig.-4.3 (D) NDT-6 × Arka Vikas



Fig.-4.3 (E) NDT-7 × Pb. Chhuhara



Fig.-4.3 (F) Arka Saurabh × Arka Vikas

Fig.-4.3 (A-F) Fruit shape of promising crosses

4.3 Estimates of heterosis over better parent and standard variety

Heterosis calculated as per cent increase or decrease over better parent, standard variety and pooled for sixteen characters in Y_1, Y_2 and pooled had given in Table 4.5 and described as follow:

4.3.1 Days to 50 % flowering

In Y_1, heterosis for days to 50 per cent flowering over better parent ranged from –19.69 per cent (NDT-4 × Arka Meghali) to 11.84 per cent (Azad T-6 × Pb. Chhuhara). Out of forty crosses, only two crosses, NDT-4 × Arka Meghali (-19.69 %) and NDT-1 × Arka Meghali (-11.12 %) showed negative and significant heterobeltiosis while, only two crosses showed positive and significant heterosis over better parent for days to 50 % flowering. Heterosis over standard variety ranged from -14.16 per cent (NDT-4 × Arka Meghali) to 12.91 per cent (NDT-6 × Arka Meghali). Out of forty crosses, only one cross, NDT-4 × Arka Meghali (-14.16%) showed negative standard heterosis while, eight crosses showed significant and positive heterosis over standard variety for days to 50 per cent flowering.

In Y_2, heterosis for days to 50 per cent flowering over better parent ranged from -17.46 per cent (NDT-4 × Arka Meghali) to 8.89 per cent (NDT-2 × Pusa Ruby). Out of forty crosses, only four crosses showed negative and significant heterosis. The best three F_1's showing heterobeltiosis in negative direction were NDT-4 × Arka Meghali (-17.46%), NDT-1 × Arka Meghali (-11.80%) and NDT-7 × Arka Vikas (-8.83%) while, only one cross showed positive and significant heterosis over better parent for days to 50 % flowering. Heterosis over standard variety ranged from -10.62 per cent (NDT-4 × Arka Meghali) to 11.60 per cent (NDT-6 × Arka Meghali). Out of forty crosses, only one cross, NDT-4 × Arka Meghali (-10.62%) showed negative standard heterosis while, seven crosses showed significant and positive heterosis over standard variety for days to 50 percent flower anthesis.

Table-4.5. Estimates of heterosis (%) over better parent (BP) and standard variety (SV) Arka Vikas over two years (Y_1, Y_2) and pooled.

Crosses	Days to 50 % flowering						Days to first fruit set					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDT-1 × Pusa Ruby	0.58	1.06	-2.44	-0.99	-1.01	-0.02	0.30	3.33	0.29	3.21	0.30	3.27
NDT-1 × Pb. Chhuhara	-1.76	-1.29	-4.16	-1.16	-2.24	-1.22	-0.95	2.03	-0.92	1.96	-0.93	2.00
NDT-1 × Arka Vikas	8.20	8.72	5.22	6.78	6.62*	7.70*	5.70	8.88*	5.51	8.58*	5.60*	8.73**
NDT-1 × Arka Meghali	-11.12*	-5.00	-11.80**	-4.49	-11.48**	-4.73	-8.51*	-1.28	-8.24*	-1.24	-8.38**	-1.26
NDT-2 × Pusa Ruby	11.11*	9.10	8.89*	7.13	9.94**	8.06**	5.27	5.73	5.09	5.53	5.18	5.63*
NDT-2 × Pb. Chhuhara	2.98	1.65	-1.60	1.48	0.52	1.56	1.81	3.54	1.75	3.42	1.78	3.48
NDT-2 × Arka Vikas	9.24	9.24	8.31	8.31	8.75**	8.75**	9.42*	9.90*	9.10*	9.56*	9.26**	9.73**
NDT-2 × Arka Meghali	1.09	8.06	0.98	9.35*	1.03	8.74**	4.40	12.65**	4.26	12.22**	4.33	12.43**
NDT-3 × Pusa Ruby	4.63	10.38*	4.18	9.33*	4.39	9.83**	4.27	11.83**	4.13	11.42**	4.20	11.62**
NDT-3 × Pb. Chhuhara	6.88	12.75**	6.21	11.46**	6.53*	12.07**	4.93	12.54**	4.78	12.11**	4.85	12.32**
NDT-3 × Arka Vikas	6.10	11.94*	5.51	10.73*	5.79*	11.30**	0.74	8.05	0.72	7.77	0.73	7.91**
NDT-3 × Arka Meghali	-4.75	1.81	-3.23	4.78	-3.95	3.38	-4.41	3.14	-4.27	3.04	-4.34	3.09
NDT-4 × Pusa Ruby	2.44	-0.13	4.43	-0.12	3.48	-0.12	3.56	2.18	3.44	2.10	3.50	2.14
NDT-4 × Pb. Chhuhara	4.73	3.38	-2.13	0.94	1.04	2.09	1.49	3.21	1.44	3.10	1.46	3.15
NDT-4 × Arka Vikas	8.85	8.85	7.95	7.95	8.37**	8.37**	8.57*	8.57*	8.27*	8.27*	8.42**	8.42**
NDT-4 × Arka Meghali	-19.69**	-14.16**	-17.46**	-10.62*	-18.51**	-12.30**	-13.90**	-7.10	-13.46**	-6.85	-13.68**	-6.97*
NDT-5 × Pusa Ruby	7.69	5.05	6.89	4.54	7.27*	4.79	5.62	5.97	5.43	5.76	5.53*	5.86*
NDT-5 × Pb. Chhuhara	-0.75	-2.02	-4.80	-1.82	-2.93	-1.92	-0.25	1.44	-0.24	1.39	-0.25	1.42
NDT-5 × Arka Vikas	8.75	8.75	7.87	7.87	8.29**	8.29**	9.67*	10.02*	9.34*	9.68*	9.50**	9.85**
NDT-5 × Arka Meghali	-1.16	5.65	-5.88	1.92	-3.66	3.69	-3.34	4.30	-3.23	4.16	-3.28	4.23
NDT-6 × Pusa Ruby	4.80	10.40*	4.33	9.35*	4.55	9.85**	3.79	10.80*	3.67	10.43*	3.73	10.61**
NDT-6 × Pb. Chhuhara	-8.28	-3.37	-8.48*	-4.08	-8.38**	-3.74	-4.81	1.62	-4.65	1.57	-4.73	1.60
NDT-6 × Arka Vikas	-0.73	4.58	0.23	5.05	-0.23	4.82	-1.41	5.24	-1.37	5.06	-1.39	5.15
NDT-6 × Arka Meghali	5.63	12.91**	3.06	11.60**	4.27	12.22**	4.40	12.65**	4.26	12.22**	4.33	12.43**
NDT-7 × Pusa Ruby	0.48	7.41	0.44	6.66	0.46	7.01*	-1.63	6.15	-1.58	5.94	-1.60	6.04*
NDT-7 × Pb. Chhuhara	-3.50	3.15	-3.17	2.83	-3.33	2.98	-2.17	5.56	-2.11	5.37	-2.14	5.46*
NDT-7 × Arka Vikas	-7.58	-1.21	-8.83*	-3.19	-8.24**	-2.25	-6.74	0.64	-6.52	0.61	-6.63**	0.63

Contd..

Crosses	Days to 50 % flowering						Days to first fruit set					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDT-7 × Arka Meghali	3.66	10.80*	-0.63	7.60	1.38	9.12**	0.31	8.24	0.30	7.95	0.30	8.09**
NDT-8 × Pusa Ruby	2.84	7.99	2.57	7.18	2.70	7.57*	1.79	8.58*	1.73	8.28*	1.76	8.43**
NDT-8 × Pb. Chhuhara	-3.09	1.77	-2.79	1.59	-2.93	1.67	-3.74	2.68	-3.62	2.59	-3.68	2.63
NDT-8 × Arka Vikas	-0.41	4.58	-0.08	4.42	-0.24	4.49	-0.39	6.25	-0.38	6.04	-0.39	6.14*
NDT-8 × Arka Meghali	3.28	10.40*	0.01	8.30	1.55	9.29**	3.20	11.36**	3.10	10.97**	3.15	11.16**
Azad T-6 × Pusa Ruby	7.86	5.98	7.05	5.37	7.43*	5.66	7.20	8.45*	6.96	8.16*	7.08**	8.30**
Azad T-6 × Pb. Chhuhara	11.84*	10.40*	7.05	10.40*	9.26**	10.40**	8.94*	10.79*	8.64*	10.42*	8.79**	10.60**
Azad T-6 × Arka Vikas	-5.24	-5.24	-1.56	-1.56	-3.30	-3.30	-0.59	0.56	-0.57	0.54	-0.58	0.55
Azad T-6 × Arka Meghali	-3.70	2.94	-4.06	3.89	-3.89	3.44	-2.03	5.72	-1.96	5.52	-1.99	5.62*
Arka Saurabh × Pusa Ruby	-3.16	2.87	-0.50	4.02	-1.77	3.47	2.83	7.69	2.74	7.42	2.78	7.55**
Arka Saurabh × Pb. Chhuhara	-0.07	6.15	0.95	5.53	0.46	5.83	3.76	8.65*	3.63	8.36*	3.69	8.50**
Arka Saurabh × Arka Vikas	-2.68	3.38	-1.44	3.04	-2.03	3.20	0.64	5.40	0.62	5.21	0.63	5.30
Arka Saurabh × Arka Meghali	1.12	8.09	-0.94	7.27	0.03	7.65*	0.99	8.98*	0.96	8.67*	0.98	8.82**
No. of crosses with significant (+) heterosis	**2**	**8**	**1**	**7**	**10**	**17**	**4**	**15**	**4**	**15**	**7**	**24**
No. of crosses with significant (-) heterosis	**2**	**1**	**4**	**1**	**4**	**1**	**2**	**0**	**2**	**0**	**3**	**1**
Range of heterosis	**-19.69-11.84**	**-14.16-12.91**	**-17.46-8.89**	**-10.62-11.60**	**-18.51-9.94**	**-12.30-12.22**	**-13.90-9.67**	**-7.10-12.65**	**-13.46-9.34**	**-6.85-12.22**	**-13.68-9.50**	**-6.97-12.43**

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table- 4.5. Contd….

Crosses	Days to first fruit harvest						Plant height (cm)					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDT-1 × Pusa Ruby	0.09	1.56	0.09	1.53	0.09	1.54	8.31**	58.92**	8.29**	58.03**	8.30**	58.47**
NDT-1 × Pb. Chhuhara	-1.36	0.08	-1.34	0.08	-1.35	0.08	-22.20**	14.16**	-21.92**	13.94**	-22.06**	14.05**
NDT-1 × Arka Vikas	2.43	3.93	2.38	3.85	2.40	3.89*	-16.14**	23.04**	-15.92**	22.70**	-16.03**	22.87**
NDT-1 × Arka Meghali	-5.54*	-1.79	-5.43*	-1.75	-5.48**	-1.77	-13.28**	27.24**	-4.90*	38.78**	-9.07**	33.05**
NDT-2 × Pusa Ruby	3.52	2.96	3.45	2.90	3.48	2.93	-2.69	31.16**	-2.15	30.69**	-2.42	30.92**
NDT-2 × Pb. Chhuhara	1.74	1.90	1.71	1.86	1.72	1.88	-23.09**	-18.58**	-21.74**	-18.30**	-22.41**	-18.43**
NDT-2 × Arka Vikas	5.07	5.07	4.96	4.96	5.01**	5.01**	-11.25**	-7.28*	-11.08**	-7.17*	-11.16**	-7.23**
NDT-2 × Arka Meghali	1.54	5.57*	1.51	5.45*	1.52	5.51**	-4.98	0.40	-4.91	0.39	-4.95*	0.40
NDT-3 × Pusa Ruby	3.19	6.69*	3.13	6.55*	3.16	6.62**	-2.99	30.74**	6.50*	42.24**	1.77	36.54**
NDT-3 × Pb. Chhuhara	3.07	6.56*	3.01	6.43*	3.04	6.49**	-13.68**	-0.41	-13.50**	-0.41	-13.59**	-0.41
NDT-3 × Arka Vikas	3.07	6.56*	3.01	6.43*	3.04	6.49**	-11.04**	2.63	-10.90**	2.59	-10.97**	2.61
NDT-3 × Arka Meghali	-2.34	1.54	-2.29	1.50	-2.31	1.52	-19.69**	-7.34*	-19.43**	-7.23*	-19.56**	-7.29**
NDT-4 × Pusa Ruby	1.97	0.33	1.93	0.33	1.95	0.33	18.15**	79.88**	17.97**	78.68**	18.06**	79.27**
NDT-4 × Pb. Chhuhara	1.14	1.29	1.11	1.26	1.12	1.28	2.09	55.44**	3.39	56.59**	2.74	56.02**
NDT-4 × Arka Vikas	4.73	4.73	4.63	4.63	4.68*	4.68*	0.41	52.87**	0.40	52.07**	0.40	52.47**
NDT-4 × Arka Meghali	-8.43**	-4.80	-8.26*	-4.70	-8.34**	-4.74*	-9.36**	38.00**	-9.27**	37.42**	-9.31**	37.71**
NDT-5 × Pusa Ruby	2.81	3.16	2.75	3.10	2.78	3.13	23.62**	82.61**	26.35**	85.35**	24.99**	83.99**
NDT-5 × Pb. Chhuhara	-0.31	0.03	-0.31	0.03	-0.31	0.03	13.50**	67.66**	13.60**	66.65**	13.55**	67.15**
NDT-5 × Arka Vikas	4.55	4.91	4.46	4.81	4.51*	4.86**	10.21**	62.80**	10.34**	61.86**	10.28**	62.33**
NDT-5 × Arka Meghali	-2.11	1.77	-2.07	1.74	-2.09	1.75	8.32**	60.01**	8.46**	59.11**	8.39**	59.56**
NDT-6 × Pusa Ruby	2.05	5.63*	2.01	5.52*	2.03	5.57**	3.98	40.14**	4.47	39.53**	4.23*	39.83**
NDT-6 × Pb. Chhuhara	-2.88	0.53	-2.82	0.52	-2.85	0.53	-8.91**	-3.56	-1.84	2.48	-5.37*	-0.52
NDT-6 × Arka Vikas	-0.24	3.26	-0.24	3.19	-0.24	3.22	-4.86	-4.86	-4.78	-4.78	-4.82*	-4.82*
NDT-6 × Arka Meghali	2.60	6.68*	2.55	6.54*	2.58	6.61**	-0.36	5.29	-0.35	5.21	-0.36	5.25*
NDT-7 × Pusa Ruby	-0.55	3.25	-0.54	3.19	-0.54	3.22	21.87**	64.26**	22.26**	63.29**	22.07**	63.77**
NDT-7 × Pb. Chhuhara	-1.66	2.10	-1.63	2.06	-1.64	2.08	-10.52**	-5.27	-9.18**	-5.19	-9.85**	-5.23*
NDT-7 × Arka Vikas	-3.74	-0.06	-3.67	-0.06	-3.70*	-0.06	3.16	3.16	0.72	0.72	1.93	1.93

Contd..

Crosses	Days to first fruit harvest						Plant height (cm)					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDT-7 × Arka Meghali	1.01	5.02	0.99	4.92	1.00	4.97**	-1.54	4.04	-2.65	2.79	-2.10	3.41
NDT-8 × Pusa Ruby	2.06	5.14*	2.02	5.03*	2.04	5.08**	11.54**	50.34**	11.99**	49.58**	11.77**	49.95**
NDT-8 × Pb. Chhuhara	-0.87	2.12	-0.85	2.08	-0.86	2.10	-21.83**	-17.24**	-20.48**	-16.98**	-21.15**	-17.11**
NDT-8 × Arka Vikas	0.57	3.60	0.56	3.53	0.56	3.56	-15.22**	-15.22**	-15.00**	-15.00**	-15.11**	-15.11**
NDT-8 × Arka Meghali	1.00	5.01	0.98	4.90	0.99	4.96**	-14.26**	-9.40**	-14.05**	-9.26**	-14.15**	-9.33**
Azad T-6 × Pusa Ruby	4.81	4.56	4.71	4.46	4.76*	4.51*	42.11**	91.54**	43.27**	91.35**	42.70**	91.45**
Azad T-6 × Pb. Chhuhara	5.40*	5.56*	5.28*	5.44*	5.34**	5.50**	13.74**	52.12**	14.20**	51.34**	13.97**	51.72**
Azad T-6 × Arka Vikas	-0.26	-0.26	-0.26	-0.26	-0.26	-0.26	14.50**	53.13**	14.95**	52.33**	14.73**	52.73**
Azad T-6 × Arka Meghali	-2.05	1.84	-2.01	1.80	-2.03	1.82	19.40**	59.68**	19.83**	58.79**	19.61**	59.23**
Arka Saurabh × Pusa Ruby	1.61	3.58	1.58	3.51	1.60	3.54	14.54**	54.37**	17.96**	57.54**	16.25**	55.97**
Arka Saurabh × Pb. Chhuhara	1.56	3.52	1.53	3.45	1.54	3.49	-15.63**	-10.67**	-14.28**	-10.51**	-14.95**	-10.59**
Arka Saurabh × Arka Vikas	0.17	2.11	0.17	2.07	0.17	2.09	-1.46	2.44	-1.44	2.40	-1.45	2.42
Arka Saurabh × Arka Meghali	0.89	4.89	0.87	4.79	0.88	4.84**	-18.77**	-14.17**	-18.50**	-13.95**	-18.64**	-14.06**
No. of crosses with significant (+) heterosis	**1**	**8**	**1**	**8**	**5**	**16**	**13**	**22**	**14**	**22**	**14**	**23**
No. of crosses with significant (-) heterosis	**2**	**0**	**2**	**0**	**3**	**1**	**16**	**8**	**15**	**8**	**18**	**10**
Range of heterosis	**-8.43-5.40**	**-4.80-6.69**	**-8.26-5.28**	**-4.70-6.55**	**-8.34-5.34**	**-4.74-6.62**	**-23.09-42.11**	**-18.58-91.54**	**-21.92-43.27**	**-18.30-91.35**	**-22.41-42.70**	**-18.43-91.45**

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table- 4.5. Contd….

Crosses	Number of primary branches per plant						Number of fruits per cluster					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDT-1 × Pusa Ruby	-1.08	4.58	-0.96	4.04	-1.02	4.29	-14.25	-0.57	-13.16	-0.52	-13.68**	-0.54
NDT-1 × Pb. Chhuhara	8.12	14.31	7.21	12.62	7.64	13.41	0.98	17.10*	0.91	15.59	0.94	16.31**
NDT-1 × Arka Vikas	-5.42	0.00	-4.80	0.00	-5.09	0.00	0.00	15.96	0.00	14.55	0.00	15.22**
NDT-1 × Arka Meghali	-18.14	-13.45	-16.09	-11.86	-17.06*	-12.61	-12.62	1.33	-11.64	1.21	-12.11*	1.27
NDT-2 × Pusa Ruby	-9.63	7.44	-8.65	6.56	-9.12	6.97	14.92	17.10*	13.62	15.59	14.24*	16.31**
NDT-2 × Pb. Chhuhara	-19.26	-4.01	-17.30	-3.53	-18.23**	-3.76	4.47	6.46	4.09	5.89	4.27	6.16
NDT-2 × Arka Vikas	-20.71*	-5.73	-18.60*	-5.05	-19.60**	-5.36	0.75	2.66	0.68	2.42	0.71	2.54
NDT-2 × Arka Meghali	-20.71*	-5.73	-18.60*	-5.05	-19.60**	-5.36	3.73	5.70	3.41	5.20	3.56	5.44
NDT-3 × Pusa Ruby	0.00	0.86	0.00	0.76	0.00	0.80	16.55	7.03	14.97	6.41	15.72*	6.70
NDT-3 × Pb. Chhuhara	-5.68	-4.87	-5.01	-4.29	-5.32	-4.56	-2.75	-12.54	-2.48	-11.43	-2.61	-11.96*
NDT-3 × Arka Vikas	-7.66	-6.87	-6.76	-6.06	-7.18	-6.44	-11.97	-11.97	-10.91	-10.91	-11.42*	-11.42
NDT-3 × Arka Meghali	-17.03	-16.32	-15.03	-14.38	-15.96**	-15.29*	-12.31	-10.64	-11.24	-9.70	-11.75	-10.15
NDT-4 × Pusa Ruby	-25.30*	-15.46	-22.61*	-13.62	-23.88**	-14.48*	11.79	2.66	10.67	2.42	11.20	2.54
NDT-4 × Pb. Chhuhara	-25.30*	-15.46	-22.61*	-13.62	-23.88**	-14.48*	14.15	2.66	12.78	2.42	13.43*	2.54
NDT-4 × Arka Vikas	-1.52	11.45	-1.36	10.09	-1.43	10.73	15.96	15.96	14.55	14.55	15.22**	15.22**
NDT-4 × Arka Meghali	-21.75*	-11.45	-19.44*	-10.09	-20.53**	-10.73	4.47	6.46	4.09	5.89	4.27	6.16
NDT-5 × Pusa Ruby	-22.42*	-6.87	-20.16*	-6.06	-21.23**	-6.44	-6.49	1.33	-5.95	1.21	-6.21	1.27
NDT-5 × Pb. Chhuhara	-7.15	11.45	-6.43	10.09	-6.77	10.73	-0.70	7.60	-0.64	6.93	-0.67	7.25
NDT-5 × Arka Vikas	-16.69	0.00	-15.01	0.00	-15.81*	0.00	-2.98	5.13	-2.74	4.68	-2.85	4.89
NDT-5 × Arka Meghali	-23.85**	-8.59	-21.44*	-7.57	-22.58**	-8.05	-18.23*	-11.40	-16.74*	-10.39	-17.45**	-10.87
NDT-6 × Pusa Ruby	0.00	0.00	0.00	0.00	0.00	0.00	4.81	7.60	4.40	6.93	4.60	7.25
NDT-6 × Pb. Chhuhara	-4.63	-5.73	-4.08	-5.05	-4.34	-5.36	-15.55	-13.30	-14.21	-12.12	-14.85**	-12.68*
NDT-6 × Arka Vikas	8.59	8.59	7.57	7.57	8.05	8.05	4.19	6.97	3.83	6.35	4.01	6.64
NDT-6 × Arka Meghali	15.44	14.12	13.59	12.45	14.46*	13.23	-11.10	-8.74	-10.15	-7.97	-10.60	-8.34
NDT-7 × Pusa Ruby	-8.59	-8.59	-7.57	-7.57	-8.05	-8.05	-17.22*	-11.40	-15.79*	-10.39	-16.47**	-10.87
NDT-7 × Pb. Chhuhara	7.89	5.73	6.93	5.05	7.38	5.36	-7.10	-0.57	-6.51	-0.52	-6.79	-0.54
NDT-7 × Arka Vikas	0.00	0.00	0.00	0.00	0.00	0.00	7.10	14.63	6.51	13.34	6.79	13.95*

Contd..

Crosses	Number of primary branches per plant						Number of fruits per cluster					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDT-7 × Arka Meghali	13.73	11.45	12.07	10.09	12.85	10.73	-9.41	-3.04	-14.05	-8.55	-11.83*	-5.92
NDT-8 × Pusa Ruby	3.72	3.72	3.28	3.28	3.49	3.49	8.07	17.10*	7.40	15.59	7.72	16.31**
NDT-8 × Pb. Chhuhara	10.61	7.44	9.32	6.56	9.92	6.97	4.09	12.79	3.76	11.66	3.92	12.20*
NDT-8 × Arka Vikas	9.45	9.45	8.33	8.33	8.85	8.85	11.92	21.28*	5.58	13.63	8.62	17.28**
NDT-8 × Arka Meghali	-6.09	-8.78	-5.35	-7.74	-5.70	-8.23	-1.75	6.46	-1.61	5.89	-1.68	6.16
Azad T-6 × Pusa Ruby	10.21	14.31	9.04	12.62	9.59	13.41	7.79	5.13	7.09	4.68	7.42	4.89
Azad T-6 × Pb. Chhuhara	4.69	8.59	4.15	7.57	4.41	8.05	-11.10	-13.30	-10.10	-12.12	-10.58	-12.68*
Azad T-6 × Arka Vikas	11.04	15.17	9.77	13.37	10.37	14.22	-3.99	-3.99	-3.64	-3.64	-3.81	-3.81
Azad T-6 × Arka Meghali	24.01*	28.63*	21.25*	25.23*	22.55**	26.82**	8.76	10.83	8.00	9.87	8.37	10.33
Arka Saurabh × Pusa Ruby	-35.15**	-22.90	-31.58**	-20.19	-33.27**	-21.46**	16.26	12.73	14.79	11.61	15.49*	12.14*
Arka Saurabh × Pb. Chhuhara	-21.67*	-6.87	-19.47*	-6.06	-20.51**	-6.44	0.00	-3.04	0.00	-2.77	0.00	-2.90
Arka Saurabh × Arka Vikas	-39.97**	-28.63*	-35.90**	-25.23*	-37.83**	-26.82**	7.60	7.60	6.93	6.93	7.25	7.25
Arka Saurabh × Arka Meghali	-30.34**	-17.18	-27.25**	-15.14	-28.71**	-16.09*	4.47	6.46	4.09	5.89	4.27	6.16
No. of crosses with significant (+) heterosis	**1**	**1**	**1**	**1**	**2**	**1**	**0**	**4**	**0**	**0**	**5**	**9**
No. of crosses with significant (-) heterosis	**10**	**1**	**11**	**1**	**15**	**6**	**2**	**0**	**2**	**0**	**7**	**3**
Range of heterosis	**-39.97-24.01**	**-28.63-28.63**	**-35.90-21.25**	**-25.23-25.23**	**-37.83-22.55**	**-26.82-26.82**	**-18.23-16.26**	**-13.30-21.28**	**-16.74-14.97**	**-12.12-15.59**	**-17.45-15.72**	**-12.68-17.28**

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table- 4.5. Contd….

Crosses	Number of fruits per plant						Average fruit weight (g)					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDT-1 × Pusa Ruby	9.29**	-1.76	8.99**	-1.71	9.14**	-1.73	-40.69**	-46.33**	-39.71**	-45.31**	-40.19**	-45.82**
NDT-1 × Pb. Chhuhara	6.53*	3.13	6.34*	3.04	6.43**	3.08	-26.80**	-33.76**	-26.15**	-33.02**	-26.47**	-33.39**
NDT-1 × Arka Vikas	-4.36	-4.36	-4.23	-4.23	-4.29*	-4.29*	-10.05**	-10.05**	-9.83**	-9.83**	-9.93**	-9.93**
NDT-1 × Arka Meghali	-11.41**	3.93	-11.12**	3.82	-11.26**	3.87	5.13	0.14	5.01	0.13	5.07*	0.14
NDT-2 × Pusa Ruby	10.28**	-0.87	9.95**	-0.84	10.12**	-0.86	-26.20**	-21.84**	-25.65**	-21.36**	-25.92**	-21.59**
NDT-2 × Pb. Chhuhara	-8.93**	-11.84**	-8.66**	-11.50**	-8.79**	-11.67**	-22.87**	-18.31**	-22.40**	-17.91**	-22.63**	-18.11**
NDT-2 × Arka Vikas	11.01**	11.01**	10.69**	10.69**	10.85**	10.85**	-41.12**	-37.64**	-40.26**	-36.81**	-40.69**	-37.22**
NDT-2 × Arka Meghali	-15.47**	-0.84	-15.09**	-0.81	-15.28**	-0.82	-53.78**	-51.05**	-52.66**	-49.92**	-53.21**	-50.48**
NDT-3 × Pusa Ruby	20.71**	8.50**	20.04**	8.26**	20.37**	8.38**	-16.95**	-46.07**	-16.39**	-45.05**	-16.67**	-45.55**
NDT-3 × Pb. Chhuhara	9.80**	6.29*	9.51**	6.11*	9.65**	6.20**	-3.80	-37.53**	-3.68	-36.70**	-3.74	-37.11**
NDT-3 × Arka Vikas	6.10*	6.10*	5.93*	5.93*	6.01**	6.01**	-28.97**	-28.97**	-28.33**	-28.33**	-28.64**	-28.64**
NDT-3 × Arka Meghali	-10.72**	4.74	-10.45**	4.60	-10.58**	4.67*	-49.39**	-51.79**	-48.25**	-50.65**	-48.81**	-51.22**
NDT-4 × Pusa Ruby	-14.80**	-8.69**	-14.40**	-8.44**	-14.60**	-8.56**	-27.55**	-53.01**	-26.63**	-51.84**	-27.08**	-52.42**
NDT-4 × Pb. Chhuhara	-16.97**	-11.01**	-16.51**	-10.69**	-16.74**	-10.85**	-4.51	-48.79**	-4.32	-47.72**	-4.41	-48.25**
NDT-4 × Arka Vikas	-24.03**	-18.58**	-23.38**	-18.04**	-23.70**	-18.31**	-45.85**	-45.85**	-44.84**	-44.84**	-45.34**	-45.34**
NDT-4 × Arka Meghali	-26.26**	-13.50**	-25.61**	-13.11**	-25.93**	-13.30**	-41.51**	-44.29**	-40.56**	-43.32**	-41.03**	-43.80**
NDT-5 × Pusa Ruby	-13.08**	-6.91*	-12.73**	-6.71*	-12.90**	-6.81**	-24.77**	-51.20**	-23.94**	-50.08**	-24.35**	-50.63**
NDT-5 × Pb. Chhuhara	-16.85**	-10.94**	-16.39**	-10.62**	-16.62**	-10.78**	-10.17*	-50.15**	-9.77*	-49.05**	-9.97**	-49.60**
NDT-5 × Arka Vikas	-17.33**	-11.46**	-16.87**	-11.13**	-17.10**	-11.29**	-49.50**	-49.50**	-48.41**	-48.41**	-48.95**	-48.95**
NDT-5 × Arka Meghali	-22.17**	-8.69*	-21.62**	-8.44**	-21.89**	-8.56**	-46.81**	-49.34**	-45.73**	-48.25**	-46.27**	-48.79**
NDT-6 × Pusa Ruby	-57.19**	-25.43**	-56.23**	-24.70**	-56.71**	-25.06**	-13.85**	-44.11**	-13.38**	-43.14**	-13.61**	-43.62**
NDT-6 × Pb. Chhuhara	-49.85**	-12.65**	-49.01**	-12.28**	-49.43**	-12.46**	1.90	-46.02**	1.82	-45.01**	1.86	-45.51**
NDT-6 × Arka Vikas	-62.61**	-34.87**	-61.55**	-33.86**	-62.08**	-34.35**	-39.92**	-39.92**	-40.20**	-40.20**	-40.06**	-40.06**
NDT-6 × Arka Meghali	-59.29**	-29.08**	-58.29**	-28.24**	-58.78**	-28.65**	-35.85**	-38.89**	-35.02**	-38.04**	-35.43**	-38.46**
NDT-7 × Pusa Ruby	-44.68**	-12.74**	-43.85**	-12.37**	-44.26**	-12.55	-6.72	-39.49**	-6.49	-38.62**	-6.60*	-39.05**
NDT-7 × Pb. Chhuhara	-47.30**	-16.87**	-46.42**	-16.38**	-46.86**	-16.62**	22.40**	-35.16**	21.49**	-34.39**	21.94**	-34.77**
NDT-7 × Arka Vikas	-56.89**	-31.99**	-55.83**	-31.07**	-56.36**	-31.52**	-27.24**	-27.24**	-26.64**	-26.64**	-26.94**	-26.94**

Contd..

Crosses	Number of fruits per plant						Average fruit weight (g)					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDT-7 × Arka Meghali	-38.66**	-3.24	-37.95**	-3.15	-38.30**	-3.20	-14.95**	-18.99**	-14.60**	-18.57**	-14.77**	-18.77**
NDT-8 × Pusa Ruby	-34.49**	-20.53**	-33.67**	-19.94**	-34.07**	-20.23**	-8.49*	-39.17**	-8.21*	-38.31**	-8.35**	-38.73**
NDT-8 × Pb. Chhuhara	-32.55**	-18.18**	-31.77**	-17.65**	-32.16**	-17.91**	-2.45	-35.16**	-2.37	-34.38**	-2.41	-34.77**
NDT-8 × Arka Vikas	-33.06**	-18.79**	-32.26**	-18.24**	-32.65**	-18.51**	-39.19**	-39.19**	-38.32**	-38.32**	-38.75**	-38.75**
NDT-8 × Arka Meghali	-44.19**	-32.29**	-43.13**	-31.36**	-43.65**	-31.82**	-20.08**	-23.88**	-19.62**	-23.35**	-19.85**	-23.61**
Azad T-6 × Pusa Ruby	-37.71**	-34.24**	-36.67**	-33.25**	-37.18**	-33.74**	0.18	-29.78**	0.17	-29.13**	0.18	-29.45**
Azad T-6 × Pb. Chhuhara	-33.64**	-29.95**	-32.72**	-29.08**	-33.17**	-29.51**	-3.63	-32.45**	-3.52	-31.74**	-3.58	-32.09**
Azad T-6 × Arka Vikas	-37.80**	-34.34**	-36.76**	-33.34**	-37.27**	-33.83**	-29.38**	-29.38**	-28.73**	-28.73**	-29.05**	-29.05**
Azad T-6 × Arka Meghali	-34.94**	-23.68**	-34.08**	-23.00**	-34.50**	-23.33**	-9.96**	-14.24**	-9.73**	-13.92**	-9.84**	-14.08**
Arka Saurabh × Pusa Ruby	-27.57**	-14.44**	-26.89**	-14.02**	-27.23**	-14.23**	39.31**	1.20	38.13**	1.18	38.71**	1.19
Arka Saurabh × Pb. Chhuhara	-22.25**	-8.15**	-21.70**	-7.92**	-21.97**	-8.03**	-11.49**	-35.70**	-11.15**	-34.92**	-11.32**	-35.31**
Arka Saurabh × Arka Vikas	-18.03**	-3.17	-17.58**	-3.07	-17.80**	-3.12	-40.25**	-40.25**	-39.36**	-39.36**	-39.80**	-39.80**
Arka Saurabh × Arka Meghali	-8.96**	7.55*	-8.74**	7.33*	-8.85**	7.44**	-38.13**	-41.07**	-37.25**	-40.17**	-37.69**	-40.62**
No. of crosses with significant (+) heterosis	**7**	**5**	**7**	**5**	**7**	**6**	**2**	**0**	**2**	**0**	**3**	**0**
No. of crosses with significant (-) heterosis	**32**	**26**	**32**	**26**	**33**	**26**	**30**	**38**	**30**	**38**	**31**	**38**
Range of heterosis	**-62.61-20.71**	**-34.87-11.01**	**-61.55-20.04**	**-33.86-10.69**	**-62.08-20.37**	**-34.35-10.85**	**-53.78-39.31**	**-53.01-1.20**	**-52.66-38.13**	**-51.84-1.18**	**-53.21-38.71**	**-52.42-1.19**

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table- 4.5. Contd….

Crosses	Fruit length (cm)						Fruit girth (cm)					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDT-1 × Pusa Ruby	-13.20*	-20.01**	-12.27*	-18.70**	-12.72**	-19.33**	-13.57	-12.27	-12.45	-11.25	-12.99**	-11.74*
NDT-1 × Pb. Chhuhara	1.74	-6.24	1.62	-5.83	1.67	-6.03	-2.65	-1.20	-2.44	-1.10	-2.54	-1.15
NDT-1 × Arka Vikas	-7.54	-7.54	-7.04	-7.04	-7.28	-7.28	-4.64	-3.22	-4.26	-2.95	-4.45	-3.08
NDT-1 × Arka Meghali	0.61	-7.28	0.57	-6.80	0.59	-7.03	-3.59	-2.15	-3.29	-1.97	-3.43	-2.05
NDT-2 × Pusa Ruby	-11.09	-11.09	-10.36	-10.36	-10.71*	-10.71*	-12.87	-12.87	-11.80	-11.80	-12.31*	-12.31*
NDT-2 × Pb. Chhuhara	-11.17	-11.17	-10.44	-10.44	-10.79**	-10.79**	-2.10	-2.10	-1.92	-1.92	-2.00	-2.00
NDT-2 × Arka Vikas	-22.48**	-22.48**	-21.00**	-21.00**	-21.72**	-21.72**	-10.10	-10.10	-9.26	-9.26	-9.66*	-9.66*
NDT-2 × Arka Meghali	-11.56	-11.56	-10.81	-10.81	-11.17**	-11.17**	-8.38	-8.38	-7.69	-7.69	-8.02	-8.02
NDT-3 × Pusa Ruby	-4.39	-18.84**	-4.05	-17.60**	-4.21	-18.20**	-17.51*	-10.48	-16.16*	-9.61	-16.81**	-10.02*
NDT-3 × Pb. Chhuhara	9.03	-7.45	8.34	-6.96	8.67	-7.20	-17.17*	-10.10	-15.85*	-9.26	-16.48**	-9.66*
NDT-3 × Arka Vikas	-14.42*	-14.42*	-13.48*	-13.48*	-13.93**	-13.93**	-14.76*	-7.48	-13.62*	-6.86	-14.16**	-7.16
NDT-3 × Arka Meghali	-8.68	-19.84**	-8.04	-18.54**	-8.35	-19.16**	-12.41	-4.94	-11.46	-4.53	-11.91**	-4.72
NDT-4 × Pusa Ruby	-4.16	-1.30	-3.90	-1.21	-4.03	-1.26	-8.12	6.36	-7.53	5.83	-7.82	6.09
NDT-4 × Pb. Chhuhara	-11.31	-8.66	-10.59	-8.09	-10.94**	-8.37*	-8.58	5.84	-7.95	5.35	-8.25	5.58
NDT-4 × Arka Vikas	-10.98	-8.32	-10.28	-7.77	-10.61**	-8.03	-18.72**	-5.91	-17.37**	-5.42	-18.02**	-5.66
NDT-4 × Arka Meghali	-22.58**	-20.27**	-21.14**	-18.94**	-21.84**	-19.58**	-22.93**	-10.78	-21.26**	-9.88	-22.06**	-10.31*
NDT-5 × Pusa Ruby	-16.09*	-28.84**	-14.86*	-26.95**	-15.45**	-27.87**	-15.40	-20.95**	-14.04	-19.21**	-14.69**	-20.05**
NDT-5 × Pb. Chhuhara	-9.50	-23.26**	-8.77	-21.73**	-9.12	-22.47**	-7.55	-13.62	-6.89	-12.49	-7.21	-13.03**
NDT-5 × Arka Vikas	-18.32**	-18.32**	-17.12**	-17.12**	-17.70**	-17.70**	-0.67	-0.67	-0.62	-0.62	-0.64	-0.64
NDT-5 × Arka Meghali	3.65	-9.01	3.38	-8.42	3.51	-8.70*	15.43	7.86	14.07	7.20	14.72**	7.52
NDT-6 × Pusa Ruby	-5.78	-21.70**	-5.33	-20.28**	-5.55	-20.96**	-4.01	-10.48	-3.66	-9.61	-3.83	-10.02*
NDT-6 × Pb. Chhuhara	2.39	-16.37**	2.20	-15.30**	2.29	-15.82**	-2.57	-9.13	-4.78	-10.66	-3.72	-9.93*
NDT-6 × Arka Vikas	-2.04	-2.04	-1.90	-1.90	-1.97	-1.97	-8.38	-8.38	-7.69	-7.69	-8.02	-8.02
NDT-6 × Arka Meghali	-4.24	-15.94**	-3.93	-14.89**	-4.08	-15.40**	-4.73	-11.15	-6.75	-12.51	-5.79	-11.86*
NDT-7 × Pusa Ruby	0.16	-16.63**	0.14	-15.54**	0.15	-16.07**	10.08	1.35	9.18	1.24	9.61	1.29
NDT-7 × Pb. Chhuhara	21.12**	0.82	19.48**	0.77	20.27**	0.79	14.17	-1.72	12.82	-1.58	13.46*	-1.65
NDT-7 × Arka Vikas	-12.73*	-12.73*	-11.90*	-11.90*	-12.30**	-12.30**	-3.74	-3.74	-3.43	-3.43	-3.58	-3.58

Contd..

Crosses	Fruit length (cm)						Fruit girth (cm)					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDT-7 × Arka Meghali	-2.86	-14.72*	-2.65	-13.76*	-2.75	-14.23**	9.21	-0.60	8.37	-0.55	8.77	-0.57
NDT-8 × Pusa Ruby	10.72	-6.54	9.90	-6.11	10.30*	-6.32	5.36	-2.99	4.88	-2.74	5.11	-2.86
NDT-8 × Pb. Chhuhara	-4.72	-19.58**	-4.36	-18.29**	-4.53	-18.91**	7.40	-2.24	6.73	-2.06	7.05	-2.15
NDT-8 × Arka Vikas	-13.51*	-13.51*	-12.63*	-12.63*	-13.05**	-13.05**	-2.62	-2.62	-2.40	-2.40	-2.51	-2.51
NDT-8 × Arka Meghali	-1.73	-13.73*	-1.60	-12.83*	-1.66	-13.26**	8.55	-1.20	7.78	-1.10	8.15	-1.15
Azad T-6 × Pusa Ruby	-1.59	-11.43	-1.47	-10.68	-1.53	-11.05**	-5.39	-4.19	-4.95	-3.84	-5.16	-4.01
Azad T-6 × Pb. Chhuhara	-3.18	-12.86*	-2.95	-12.02*	-3.06	-12.43**	-12.49	-11.37	-11.46	-10.43	-11.95*	-10.88*
Azad T-6 × Arka Vikas	-10.52	-10.52	-9.83	-9.83	-10.17*	-10.17*	-10.64	-9.50	-9.77	-8.71	-10.19*	-9.09
Azad T-6 × Arka Meghali	-0.48	-10.44	-0.45	-9.75	-0.46	-10.08*	-3.40	-2.17	-3.12	-1.99	-3.25	-2.08
Arka Saurabh × Pusa Ruby	-13.50*	-6.76	-12.67*	-6.31	-13.07**	-6.53	-14.40*	-2.62	-13.34*	-2.40	-13.85**	-2.51
Arka Saurabh × Pb. Chhuhara	-21.86**	-15.76*	-20.52**	-14.73*	-21.17**	-15.23**	-2.63	10.78	-2.44	9.88	-2.53	10.31*
Arka Saurabh × Arka Vikas	-7.71	-0.52	-7.24	-0.49	-7.47	-0.50	0.53	14.37	0.49	13.17	0.51	13.75**
Arka Saurabh × Arka Meghali	-20.97**	-14.81*	-19.69**	-13.84*	-20.31**	-14.31**	-19.73**	-8.68	-18.28**	-7.96	-18.98**	-8.30
No. of crosses with significant (+) heterosis	**1**	**0**	**1**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**1**	**2**
No. of crosses with significant (-) heterosis	**11**	**21**	**11**	**21**	**17**	**28**	**7**	**1**	**7**	**1**	**14**	**12**
Range of heterosis	**-22.58-21.12**	**-28.84-0.82**	**-21.14-19.48**	**-26.95-0.77**	**-21.84-20.27**	**-27.87-0.79**	**-22.93-15.43**	**-20.95-14.37**	**-21.26-14.07**	**-19.21-13.17**	**-22.06-14.72**	**-20.05-13.75**

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table- 4.5. Contd….

Crosses	Number of locules per fruit						Pericarp thickness (mm)					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDT-1 × Pusa Ruby	-9.85	5.65	-9.16	5.19	-9.49	5.41	-29.33**	-24.26**	-27.30**	-22.47**	-28.28**	-23.33**
NDT-1 × Pb. Chhuhara	-6.29	9.83	-5.85	9.03	-6.06	9.41	-22.99**	-17.46**	-21.40**	-16.18*	-22.17**	-16.80**
NDT-1 × Arka Vikas	-5.66	10.57	-5.26	9.71	-5.45	10.12	-26.80**	-21.54**	-24.94**	-19.95**	-25.84**	-20.72**
NDT-1 × Arka Meghali	0.00	17.20	0.00	15.80	0.00	16.47*	-28.79**	-23.67**	-26.80**	-21.93**	-27.76**	-22.77**
NDT-2 × Pusa Ruby	-10.44	13.76	-9.76	12.64	-10.09	13.18	-6.91	-11.06	-6.37	-10.25	-6.63	-10.64*
NDT-2 × Pb. Chhuhara	-20.70*	0.74	-19.35*	0.68	-20.00**	0.71	-2.64	-6.99	-2.44	-6.47	-2.53	-6.72
NDT-2 × Arka Vikas	-0.77	26.04*	-0.72	23.93*	-0.75	24.94**	-1.55	-1.55	-1.44	-1.44	-1.49	-1.49
NDT-2 × Arka Meghali	-15.47	7.37	-14.47	6.77	-14.95*	7.06	-6.30	-10.48	-5.81	-9.71	-6.04	-10.08*
NDT-3 × Pusa Ruby	-59.31**	-53.32**	-55.07**	-48.98**	-57.11**	-51.06**	-6.34	-11.06	-5.85	-10.25	-6.08	-10.64*
NDT-3 × Pb. Chhuhara	-22.91*	-11.55	-21.27*	-10.61	-22.06**	-11.06	-11.04	-15.52*	-10.18	-14.38*	-10.59*	-14.93**
NDT-3 × Arka Vikas	-28.77**	-18.26	-26.71**	-16.78	-27.70**	-17.49	-11.64	-11.64	-10.78	-10.78	-11.20*	-11.20*
NDT-3 × Arka Meghali	-4.28	9.83	-3.98	9.03	-4.12	9.41	-16.35*	-20.57**	-15.08*	-19.05**	-15.69**	-19.78**
NDT-4 × Pusa Ruby	7.33	18.67	6.79	17.16	7.05	17.88*	-9.33	-22.70**	-8.54	-21.03**	-8.92	-21.84**
NDT-4 × Pb. Chhuhara	10.44	22.11	9.67	20.32	10.04	21.18*	-17.93*	-22.70**	-16.53*	-21.03**	-17.20**	-21.84**
NDT-4 × Arka Vikas	-9.56	0.00	-8.85	0.00	-9.19	0.00	-4.66	-4.66	-4.31	-4.31	-4.48	-4.48
NDT-4 × Arka Meghali	-8.22	1.47	-7.61	1.35	-7.91	1.41	-1.58	-15.52*	-1.45	-14.38*	-1.51	-14.93**
NDT-5 × Pusa Ruby	-13.04	-6.63	-12.05	-6.09	-12.53	-6.35	0.45	-13.20	0.41	-12.22	0.43	-12.69**
NDT-5 × Pb. Chhuhara	-9.15	-2.46	-8.46	-2.26	-8.79	-2.35	-6.59	-12.03	-6.08	-11.14	-6.33	-11.57*
NDT-5 × Arka Vikas	-17.62	-11.55	-16.28	-10.61	-16.92*	-11.06	-8.93	-8.93	-8.27	-8.27	-8.58	-8.58
NDT-5 × Arka Meghali	-6.00	3.93	-5.56	3.61	-5.77	3.76	5.39	-8.93	4.93	-8.27	5.15	-8.58
NDT-6 × Pusa Ruby	34.75**	40.05**	32.03**	36.79**	33.33**	38.35**	-3.87	-18.05*	-3.54	-16.72*	-3.70	-17.36**
NDT-6 × Pb. Chhuhara	22.22	27.03*	20.48	24.83*	21.32**	25.88**	-2.61	-8.28	-2.41	-7.67	-2.50	-7.96
NDT-6 × Arka Vikas	-7.80	-4.18	-7.19	-3.84	-7.48	-4.00	-14.17	-14.17	-13.12	-13.12	-13.62**	-13.62**
NDT-6 × Arka Meghali	-12.67	-3.44	-11.73	-3.16	-12.18	-3.29	15.83	-0.58	14.48	-0.54	15.12**	-0.56
NDT-7 × Pusa Ruby	-9.09	-1.72	-8.40	-1.58	-8.73	-1.65	-2.43	-16.82*	-2.22	-15.58*	-2.32	-16.17**
NDT-7 × Pb. Chhuhara	-1.59	6.39	-1.47	5.87	-1.53	6.12	-8.86	-14.17	-8.17	-13.12	-8.50	-13.62**
NDT-7 × Arka Vikas	-12.95	-5.90	-11.97	-5.42	-12.45	-5.65	-5.82	-5.82	-5.39	-5.39	-5.60	-5.60

Contd..

Crosses	Number of locules per fruit						Pericarp thickness (mm)					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDT-7 × Arka Meghali	8.22	19.66	7.61	18.06	7.91	18.82*	-2.03	-15.91*	-1.86	-14.74*	-1.94	-15.30**
NDT-8 × Pusa Ruby	1.79	-2.46	1.64	-2.26	1.72	-2.35	-7.57	-19.40*	-6.93	-17.97*	-7.24	-18.66**
NDT-8 × Pb. Chhuhara	1.59	-5.90	1.45	-5.42	1.52	-5.65	10.10	3.69	9.31	3.42	9.69	3.55
NDT-8 × Arka Vikas	-4.18	-4.18	-3.84	-3.84	-4.00	-4.00	-2.91	-2.91	-2.70	-2.70	-2.80	-2.80
NDT-8 × Arka Meghali	14.00	26.04*	12.96	23.93*	13.46	24.94**	9.12	-4.85	8.36	-4.49	8.73	-4.67
Azad T-6 × Pusa Ruby	8.70	22.85	8.06	20.99	8.37	21.88**	-18.99**	-8.93	-17.73**	-8.27	-18.34**	-8.58
Azad T-6 × Pb. Chhuhara	-5.00	7.37	-4.64	6.77	-4.81	7.06	-25.03**	-15.72*	-23.37**	-14.56*	-24.17**	-15.12**
Azad T-6 × Arka Vikas	5.87	19.66	5.44	18.06	5.65	18.82*	-20.71**	-10.87	-19.34**	-10.07	-20.01**	-10.45*
Azad T-6 × Arka Meghali	-0.65	12.29	-0.60	11.29	-0.63	11.76	-21.98**	-12.29	-20.53**	-11.38	-21.23**	-11.82*
Arka Saurabh × Pusa Ruby	6.70	5.65	6.15	5.19	6.41	5.41	-11.54	-16.69*	-10.64	-15.46*	-11.07*	-16.05**
Arka Saurabh × Pb. Chhuhara	20.84	19.66	19.13	18.06	19.95*	18.82*	-4.12	-9.70	-3.80	-8.99	-3.95	-9.33
Arka Saurabh × Arka Vikas	17.20	17.20	15.80	15.80	16.47*	16.47*	-23.29**	-23.29**	-21.57**	-21.57**	-22.40**	-22.40**
Arka Saurabh × Arka Meghali	-8.22	1.47	-7.61	1.35	-7.91	1.41	-11.54	-16.69*	-10.64	-15.46*	-11.07*	-16.05**
No. of crosses with significant (+) heterosis	**1**	**4**	**1**	**4**	**4**	**12**	**0**	**0**	**0**	**0**	**1**	**0**
No. of crosses with significant (-) heterosis	**4**	**1**	**4**	**1**	**6**	**1**	**11**	**16**	**11**	**17**	**16**	**27**
Range of heterosis	**-59.31-34.75**	**-53.32-40.05**	**-55.07-32.03**	**-48.98-36.79**	**-57.11-33.33**	**-51.06-38.35**	**-29.33-15.83**	**-24.26-3.69**	**-27.30-14.48**	**-22.47-3.42**	**-28.28-15.12**	**-23.33-3.55**

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table- 4.5. Contd….

Crosses	Total soluble solid (TSS)						Ascorbic acid (mg/100 g fresh fruit)					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDT-1 × Pusa Ruby	-14.18	-15.04*	-13.31	-14.12*	-13.73**	-14.57**	-18.28**	-12.36*	-18.54**	-12.82*	-18.41**	-12.59**
NDT-1 × Pb. Chhuhara	-15.53*	-16.38*	-14.57*	-15.38*	-15.04**	-15.86**	-37.39**	-32.86**	-22.99**	-17.59**	-30.09**	-25.10**
NDT-1 × Arka Vikas	-2.34	-2.34	-2.20	-2.20	-2.27	-2.27	-34.94**	-30.23**	-36.31**	-31.84**	-35.63**	-31.05**
NDT-1 × Arka Meghali	-15.87*	-16.71*	-14.89*	-15.69*	-15.36**	-16.19**	-11.59*	-5.10	15.71**	23.93**	2.26	9.64*
NDT-2 × Pusa Ruby	10.14	-0.17	9.46	-0.16	9.79	-0.16	26.60**	13.65*	10.03	12.37*	21.37**	13.00**
NDT-2 × Pb. Chhuhara	-2.70	-9.69	-2.52	-9.10	-2.61	-9.39	-6.99	-8.15	-8.16	-6.20	-6.00	-7.16
NDT-2 × Arka Vikas	3.34	3.34	3.14	3.14	3.24	3.24	-17.05*	-17.05**	-16.60**	-14.82**	-15.92**	-15.92**
NDT-2 × Arka Meghali	12.91	2.34	12.04	2.20	12.46*	2.27	-19.73**	-13.84**	-19.16**	-13.41*	-19.44**	-13.62**
NDT-3 × Pusa Ruby	19.58*	-1.00	18.15*	-0.94	18.84**	-0.97	-6.01	-15.63**	-5.81	-15.14**	-5.91	-15.38**
NDT-3 × Pb. Chhuhara	-3.78	-10.70	-3.53	-10.04	-3.65	-10.36*	-6.56	-7.73	-6.35	-7.49	-6.45	-7.61*
NDT-3 × Arka Vikas	-3.68	-3.68	-3.45	-3.45	-3.56	-3.56	2.77	2.77	2.42	2.42	2.59	2.59
NDT-3 × Arka Meghali	10.16	-0.33	9.48	-0.31	9.81	-0.32	-8.70	-2.00	-6.76	-0.13	-7.71*	-1.05
NDT-4 × Pusa Ruby	5.45	-12.70	5.05	-11.92	5.24	-12.30*	18.59**	6.46	17.46**	5.82	18.01**	6.13
NDT-4 × Pb. Chhuhara	-5.94	-12.70	-5.55	-11.92	-5.74	-12.30*	11.84*	10.44*	11.42*	10.06	11.63**	10.25**
NDT-4 × Arka Vikas	-7.69	-7.69	-7.22	-7.22	-7.45	-7.45	15.89**	15.89**	15.40**	15.40**	15.64**	15.64**
NDT-4 × Arka Meghali	-5.36	-14.37	-5.00	-13.49	-5.17	-13.92**	5.41	13.14*	5.25	12.73*	5.33	12.93**
NDT-5 × Pusa Ruby	-29.89**	-24.74**	-28.18**	-23.22**	-29.01**	-23.95**	37.28**	23.24**	57.67**	42.05**	47.65**	32.79**
NDT-5 × Pb. Chhuhara	-6.54	0.33	-6.16	0.31	-6.35	0.32	62.68**	60.64**	58.12**	56.20**	60.36**	58.39**
NDT-5 × Arka Vikas	-22.73**	-17.05*	-21.43**	-16.00*	-22.06**	-16.51**	54.35**	54.35**	50.11**	50.11**	52.20**	52.20**
NDT-5 × Arka Meghali	-10.90	-4.35	-10.27	-4.08	-10.58*	-4.21	47.75**	58.59**	46.36**	56.76**	47.04**	57.66**
NDT-6 × Pusa Ruby	-12.75	-16.55*	-11.94	-15.53*	-12.33*	-16.02**	-16.41**	-13.59*	-17.27**	-13.16*	-16.85**	-13.37**
NDT-6 × Pb. Chhuhara	0.35	-4.01	0.33	-3.77	0.34	-3.88	-17.25**	-14.45**	-18.07**	-14.00*	-17.67**	-14.23**
NDT-6 × Arka Vikas	-2.45	-2.45	-2.30	-2.30	-2.37	-2.37	-21.49**	-18.84**	-22.12**	-18.25**	-21.81**	-18.54**
NDT-6 × Arka Meghali	-18.17*	-21.73**	-17.01*	-20.40**	-17.57**	-21.04**	-20.31**	-14.46**	-19.72**	-14.01*	-20.01**	-14.23**
NDT-7 × Pusa Ruby	-6.32	-15.71*	-5.89	-14.75*	-6.10	-15.21**	-33.75**	-24.39**	-22.37**	-11.75*	-27.98**	-17.97**
NDT-7 × Pb. Chhuhara	15.31	7.02	14.30	6.59	14.79**	6.80	-37.33**	-28.49**	-36.31**	-27.60**	-36.82**	-28.04**
NDT-7 × Arka Vikas	-16.21*	-16.21*	-15.22*	-15.22*	-15.70**	-15.70**	-33.75**	-24.39**	-32.83**	-23.63**	-33.28**	-24.01**

Contd..

Crosses	Total soluble solid (TSS)						Ascorbic acid (mg/100 g fresh fruit)					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDT-7 × Arka Meghali	-10.34	-18.89*	-9.65	-17.73*	-9.99	-18.29**	-34.51**	-25.26**	-33.56**	-24.48**	-34.03**	-24.86**
NDT-8 × Pusa Ruby	-8.17	-6.02	-7.68	-5.65	-7.91	-5.83	-38.28**	-23.52**	-37.32**	-22.79**	-37.80**	-23.15**
NDT-8 × Pb. Chhuhara	-27.60**	-25.91**	-25.95**	-24.32**	-26.75**	-25.09**	-18.08**	1.52	-26.59**	-9.57	-22.39**	-4.11
NDT-8 × Arka Vikas	-7.08	-4.90	-6.65	-4.60	-6.86	-4.75	-10.30*	11.17*	-6.59	15.07**	-8.42**	13.15**
NDT-8 × Arka Meghali	-17.31*	-15.38*	-16.27*	-14.44*	-16.78**	-14.89**	3.37	28.10**	5.35	29.77**	4.37	28.95**
Azad T-6 × Pusa Ruby	-11.14	-12.03	-10.45	-11.30	-10.79*	-11.65*	-0.46	29.87**	1.51	31.49**	0.54	30.69**
Azad T-6 × Pb. Chhuhara	-3.38	-4.35	-3.17	-4.08	-3.27	-4.21	9.06*	42.30**	13.43**	46.93**	11.27**	44.65**
Azad T-6 × Arka Vikas	-8.19	-8.19	-7.69	-7.69	-7.93	-7.93	11.74**	45.80**	14.08**	47.77**	12.93**	46.80**
Azad T-6 × Arka Meghali	-0.34	-1.34	-0.32	-1.26	-0.33	-1.29	16.02**	51.38**	15.64**	49.78**	15.83**	50.57**
Arka Saurabh × Pusa Ruby	10.03	-1.00	9.35	-0.94	9.68	-0.97	-31.33**	-25.13**	1.69	3.68	-15.11**	-10.50**
Arka Saurabh × Pb. Chhuhara	-3.78	-10.70	-3.53	-10.04	-3.65	-10.36*	-24.22**	-17.38**	-18.43**	-16.84**	-21.38**	-17.11**
Arka Saurabh × Arka Vikas	-17.72*	-17.72*	-16.63*	-16.63*	-17.16**	-17.16**	-19.66**	-12.41*	-18.71**	-17.12**	-19.19**	-14.80**
Arka Saurabh × Arka Meghali	27.89**	15.71*	26.02**	14.75*	26.92**	15.21**	-24.09**	-17.23**	-19.85**	-14.15**	-21.35**	-15.67**
No. of crosses with significant (+) heterosis	**2**	**1**	**2**	**1**	**4**	**1**	**11**	**14**	**11**	**14**	**11**	**15**
No. of crosses with significant (-) heterosis	**9**	**13**	**9**	**13**	**13**	**19**	**21**	**19**	**18**	**18**	**21**	**20**
Range of heterosis	**-29.89-27.89**	**-25.91-15.71**	**-28.18-26.02**	**-24.32-14.75**	**-29.01-26.92**	**-25.09-15.21**	**-38.28-62.68**	**-32.86-60.64**	**-37.32-58.12**	**-31.84-56.76**	**-37.80-60.36**	**-31.05-58.39**

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table- 4.5. Contd….

Crosses	Total fruit yield per plant (kg)					
	Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV
NDT-1 × Pusa Ruby	-3.62	-22.67**	-3.19	-20.47**	-3.40	-21.52**
NDT-1 × Pb. Chhuhara	0.72	-19.19**	-4.47	-21.52**	-2.04	-20.41**
NDT-1 × Arka Vikas	-22.38**	-22.38**	-20.21**	-20.21**	-21.24**	-21.24**
NDT-1 × Arka Meghali	-25.14**	-23.26**	-22.75**	-21.00**	-23.89**	-22.07**
NDT-2 × Pusa Ruby	-12.09	-16.18*	-10.87	-14.61*	-11.45*	-15.36**
NDT-2 × Pb. Chhuhara	-20.73**	-24.42**	-18.63**	-22.05**	-19.62**	-23.17**
NDT-2 × Arka Vikas	-13.08	-13.08	-11.81	-11.81	-12.41*	-12.41*
NDT-2 × Arka Meghali	-13.80*	-11.63	-12.49*	-10.50	-13.11**	-11.03*
NDT-3 × Pusa Ruby	1.52	-22.38**	1.33	-20.21**	1.42	-21.24**
NDT-3 × Pb. Chhuhara	8.49	-17.05*	7.44	-15.40*	7.93	-16.18**
NDT-3 × Arka Vikas	-7.85	-7.85	-7.09	-7.09	-7.45	-7.45
NDT-3 × Arka Meghali	-26.28**	-24.42**	-23.78**	-22.05**	-24.97**	-23.17**
NDT-4 × Pusa Ruby	-1.21	-29.07**	-1.06	-26.25**	-1.13	-27.59**
NDT-4 × Pb. Chhuhara	-0.81	-29.07**	-0.71	-26.25**	-0.76	-27.59**
NDT-4 × Arka Vikas	-14.53*	-14.53*	-13.12*	-13.12*	-13.79**	-13.79**
NDT-4 × Arka Meghali	-34.22**	-32.56**	-30.97**	-29.40**	-32.51**	-30.90**
NDT-5 × Pusa Ruby	-30.68**	-49.42**	-26.74**	-44.62**	-28.57**	-46.90**
NDT-5 × Pb. Chhuhara	-6.37	-31.69**	-5.56	-28.61**	-5.94	-30.07**
NDT-5 × Arka Vikas	-49.42**	-49.42**	-44.62**	-44.62**	-46.90**	-46.90**
NDT-5 × Arka Meghali	-34.78**	-33.14**	-31.48**	-29.92**	-33.05**	-31.45**
NDT-6 × Pusa Ruby	-3.62	-22.67**	-3.19	-20.47**	-3.40	-21.52**
NDT-6 × Pb. Chhuhara	-43.12**	-54.36**	-38.02**	-49.08**	-40.41**	-51.59**
NDT-6 × Arka Vikas	-30.14**	-30.14**	-27.21**	-27.21**	-28.60**	-28.60**
NDT-6 × Arka Meghali	-34.78**	-33.14**	-31.48**	-29.92**	-33.05**	-31.45**
NDT-7 × Pusa Ruby	-29.59**	-43.51**	-23.57**	-39.28**	-26.44**	-41.29**
NDT-7 × Pb. Chhuhara	-33.33**	-46.51**	-26.98**	-41.99**	-30.01**	-44.14**
NDT-7 × Arka Vikas	-31.69**	-31.69**	-28.61**	-28.61**	-30.07**	-30.07**
NDT-7 × Arka Meghali	-30.91**	-29.17**	-30.71**	-29.13**	-30.80**	-29.15**
NDT-8 × Pusa Ruby	-12.75	-24.42**	-4.81	-22.05**	-8.69	-23.17**
NDT-8 × Pb. Chhuhara	-12.08	-23.84**	-5.98	-23.01**	-8.96	-23.40**
NDT-8 × Arka Vikas	-24.13**	-24.13**	-21.78**	-21.78**	-22.90**	-22.90**
NDT-8 × Arka Meghali	-35.07**	-33.43**	-26.95**	-25.28**	-30.80**	-29.15**
Azad T-6 × Pusa Ruby	-7.80	-24.42**	-7.94	-22.92**	-7.88	-23.63**
Azad T-6 × Pb. Chhuhara	-16.43*	-31.49**	-15.99*	-29.66**	-16.20**	-30.53**
Azad T-6 × Arka Vikas	-24.71**	-24.71**	-22.31**	-22.31**	-23.45**	-23.45**
Azad T-6 × Arka Meghali	-34.59**	-32.95**	-31.31**	-29.75**	-32.87**	-31.26**
Arka Saurabh × Pusa Ruby	-8.25	-17.05*	-1.12	-15.40*	-4.60	-16.18**
Arka Saurabh × Pb. Chhuhara	-15.43*	-23.55**	-7.98	-21.26**	-11.62*	-22.34**
Arka Saurabh × Arka Vikas	-27.13**	-27.13**	-24.50**	-24.50**	-25.75**	-25.75**
Arka Saurabh × Arka Meghali	-30.81**	-29.07**	-25.24**	-23.53**	-27.89**	-26.16**
No. of crosses with significant (+) heterosis	**0**	**0**	**0**	**0**	**0**	**0**
No. of crosses with significant (-) heterosis	**26**	**37**	**24**	**37**	**27**	**39**
Range of heterosis	**-49.42-8.49**	**-54.36-(-7.85)**	**-44.62-7.44**	**-49.08-(-7.09)**	**-46.90-7.93**	**-51.59-(-7.45)**

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

In pooled, heterosis for days to 50 per cent flowering over better parent ranged from -18.51 per cent (NDT-4 × Arka Meghali) to 9.94 per cent (NDT-2 × Pusa Ruby). Out of forty crosses, only four crosses showed negative and significant heterosis. The best three F_1's showing heterobeltiosis in negative direction were NDT-4 × Arka Meghali (-18.51%), NDT-1 × Arka Meghali (-11.48%) and NDT-6 × Pb. Chhuhara (-8.38%) while, ten crosses showed positive and significant heterosis over better parent for days to 50 % flowering. Heterosis over standard variety ranged from -12.30 per cent (NDT-4 × Arka Meghali) to 12.22 per cent (NDT-6 × Arka Meghali). Out of forty crosses, only one cross, NDT-4 × Arka Meghali (-12.30%) showed negative standard heterosis while, seventeen crosses showed significant and positive heterosis over standard variety for days to 50 per cent flower anthesis.

4.3.2 Days to first fruit set

In Y_1, heterosis for days to first fruit set over better parent ranged from –13.90 per cent (NDT-4 × Arka Meghali) to 9.67 per cent (NDT-5 × Arka Vikas). Out of forty crosses, only two crosses, NDT-4 × Arka Meghali (-13.90%) and NDT-1 × Arka Meghali (-8.51 %) showed negative and significant heterobeltiosis while, only four crosses showed positive and significant heterosis over better parent for days to first fruit set. Heterosis over standard variety ranged from -7.10 per cent (NDT-4 × Arka Meghali) to 12.65 per cent (NDT-2 × Arka Meghali). Out of forty crosses, none of the cross showed negative standard heterosis while, fifteen crosses showed significant and positive heterosis over standard variety for days to first fruit set.

In Y_2, heterosis for days to first fruit set over better parent ranged from -13.46 per cent (NDT-4 × Arka Meghali) to 9.34 per cent (NDT-5 × Arka Vikas). Out of forty crosses, only two crosses, NDT-4 × Arka Meghali (-13.46%) and NDT-1 × Arka Meghali (-8.24 %) showed negative and

significant heterobeltiosis while, only four crosses showed positive and significant heterosis over better parent for days to first fruit set. Heterosis over standard variety ranged from -6.85 per cent (NDT-4 × Arka Meghali) to 12.22 per cent (NDT-2 × Arka Meghali). Out of forty crosses, none of the cross showed negative standard heterosis while, fifteen crosses showed significant and positive heterosis over standard variety for days to first fruit set.

In pooled, heterosis for days to first fruit set over better parent ranged from -13.68 per cent (NDT-4 × Arka Meghali) to 9.50 per cent (NDT-5 × Arka Vikas). Out of forty crosses, only three crosses, NDT-4 × Arka Meghali (-13.68%), NDT-1 × Arka Meghali (-8.38 %) and NDT-7 × Arka Vikas (-6.63%) showed negative and significant heterobeltiosis while, seven crosses showed positive and significant heterosis over better parent for days to first fruit set. Heterosis over standard variety ranged from -6.97 per cent (NDT-4 × Arka Meghali) to 12.43 per cent (NDT-2 × Arka Meghali and NDT-6 × Arka Meghali). Out of forty crosses, only one cross, NDT-4 × Arka Meghali (-6.97%) showed negative standard heterosis while, twenty four crosses showed significant and positive heterosis over standard variety for days to first fruit set.

4.3.3 Days to first fruit harvest

In Y_1, heterosis for days to first fruit harvest over better parent ranged from -8.43 per cent (NDT-4 × Arka Meghali) to 5.40 per cent (Azad T-6 × Pb. Chhuhara). Out of forty crosses, only two crosses, NDT-4 × Arka Meghali (-8.43%) and NDT-1 × Arka Meghali (-5.54 %) showed negative and significant heterobeltiosis while, only one cross showed positive and significant heterosis over better parent for days to first fruit harvest. Heterosis over standard variety ranged from -4.80 per cent (NDT-4 × Arka Meghali) to 6.69 per cent (NDT-3 × Pusa Ruby). Out of forty crosses, none of the cross showed negative standard heterosis while, eight crosses showed significant

and positive heterosis over standard variety for days to first fruit harvest.

In Y_2, heterosis for days to first fruit harvest over better parent ranged from -8.26 per cent (NDT-4 × Arka Meghali) to 5.28 per cent (Azad T-6 × Pb. Chhuhara). Out of forty crosses, only two crosses, NDT-4 × Arka Meghali (-8.26%) and NDT-1 × Arka Meghali (-5.43%) showed negative and significant heterobeltiosis while, only one cross showed positive and significant heterosis over better parent for days to first fruit harvest. Heterosis over standard variety ranged from -4.70 per cent (NDT-4 × Arka Meghali) to 6.55 per cent (NDT-3 × Pusa Ruby). Out of forty crosses, none of the cross showed negative standard heterosis while, eight crosses showed significant and positive heterosis over standard variety for days to first fruit harvest.

In pooled, heterosis for days to first fruit harvest over better parent ranged from -8.34 per cent (NDT-4 × Arka Meghali) to 5.34 per cent (Azad T-6 × Pb. Chhuhara). Out of forty crosses, only three crosses, NDT-4 × Arka Meghali (-8.34%), NDT-1 × Arka Meghali (-5.48%) and NDT-7 × Arka Vikas (-3.70%) showed negative and significant heterobeltiosis while, five crosses showed positive and significant heterosis over better parent for days to first fruit harvest. Heterosis over standard variety ranged from -4.74 per cent (NDT-4 × Arka Meghali) to 6.62 per cent (NDT-3 × Pusa Ruby). Out of forty crosses, only one cross NDT-4 × Arka Meghali (-4.74%) showed negative standard heterosis while, sixteen crosses showed significant and positive heterosis over standard variety for days to first fruit harvest.

4.3.4 Plant height (cm)

In Y_1, the estimates of heterosis over better parent ranged from -23.09 to 42.11 per cent for cross NDT-2 × Pb. Chhuhara and Azad T-6 × Pusa Ruby, respectively. Out of forty crosses, best five F_1's namely Azad T-6 × Pusa Ruby (42.11%), NDT-5 × Pusa Ruby (23.62%), NDT-7 × Pusa Ruby (21.87%), Azad T-6 × Arka Meghali (19.40%) and NDT-4 × Pusa Ruby (18.15%)

exhibited significant heterosis over better parent in positive direction. Sixteen crosses showed negative and significant heterosis over better parent. The heterosis over standard variety ranged from -18.58 to 91.94 % for cross NDT-2 × Pb. Chhuhara and Azad T-6 × Pusa Ruby, respectively. Out of forty crosses, twenty two crosses showed positive and significant heterosis over standard variety. The best five F_1's showing standard heterosis in positive direction were Azad T-6 × Pusa Ruby (91.54%), NDT-5 × Pusa Ruby (82.61%), NDT-4 × Pusa Ruby (79.88%), NDT-5 × Pb. Chhuhara (67.66%) and NDT-7 × Pusa Ruby (64.26%) while, eight crosses showed significant and negative heterosis over standard variety for plant hieght at last picking stage.

In Y_2, the estimates of heterosis over better parent ranged from -21.92 to 43.27 per cent for cross NDT-1 × Pb. Chhuhara and Azad T-6 × Pusa Ruby, respectively. Out of forty crosses, best five F_1's namely Azad T-6 × Pusa Ruby (43.27%), NDT-5 × Pusa Ruby (26.35%), NDT-7 × Pusa Ruby (22.26%), Azad T-6 × Arka Meghali (19.83%) and NDT-4 × Pusa Ruby (17.97%) exhibited significant heterosis over better parent in positive direction. Fifteen crosses showed negative and significant heterosis over better parent. The heterosis over standard variety ranged from -18.30 to 91.35 % for cross NDT-2 × Pb. Chhuhara and Azad T-6 × Pusa Ruby, respectively. Out of forty crosses, twenty two crosses showed positive and significant heterosis over standard variety. The best five F_1's showing standard heterosis in positive direction were Azad T-6 × Pusa Ruby (91.35%), NDT-5 × Pusa Ruby (85.35%), NDT-4 × Pusa Ruby (78.68%), NDT-5 × Pb. Chhuhara (66.65%) and NDT-7 × Pusa Ruby (63.29%) while, eight crosses showed significant and negative heterosis over standard variety for plant hieght at last picking stage.

In pooled, the estimates of heterosis over better parent ranged from

-22.41 to 42.70 per cent for cross NDT-2 × Pb. Chhuhara and Azad T-6 × Pusa Ruby, respectively. Out of forty crosses, best five F_1's namely Azad T-6 × Pusa Ruby (42.70%), NDT-5 × Pusa Ruby (24.99%), NDT-7 × Pusa Ruby (22.07%), Azad T-6 × Arka Meghali (19.61%) and NDT-4 × Pusa Ruby (18.06%) exhibited significant heterosis over better parent in positive direction. Eightteen crosses showed negative and significant heterosis over better parent. The heterosis over standard variety ranged from -18.43 to 91.45 % for cross NDT-2 × Pb. Chhuhara and Azad T-6 × Pusa Ruby, respectively. Out of forty crosses, twenty three crosses showed positive and significant heterosis over standard variety. The best five F_1's showing standard heterosis in positive direction were Azad T-6 × Pusa Ruby (91.45%), NDT-5 × Pusa Ruby (83.99%), NDT-4 × Pusa Ruby (79.27%), NDT-5 × Pb. Chhuhara (67.15%) and NDT-7 × Pusa Ruby (63.77%) while, ten crosses showed significant and negative heterosis over standard variety for plant hieght at last picking stage.

4.3.5 Number of primary branches per plant

In Y_1, the estimates of heterosis over better parent ranged from -39.97 to 24.01 per cent for cross Arka Saurabh × Arka Vikas and Azad T-6 × Arka Meghali, respectively. Out of forty crosses, only one F_1's namely Azad T-6 × Arka Meghali (24.01%) exhibited significant heterosis over better parent in positive direction. ten crosses showed negative and significant heterosis over better parent. The heterosis over standard variety ranged from -28.63 to 28.63 % for cross Arka Saurabh × Arka Vikas and Azad T-6 × Arka Meghali, respectively. Out of forty crosses, only one cross, Azad T-6 × Arka Meghali (28.63%) showed positive and significant heterosis over standard variety. while, only one crosses showed significant and negative heterosis over standard variety for number of primary branches per plant.

In Y_2, the estimates of heterosis over better parent ranged from -35.90

to 21.25 per cent for cross Arka Saurabh × Arka Vikas and Azad T-6 × Arka Meghali, respectively. Out of forty crosses, only one F_1's namely Azad T-6 × Arka Meghali (21.25%) exhibited significant heterosis over better parent in positive direction. Eleven crosses showed negative and significant heterosis over better parent. The heterosis over standard variety ranged from -25.23 to 25.23 % for cross Arka Saurabh × Arka Vikas and Azad T-6 × Arka Meghali, respectively. Out of forty crosses, only one cross, Azad T-6 × Arka Meghali (25.23%) showed positive and significant heterosis over standard variety. while, only one crosses showed significant and negative heterosis over standard variety for number of primary branches per plant.

In pooled, the estimates of heterosis over better parent ranged from -37.83 to 22.55 per cent for cross Arka Saurabh × Arka Vikas and Azad T-6 × Arka Meghali, respectively. Out of forty crosses, only two F_1's namely Azad T-6 × Arka Meghali (21.25%) and NDT-6 × Arka Meghali (14.46%) exhibited significant heterosis over better parent in positive direction. Fifteen crosses showed negative and significant heterosis over better parent. The heterosis over standard variety ranged from -26.82 to 26.82 % for cross Arka Saurabh × Arka Vikas and Azad T-6 × Arka Meghali, respectively. Out of forty crosses, only one cross, Azad T-6 × Arka Meghali (26.82%) showed positive and significant heterosis over standard variety. while, six crosses showed significant and negative heterosis over standard variety for number of primary branches per plant.

4.3.6 Number of fruits per cluster

The heterosis in year Y_1 over better parent ranged from -18.23 per cent (NDT-5 × Arka Meghali) to 16.26 per cent (Arka Saurabh × Pusa Ruby). Out of forty crosses, none of the cross showed significant heterosis over better parent in positive direction. However, over better parent, only two crosses showed heterosis in negative direction. The heterosis over standard variety

ranged from -13.30 to 21.28 per cent for cross NDT-6 × Pb. Chhuhara, Azad T-6 × Pb. Chhuhara and NDT-8 × Arka Vikas, respectively. Out of forty crosses, only four F_1's showed significant heterosis over standard variety in positive direction. The four F_1's showing standard heterosis over standard variety in positive direction were NDT-8 × Arka Vikas (21.28%), NDT-8 × Pusa Ruby (17.10%) and NDT-1 × Pb. Chhuhara and NDT-2 × Pusa Ruby (17.10%). However, over standard variety, none of the crosses showed significant heterosis in negative direction for number of fruits per cluster.

In year Y_2, the heterosis over better parent ranged from -16.74 per cent (NDT-5 × Arka Meghali) to 14.97 per cent (NDT-3 × Pusa Ruby). Out of forty crosses, none of the cross showed significant heterosis over better parent in positive direction. However, over better parent, two crosses showed heterosis in negative direction. The heterosis over standard variety ranged from -12.12 to 15.59 per cent for cross NDT-6 × Pb. Chhuhara, Azad T-6 × Pb. Chhuhara and NDT-1 × Pb. Chhuhara, NDT-2 × Pusa Ruby, NDT-8 × Pusa Ruby, respectively. Out of forty crosses, none of the F_1's showed significant heterosis over standard variety in positive direction. However, over standard variety, none of the crosses showed significant heterosis in negative direction for number of fruits per cluster.

The heterosis in pooled over better parent ranged from -17.45 per cent (NDT-5 × Arka Meghali) to 15.72 per cent (NDT-3 × Pusa Ruby). Out of forty crosses, only five crosses namely NDT-3 × Pusa Ruby (15.72%), Arka Saurabh × Pusa Ruby (15.49%), NDT-4 × Arka Vikas (15.22%), NDT-2 × Pusa Ruby (14.24%) and NDT-4 × Pb. Chhuhara (13.43%) showed significant and positive heterosis over better parent. However, over better parent, seven crosses showed heterosis in negative direction. The heterosis over standard variety ranged from -12.68 to 17.28 per cent for cross NDT-6 × Pb. Chhuhara, Azad T-6 × Pb. Chhuhara and NDT-8 × Arka Vikas, respectively. Out of forty

crosses, nine F_1's showed significant heterosis over standard variety in positive direction. The best five F_1's showing standard heterosis over standard variety in positive direction were NDT-8 × Arka Vikas (17.28%), NDT-1 × Pb. Chhuhara, NDT-2 × Pusa Ruby and NDT-8 × Pusa Ruby (16.31%), NDT-1 × Arka Vikas and NDT-4 × Arka Vikas (15.22%), NDT-7 × Arka Vikas (13.95%) and NDT-8 × Pb. Chhuhara (12.20%). However, over standard variety, only three crosses showed significant heterosis in negative direction for number of fruits per cluster.

4.3.7 Number of fruits per plant

In Y_1, the estimates of heterosis over better parent ranged from -62.61 to 20.71 per cent for cross NDT-6 × Arka Vikas and NDT-3 × Pusa Ruby, respectively. Out of forty crosses, seven F_1's showed significant and positive heterobeltiosis. The best five crosses *viz.,* NDT-3 × Pusa Ruby (20.71%), NDT-2 × Arka Vikas (11.01%), NDT-2 × Pusa Ruby (10.28%), NDT-3 × Pb. Chhuhara (9.80%) and NDT-1 × Pusa Ruby (9.29%) exhibited significant heterosis over better parent in positive direction while, thirty two crosses showed significant and negative heterobeltiosis. The heterosis over standard variety ranged from -34.87 to 11.01 per cent for cross NDT-6 × Arka Vikas and NDT-2 × Arka Vikas, respectively. Out of forty crosses, five crosses showed heterosis over standard variety in positive direction. The best five crosses *viz.,* NDT-2 × Arka Vikas (11.01%), NDT-3 × Pusa Ruby (8.50%), Arka Saurabh × Arka Meghali (7.55%), NDT-3 × Pb. Chhuhara (6.29%) and NDT-3 × Arka Vikas (6.10%) while, twenty six crosses exhibited significant and negative heterosis over standard variety for number of fruits per plant.

In Y_2, the estimates of heterosis over better parent ranged from -61.55 to 20.04 per cent for cross NDT-6 × Arka Vikas and NDT-3 × Pusa Ruby, respectively. Out of forty crosses, seven F_1's showed significant and positive heterobeltiosis. The best five crosses *viz.,* NDT-3 × Pusa Ruby (20.04%),

NDT-2 × Arka Vikas (10.69%), NDT-2 × Pusa Ruby (9.95%), NDT-3 × Pb. Chhuhara (9.51%) and NDT-1 × Pusa Ruby (8.99%) exhibited significant heterosis over better parent in positive direction while, thirty two crosses showed significant and negative heterobeltiosis. The heterosis over standard variety ranged from -33.86 to 10.69 per cent for cross NDT-6 × Arka Vikas and NDT-2 × Arka Vikas, respectively. Out of forty crosses, five crosses showed heterosis over standard variety in positive direction. The best five crosses *viz.,* NDT-2 × Arka Vikas (10.69%), NDT-3 × Pusa Ruby (8.26%), Arka Saurabh × Arka Meghali (7.33%), NDT-3 × Pb. Chhuhara (6.11%) and NDT-3 × Arka Vikas (5.93%) while, twenty six crosses exhibited significant and negative heterosis over standard variety for number of fruits per plant.

In pooled, the estimates of heterosis over better parent ranged from -62.08 to 20.37 per cent for cross NDT-6 × Arka Vikas and NDT-3 × Pusa Ruby, respectively. Out of forty crosses, seven F_1's showed significant and positive heterobeltiosis. The best five crosses *viz.*, NDT-3 × Pusa Ruby (20.37%), NDT-2 × Arka Vikas (10.85%), NDT-2 × Pusa Ruby (10.12%), NDT-3 × Pb. Chhuhara (9.65%) and NDT-1 × Pusa Ruby (9.14%) exhibited significant heterosis over better parent in positive direction while, thirty three crosses showed significant and negative heterobeltiosis. The heterosis over standard variety ranged from -34.35 to 10.85 per cent for cross NDT-6 × Arka Vikas and NDT-2 × Arka Vikas, respectively. Out of forty crosses, six crosses showed heterosis over standard variety in positive direction. The best five crosses *viz.,* NDT-2 × Arka Vikas (10.85%), NDT-3 × Pusa Ruby (8.38%), Arka Saurabh × Arka Meghali (7.44%), NDT-3 × Pb. Chhuhara (6.20%) and NDT-3 × Arka Vikas (6.01%) while, twenty six crosses exhibited significant and negative heterosis over standard variety for number of fruits per plant.

4.3.8 Average fruit weight (g)

In Y_1, the estimates of heterosis over better parent ranged from -53.78

to 39.31 per cent for the cross NDT-2 × Arka Meghali and Arka Saurabh × Pusa Ruby, respectively. Out of forty crosses, two crosses showed significant and positive heterosis and thirty crosses showed significant negative heterosis over better parent. The best F_1's for positive heterobeltiosis were Arka Saurabh × Pusa Ruby (39.31%) and NDT-7 × Pb. Chhuhara (22.40%). The estimates of heterosis over standard variety ranged from -53.01 to 1.20 per cent for the cross NDT-4 × Pusa Ruby and Arka Saurabh × Pusa Ruby, respectively. Out of forty crosses, none of the crosses showed significant and positive heterosis while, thirty eight crosses showed negative heterosis over standard variety.

In year Y_2, the estimates of heterosis over better parent ranged from -52.66 to 38.13 per cent for the cross NDT-2 × Arka Meghali and Arka Saurabh × Pusa Ruby, respectively. Out of forty crosses, two crosses showed significant and positive heterosis and thirty crosses showed significant negative heterosis over better parent. The best F_1's for positive heterobeltiosis were Arka Saurabh × Pusa Ruby (38.13%) and NDT-7 × Pb. Chhuhara (21.49%). The estimates of heterosis over standard variety ranged from -51.84 to 1.18 per cent for the cross NDT-4 × Pusa Ruby and Arka Saurabh × Pusa Ruby, respectively. Out of forty crosses, none of the crosses showed significant and positive heterosis while, thirty eight crosses showed negative heterosis over standard variety.

In pooled, the estimates of heterosis over better parent ranged from -53.21 to 38.71 per cent for the cross NDT-2 × Arka Meghali and Arka Saurabh × Pusa Ruby, respectively. Out of forty crosses, three crosses showed significant and positive heterosis and thirty one crosses showed significant negative heterosis over better parent. The best F_1's for positive heterobeltiosis were Arka Saurabh × Pusa Ruby (38.711%), NDT-7 × Pb. Chhuhara (21.94%) and NDT-1 × Arka Meghali (5.07%). The estimates of heterosis over standard

variety ranged from -52.42 to 1.19 per cent for the cross NDT-4 × Pusa Ruby and Arka Saurabh × Pusa Ruby, respectively. Out of forty crosses, none of the crosses showed significant and positive heterosis while, thirty eight crosses showed negative heterosis over standard variety.

4.3.9 Fruit length (cm)

In Y_1, the heterosis over better parent ranged from -22.58 per cent (NDT-4 × Arka Meghali) to 21.12 per cent (NDT-7 × Pb. Chhuhara). Out of forty crosses, only one F_1's *viz.,* NDT-7 × Pb. Chhuhara (21.12%) showed significant heterosis over better parent in positive direction. However, over better parent, eleven crosses showed heterosis in negative direction. The heterosis over standard variety ranged from -28.84 to 0.82 per cent for cross NDT-5 × Pusa Ruby and NDT-7 × Pb. Chhuhara, respectively. Out of forty crosses, none of the crosses showed significant heterosis over standard variety in positive direction. However, over standard variety, twenty one crosses showed significant heterosis in negative direction.

In Y_2, the heterosis over better parent ranged from -21.14 per cent (NDT-4 × Arka Meghali) to 19.48 per cent (NDT-7 × Pb. Chhuhara). Out of forty crosses, only one F_1's *viz.,* NDT-7 × Pb. Chhuhara (19.48%) showed significant heterosis over better parent in positive direction. However, over better parent, eleven crosses showed heterosis in negative direction. The heterosis over standard variety ranged from -26.95 to 0.77 per cent for cross NDT-5 × Pusa Ruby and NDT-7 × Pb. Chhuhara, respectively. Out of forty crosses, none of the crosses showed significant heterosis over standard variety in positive direction. However, over standard variety, twenty one crosses showed significant heterosis in negative direction.

In pooled, the heterosis over better parent ranged from -21.84 per cent (NDT-4 × Arka Meghali) to 20.27 per cent (NDT-7 × Pb. Chhuhara). Out of forty crosses, only two F_1's *viz.*, NDT-7 × Pb. Chhuhara (20.27%) and NDT-8

× Pusa Ruby (10.30%) showed significant heterosis over better parent in positive direction. However, over better parent, seventeen crosses showed heterosis in negative direction. The heterosis over standard variety ranged from -27.87 to 0.79 per cent for cross NDT-5 × Pusa Ruby and NDT-7 × Pb. Chhuhara, respectively. Out of forty crosses, none of the crosses showed significant heterosis over standard variety in positive direction. However, over standard variety, twenty eight crosses showed significant heterosis in negative direction.

4.3.10 Fruit girth (cm)

In Y_1, the heterosis over better parent ranged from -22.93 per cent (NDT-4 × Arka Meghali) to 15.43 per cent (NDT-5 × Arka Meghali). Out of forty crosses, none of the crosses showed significant heterosis over better parent in positive direction. However, over better parent, seven crosses showed heterosis in negative direction. The heterosis over standard variety ranged from -20.95 to 14.37 per cent for cross NDT-5 × Pusa Ruby and Arka Saurabh × Arka Vikas, respectively. Out of forty crosses, none of the crosses showed significant heterosis over standard variety in positive direction. However, over standard variety, only one crosses showed significant heterosis in negative direction for fruit girth.

In Y_2, the heterosis over better parent ranged from -21.26 per cent (NDT-4 × Arka Meghali) to 14.07 per cent (NDT-5 × Arka Meghali). Out of forty crosses, none of the crosses showed significant heterosis over better parent in positive direction. However, over better parent, seven crosses showed heterosis in negative direction. The heterosis over standard variety ranged from -19.21 to 13.17 per cent for cross NDT-5 × Pusa Ruby and Arka Saurabh × Arka Vikas, respectively. Out of forty crosses, none of the crosses showed significant heterosis over standard variety in positive direction. However, over standard variety, only one crosses showed significant heterosis

in negative direction for fruit girth.

In pooled, the heterosis over better parent ranged from -22.06 per cent (NDT-4 × Arka Meghali) to 14.72 per cent (NDT-5 × Arka Meghali). Out of forty crosses, only one F_1's *viz.,* NDT-5 × Arka Meghali (14.72%) showed significant heterosis over better parent in positive direction. However, over better parent, fourteen crosses showed heterosis in negative direction. The heterosis over standard variety ranged from -20.05 to 13.75 per cent for cross NDT-5 × Pusa Ruby and Arka Saurabh × Arka Vikas, respectively. Out of forty crosses, only two crosses, *viz.,* Arka Saurabh × Arka Vikas (13.75%) and Arka Saurabh × Pb. Chhuhara (10.31%) showed significant heterosis over standard variety in positive direction. However, over standard variety, two crosses showed significant heterosis in negative direction for fruit girth.

4.3.11 Number of locules per fruit

In Y_1, the estimates of heterosis over better parent ranged from -59.31 to 34.75 per cent for cross NDT-3 × Pusa Ruby and NDT-6 × Pusa Ruby, respectively. Out of forty crosses, only one F_1's namely NDT-6 × Pusa Ruby (34.75%) showed significant heterosis over better parent in positive direction while, four crosses exhibited negative heterobeltiosis. The heterosis over standard variety ranged from -53.32 to 40.05 per cent for cross NDT-3 × Pusa Ruby and NDT-6 × Pusa Ruby, respectively. The best F_1 showing heterosis over standard variety in positive direction were NDT-6 × Pusa Ruby (40.05%), NDT-6 × Pb. Chhuhara (27.03%) and NDT-2 × Arka Vikas and NDT-8 × Arka Meghali (26.04%) while, four crosses exhibited significant and negative heterosis over standard variety for number of locules per fruit.

In Y_2, the estimates of heterosis over better parent ranged from -55.07 to 32.03 per cent for cross NDT-3 × Pusa Ruby and NDT-6 × Pusa Ruby, respectively. Out of forty crosses, only one F_1's namely NDT-6 × Pusa Ruby (34.75%) showed significant heterosis over better parent in positive direction

while, four crosses exhibited negative heterobeltiosis. The heterosis over standard variety ranged from -48.98 to 36.79 per cent for cross NDT-3 × Pusa Ruby and NDT-6 × Pusa Ruby, respectively. The best F_1 showing heterosis over standard variety in positive direction were NDT-6 × Pusa Ruby (36.79%), NDT-6 × Pb. Chhuhara (24.83%) and NDT-2 × Arka Vikas and NDT-8 × Arka Meghali (23.93%) while, four crosses exhibited significant and negative heterosis over standard variety for number of locules per fruit.

In pooled, the estimates of heterosis over better parent ranged from -57.11 to 33.33 per cent for cross NDT-3 × Pusa Ruby and NDT-6 × Pusa Ruby, respectively. Out of forty crosses, only four F_1's namely NDT-6 × Pusa Ruby (33.33%), NDT-6 × Pb. Chhuhara (21.32%), Arka Saurabh × Pb. Chhuhara (19.95%) and Arka Saurabh × Arka Vikas (16.47%) showed significant heterosis over better parent in positive direction while, sixteen crosses showed negative heterobeltiosis. The heterosis over standard variety ranged from -51.06 to 38.35 per cent for cross NDT-3 × Pusa Ruby and NDT-6 × Pusa Ruby, respectively. The best five F_1's showing heterosis over standard variety in positive direction were NDT-6 × Pusa Ruby (38.35%), NDT-6 × Pb. Chhuhara (25.88%), NDT-2 × Arka Vikas and NDT-8 × Arka Meghali (24.94%), Azad T-6 × Pusa Ruby (21.88%) and NDT-4 × Pb. Chhuhara (21.18%) while, only one cross exhibited significant and negative heterosis over standard variety for number of locules per fruit.

4.3.12 Pericarp thickness (mm)

In Y_1, the estimates of heterosis over better parent ranged from -29.33 to 15.83 per cent for the cross NDT-1 × Pusa Ruby and NDT-6 × Arka Meghali, respectively. Out of forty crosses, none of the crosses showed significant and positive heterosis and eleven crosses exhibited significant negative heterosis over better parent. The estimates of heterosis over standard variety ranged from -24.26 to 3.69 per cent for the cross NDT-1 × Pusa Ruby

and NDT-8 × Pb. Chhuhara, respectively. Out of forty crosses, none of the crosses showed significant and positive heterosis while, sixteen crosses showed negative heterosis over standard variety for Pericarp thickness.

In Y_2, the estimates of heterosis over better parent ranged from -27.30 to 14.48 per cent for the cross NDT-1 × Pusa Ruby and NDT-6 × Arka Meghali, respectively. Out of forty crosses, none of the crosses showed significant and positive heterosis and eleven crosses exhibited significant negative heterosis over better parent. The estimates of heterosis over standard variety ranged from -22.47 to 3.42 per cent for the cross NDT-1 × Pusa Ruby and NDT-8 × Pb. Chhuhara, respectively. Out of forty crosses, none of the crosses showed significant and positive heterosis while, seventeen crosses showed negative heterosis over standard variety for Pericarp thickness.

In pooled, the estimates of heterosis over better parent ranged from -28.28 to 15.12 per cent for the cross NDT-1 × Pusa Ruby and NDT-6 × Arka Meghali, respectively. Out of forty crosses, only one cross namely NDT-6 × Arka Meghali (15.12%) showed significant and positive heterosis and sixteen crosses exhibited significant negative heterosis over better parent. The estimates of heterosis over standard variety ranged from -23.33 to 3.55 per cent for the cross NDT-1 × Pusa Ruby and NDT-8 × Pb. Chhuhara, respectively. Out of forty crosses, none of the crosses showed significant and positive heterosis while, twenty seven crosses showed negative heterosis over standard variety for Pericarp thickness.

4.3.13 Total soluble solids (B^o)

In Y_1, the estimates of heterosis over better parent ranged from -29.89 to 27.89 per cent for cross NDT-5 × Pusa Ruby and Arka Saurabh × Arka Meghali, respectively. Out of forty crosses, only two F_1's Arka Saurabh × Arka Meghali (27.89%) and NDT-3 × Pusa Ruby (19.58%) showed significant heterosis over better parent in positive direction while, nine

crosses expressed negative heterosis. The heterosis over standard variety ranged from -25.91 to 15.71 per cent for cross NDT-8 × Pb. Chhuhara and Arka Saurabh × Arka Meghali, respectively. Out of forty crosses, one F_1 namely Arka Saurabh × Arka Meghali (15.71%) showing standard heterosis over standard variety in positive direction while, thirteen crosses showed significant and negative heterosis over standard variety for total soluble solids.

In Y_2, the estimates of heterosis over better parent ranged from -28.18 to 26.02 per cent for cross NDT-5 × Pusa Ruby and Arka Saurabh × Arka Meghali, respectively. Out of forty crosses, only two F_1's Arka Saurabh × Arka Meghali (26.02%) and NDT-3 × Pusa Ruby (18.15%) showed significant heterosis over better parent in positive direction while, nine crosses expressed negative heterosis. The heterosis over standard variety ranged from -24.32 to 14.75 per cent for cross NDT-8 × Pb. Chhuhara and Arka Saurabh × Arka Meghali, respectively. Out of forty crosses, one F_1 namely Arka Saurabh × Arka Meghali (14.75%) showing standard heterosis over standard variety in positive direction while, thirteen crosses showed significant and negative heterosis over standard variety for total soluble solids.

In pooled, the estimates of heterosis over better parent ranged from -29.01 to 26.92 per cent for cross NDT-5 × Pusa Ruby and Arka Saurabh × Arka Meghali, respectively. Out of forty crosses, only four F_1's Arka Saurabh × Arka Meghali (26.92%), NDT-3 × Pusa Ruby (18.84%), NDT-7 × Pb. Chhuhara (14.79%) and NDT-2 × Arka Meghali (12.46%) showed significant heterosis over better parent in positive direction while, thirteen crosses expressed negative heterosis. The heterosis over standard variety ranged from -25.09 to 15.21 per cent for cross NDT-8 × Pb. Chhuhara and Arka Saurabh × Arka Meghali, respectively. Out of forty crosses, one F_1 namely Arka Saurabh

× Arka Meghali (15.21%) showing standard heterosis over standard variety in positive direction while, nineteen crosses showed significant and negative heterosis over standard variety for total soluble solids.

4.3.14 Ascorbic acid (Mg/100g)

In Y_1, the heterosis over better parent ranged from -38.28 per cent (NDT-8 × Pusa Ruby) to 62.68 per cent (NDT-5 × Pb. Chhuhara). Out of forty crosses, eleven F_1's showed significant heterosis over better parent in positive direction. The best five crosses were NDT-5 × Pb. Chhuhara (62.68%), NDT-5 × Arka Vikas (54.35%), NDT-5 × Arka Meghali (47.75%), NDT-5 × Pusa Ruby (37.28%) and NDT-2 × Pusa Ruby (26.60%). However, over better parent, twenty one crosses showed heterosis in negative direction. The heterosis over standard variety ranged from -32.86 to 60.64 per cent for cross NDT-1 × Pb. Chhuhara and NDT-5 × Pb. Chhuhara, respectively. Out of forty crosses, fourteen F_1's exhibited significant heterosis over standard variety in positive direction. The best five F_1's showing standard heterosis over standard variety in positive direction were NDT-5 × Pb. Chhuhara (60.64%), NDT-5 × Arka Meghali (58.59%), NDT-5 × Arka Vikas (54.35%), Azad T-6 × Arka Meghali (51.38%) and Azad T-6 × Arka Vikas (45.80%). However, over standard variety, nineteen crosses showed significant heterosis in negative direction for ascorbic acid.

In Y_2, the heterosis over better parent ranged from -37.32 per cent (NDT-8 × Pusa Ruby) to 58.12 per cent (NDT-5 × Pb. Chhuhara). Out of forty crosses, eleven F_1's showed significant heterosis over better parent in positive direction. The best five crosses were NDT-5 × Pb. Chhuhara (58.12%), NDT-5 × Pusa Ruby (57.67%), NDT-5 × Arka Vikas (50.11%), NDT-5 × Arka Meghali (46.36%) and NDT-4 × Pusa Ruby (17.46%). However, over better parent, eighteen crosses showed heterosis in negative direction. The heterosis over standard variety ranged from -31.84 to 56.76 per cent for cross NDT-1 ×

Arka Vikas and NDT-5 × Arka Meghali, respectively. Out of forty crosses, fourteen F_1's exhibited significant heterosis over standard variety in positive direction. The best five F_1's showing standard heterosis over standard variety in positive direction were NDT-5 × Arka Meghali (56.76%), NDT-5 × Pb. Chhuhara (56.20%), NDT-5 × Arka Vikas (50.11%), Azad T-6 × Arka Meghali (49.78%) and Azad T-6 × Arka Vikas (47.77%). However, over standard variety, eighteen crosses showed significant heterosis in negative direction for ascorbic acid.

In pooled, the heterosis over better parent ranged from -37.80 per cent (NDT-8 × Pusa Ruby) to 60.36 per cent (NDT-5 × Pb. Chhuhara). Out of forty crosses, eleven F_1's showed significant heterosis over better parent in positive direction. The best five crosses were NDT-5 × Pb. Chhuhara (60.36%), NDT-5 × Arka Vikas (52.20%), NDT-5 × Pusa Ruby (47.65%), NDT-5 × Arka Meghali (47.04%) and NDT-2 × Pusa Ruby (21.37%). However, over better parent, twenty one crosses showed heterosis in negative direction. The heterosis over standard variety ranged from -31.05 to 58.39 per cent for cross NDT-1 × Arka Vikas and NDT-5 × Pb. Chhuhara, respectively. Out of forty crosses, fifteen F_1's exhibited significant heterosis over standard variety in positive direction. The best five F_1's showing standard heterosis over standard variety in positive direction were NDT-5 × Pb. Chhuhara (58.39%), NDT-5 × Arka Meghali (57.66%), NDT-5 × Arka Vikas (52.20%), Azad T-6 × Arka Meghali (50.57%) and Azad T-6 × Arka Vikas (46.80%). However, over standard variety, twenty crosses showed significant heterosis in negative direction for ascorbic acid.

4.3.15 Total fruit yield per plant (kg)

In Y_1, the estimates of heterosis over better parent ranged from -49.42 per cent (NDT-5 × Arka Vikas) to 8.49 per cent (NDT-3 × Pb. Chhuhara). Out of forty crosses, none of the F_1's showed significant heterosis over better

parent in positive direction while, twenty six crosses showed significant and negative heterosis over better parent. The heterosis over standard variety ranged from -54.36 to -7.85 per cent for cross NDT-6 × Pb. Chhuhara and NDT-3 × Arka Vikas, respectively. Out of forty crosses, none of the crosses exhibited significant and positive heterosis while, thirty seven crosses showed negative heterosis over standard variety for total fruit yield per plant.

In Y_2, the estimates of heterosis over better parent ranged from -44.62 per cent (NDT-5 × Arka Vikas) to 7.44 per cent (NDT-3 × Pb. Chhuhara). Out of forty crosses, none of the F_1's showed significant heterosis over better parent in positive direction while, twenty four crosses showed significant and negative heterosis over better parent. The heterosis over standard variety ranged from -49.08 to -7.09 per cent for cross NDT-6 × Pb. Chhuhara and NDT-3 × Arka Vikas, respectively. Out of forty crosses, none of the crosses exhibited significant and positive heterosis while, thirty seven crosses showed negative heterosis over standard variety for total fruit yield per plant.

In pooled, the estimates of heterosis over better parent ranged from -46.90 per cent (NDT-5 × Arka Vikas) to 7.93 per cent (NDT-3 × Pb. Chhuhara). Out of forty crosses, none of the F_1's showed significant heterosis over better parent in positive direction while, twenty seven crosses showed significant and negative heterosis over better parent. The heterosis over standard variety ranged from -51.59 to -7.45 per cent for cross NDT-6 × Pb. Chhuhara and NDT-3 × Arka Vikas, respectively. Out of forty crosses, none of the crosses exhibited significant and positive heterosis while, thirty nine crosses showed negative heterosis over standard variety for total fruit yield per plant.

4.4 Combining ability variances and their effects

4.4.1 Analysis of variance for combining ability

Analysis of variances for combining ability in both the years (Y_1 and Y_2) had presented in Table 4.6.1 Analysis of variances for combining ability revealed that the partitioning of variances due to lines × testers showed highly significant for days to 50 % flowering, days to first fruit set, plant height, number of fruits per plant, average fruit weight, fruit length, number of locules per fruit, total soluble solids, ascorbic acid in both years and total fruit yield per plant in Y_1 whereas, significant for days to first fruit harvest, number of fruits per cluster, fruit girth in both years and total fruit yield per plant in Y_2 except number of primary branches per plant and pericarp thickness in both years. Variances due to lines were highly significant for plant height (5832.09) followed by Ascorbic acid (1163.36), number of fruits per plant (316.70), number of primary branches per plant (1.25) and total fruit yield per plant (0.95) in Y_1 and plant height (5821.39) followed by Ascorbic acid (1128.72), number of fruits per plant (316.70), number of primary branches per plant (1.25) and total fruit yield per plant (0.98) in Y_2, whereas, variances due to testers was also highly significant for plant height (9345.01, 10036.59) in both the years.

Analysis of variances for combining ability in pooled had presented in Table 4.6.2. Analysis of variances for combining ability revealed that the partitioning of variances due to envirоonments showed highly significant for all the charecters. Analysis of variances for combining ability revealed that the partitioning of variances due to lines × testers showed highly significant for all the charecters. Variances due to lines were highly significant for plant height (11646.74) followed by Ascorbic acid (2281.23), number of fruits per plant (633.39), number of primary branches per plant (2.51) and total fruit yield per plant (1.93) whereas, variances due to testers was also highly

significant for plant height (19371.80).

4.4.2 Estimates of general combining ability effects

The estimates of general combining ability (gca) effects for all the fifteen characters in respect to 14 parents (10 females and 4 males) in Y_1, Y_2 and pooled had presented in Table 4.7. The negative estimates of general combining ability were considered desirable for days to 50 % flowering, days to first fruit set and days to first fruit harvest. However, for rest of the characters positive estimates of general combining ability were considered desirable. The character wise results are presented below in sub-heads:

4.4.2.1 Days to 50 % flowering

In Y_1, among lines NDT-4 (-1.48) followed by NDT-1 (-1.09) exhibited significant and negative gca effects for days to 50 % flowering. However, none of the parents among testers exhibited significant and negative gca effects for days to 50 % flowering.

In case of Y_2, among females significant and negative gca effects were observed for NDT-4 (-1.48) followed by NDT-1 (-1.32). However, none of the parents among testers exhibited significant and negative gca effects for days to 50 % flowering.

In case of pooled, among females significant and negative gca effects were observed for NDT-4 (-1.48) followed by NDT-1 (-1.21). However, among testers Punjab Chuhara (-0.44) exhibited significant and negative gca effect for days to 50 % flowering.

Thus, among the parents NDT-4 and NDT-1 were found good general combiner for days to 50 % flowering in both the years and pooled.

4.4.2.2 Days to first fruit set

In Y_1, among lines NDT-4 (-1.55) exhibited significant and negative

gca effects for days to first fruit set. However, none of the parents among testers exhibited significant and negative gca effects for days to first fruit set.

In case of Y_2, among females significant and negative gca effects were observed for NDT-4 (-1.55). However, none of the parents among testers exhibited significant and negative gca effects for days to first fruit set.

In case of pooled, among females significant and negative gca effects were observed for NDT-4 (-1.55) followed by NDT-1 (-1.01). However, none of the parents among testers exhibited significant and negative gca effects for days to first fruit set.

Thus, among the parents NDT-4 was found good general combiner for days to first fruit set in both the years and pooled.

4.4.2.3 Days to first fruit harvest

In Y_1, among lines NDT-4 (-1.55) followed by NDT-1 (1.22) exhibited significant and negative gca effects for days to first fruit harvest. However, none of the parents among testers exhibited significant and negative gca effects for days to first fruit harvest.

In case of Y_2, among females significant and negative gca effects were observed for NDT-4 (-1.55) followed by NDT-1 (1.22). However, none of the parents among testers exhibited significant and negative gca effects for days to first fruit harvest.

In case of pooled, among females significant and negative gca effects were observed for NDT-4 (-1.55) followed by NDT-1 (-1.22). However, none of the parents among testers exhibited significant and negative gca effects for days to first fruit harvest.

Thus, among the parents NDT-4 and NDT-1 were found good general combiner for days to first fruit harvest in both the years and pooled.

Table-4.6.1 Analysis of variance for combining ability following line × tester mating design for 15 characters in tomato (Y_1=2016-17 and Y_2=2017-18)

Source of Variation	Years	d.f.	Days to 50 % flowering	Days to first fruit set	Days to first fruit harvest	Plant height (cm)	Number of primary branches per plant	Number of fruits per cluster	Number of fruits per plant	Average fruit weight (g)
Replications	Y_1	2	0.42	2.89	2.49	7.74	0.43	0.08	0.04	0.63
	Y_2	2	0.10	2.89	2.49	22.26	0.44	0.07	0.04	0.95
Lines	Y_1	9	7.97	7.55	9.35	5832.09**	1.25**	1.32*	316.70**	325.21
	Y_2	9	9.89	7.55	9.35	5821.39**	1.25**	1.25	316.70**	326.89*
Testers	Y_1	3	3.68	2.27	4.21	9345.01**	0.13	1.13	19.05	33.13
	Y_2	3	3.92	2.27	4.21	10036.59**	0.13	1.11	19.05	32.56
Lines × Testers	Y_1	27	8.58**	7.13**	6.24*	180.03**	0.33	0.57*	28.50**	144.92**
	Y_2	27	7.21**	7.13**	6.24*	199.56**	0.33	0.58*	28.50**	144.82**
Error	Y_1	78	2.35	2.86	3.56	11.92	0.22	0.30	2.54	3.90
	Y_2	78	2.43	2.86	3.56	12.50	0.21	0.31	2.54	3.96

Cont…

Source of Variation	Years	d.f.	Fruit length (cm)	Fruit girth (cm)	Number of locules per fruit	Pericarp thickness (mm)	Total soluble solid (TSS)	Ascorbic acid (mg/100 g fresh fruit)	Total fruit yield per plant (kg)
Replications	Y_1	2	0.01	1.58	0.06	0.39	0.11	0.32	0.19
	Y_2	2	0.01	1.54	0.06	0.22	0.11	16.74	0.17
Lines	Y_1	9	0.73	3.77	2.16	0.70*	0.84	1163.36**	0.95**
	Y_2	9	0.73	4.12	2.16	0.70*	0.84	1128.72**	0.98**
Testers	Y_1	3	0.41	1.34	0.45	0.47	0.20	98.41	0.19
	Y_2	3	0.41	1.22	0.45	0.47	0.20	88.88	0.24
Lines × Testers	Y_1	27	0.85**	2.46*	1.04**	0.25	0.94**	53.92**	0.21**
	Y_2	27	0.85**	2.49*	1.04**	0.25	0.94**	73.95**	0.18*
Error	Y_1	78	0.33	1.36	0.36	0.20	0.30	5.47	0.10
	Y_2	78	0.33	1.38	0.36	0.18	0.30	7.51	0.10

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table-4.6.2: Analysis of variance (mean squares) for combining ability following line × tester mating design for 15 characters in tomato (Pooled)

Source of Variation	d.f.	Days to 50 % flowering	Days to first fruit set	Days to first fruit harvest	Plant height (cm)	Number of primary branches per plant	Number of fruits per cluster	Number of fruits per plant	Average fruit weight (g)
Replications	2	0.44	5.79	4.98	3.55	0.87	0.15	0.08	1.57
Environmets	1	617.89**	93.75**	95.26**	250.51**	13.25**	14.60**	95.26**	92.75**
Rep × Env.	2	0.07	0.00	0.00	26.46	0.00	0.01	0.00	0.02
Lines	9	17.52	15.10	18.71	11646.74**	2.51**	2.56	633.39**	652.08*
Testers	3	7.53	4.55	8.42	19371.80**	0.26	2.23	38.10	65.68
Lines × Testers	27	15.54**	14.26**	12.47**	370.06**	0.66**	1.14**	56.99**	289.73**
Error	156	2.39	2.86	3.56	12.21	0.22	0.31	2.54	3.93

Cont…

Source of Variation	d.f.	Fruit length (cm)	Fruit girth (cm)	Number of locules per fruit	Pericarp thickness (mm)	Total soluble solid (TSS)	Ascorbic acid (mg/100 g fresh fruit)	Total fruit yield per plant (kg)
Replications	2	0.01	3.10	0.12	0.58	0.21	7.52	0.36*
Environmets	1	17.50**	85.44**	7.78**	10.09**	9.13**	297.97**	8.09**
Rep × Env.	2	0.00	0.02	0.00	0.03	0.00	9.54	0.00
Lines	9	1.46	7.87	4.32	1.40*	1.69	2281.23**	1.93**
Testers	3	0.81	2.55	0.89	0.94	0.40	169.64	0.43
Lines × Testers	27	1.70**	4.94**	2.08**	0.50**	1.88**	113.39**	0.39**
Error	156	0.33	1.37	0.36	0.19	0.30	6.49	0.10

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table-4.7. Estimates of general combining ability (gca) effects of parents (lines and testers) for 15 characters in tomato over two years (Y_1, Y_2) and pooled

Traits / Lines	Days to 50 % flowering			Days to first fruit set			Days to first fruit harvest			Plant height (cm)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1	-1.09*	-1.32**	-1.21**	-1.01	-1.01	-1.01**	-1.22*	-1.22*	-1.22**	3.70**	5.41**	4.55**
NDT-2	0.66	0.75	0.70*	0.64	0.64	0.64	0.51	0.51	0.51	-20.53**	-21.31**	-20.92**
NDT-3	1.29**	1.54**	1.41**	0.97	0.97	0.97**	1.38*	1.38*	1.38**	-16.43**	-14.71**	-15.57**
NDT-4	-1.48**	-1.48**	-1.48**	-1.55**	-1.55**	-1.55**	-1.55**	-1.55**	-1.55**	24.87**	24.50**	24.69**
NDT-5	-0.10	-0.34	-0.22	-0.24	-0.24	-0.24	-0.32	-0.32	-0.32	34.53**	34.58**	34.55**
NDT-6	0.41	0.40	0.40	0.51	0.51	0.51	0.61	0.61	0.61	-14.08**	-13.62**	-13.85**
NDT-7	0.10	-0.23	-0.07	-0.34	-0.34	-0.34	-0.25	-0.25	-0.25	-8.07**	-9.61**	-8.84**
NDT-8	0.42	0.37	0.40	0.38	0.38	0.38	0.57	0.57	0.57	-19.96**	-20.74**	-20.35**
Azad T-6	-0.33	0.10	-0.12	0.09	0.09	0.09	-0.05	-0.05	-0.05	31.11**	30.57**	30.84**
Arka Saurabh	0.12	0.24	0.18	0.55	0.55	0.55	0.31	0.31	0.31	-15.12**	-15.07**	-15.10**
SE (gi) lines	**0.47**	**0.47**	**0.31**	**0.52**	**0.52**	**0.34**	**0.54**	**0.54**	**0.38**	**0.97**	**1.00**	**0.71**
SE(gi – gj)	**0.66**	**0.66**	**0.45**	**0.74**	**0.74**	**0.49**	**0.76**	**0.76**	**0.54**	**1.38**	**1.42**	**1.01**
Testers												
Pusa Ruby	0.38	0.33	0.35	0.33	0.33	0.33	0.40	0.40	0.40	26.39**	27.38**	26.89**
Punjab Chhuhara	-0.41	-0.48	-0.44*	-0.32	-0.32	-0.32	-0.38	-0.38	-0.38	-10.70**	-10.81**	-10.75**
Arka Vikas	0.19	0.23	0.21	0.08	0.08	0.08	0.23	0.23	0.23	-7.48**	-8.46**	-7.97**
Arka Meghali	-0.16	-0.08	-0.12	-0.09	-0.09	-0.09	-0.25	-0.25	-0.25	-8.22**	-8.10**	-8.16**
SE (gi) testers	**0.30**	**0.30**	**0.20**	**0.33**	**0.33**	**0.22**	**0.34**	**0.34**	**0.24**	**0.62**	**0.63**	**0.45**
SE (gi-gj)	**0.42**	**0.42**	**0.28**	**0.47**	**0.47**	**0.31**	**0.48**	**0.48**	**0.34**	**0.87**	**0.90**	**0.64**

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table-4.7 Contd…..

Traits / Lines	Number of primary branches per plant			Number of fruits per cluster			Number of fruits per plant			Average fruit weight (g)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1	0.08	0.08	0.08	0.26	0.28	0.27*	4.99**	4.99**	4.99**	7.34**	7.36**	7.35**
NDT-2	-0.04	-0.04	-0.04	0.24	0.25	0.24*	4.62**	4.62**	4.62**	1.90**	1.92**	1.91**
NDT-3	-0.21	-0.21	-0.21*	-0.55**	-0.54**	-0.55**	7.59**	7.59**	7.59**	-3.07**	-3.05**	-3.06**
NDT-4	-0.24	-0.24	-0.24*	0.18	0.20	0.19	-0.58	-0.58	-0.58	-6.93**	-6.92**	-6.93**
NDT-5	0.00	0.00	0.00	-0.15	-0.13	-0.14	0.87*	0.87*	0.87**	-8.09**	-8.07**	-8.08**
NDT-6	0.18	0.18	0.18	-0.28	-0.27	-0.27*	-5.88**	-5.88**	-5.88**	-3.71**	-3.86**	-3.79**
NDT-7	0.11	0.11	0.11	-0.19	-0.26	-0.22	-1.96**	-1.96**	-1.96**	3.02**	3.03**	3.02**
NDT-8	0.13	0.13	0.13	0.57**	0.51**	0.54**	-4.59**	-4.59**	-4.59**	0.70	0.72	0.71
Azad T-6	0.61**	0.61**	0.61**	-0.20	-0.19	-0.19	-8.02**	-8.02**	-8.02**	5.12**	5.14**	5.13**
Arka Saurabh	-0.63**	-0.63**	-0.63**	0.13	0.14	0.14	2.96**	2.96**	2.96**	3.72**	3.74**	3.73**
SE (gi) lines	**0.14**	**0.15**	**0.10**	**0.16**	**0.16**	**0.11**	**0.44**	**0.44**	**0.33**	**0.56**	**0.55**	**0.41**
SE(gi – gj)	**0.20**	**0.20**	**0.13**	**0.22**	**0.23**	**0.16**	**0.62**	**0.62**	**0.46**	**0.78**	**0.78**	**0.57**
Testers												
Pusa Ruby	-0.05	-0.05	-0.05	0.12	0.14	0.13	-0.06	-0.06	-0.06	-0.77*	-0.75*	-0.76**
Punjab Chhuhara	0.07	0.07	0.07	-0.16	-0.15	-0.16*	0.23	0.23	0.23	-0.95**	-0.94**	-0.94**
Arka Vikas	0.04	0.04	0.04	0.21*	0.19	0.20**	-1.04**	-1.04**	-1.04**	0.45	0.40	0.43
Arka Meghali	-0.06	-0.06	-0.06	-0.17	-0.18	-0.17*	0.87**	0.87**	0.87**	1.27**	1.29**	1.28**
SE (gi) testers	**0.09**	**0.09**	**0.06**	**0.10**	**0.10**	**0.07**	**0.28**	**0.28**	**0.21**	**0.35**	**0.35**	**0.26**
SE(gi – gj)	**0.13**	**0.13**	**0.09**	**0.14**	**0.14**	**0.10**	**0.39**	**0.39**	**0.29**	**0.49**	**0.49**	**0.36**

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table-4.7 Contd…..

Traits / Lines	Fruit length (cm)			Fruit girth (cm)			Number of locules per fruit			Pericarp thickness (mm)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1	0.19	0.19	0.19	-0.02	0.00	-0.01	0.19	0.19	0.19	-0.46**	-0.46**	-0.46**
NDT-2	-0.10	-0.10	-0.10	-0.50	-0.49	-0.50*	0.24	0.24	0.24*	0.28	0.28	0.28**
NDT-3	-0.18	-0.18	-0.18	-0.49	-0.47	-0.48*	-0.99**	-0.99**	-0.99**	-0.09	-0.09	-0.09
NDT-4	0.24	0.24	0.24*	0.46	0.48	0.47	0.18	0.18	0.18	-0.18	-0.18	-0.18*
NDT-5	-0.54**	-0.54**	-0.54**	-0.30	-0.29	-0.29	-0.42*	-0.42*	-0.42**	0.11	0.11	0.11
NDT-6	-0.09	-0.09	-0.09	-0.69*	-0.84*	-0.77**	0.36*	0.36*	0.36**	0.14	0.14	0.14
NDT-7	0.15	0.15	0.15	0.46	0.47	0.46	-0.06	-0.06	-0.06	-0.01	-0.01	-0.01
NDT-8	-0.04	-0.04	-0.04	0.31	0.33	0.32	-0.11	-0.11	-0.11	0.36*	0.36*	0.36**
Azad T-6	0.11	0.11	0.11	-0.30	-0.28	-0.29	0.39*	0.39*	0.39**	0.05	0.05	0.05
Arka Saurabh	0.26	0.26	0.26*	1.08**	1.09**	1.08**	0.20	0.20	0.20	-0.19	-0.19	-0.19*
SE (gi) lines	**.016**	**0.16**	**0.12**	**0.35**	**0.35**	**0.24**	**0.17**	**0.17**	**0.12**	**0.14**	**0.14**	**0.09**
SE(gi – gj)	**0.23**	**0.23**	**0.17**	**0.49**	**0.49**	**0.34**	**0.25**	**0.25**	**0.17**	**0.20**	**0.20**	**0.13**
Testers												
Pusa Ruby	-0.12	-0.12	-0.12	-0.31	-0.29	-0.30*	-0.07	-0.07	-0.07	-0.17	-0.17	-0.17**
Punjab Chhuhara	0.06	0.06	0.06	0.15	0.13	0.14	0.05	0.05	0.05	0.05	0.05	0.05
Arka Vikas	0.13	0.13	0.13	0.11	0.13	0.12	-0.13	-0.13	-0.13	0.12	0.12	0.12*
Arka Meghali	-0.07	-0.07	-0.07	0.05	0.03	0.04	0.14	0.14	0.14	0.00	0.00	0.00
SE (gi) testers	**0.10**	**0.10**	**0.07**	**0.22**	**0.22**	**0.15**	**0.11**	**0.11**	**0.08**	**0.09**	**0.09**	**0.06**
SE (gi-gj)	**0.15**	**0.15**	**0.10**	**0.31**	**0.31**	**0.21**	**0.16**	**0.16**	**0.11**	**0.13**	**0.13**	**0.08**

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table-4.7 Contd…..

Traits / Lines	Total soluble solid (TSS)			Ascorbic acid (mg/100 g fresh fruit)			Total fruit yield per plant (kg)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1	-0.24	-0.24	-0.24*	-8.27**	-5.38**	-6.83**	0.19*	0.16	0.18**
NDT-2	0.45**	0.45**	0.45**	-3.03**	-3.79**	-3.41**	0.39**	0.39**	0.39**
NDT-3	0.28	0.28	0.28*	-2.76**	-3.62**	-3.19**	0.33**	0.33**	0.33**
NDT-4	-0.20	-0.20	-0.20	3.75**	2.69**	3.22**	0.04	0.04	0.04
NDT-5	-0.17	-0.17	-0.17	18.10**	18.50**	18.30**	-0.46**	-0.46**	-0.46**
NDT-6	-0.15	-0.15	-0.15	-6.45**	-7.46**	-6.95**	-0.26**	-0.26**	-0.26**
NDT-7	-0.14	-0.14	-0.14	-10.36**	-10.21**	-10.29**	-0.35**	-0.37**	-0.36**
NDT-8	-0.27	-0.27	-0.27*	1.03	-0.40	0.31	0.04	0.07	0.05
Azad T-6	0.13	0.13	0.13	15.48**	15.64**	15.56**	-0.03	-0.05	-0.04
Arka Saurabh	0.31*	0.31*	0.31**	-7.48**	-5.98**	-6.73**	0.11	0.14	0.13*
SE (gi) lines	**0.15**	**0.15**	**0.11**	**0.70**	**0.76**	**0.52**	**0.08**	**0.09**	**0.07**
SE(gi – gj)	**0.22**	**0.22**	**0.16**	**0.99**	**1.07**	**0.74**	**0.12**	**0.12**	**0.09**
Testers									
Pusa Ruby	-0.11	-0.11	-0.11	-2.19**	-0.85	-1.52**	0.01	0.01	0.01
Punjab Chhuhara	-0.01	-0.01	-0.01	-0.39	-1.08*	-0.74*	-0.09	-0.11*	-0.10*
Arka Vikas	0.05	0.05	0.05	0.41	-0.64	-0.11	0.10*	0.11	0.11*
Arka Meghali	0.07	0.07	0.07	2.17**	2.57**	2.37**	-0.03	0.00	-0.02
SE (gi) testers	**0.09**	**0.10**	**0.07**	**0.44**	**0.48**	**0.33**	**0.05**	**0.05**	**0.04**
SE (gi-gj)	**0.14**	**0.14**	**0.10**	**0.63**	**0.68**	**0.47**	**0.07**	**0.08**	**0.30**

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

4.4.2.4 Plant height (cm)

General combining ability effects with positive values are desirable for plant height. In Y_1, significant and positive gca effects for plant height at last picking stage were possessed by NDT-5 (34.53) followed by Azad T-6 (31.11), NDT-4 (24.87) and NDT-1 (3.70) among lines and Pusa Ruby (26.39) among testers.

In Y_2, NDT-5 (34.58) followed by Azad T-6 (30.57), NDT-4 (24.50) and NDT-1 (5.41) among lines and Pusa Ruby (26.38) among testers exhibited significant and positive gca effects for plant height.

In pooled, NDT-5 (34.55) followed by Azad T-6 (30.84), NDT-4 (24.69) and NDT-1 (4.55) among lines and Pusa Ruby (26.89) among testers exhibited significant and positive gca effects for plant height.

Thus, among the parents NDT-5, Azad T-6, NDT-4 and NDT-1 were found as the top four good general combiners for plant height at last picking stage in both the years and pooled.

4.4.2.5 Number of primary branches per plant

In Y_1, significant and positive gca effects for number of primary branches per plant was possessed by Azad T-6 (0.61) among lines and none of the parents among testers exhibited significant and positive gca effects.

In Y_2, significant and positive gca effects for number of primary branches per plant was possessed by Azad T-6 (0.61) among lines and none of the parents among testers exhibited significant and positive gca effects.

In pooled, significant and positive gca effects for number of primary branches per plant was possessed by Azad T-6 (0.61) among lines and none of the parents among testers exhibited significant and positive gca effects.

Thus, among the parents Azad T-6 was found good general combiner for number of primary branches per plant.

4.4.2.6 Number of fruits per cluster

In Y_1, highly significant and positive gca effect for number of fruits per cluster was possessed by NDT-8 (0.57) among lines and significant and positive was possessed by Arka Vikas (0.21) among testers.

In Y_2, significant and positive gca effect for number of fruits per cluster was possessed by NDT-8 (0.51) among lines and none of the parents among tester exhibited significant and positive gca effects.

In pooled, significant and positive gca effect for number of fruits per cluster was possessed by NDT-8 (0.54) followed by NDT-1 (0.27) and NDT-2 (0.24) among lines and significant and positive was possessed by Arka Vikas (0.20) among tester.

Thus, among the parents, NDT-8 was found good general combiners in both the years and pooled for number of fruits per cluster.

4.4.2.7 Number of fruits per plant

In Y_1, significant positive gca effects for number of fruits per plant were possessed by NDT- 3 (7.59) followed by NDT- 1 (4.99), NDT-2 (4.62), Arka Saurabh (2.96) and NDT-5 (0.87) among lines and significant and positive was possessed by Arka Meghali (0.87) among tester.

In Y_2, significant positive gca effects for number of fruits per plant were possessed by NDT- 3 (7.59) followed by NDT- 1 (4.99), NDT-2 (4.62), Arka Saurabh (2.96) and NDT-5 (0.87) among lines and significant and positive was possessed by Arka Meghali (0.87) among tester.

In pooled, significant positive gca effects for number of fruits per plant were possessed by NDT- 3 (7.59) followed by NDT- 1 (4.99), NDT-2 (4.62), Arka Saurabh (2.96) and NDT-5 (0.87) among lines and significant and positive was possessed by Arka Meghali (0.87) among tester.

Thus, among the parents, NDT- 3, NDT- 1, NDT-2, Arka Saurabh and NDT-5 were found good general combiners in both the years and pooled for number of fruits per plant.

4.4.2.8 Average fruit weight (g)

In Y_1, significant and positive gca effects for average fruit weight were possessed by NDT-1 (7.34) followed by Azad T-6 (5.12), Arka Saurabh (3.72), NDT-7 (3.02) and NDT-2 (1.90) among lines and Arka Meghali (1.27) among testers.

In Y_2, significant and positive gca effects for average fruit weight were possessed by NDT-1 (7.36) followed by Azad T-6 (5.14), Arka Saurabh (3.74), NDT-7 (3.03) and NDT-2 (1.92) among lines and Arka Meghali (1.29) among testers.

In pooled, significant and positive gca effects for average fruit weight were possessed by NDT-1 (7.35) followed by Azad T-6 (5.13), Arka Saurabh (3.73), NDT-7 (3.02) and NDT-2 (1.91) among lines and Arka Meghali (1.28) among testers.

Thus, based on result both the years and pooled NDT-1, Azad T-6, Arka Saurabh, NDT-7 and NDT-2 were found as the top good general combiners for average fruit weight.

4.4.2.9 Fruit length (cm)

In Y_1, none of the parent possessed significant and positive gca effects for fruit length among lines and tester.

In Y_2, none of the parent possessed significant and positive gca effects for fruit length among lines and tester.

In pooled, Arka Saurabh (0.26) and NDT-4 (0.24) among lines and none of the parent among testers exhibited significant positive gca effects.

Thus, none of the parents was found as the good general combiners for fruit length over both the years and pooled.

4.4.2.10 Fruit girth (cm)

In Y_1, Arka Saurabh (1.08) among lines and none of the parent among testers exhibited significant and positive gca effects.

In Y_2, Arka Saurabh (1.09) among lines and none of the parent among testers exhibited significant and positive gca effects.

In pooled, Arka Saurabh (1.08) among lines and none of the parent among testers exhibited significant and positive gca effects.

Thus, among the parents Arka Saurabh was found as good general combiners for fruit length over both the years and pooled.

4.4.2.11 Number of locules per fruit

In Y_1, significant positive gca effects for number of locules per fruit were possessed by Azad T-6 (0.39) followed by NDT-6 (0.36) among lines and none of the parent among testers.

In Y_2, Azad T-6 (0.39) followed by NDT-6 (0.36) among lines and no one among testers exhibited significant and positive gca effects.

In pooled, significant positive gca effects for number of locules per fruit were possessed by Azad T-6 (0.39) followed by NDT-6 (0.36) and NDT-2 (0.24) among lines and none of the parent among testers.

Thus, among the parents Azad T-6 and NDT-6 were found as the top two good general combiners for fruit length over both the years and pooled.

4.4.2.12 Pericarp thickness (mm)

In Y_1, significant and positive gca effects for pericarp thickness was possessed by NDT-8 (0.36) among lines and no one among testers.

In Y_2, significant and positive gca effects for pericarp thickness was possessed by NDT-8 (0.36) among lines and no one among testers.

In pooled, significant and positive gca effects for pericarp thickness was possessed by NDT-8 (0.36) followed by NDT-2 (0.28) among lines and Arka Vikas (0.12) among testers.

Thus, among the parents NDT-8 were found as good general combiners for pericarp thickness over both the years and pooled.

4.4.2.13 Total soluble solids (B^o)

In Y_1, significant and positive gca effects for total soluble solids were possessed by NDT-2 (0.45) followed by Arka Saurabh (0.31) among lines and no one among testers.

In Y_2, NDT-2 (0.45) followed by Arka Saurabh (0.31) among lines and no one among testers exhibited significant and positive gca effects.

In pooled, significant and positive gca effects for total soluble solids were possessed by NDT-2 (0.45) followed by Arka Saurabh (0.31), NDT-3 (0.28) among lines and no one among testers.

Thus, NDT-2 and Arka Saurabh were found as top two good general combiners for total soluble solids over both the years and pooled.

4.4.2.14 Ascorbic acid (mg/100g)

In Y_1, significant and positive gca effects for ascorbic acid were possessed by NDT-5 (18.10) followed by Azad T-6 (15.48) and NDT-4 (3.75) among lines and Arka Meghali (2.17) among testers.

In Y_2, NDT-5 (18.50) followed by Azad T-6 (15.64) and NDT-4 (2.69) among lines and Arka Meghali (2.57) among testers exhibited significant and positive gca effects.

In pooled, significant and positive gca effects for ascorbic acid were

possessed by NDT-5 (18.30) followed by Azad T-6 (15.56) and NDT-4 (3.22) among lines and Arka Meghali (3.37) among testers.

Thus, among the parents NDT-5, Azad T-6 and NDT-4 were found good general combiners in both the years and pooled for ascorbic acid.

4.4.2.15 Total fruit yield per plant (kg)

In Y_1, significant and positive gca effects for total fruit yield per plant were possessed by NDT-2 (0.39) followed by NDT-3 (0.33) and NDT-1 (0.19) among lines and Arka Vikas (0.10) among testers.

In Y_2, NDT-2 (0.39) followed by NDT-3 (0.33) among lines and none of the parent among testers exhibited significant and positive gca effects.

In pooled, significant and positive gca effects for total fruit yield per plant were possessed by NDT-2 (0.39) followed by NDT-3 (0.33), NDT-1 (0.19) and Arka Saurabh (0.13) among lines and Arka Vikas (0.11) among testers.

Thus, among the parents NDT-2, NDT-3 were found good general combiners in both the years and pooled for total fruit yield per plant.

4.4.3 Estimates of specific combining ability effects

The estimates of specific combining ability (sca) effects for all the fifteen characters in respect to 14 parents (10 females and 4 males) in Y_1, Y_2 and pooled had presented in Table 4.8. The negative estimates of specific combining ability were considered desirable for days to 50% flowering, days to first fruit set and days to first fruit harvest. However, for rest of the characters positive estimates of specific combining ability were considered desirable. The character wise results are presented below in sub-heads:

4.4.3.1 Days to 50% flowering

In Y_1, out of forty crosses combinations only five crosses showed significant and negative sca effects. Based on magnitude of sca effects best

five crosses combinations in order of merit were NDT-4 × Arka Meghali (-3.73), Azad T-6 × Arka Vikas (-2.68), NDT-6 × Pb. Chhuhara (-2.30), NDT-7 × Arka Vikas (-1.97) and NDT-3 × Arka Meghali (-1.95) while, four crosses exhibited positive and significant sca effects for days to 50% flowering.

In case of Y_2, out of forty crosses combinations only four crosses namely NDT-4 × Arka Meghali (-3.14), NDT-6 × Pb. Chhuhara (-2.55), NDT-7 × Arka Vikas (-2.34) and Azad T-6 × Arka Vikas (-2.16) showed significant and negative sca effects for days to 50% flowering. On the other hand four crosses exhibited positive and significant sca effects for days to 50% flowering.

In pooled, out of forty crosses combinations seven crosses showed significant and negative sca effects. Based on magnitude of sca effects best five crosses combinations in order of merit were NDT-4 × Arka Meghali (-3.44), NDT-6 × Pb. Chhuhara (-2.43), Azad T-6 × Arka Vikas (-2.42), NDT-7 × Arka Vikas (-2.15) and NDT-3 × Arka Meghali (-1.62) while, six crosses exhibited positive and significant sca effects for days to 50% flowering.

4.4.3.2 Days to first fruit set

In Y_1, out of forty crosses combinations only two crosses namely NDT-4 × Arka Meghali (-3.00) and Azad T-6 × Arka Vikas (-2.12) showed significant and negative sca effects while, only one cross exhibited positive and significant sca effects for days to first fruit set.

In Y_2, out of forty crosses combinations only two crosses namely NDT-4 × Arka Meghali (-3.00) and Azad T-6 × Arka Vikas (-2.12) showed significant and negative sca effects while, only one cross exhibited positive and significant sca effects for days to first fruit set.

Table-4.8. Estimates of specific combining ability (sca) effects of crosses for 15 characters in tomato over two years (Y_1, Y_2) and pooled

Traits / Crosses	Days to 50 % flowering			Days to first fruit set			Days to first fruit harvest			Plant height (cm)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1 × Pusa Ruby	-0.32	-0.65	-0.49	-0.30	-0.30	-0.30	-0.04	-0.04	-0.04	-3.26	-6.75**	-5.01**
NDT-1 × Pb. Chhuhara	-0.21	0.10	-0.05	-0.10	-0.10	-0.10	-0.14	-0.14	-0.14	-3.04	-5.43**	-4.24**
NDT-1 × Arka Vikas	2.05*	1.91*	1.98**	1.90	1.90	1.90**	1.54	1.54	1.54*	1.06	-0.46	0.30
NDT-1 × Arka Meghali	-1.52	-1.35	-1.44*	-1.50	-1.50	-1.50*	-1.36	-1.36	-1.36	5.25**	12.63**	8.94**
NDT-2 × Pusa Ruby	0.22	-0.15	0.04	-1.11	-1.11	-1.11	-0.94	-0.94	-0.94	-1.90	-2.89	-2.40
NDT-2 × Pb. Chhuhara	-1.12	-1.14	-1.13	-1.23	-1.23	-1.23	-0.79	-0.79	-0.79	-5.78**	-5.66**	-5.72**
NDT-2 × Arka Vikas	0.45	0.32	0.38	0.60	0.60	0.60	0.48	0.48	0.48	0.31	1.29	0.80
NDT-2 × Arka Meghali	0.45	0.96	0.71	1.74	1.74	1.74*	1.26	1.26	1.26	7.37**	7.26**	7.32**
NDT-3 × Pusa Ruby	-0.05	-0.25	-0.15	0.70	0.70	0.70	0.39	0.39	0.39	-6.35**	0.17	-3.09*
NDT-3 × Pb. Chhuhara	1.42	1.23	1.32*	1.60	1.60	1.60*	1.10	1.10	1.10	5.08*	2.70	3.89**
NDT-3 × Arka Vikas	0.58	0.29	0.44	-0.38	-0.38	-0.38	0.50	0.50	0.50	4.37*	2.85	3.61*
NDT-3 × Arka Meghali	-1.95*	-1.28	-1.62*	-1.93	-1.93	-1.93**	-2.00	-2.00	-2.00*	-3.11	-5.72**	-4.41**
NDT-4 × Pusa Ruby	-0.27	-0.22	-0.24	-0.17	-0.17	-0.17	-0.44	-0.44	-0.44	-7.17**	-8.57**	-7.87**
NDT-4 × Pb. Chhuhara	1.52	0.92	1.22	0.85	0.85	0.85	0.91	0.91	0.91	9.78**	11.15**	10.47**
NDT-4 × Arka Vikas	2.48**	2.44*	2.46**	2.33*	2.33*	2.33**	2.34*	2.34*	2.34**	4.45*	5.02*	4.74**
NDT-4 × Arka Meghali	-3.73**	-3.14**	-3.44**	-3.00**	-3.00**	-3.00**	-2.82*	-2.82*	-2.82**	-7.06**	-7.59**	-7.33**
NDT-5 × Pusa Ruby	-0.18	0.12	-0.03	-0.14	-0.14	-0.14	0.01	0.01	0.01	-14.59**	-13.07**	-13.83**
NDT-5 × Pb. Chhuhara	-1.41	-1.09	-1.25*	-1.08	-1.08	-1.08	-1.07	-1.07	-1.07	10.20**	9.48**	9.84**
NDT-5 × Arka Vikas	1.06	1.27	1.17	1.53	1.53	1.53*	1.22	1.22	1.22	2.98	3.13	3.05*
NDT-5 × Arka Meghali	0.52	-0.30	0.11	-0.31	-0.31	-0.31	-0.16	-0.16	-0.16	1.41	0.46	0.94
NDT-6 × Pusa Ruby	0.84	0.90	0.87	0.80	0.80	0.80	0.55	0.55	0.55	-0.95	-3.19	-2.07
NDT-6 × Pb. Chhuhara	-2.30*	-2.55**	-2.43**	-1.77	-1.77	-1.77*	-1.69	-1.69	-1.69*	0.15	4.01*	2.08
NDT-6 × Arka Vikas	-0.63	-0.37	-0.50	-0.90	-0.90	-0.90	-0.68	-0.68	-0.68	-4.14*	-4.41*	-4.27**
NDT-6 × Arka Meghali	2.09*	2.02*	2.05**	1.87	1.87	1.87**	1.82	1.82	1.82*	4.95*	3.58	4.27**

Cont….

Traits / Crosses	Days to 50 % flowering			Days to first fruit set			Days to first fruit harvest			Plant height (cm)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-7 × Pusa Ruby	0.30	0.68	0.49	0.02	0.02	0.02	0.00	0.00	-0.01	12.91**	12.67**	12.79**
NDT-7 × Pb. Chhuhara	-0.13	0.27	0.07	0.47	0.47	0.47	0.09	0.09	0.09	-7.27**	-6.41**	-6.84**
NDT-7 × Arka Vikas	-1.97*	-2.34*	-2.15**	-1.66	-1.66	-1.66*	-1.79	-1.79	-1.79*	-3.55	-3.82	-3.68*
NDT-7 × Arka Meghali	1.80	1.39	1.59*	1.17	1.17	1.17	1.70	1.70	1.70*	-2.08	-2.45	-2.27
NDT-8 × Pusa Ruby	0.14	0.25	0.19	0.15	0.15	0.15	0.29	0.29	0.29	13.32**	12.34**	12.83**
NDT-8 × Pb. Chhuhara	-0.85	-0.72	-0.79	-1.27	-1.27	-1.27	-0.72	-0.72	-0.72	-5.25**	-5.13*	-5.19**
NDT-8 × Arka Vikas	-0.65	-0.53	-0.59	-0.42	-0.42	-0.42	-0.44	-0.44	-0.44	-6.81**	-5.82**	-6.31**
NDT-8 × Arka Meghali	1.36	1.01	1.18	1.54	1.54	1.54*	0.87	0.87	0.87	-1.27	-1.38	-1.33
Azad T-6 × Pusa Ruby	0.33	-0.06	0.13	0.39	0.39	0.39	0.56	0.56	0.56	-3.81	-4.04*	-3.93**
Azad T-6 × Pb. Chhuhara	2.37*	2.34*	2.35**	1.87	1.87	1.87**	1.93	1.93	1.93*	0.81	0.68	0.75
Azad T-6 × Arka Vikas	-2.68**	-2.16*	-2.42**	-2.12*	-2.12*	-2.12**	-2.11	-2.11	-2.11**	-1.57	-0.84	-1.21
Azad T-6 × Arka Meghali	-0.01	-0.12	-0.07	-0.14	-0.14	-0.14	-0.39	-0.39	-0.39	4.57*	4.20*	4.38**
Arka Saurabh × Pusa Ruby	-1.02	-0.63	-0.82	-0.33	-0.33	-0.33	-0.37	-0.37	-0.37	11.81**	13.33**	12.57**
Arka Saurabh × Pb. Chhuhara	0.70	0.66	0.68	0.66	0.66	0.66	0.37	0.37	0.37	-4.68*	-5.39**	-5.04**
Arka Saurabh × Arka Vikas	-0.68	-0.84	-0.76	-0.88	-0.88	-0.88	-1.06	-1.06	-1.06	2.90	3.05	2.98*
Arka Saurabh × Arka Meghali	1.00	0.81	0.91	0.55	0.55	0.55	1.06	1.06	1.06	-10.04**	-10.99**	-10.51**
SE (Sij)	**0.94**	**0.94**	**0.63**	**1.05**	**1.05**	**0.69**	**1.08**	**1.08**	**0.77**	**1.95**	**2.00**	**1.43**
SE (Sij-Sik)	**2.20**	**2.20**	**1.48**	**2.46**	**2.46**	**1.62**	**2.53**	**2.53**	**1.81**	**4.57**	**4.70**	**3.35**

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table -4.8 Cont….

Traits / Crosses	Number of primary branches per plant			Number of fruits per cluster			Number of fruits per plant			Average fruit weight (g)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1 × Pusa Ruby	0.16	0.16	0.16	-0.60	-0.62	-0.61**	-0.78	-0.78	-0.78	-12.58**	-12.59**	-12.59**
NDT-1 × Pb. Chhuhara	0.38	0.38	0.38*	0.62	0.60	0.61**	0.99	0.99	0.99	-5.36**	-5.37**	-5.36**
NDT-1 × Arka Vikas	-0.09	-0.09	-0.09	0.19	0.21	0.20	-0.89	-0.89	-0.89	6.52**	6.57**	6.55**
NDT-1 × Arka Meghali	-0.45	-0.45	-0.45*	-0.21	-0.19	-0.20	0.69	0.69	0.69	11.41**	11.39**	11.40**
NDT-2 × Pusa Ruby	0.38	0.38	0.38*	0.36	0.34	0.35	-0.04	-0.04	-0.04	6.58**	6.56**	6.57**
NDT-2 × Pb. Chhuhara	-0.14	-0.14	-0.14	0.08	0.07	0.08	-4.97**	-4.97**	-4.97**	8.73**	8.72**	8.73**
NDT-2 × Arka Vikas	-0.17	-0.17	-0.17	-0.49	-0.47	-0.48*	5.96**	5.96**	5.96**	-3.49**	-3.44**	-3.47**
NDT-2 × Arka Meghali	-0.07	-0.07	-0.07	0.05	0.06	0.05	-0.96	-0.96	-0.96	-11.82**	-11.84**	-11.83**
NDT-3 × Pusa Ruby	0.32	0.32	0.32	0.62	0.60	0.61**	0.94	0.94	0.94	-2.02	-2.04	-2.03*
NDT-3 × Pb. Chhuhara	0.00	0.00	0.00	-0.13	-0.14	-0.13	-0.28	-0.28	-0.28	2.95**	2.93**	2.94**
NDT-3 × Arka Vikas	-0.05	-0.05	-0.05	-0.47	-0.45	-0.46*	0.92	0.92	0.92	6.34**	6.39**	6.36**
NDT-3 × Arka Meghali	-0.27	-0.27	-0.27	-0.02	-0.01	-0.02	-1.58	-1.58	-1.58*	-7.26**	-7.28**	-7.27**
NDT-4 × Pusa Ruby	-0.22	-0.22	-0.22	-0.35	-0.37	-0.36	1.86*	1.86*	1.86**	-2.04	-2.06	-2.05*
NDT-4 × Pb. Chhuhara	-0.34	-0.34	-0.34	-0.06	-0.08	-0.07	0.58	0.58	0.58	0.50	0.48	0.49
NDT-4 × Arka Vikas	0.63*	0.63*	0.63**	0.27	0.29	0.28	-1.34	-1.34	-1.34*	0.74	0.79	0.77
NDT-4 × Arka Meghali	-0.07	-0.07	-0.07	0.14	0.16	0.15	-1.10	-1.10	-1.10	0.80	0.78	0.79
NDT-5 × Pusa Ruby	-0.16	-0.16	-0.16	-0.09	-0.11	-0.10	1.15	1.15	1.15	0.12	0.11	0.12
NDT-5 × Pb. Chhuhara	0.37	0.37	0.37	0.53	0.51	0.52*	-0.84	-0.84	-0.84	0.89	0.88	0.88
NDT-5 × Arka Vikas	-0.01	-0.01	-0.01	0.03	0.05	0.04	0.22	0.22	0.22	-0.15	-0.10	-0.12
NDT-5 × Arka Meghali	-0.20	-0.20	-0.20	-0.47	-0.45	-0.46*	-0.53	-0.53	-0.53	-0.87	-0.89	-0.88
NDT-6 × Pusa Ruby	-0.10	-0.10	-0.10	0.37	0.36	0.37	0.09	0.09	0.09	-0.28	-0.13	-0.21
NDT-6 × Pb. Chhuhara	-0.42	-0.42	-0.42*	-0.44	-0.45	-0.45	5.20**	5.20**	5.20**	-1.17	-1.02	-1.09
NDT-6 × Arka Vikas	0.11	0.11	0.11	0.26	0.28	0.27	-2.91**	-2.91**	-2.91**	0.85	0.40	0.62
NDT-6 × Arka Meghali	0.41	0.41	0.41*	-0.20	-0.18	-0.19	-2.38**	-2.38**	-2.38**	0.60	0.75	0.68

Cont….

Traits / Crosses	Number of primary branches per plant			Number of fruits per cluster			Number of fruits per plant			Average fruit weight (g)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-7 × Pusa Ruby	-0.33	-0.33	-0.33	-0.72*	-0.65*	-0.69**	1.53	1.53	1.53*	-4.42**	-4.44**	-4.43**
NDT-7 × Pb. Chhuhara	0.06	0.06	0.06	0.14	0.21	0.17	-0.51	-0.51	-0.51	-1.82	-1.83	-1.82*
NDT-7 × Arka Vikas	-0.12	-0.12	-0.12	0.57	0.67*	0.62**	-5.62**	-5.62**	-5.62**	1.22	1.27	1.24
NDT-7 × Arka Meghali	0.39	0.39	0.39*	0.01	-0.22	-0.11	4.61**	4.61**	4.61**	5.02**	5.01**	5.01**
NDT-8 × Pusa Ruby	0.08	0.08	0.08	0.02	0.08	0.05	0.87	0.87	0.87	-1.93	-1.95	-1.94*
NDT-8 × Pb. Chhuhara	0.09	0.09	0.09	0.08	0.15	0.11	1.57	1.57	1.57*	0.50	0.48	0.49
NDT-8 × Arka Vikas	0.18	0.18	0.18	0.16	-0.08	0.04	2.59**	2.59**	2.59**	-3.16**	-3.11**	-3.14**
NDT-8 × Arka Meghali	-0.35	-0.35	-0.35	-0.25	-0.15	-0.20	-5.03**	-5.03**	-5.03**	4.59**	4.58**	4.59**
Azad T-6 × Pusa Ruby	-0.03	-0.03	-0.03	0.16	0.15	0.15	-1.50	-1.50	-1.50*	-1.09	-1.11	-1.10
Azad T-6 × Pb. Chhuhara	-0.35	-0.35	-0.35	-0.52	-0.54	-0.53*	0.02	0.02	0.02	-2.40*	-2.42*	-2.41**
Azad T-6 × Arka Vikas	-0.10	-0.10	-0.10	-0.40	-0.38	-0.39	-0.55	-0.55	-0.55	-2.09	-2.04	-2.06*
Azad T-6 × Arka Meghali	0.48	0.48	0.48*	0.75*	0.77*	0.76**	2.03*	2.03*	2.03**	5.58**	5.56**	5.57**
Arka Saurabh × Pusa Ruby	-0.09	-0.09	-0.09	0.23	0.22	0.22	-4.11**	-4.11**	-4.11**	17.66**	17.64**	17.65**
Arka Saurabh × Pb. Chhuhara	0.35	0.35	0.35	-0.31	-0.33	-0.32	-1.75*	-1.75*	-1.75**	-2.83*	-2.84*	-2.84**
Arka Saurabh × Arka Vikas	-0.38	-0.38	-0.38*	-0.12	-0.10	-0.11	1.63	1.63	1.63*	-6.78**	-6.73**	-6.75**
Arka Saurabh × Arka Meghali	0.12	0.12	0.12	0.19	0.21	0.20	4.24**	4.24**	4.24**	-8.06**	-8.07**	-8.06**
SE (Sij)	**0.29**	**0.29**	**0.19**	**0.32**	**0.32**	**0.23**	**0.87**	**0.87**	**0.65**	**1.10**	**1.10**	**0.81**
SE (Sij-Sik)	**0.68**	**0.68**	**0.45**	**0.74**	**0.75**	**0.53**	**2.04**	**2.04**	**1.53**	**2.57**	**2.59**	**1.90**

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table -4.8 Cont….

Traits / Crosses	Fruit length (cm)			Fruit girth (cm)			Number of locules per fruit			Pericarp thickness (mm)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1 × Pusa Ruby	-0.63	-0.63	-0.63**	-0.70	-0.72	-0.71	-0.14	-0.14	-0.14	0.04	0.04	0.04
NDT-1 × Pb. Chhuhara	0.25	0.25	0.25	0.32	0.34	0.33	-0.09	-0.09	-0.09	0.17	0.17	0.17
NDT-1 × Arka Vikas	0.08	0.08	0.08	0.08	0.07	0.08	0.12	0.12	0.12	-0.11	-0.11	-0.11
NDT-1 × Arka Meghali	0.30	0.30	0.30	0.29	0.31	0.30	0.12	0.12	0.12	-0.10	-0.10	-0.10
NDT-2 × Pusa Ruby	0.35	0.35	0.35	-0.29	-0.31	-0.30	0.14	0.14	0.14	-0.01	-0.01	-0.01
NDT-2 × Pb. Chhuhara	0.17	0.17	0.17	0.69	0.71	0.70	-0.51	-0.51	-0.51*	-0.02	-0.02	-0.02
NDT-2 × Arka Vikas	-0.78*	-0.78*	-0.78**	-0.35	-0.36	-0.36	0.70*	0.70*	0.70**	0.19	0.19	0.19
NDT-2 × Arka Meghali	0.27	0.27	0.27	-0.05	-0.04	-0.04	-0.33	-0.33	-0.33	-0.15	-0.15	-0.15
NDT-3 × Pusa Ruby	-0.17	-0.17	-0.17	0.01	0.00	0.01	-1.35**	-1.35**	-1.35**	0.36	0.36	0.36*
NDT-3 × Pb. Chhuhara	0.53	0.53	0.53*	-0.39	-0.38	-0.39	0.22	0.22	0.22	-0.09	-0.09	-0.09
NDT-3 × Arka Vikas	-0.08	-0.08	-0.08	-0.01	-0.03	-0.02	0.13	0.13	0.13	0.04	0.04	0.04
NDT-3 × Arka Meghali	-0.29	-0.29	-0.29	0.39	0.41	0.40	1.00**	1.00*	1.00**	-0.30	-0.30	-0.30
NDT-4 × Pusa Ruby	0.76**	0.76*	0.76**	1.31	1.29	1.30**	0.40	0.40	0.40	-0.15	-0.15	-0.15
NDT-4 × Pb. Chhuhara	0.02	0.02	0.02	0.78	0.80	0.79	0.42	0.42	0.42	-0.38	-0.38	-0.38*
NDT-4 × Arka Vikas	-0.03	-0.03	-0.03	-0.75	-0.77	-0.76	-0.30	-0.30	-0.30	0.48	0.48	0.48**
NDT-4 × Arka Meghali	-0.74*	-0.74*	-0.74**	-1.34	-1.32	-1.33**	-0.51	-0.51	-0.51*	0.05	0.05	0.05
NDT-5 × Pusa Ruby	-0.57	-0.57	-0.57*	-1.57*	-1.59*	-1.58**	-0.03	-0.03	-0.03	0.05	0.05	0.05
NDT-5 × Pb. Chhuhara	-0.32	-0.32	-0.32	-1.05	-1.04	-1.04*	0.02	0.02	0.02	-0.12	-0.12	-0.12
NDT-5 × Arka Vikas	-0.02	-0.02	-0.02	0.71	0.69	0.70	-0.17	-0.17	-0.17	-0.03	-0.03	-0.03
NDT-5 × Arka Meghali	0.91**	0.91**	0.91**	1.92**	1.93**	1.92**	0.19	0.19	0.19	0.10	0.10	0.10
NDT-6 × Pusa Ruby	-0.47	-0.47	-0.47*	0.22	0.37	0.29	1.10**	1.10**	1.10**	-0.23	-0.23	-0.23
NDT-6 × Pb. Chhuhara	-0.24	-0.24	-0.24	-0.06	-0.21	-0.13	0.44	0.44	0.44	0.05	0.05	0.05
NDT-6 × Arka Vikas	0.79*	0.79*	0.79**	0.07	0.22	0.15	-0.65	-0.65	-0.65**	-0.32	-0.32	-0.32
NDT-6 × Arka Meghali	-0.07	-0.07	-0.07	-0.23	-0.38	-0.31	-0.89*	-0.89*	-0.89**	0.50	0.50	0.50**

Cont….

Traits / Crosses	Fruit length (cm)			Fruit girth (cm)			Number of locules per fruit			Pericarp thickness (mm)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-7 × Pusa Ruby	-0.33	-0.33	-0.33	0.65	0.63	0.64	-0.19	-0.19	-0.19	-0.02	-0.02	-0.02
NDT-7 × Pb. Chhuhara	0.84*	0.84*	0.84**	-0.22	-0.20	-0.21	0.02	0.02	0.02	-0.10	-0.10	-0.10
NDT-7 × Arka Vikas	-0.28	-0.28	-0.28	-0.46	-0.47	-0.47	-0.30	-0.30	-0.30	0.26	0.26	0.26
NDT-7 × Arka Meghali	-0.23	-0.23	-0.23	0.03	0.04	0.04	0.47	0.47	0.47	-0.14	-0.14	-0.14
NDT-8 × Pusa Ruby	0.64	0.64	0.64**	0.21	0.20	0.21	-0.17	-0.17	-0.17	-0.53	-0.53	-0.53**
NDT-8 × Pb. Chhuhara	-0.54	-0.54	-0.54*	-0.14	-0.13	-0.14	-0.43	-0.43	-0.43	0.44	0.44	0.44*
NDT-8 × Arka Vikas	-0.15	-0.15	-0.15	-0.16	-0.18	-0.17	-0.18	-0.18	-0.18	0.03	0.03	0.03
NDT-8 × Arka Meghali	0.04	0.04	0.04	0.09	0.11	0.10	0.78*	0.78*	0.78**	0.06	0.06	0.06
Azad T-6 × Pusa Ruby	0.11	0.11	0.11	0.66	0.64	0.65	0.37	0.37	0.37	0.33	0.33	0.33
Azad T-6 × Pb. Chhuhara	-0.18	-0.18	-0.18	-0.76	-0.74	-0.75	-0.39	-0.39	-0.39	-0.25	-0.25	-0.25
Azad T-6 × Arka Vikas	-0.07	-0.07	-0.07	-0.47	-0.49	-0.48	0.29	0.29	0.29	-0.07	-0.07	-0.07
Azad T-6 × Arka Meghali	0.14	0.14	0.14	0.57	0.59	0.58	-0.28	-0.28	-0.28	-0.01	-0.01	-0.01
Arka Saurabh × Pusa Ruby	0.33	0.33	0.33	-0.50	-0.52	-0.51	-0.15	-0.15	-0.15	0.17	0.17	0.17
Arka Saurabh × Pb. Chhuhara	-0.54	-0.54	-0.54*	0.83	0.85	0.84	0.30	0.30	0.30	0.30	0.30	0.30
Arka Saurabh × Arka Vikas	0.55	0.55	0.55*	1.34	1.33	1.33**	0.38	0.38	0.38	-0.47	-0.47	-0.47*
Arka Saurabh × Arka Meghali	-0.34	-0.34	-0.34	-1.67*	-1.66*	-1.66**	-0.53	-0.53	-0.53*	0.00	0.00	0.00
SE (Sij)	**0.33**	**0.33**	**0.23**	**0.70**	**0.70**	**0.48**	**0.35**	**0.35**	**0.25**	**0.28**	**0.28**	**0.18**
SE (Sij-Sik)	**0.77**	**0.77**	**0.55**	**1.63**	**1.64**	**1.12**	**0.81**	**0.81**	**0.57**	**0.66**	**0.66**	**0.42**

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table -4.8 Cont….

Traits / Crosses	Total soluble solid (TSS)			Ascorbic acid (mg/100 g fresh fruit)			Total fruit yield per plant (kg)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1 × Pusa Ruby	-0.03	-0.03	-0.03	5.15**	-0.42	2.36*	-0.04	0.00	-0.02
NDT-1 × Pb. Chhuhara	-0.22	-0.22	-0.22	-4.44**	-2.06	-3.25**	0.18	0.09	0.13
NDT-1 × Arka Vikas	0.56	0.56	0.56*	-4.25**	-8.10**	-6.17**	-0.12	-0.08	-0.10
NDT-1 × Arka Meghali	-0.31	-0.31	-0.31	3.55*	10.59**	7.07**	-0.02	0.00	-0.01
NDT-2 × Pusa Ruby	0.17	0.17	0.17	9.79**	7.87**	8.83**	-0.01	-0.01	-0.01
NDT-2 × Pb. Chhuhara	-0.51	-0.51	-0.51*	-0.29	0.81	0.26	-0.19	-0.17	-0.18
NDT-2 × Arka Vikas	0.21	0.21	0.21	-4.48**	-3.01*	-3.75**	0.01	0.01	0.01
NDT-2 × Arka Meghali	0.14	0.14	0.14	-5.02**	-5.67**	-5.34**	0.19	0.17	0.18
NDT-3 × Pusa Ruby	0.29	0.29	0.29	-1.61	-3.10*	-2.35*	-0.16	-0.16	-0.16
NDT-3 × Pb. Chhuhara	-0.40	-0.40	-0.40	-0.40	0.13	-0.13	0.12	0.14	0.13
NDT-3 × Arka Vikas	-0.04	-0.04	-0.04	2.79*	3.59*	3.19**	0.24	0.24	0.24
NDT-3 × Arka Meghali	0.15	0.15	0.15	-0.78	-0.62	-0.70	-0.20	-0.22	-0.21
NDT-4 × Pusa Ruby	0.06	0.06	0.06	0.28	-1.19	-0.45	-0.11	-0.11	-0.11
NDT-4 × Pb. Chhuhara	-0.04	-0.04	-0.04	0.00	0.71	0.35	-0.01	0.02	0.01
NDT-4 × Arka Vikas	0.20	0.20	0.20	1.26	2.36	1.81	0.30	0.30	0.30*
NDT-4 × Arka Meghali	-0.22	-0.22	-0.22	-1.54	-1.89	-1.72	-0.19	-0.21	-0.20
NDT-5 × Pusa Ruby	-0.68*	-0.68*	-0.68**	-7.68**	-2.78	-5.23**	-0.30	-0.30	-0.30*
NDT-5 × Pb. Chhuhara	0.71*	0.71*	0.71**	4.74**	3.01*	3.88**	0.41*	0.43*	0.42**
NDT-5 × Arka Vikas	-0.39	-0.39	-0.39	1.55	0.18	0.86	-0.40*	-0.40*	-0.40**
NDT-5 × Arka Meghali	0.36	0.36	0.36	1.40	-0.42	0.49	0.29	0.27	0.28*
NDT-6 × Pusa Ruby	-0.21	-0.21	-0.21	2.86*	1.51	2.18*	0.41*	0.42*	0.42**
NDT-6 × Pb. Chhuhara	0.44	0.44	0.44	0.73	1.41	1.07	-0.57**	-0.55**	-0.56**
NDT-6 × Arka Vikas	0.47	0.47	0.47*	-1.74	-0.69	-1.22	0.07	0.06	0.06
NDT-6 × Arka Meghali	-0.70*	-0.70*	-0.70**	-1.84	-2.24	-2.04	0.09	0.07	0.08

Cont….

Traits / Crosses	Total soluble solid (TSS)			Ascorbic acid (mg/100 g fresh fruit)			Total fruit yield per plant (kg)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-7 × Pusa Ruby	-0.17	-0.17	-0.17	2.66	4.82**	3.74**	-0.21	-0.18	-0.20
NDT-7 × Pb. Chhuhara	1.08**	1.08**	1.08**	-0.69	-1.17	-0.93	-0.21	-0.16	-0.19
NDT-7 × Arka Vikas	-0.37	-0.37	-0.37	0.06	-0.06	0.00	0.10	0.13	0.12
NDT-7 × Arka Meghali	-0.54	-0.54	-0.54*	-2.03	-3.59*	-2.81**	0.32	0.22	0.27*
NDT-8 × Pusa Ruby	0.53	0.53	0.53*	-8.39**	-9.32**	-8.86**	0.06	0.03	0.04
NDT-8 × Pb. Chhuhara	-0.76*	-0.76*	-0.76**	-0.67	-3.90*	-2.29*	0.18	0.11	0.15
NDT-8 × Arka Vikas	0.43	0.43	0.43	2.19	5.33**	3.76**	-0.02	-0.06	-0.04
NDT-8 × Arka Meghali	-0.20	-0.20	-0.20	6.87**	7.89**	7.38**	-0.21	-0.08	-0.15
Azad T-6 × Pusa Ruby	-0.22	-0.22	-0.22	-2.55	-4.06**	-3.30**	0.12	0.11	0.12
Azad T-6 × Pb. Chhuhara	0.13	0.13	0.13	0.38	2.23	1.31	-0.02	-0.02	-0.02
Azad T-6 × Arka Vikas	-0.16	-0.16	-0.16	0.90	2.12	1.51	0.02	0.04	0.03
Azad T-6 × Arka Meghali	0.24	0.24	0.24	1.27	-0.30	0.49	-0.13	-0.13	-0.13
Arka Saurabh × Pusa Ruby	0.26	0.26	0.26	-0.51	6.65**	3.07**	0.23	0.21	0.22
Arka Saurabh × Pb. Chhuhara	-0.43	-0.43	-0.43	0.64	-1.17	-0.26	0.11	0.11	0.11
Arka Saurabh × Arka Vikas	-0.91**	-0.91**	-0.91**	1.73	-1.72	0.00	-0.20	-0.23	-0.22
Arka Saurabh × Arka Meghali	1.08**	1.08**	1.08**	-1.87	-3.76*	-2.81**	-0.14	-0.09	-0.11
SE (Sij)	**0.31**	**0.31**	**0.22**	**1.40**	**1.51**	**1.04**	**0.16**	**0.17**	**0.13**
SE (Sij-Sik)	**0.72**	**0.72**	**0.53**	**3.28**	**3.54**	**2.44**	**0.38**	**0.40**	**0.30**

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

In pooled, out of forty crosses combinations only six crosses showed significant and negative sca effects. Based on magnitude of sca effects best five crosses combinations in order of merit were NDT-4 × Arka Meghali (-3.00), Azad T-6 × Arka Vikas (-2.12), NDT-3 × Arka Meghali (-1.93), NDT-6 × Pb. Chhuhara (-1.77) and NDT-7 × Arka Vikas (-1.66) while, eight crosses exhibited positive and significant sca effects for days to first fruit set.

4.4.3.3 Days to first fruit harvest

In Y_1, out of forty crosses combinations only one cross namely NDT-4 × Arka Meghali (-2.82) showed significant and negative sca effects while, only one cross exhibited positive and significant sca effects for days to first fruit harvest.

In Y_2, out of forty crosses combinations only one cross namely NDT-4 × Arka Meghali (-2.82) showed significant and negative sca effects while, only one cross exhibited positive and significant sca effects for days to first fruit harvest.

In pooled, out of forty crosses combinations only five crosses showed significant and negative sca effects. Based on magnitude of sca effects best five crosses combinations in order of merit were NDT-4 × Arka Meghali (-2.82), Azad T-6 × Arka Vikas (-2.11), NDT-3 × Arka Meghali (-2.00), NDT-7 × Arka Vikas (-1.79) and NDT-6 × Pb. Chhuhara (-1.69) while, five crosses exhibited positive and significant sca effects for days to first fruit harvest.

4.4.3.4 Plant height (cm)

For this trait, among forty crosses in Y_1 only twelve crosses combinations showed significant and positive sca effects. The best five crosses were NDT-8 × Pusa Ruby (13.32), NDT-7 × Pusa Ruby (12.91), Arka

Saurabh × Pusa Ruby (11.81), NDT-5 × Pb. Chhuhara (10.20) and NDT-4 × Pb. Chhuhara (9.78). On the other hand eleven crosses exhibited significant and negative sca effects for plant hight at last picking stage.

In Y_2, out of forty crosses only ten crosses combinations showed significant and positive sca effects. The best five crosses were Arka Saurabh × Pusa Ruby (13.33), NDT-7 × Pusa Ruby (12.67), NDT-1 × Arka Meghali (12.63), NDT-8 × Pusa Ruby (12.34) and NDT-4 × Pb. Chhuhara (11.15) which exhibited positive and significant sca effects whereas, only twelve cross combinations showed negative and significant sca effects for plant height at last picking stage.

In pooled, out of forty crosses only fourteen crosses combinations showed significant and positive sca effects. The best five crosses were NDT-8 × Pusa Ruby (12.83), NDT-7 × Pusa Ruby (12.79), Arka Saurabh × Pusa Ruby (12.57), NDT-4 × Pb. Chhuhara (10.47) and NDT-5 × Pb. Chhuhara (9.84). On the other hand sixteen crosses exhibited significant and negative sca effects for plant hight at last picking stage.

4.4.3.5 Number of primary branches per plant

In Y_1, out of forty crosses studied, only one cross namely NDT-4 × Arka Vikas (0.63) combinations exhibited significant and positive sca effects. On the other hand, none of the crosses showed negative and significant sca effects for this trait.

In Y_2, out of forty crosses studied, only one cross namely NDT-4 × Arka Vikas (0.63) combinations exhibited significant and positive sca effects. On the other hand, none of the crosses showed negative and significant sca effects for this trait.

In case of pooled, only six crosses combinations showed significant and positive sca effects for this trait among forty crosses. These crosses were

NDT-4 × Arka Vikas (0.63) followed by Azad T-6 × Arka Meghali (0.48), NDT-6 × Arka Meghali (0.41), NDT-7 × Arka Meghali (0.39) and NDT-1 × Pb. Chhuhara and NDT-2 × Pusa Ruby (0.38). On the other hand three crosses combinations showed negative and significant sca effects for number of primary branches per plant.

4.4.3.6 Number of fruits per cluster

In Y_1, for this trait out of forty crosses only one cross namely Azad T-6 × Arka Meghali (0.75) combinations showed significant and positive sca effects. Likewise only one cross exhibited significant and negative sca effects for number of fruits per cluster.

In Y_2, for this trait out of forty crosses only two crosses namely Azad T-6 × Arka Meghali (0.77) and NDT-7 × Arka Vikas (0.67) combinations showed significant and positive sca effects. Likewise only one cross exhibited significant and negative sca effects for number of fruits per cluster.

In case of pooled, only five crosses combinations showed significant and positive sca effects for this trait among forty crosses. These crosses were Azad T-6 × Arka Meghali (0.76) followed by NDT-7 × Arka Vikas (0.62), NDT-1 × Pb. Chhuhara and NDT-3 × Pusa Ruby (0.61) and NDT-5 × Pb. Chhuhara (0.52). On the other hand six crosses combinations showed negative and significant sca effects for number of fruits per cluster.

4.4.3.7 Number of fruits per plant

In Y_1, for this important trait out of forty crosses seven crosses combinations showed significant and positive sca effects. These crosses were NDT-2 × Arka Vikas (5.96), NDT-6 × Pb. Chhuhara (5.20), NDT-7 × Arka Meghali (4.61), Arka Saurabh × Arka Meghali (4.24) and NDT-8 × Arka Vikas (2.59). Six crosses exhibited significant and negative sca effects for number of fruits per plant.

In Y_2, for this trait out of forty crosses seven crosses combinations showed significant and positive sca effects. These crosses were NDT-2 × Arka Vikas (5.96), NDT-6 × Pb. Chhuhara (5.20), NDT-7 × Arka Meghali (4.61), Arka Saurabh × Arka Meghali (4.24) and NDT-8 × Arka Vikas (2.59). Seven crosses exhibited significant and negative sca effects for number of fruits per plant.

In case of pooled, out of forty crosses ten crosses combinations showed significant and positive sca effects. These crosses were NDT-2 × Arka Vikas (5.96), NDT-6 × Pb. Chhuhara (5.20), NDT-7 × Arka Meghali (4.61), Arka Saurabh × Arka Meghali (4.24) and NDT-8 × Arka Vikas (2.59). Ten crosses exhibited significant and negative sca effects for number of fruits per plant.

4.4.3.8 Average fruit weight (g)

In Y_1, out of forty crosses ten crosses combinations showed significant and positive sca effects. These crosses were Arka Saurabh × Pusa Ruby (17.66), NDT-1 × Arka Meghali (11.41), NDT-2 × Pb. Chhuhara (8.73), NDT-2 × Pusa Ruby (6.58) and NDT-1 × Arka Vikas (6.52). Eleven crosses exhibited significant and negative sca effects for average fruit weight.

In Y_2, out of forty crosses ten crosses combinations showed significant and positive sca effects. These crosses were Arka Saurabh × Pusa Ruby (17.64), NDT-1 × Arka Meghali (11.39), NDT-2 × Pb. Chhuhara (8.72), NDT-1 × Arka Vikas (6.57) and NDT-2 × Pusa Ruby (6.56). Eleven crosses exhibited significant and negative sca effects for average fruit weight.

In case of pooled, out of forty crosses ten crosses combinations showed significant and positive sca effects. These crosses were Arka Saurabh × Pusa Ruby (17.65), NDT-1 × Arka Meghali (11.40), NDT-2 × Pb. Chhuhara (8.73), NDT-2 × Pusa Ruby (6.57) and NDT-1 × Arka Vikas (6.55). Sixteen crosses exhibited significant and negative sca effects for average fruit weight.

4.4.3.9 Fruit length (cm)

In case of Y_1, out of forty crosses, only four crosses combinations showed positive and significant sca effects. These crosses were NDT-5 × Arka Meghali (0.91), NDT-7 × Pb. Chhuhara (0.84), NDT-6 × Arka Vikas (0.79) and NDT-4 × Pusa Ruby (0.76). Only two cross exhibited negative and significant sca effects for fruit length.

In Y_2, out of forty crosses, only four crosses combinations showed positive and significant sca effects. These crosses were NDT-5 × Arka Meghali (0.91), NDT-7 × Pb. Chhuhara (0.84), NDT-6 × Arka Vikas (0.79) and NDT-4 × Pusa Ruby (0.76). Only two cross exhibited negative and significant sca effects for fruit length.

In pooled, out of forty crosses, only seven crosses combinations showed positive and significant sca effects. These crosses were NDT-5 × Arka Meghali (0.91), NDT-7 × Pb. Chhuhara (0.84), NDT-6 × Arka Vikas (0.79), NDT-4 × Pusa Ruby (0.76) and NDT-8 × Pusa Ruby (0.64). Only seven cross exhibited negative and significant sca effects for fruit length.

4.4.3.10 Fruit girth (cm)

In thes case of Y_1, out of forty crosses, only one cross combination, NDT-5 × Arka Meghali (1.92) showed positive and significant sca effects whereas, only two crosses combination exhibited negative and significant sca effects for fruit girth.

In Y_2, out of forty crosses, only one cross combination, NDT-5 × Arka Meghali (1.93) showed positive and significant sca effects whereas, only two crosses combination exhibited negative and significant sca effects for fruit girth.

In pooled, out of forty crosses, only three cross combination, NDT-5 × Arka Meghali (1.92), Arka Saurabh × Arka Vikas (1.33) and NDT-4 × Pusa

Ruby (1.30) showed positive and significant sca effects whereas, only four crosses combination exhibited negative and significant sca effects for fruit girth.

4.4.3.11 Number of locules per fruit

In Y_1, out of forty crosses, four crosses combinations showed positive and significant sca effects. Among them the four noteworthy crosses were NDT-6 × Pusa Ruby (1.10), NDT-3 × Arka Meghali (1.00), NDT-8 × Arka Meghali (0.78) and NDT-2 × Arka Vikas (0.70). Two crosses combinations exhibited negative and significant sca effects for number of locules per fruit.

In Y_2, out of forty crosses, four crosses combinations showed positive and significant sca effects. Among them the four noteworthy crosses were NDT-6 × Pusa Ruby (1.10), NDT-3 × Arka Meghali (1.00), NDT-8 × Arka Meghali (0.78) and NDT-2 × Arka Vikas (0.70). Two crosses combinations exhibited negative and significant sca effects for number of locules per fruit.

In pooled, out of forty crosses, four crosses combinations showed positive and significant sca effects. Among them the four noteworthy crosses were NDT-6 × Pusa Ruby (1.10), NDT-3 × Arka Meghali (1.00), NDT-8 × Arka Meghali (0.78) and NDT-2 × Arka Vikas (0.70). Six crosses combinations exhibited negative and significant sca effects for number of locules per fruit.

4.4.3.12 Pericarp thickness (mm)

In this case of Y_1, out of forty crosses, none of the crosses combination showed positive and significant sca effects whereas, none of the crosses combination exhibited negative and significant sca effects for pericarp thickness.

In Y_2, out of forty crosses, none of the crosses combination showed positive and significant sca effects whereas, none of the crosses combination

exhibited negative and significant sca effects for pericarp thickness.

In pooled, high order of desirable sca effects were expressed by four combinations. These four cross combinations namely NDT-6 × Arka Meghali (0.50), NDT-4 × Arka Vikas (0.48), NDT-8 × Pb. Chhuhara (0.44) and NDT-3 × Pusa Ruby (0.36). On the other hand two crosses exhibited negative significant sca effects for fruit girth.

4.4.3.13 Total soluble solids (B^o)

In Y_1, perusal of sca values of crosses, NDT-7 × Pb. Chhuhara and Arka Saurabh × Arka Meghali (1.08) and NDT-5 × Pb. Chhuhara (0.71) identified, good specific combiner for total soluble solids whereas, negative and significant sca effects were recorded for four crosses combinations.

In Y_2, perusal of sca values of crosses, NDT-7 × Pb. Chhuhara and Arka Saurabh × Arka Meghali (1.08) and NDT-5 × Pb. Chhuhara (0.71) identified, good specific combiner for total soluble solids whereas, negative and significant sca effects were recorded for four crosses combinations.

In pooled, perusal of sca values of crosses, NDT-7 × Pb. Chhuhara and Arka Saurabh × Arka Meghali (1.08), NDT-5 × Pb. Chhuhara (0.71), NDT-1 × Arka Vikas (0.56), NDT-8 × Pusa Ruby (0.53) and NDT-6 × Arka Vikas (0.47) identified, good specific combiner for total soluble solids whereas, negative and significant sca effects were recorded for six crosses combinations.

4.4.3.14 Ascorbic acid (mg/100g)

For this character in Y_1, seven crosses combination showed positive and significant sca effects whereas, six cross combinations showed negative and significant sca effects. The desirable cross combinations sorted out for ascorbic acid were NDT-2 × Pusa Ruby (9.79), NDT-8 × Arka Meghali (6.87), NDT-1 × Pusa Ruby (5.15), NDT-5 × Pb. Chhuhara (4.74) and NDT-1 × Arka Meghali (3.55).

In case of Y_2, eight cross combinations showed positive and significant sca effects whereas, nine cross combinations showed negative and significant sca effects. The desirable cross combinations sorted out were NDT-1 × Arka Meghali (10.59), NDT-8 × Arka Meghali (7.89), NDT-2 × Pusa Ruby (7.87), Arka Saurabh × Pusa Ruby (6.65) and NDT-8 × Arka Vikas (5.33) for ascorbic acid.

For this character in pooled, ten crosses combination showed positive and significant sca effects whereas, eleven cross combinations showed negative and significant sca effects. The desirable cross combinations sorted out for ascorbic acid were NDT-2 × Pusa Ruby (8.83), NDT-8 × Arka Meghali (7.38), NDT-1 × Arka Meghali (7.07), NDT-5 × Pb. Chhuhara (3.88) and NDT-8 × Arka Vikas (3.76).

4.4.3.15 Total fruit yield per plant (kg)

For total fruit yield per plant, two cross combinations among forty crosses showed significant and positive sca effects for this trait in Y_1. Amongst these, the notable crosses were NDT-5 × Pb. Chhuhara and NDT-6 × Pusa Ruby (0.41). On the other hand two cross combinations showed negative and significant sca effects for this traits.

In case of Y_2, two cross combinations showed positive and significant sca effects. The best positive and significant cross combinations were NDT-5 × Pb. Chhuhara (0.43) and NDT-6 × Pusa Ruby (0.42). Two cross combinations showed negative sca effects for total fruit yield per plant.

In case of pooled, five cross combinations showed positive and significant sca effects. The best positive and significant cross combinations were NDT-5 × Pb. Chhuhara and NDT-6 × Pusa Ruby (0.42), NDT-4 × Arka Vikas (0.30), NDT-5 × Arka Meghali (0.28) and NDT-7 × Arka Meghali (0.27). Three cross combinations showed negative sca effects for total fruit yield per plant.

4.4.4 Proportional contribution of lines, testers and lines × testers towards total variance (%)

Proportional contribution of line, tester and lines × testers for the fifteen characters in Y_1 and Y_2 had been presented in Table 4.9.

4.4.4.1 Proportional contribution of lines (%)

The proportional contribution of lines in Y_1 varied from 21.37 per cent (fruit length) to 85.67 per cent (ascorbic acid). The maximum contribution of lines were recorded for ascorbic acid (85.67 %) followed by number of fruits per plant (77.52%), plant height (61.47%), total fruit yield per plant (58.16%), number of primary branches per plant (54.73%), pericarp thickness (43.55%), average fruit weight (42.18%), number of locules per fruit (39.74%), number of fruits per cluster (38.65%), fruit girth (32.55%) and days to first fruit harvest (31.74%) while, minimum contribution of lines were recorded for fruit length (21.37%) followed by total soluble solid (22.63%), days to 50 % flowering (22.81%) and days to first fruit set (25.42%).

In Y_2, proportional contribution of lines varied from 21.37 per cent (fruit length) to 81.78 per cent (ascorbic acid). The maximum contribution of lines were recorded for ascorbic acid (81.78 %) followed by number of fruits per plant (77.52%), total fruit yield per plant (60.61%), plant height (59.68%), number of primary branches per plant (54.73%), pericarp thickness (43.55%), fruit girth (43.31%), average fruit weight (42.33%), number of locules per fruit (39.74%), number of fruits per cluster (37.24%) and days to first fruit harvest (31.74%) while, minimum contribution of lines were recorded for fruit length (21.37%) followed by total soluble solid (22.63%), days to first fruit set (25.42%) and days to 50 % flowering (30.13%).

4.4.4.2 Proportional contribution of testers (%)

The proportional contribution of testers towards the variability for

different characters in Y_1 ranged from 1.43 per cent (average fruit weight) to 32.83 per cent (plant hieght). The maximum contribution of testers were recorded for plant hieght (32.83 %) followed by number of fruits per cluster (11.02%), pericarp thickness (9.68%), days to first fruit harvest (4.76%), fruit length and total fruit yield per plant (3.97%), fruit girth (3.85%), days to 50 % flowering (3.51%), number of locules per fruit (2.74%), days to first fruit set (2.55%) and ascorbic acid (2.42%) while, minimum contribution of testers were recorded for average fruit weight (1.43%) followed by number of fruits per plant (1.55%), total soluble solid (1.80%) and number of primary branches per plant (1.89%).

In Y_2, the contribution of testers towards the variability for different characters ranged from 1.40 per cent (average fruit weight) to 34.26 per cent (plant hieght). Maximum contribution of testers were recorded for plant hieght (34.26%) followed by number of fruits per cluster (11.07%), pericarp thickness (9.68%), total fruit yield per plant (5.01%), days to first fruit harvest (4.76%), days to 50 % flowering (3.98%), fruit length (3.97%), fruit girth (3.39%), number of locules per fruit (2.74%), days to first fruit set (2.55%) and ascorbic acid (2.15%) while, minimum contribution of testers were recorded for average fruit weight (1.40%) followed by number of fruits per plant (1.55%), total soluble solid (1.80%) and number of primary branches per plant (1.89%).

Table-4.9 Proportional contribution of lines, testers and their interactions to total variance in a set of line × tester crosses in tomato

Characters	Contribution (%)							
	Lines			Testers			Lines × Testers	
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2
Days to 50 % flowering	22.81	30.13	3.77	3.51	3.98	69.94	73.68	65.89
Days to first fruit set	25.42	25.42	2.55	2.55	2.55	72.03	72.03	72.03
Days to first fruit harvest	31.74	31.74	4.76	4.76	4.76	63.49	63.49	63.49
Plant height (cm)	61.47	59.61	33.61	32.83	34.26	5.78	5.69	6.13
Number of primary branches per plant	54.73	54.73	1.89	1.89	1.89	43.37	43.37	43.37
Number of fruits per cluster	38.65	37.24	11.07	11.02	11.07	50.89	50.34	51.69
Number of fruits per plant	77.52	77.52	1.55	1.55	1.55	20.93	20.92	20.93
Average fruit weight (g)	42.18	42.33	1.42	1.43	1.40	56.32	56.39	56.26
Fruit length (cm)	21.37	21.37	3.97	3.97	3.97	74.66	74.66	74.66
Fruit girth (cm)	32.55	43.31	3.61	3.85	3.39	62.96	63..60	62.29
Number of locules per fruit	39.74	39.74	2.74	2.74	2.74	57.51	57.51	57.51
Pericarp thickness (mm)	43.55	43.55	9.68	9.68	9.68	46.76	46.76	46.76
Total soluble solid (TSS)	22.63	22.63	1.80	1.80	1.80	75.57	75.57	75.57
Ascorbic acid (mg/100 g fresh fruit)	85.67	81.78	2.11	2.42	2.15	12.70	11.91	16.07
Total fruit yield per plant (kg)	58.16	60.61	4.56	3.97	5.01	35.98	37.87	34.37

Y_1=2016-17 and Y_2=2017-18

4.4.4.3 Proportional contribution of line × testers (%)

Proportional contribution of line × testers for different characters in Y_1 varied from 5.69 per cent (plant height) to 75.57 per cent (total soluble solids). Lines × testers component displayed greater contribution for total soluble solids (75.57%) followed by fruit length (74.66%), days to 50 % flowering (73.68%), days to first fruit set (72.03%), fruit girth (63.60%), days to first fruit harvest (63.49%), number of locules per fruit (57.51%), average fruit weight (56.39%), number of fruits per cluster (50.34%), pericarp thickness (46.76%), number of primary branches per plant (43.37%) and total fruit yield per plant (37.87%) while, lines × testers component displayed lesser contribution for plant height (5.69%) followed by ascorbic acid (11.91%) and number of fruits per plant (20.92%).

In Y_2, the proportional contribution of line × testers for different characters varied from 6.13 per cent (plant height) to 75.57 per cent (total soluble solids). Lines × testers component displayed greater contribution for total soluble solids (75.57%) followed by fruit length (74.66%), days to first fruit set (72.03%), days to 50 % flowering (65.89%), days to first fruit harvest (63.49%), fruit girth (62.29%), number of locules per fruit (57.51%), average fruit weight (56.26%), number of fruits per cluster (51.69%), pericarp thickness (46.76%), number of primary branches per plant (43.37%) and total fruit yield per plant (34.37%) while, lines × testers component displayed lesser contribution for plant height (6.13%) followed by ascorbic acid (16.07%) and number of fruits per plant (20.93%).

4.4.4.4 Estimates the components of variation

The estimates of gca and sca variances, predictability ratio and average degree of dominance had given in Table 4.10.

In the year Y_1, estimates of sca variance were higher than gca variances

for all the traits except plant height, pericarp thickness and ascorbic acid.The value of sca variances were found significant and positive for all the characters except number of primary branches per plant and pericarp thickness. Likewise, positive and significant gca variances were also exhibited by almost all the characters except days to 50 % flowering, days to first fruit set, fruit length, fruit girth and total soluble solids. The value of average degree of dominance was more than unity (1) and highest for plant height (12.84) followed by pericarp thickness (6.94), ascorbic acid (3.72), number of fruits per plant (1.80), number of primary branches per plant (1.54) and total fruit yield per plant (1.10) revealed over dominance. Less than unity (1) and lowest for total soluble solids (0.10), days to first fruit set (0.12), fruit length (0.13), days to 50 % flowering (0.15), fruit girth (0.31), days to first fruit harvest (0.34), average fruit weight (0.35), number of locules per fruit (0.39) and number of fruits per cluster (0.97) indicating partial dominance.

The general predictability ratio was less than one for all the characters. σ^2A greter then σ^2D in plant height (721.63), number of primary branches per plant (0.04), number of fruits per plant (15.77), pericarp thickness (0.03) and ascorbic acid (59.53) then it repregent the preponderance of recessive effect and σ^2D greter then σ^2A in all traits except plant height (56.20), number of primary branches per plant (0.03), number of fruits per plant (8.74), pericarp thickness (0.01) and ascorbic acid (16.02) then it repregent the preponderance of dominance effect.

In the year Y_2, estimates of sca variance were higher than gca variances for all the traits except plant height, pericarp thickness and ascorbic acid.The value of sca variances were found significant and positive for all the characters except number of primary branches per plant and pericarp thickness. Likewise, positive and significant gca variances were also exhibited by almost all the characters except days to 50 % flowering, days to first fruit set, fruit length and total soluble solids. The value of average degree

of dominance was more than unity (1) and highest for plant height (12.06) followed by pericarp thickness (7.53), ascorbic acid (2.56), number of fruits per plant (1.80), number of primary branches per plant (1.56) and total fruit yield per plant (1.53) revealed over dominance. Less than unity (1) and lowest for total soluble solids (0.10), days to first fruit set (0.12), fruit length (0.13), days to 50 % flowering (0.27), fruit girth (0.33), days to first fruit harvest (0.34), average fruit weight (0.36), number of locules per fruit (0.39) and number of fruits per cluster (0.93) indicating partial dominance. The general predictability ratio was less than one for all the characters. σ^2A greter then σ^2D in plant height (754.00), number of primary branches per plant (0.04), number of fruits per plant (15.77), pericarp thickness (0.03) and ascorbic acid (57.33) then it repregent the preponderance of recessive effect and σ^2D greter then σ^2A in all traits except plant height (62.50), number of primary branches per plant (0.03), number of fruits per plant (8.74), pericarp thickness (0.00) and ascorbic acid (22.37) then it repregent the preponderance of dominance effect.

In case of pooled, estimates of sca variance were higher than gca variances for all the traits, except plant height and ascorbic acid.The value of sca variances were found significant and positive for all the characters. Likewise, positive and significant gca variances were plant height, number of fruits per plant, pericarp thickness, ascorbic acid and total fruit yield per plant. The value of average degree of dominance was more than unity (1) and highest for plant height (12.37) followed by ascorbic acid (3.26) and number of fruits per plant (1.75) revealed over dominance. Less than unity (1) and lowest for total fruit yield per plant (0.07) followed by total soluble solids (0.13), days to first fruit set and fruit length (0.17), days to 50 % flowering (0.22), fruit girth (0.31), days to first fruit harvest (0.32), average fruit weight (0.35), number of locules per fruit (0.37), number of fruits per cluster (0.72), number of primary branches per plant (0.75) and pericarp thickness (0.90)

Table 4.10 Components of genetic variance, average degree of dominance, predictability ratio and heritability in narrow sense for 15 characters in tomato over two years and pooled

Parameters / Characters	gca variance (σ^2g)			sca variance (σ^2s)			Average degree of dominance $\sqrt{\sigma^2s/2\sigma^2g}$			Predictability ratio $2\sigma^2g/2\sigma^2g+\sigma^2s)$		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
Days to 50 % flowering	0.15	0.20	0.24	1.98**	1.52**	2.19**	0.15	0.27	0.22	0.13	0.21	0.18
Days to first fruit set	0.08	0.08	0.17	1.28**	1.28**	1.90**	0.12	0.12	0.17	0.11	0.11	0.15
Days to first fruit harvest	0.16*	0.16*	0.24	0.92*	0.92*	1.48**	0.34	0.34	0.32	0.25	0.25	0.24
Plant height (cm)	360.82**	377.00**	368.98**	56.20**	62.50**	59.64**	12.84	12.06	12.37	0.93	0.92	0.92
Number of primary branches per plant	0.02**	0.02**	0.03	0.03	0.03	0.07**	1.54	1.56	0.75	0.61	0.61	0.43
Number of fruits per cluster	0.04**	0.04**	0.05	0.09*	0.09*	0.14**	0.97	0.93	0.72	0.49	0.48	0.42
Number of fruits per plant	7.89**	7.89**	7.93**	8.74**	8.74**	9.07**	1.80	1.80	1.75	0.64	0.64	0.64
Average fruit weight (gm)	8.36*	8.38*	8.45	47.10**	47.06**	47.63**	0.35	0.36	0.35	0.26	0.26	0.26
Fruit length (cm)	0.01	0.01	0.02	0.18**	0.18**	0.23**	0.13	0.13	0.17	0.12	0.12	0.14
Fruit girth (cm)	0.05	0.06*	0.09	0.34*	0.34*	0.59**	0.31	0.33	0.31	0.24	0.25	0.23
Number of locules per fruit	0.04*	0.04*	0.05	0.23**	0.23**	0.29**	0.39	0.39	0.37	0.28	0.28	0.27
Pericarp thickness (mm)	0.02**	0.02**	0.02*	0.01	0.00	005**	6.94	7.53	0.90	0.87	0.88	0.47
Total soluble solid (TSS)	0.01	0.01	0.02	0.22**	0.22**	0.26**	0.10	0.10	0.13	0.09	0.09	0.12
Ascorbic acid (mg/100 g fresh fruit)	29.76**	28.66**	29.02**	16.02**	22.37**	17.82**	3.72	2.56	3.26	0.79	0.72	0.76
Total fruit yield per plant (kg)	0.02**	0.02**	0.03**	0.04**	0.03**	0.05**	1.10	1.53	0.07	0..52	0.60	0.52

Table 4.10 Contd.....

Parameters / Characters	σ^2A			σ^2D			Heritability (h^2ns %)			Genetic advance in per cent of mean		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
Days to 50 % flowering	0.30	0.40	0.48	1.98	1.52	2.19	9..59	14.42	22.44	0.35	0.50	0.68
Days to first fruit set	0.15	0.15	0.33	1.28	1.28	1.90	6.05	6.05	22.38	0.20	0.20	0.56
Days to first fruit harvest	0.31	0.31	0.48	0.92	0.92	1.48	13.11	13.11	46.34	0.42	0.42	0.97
Plant height (cm)	721.63	754.00	737.95	56.20	62.50	59.64	92.32	91.89	92.43	53.17	54.22	53.80
Number of primary branches per plant	0.04	0.04	0.06	0.03	0.03	0.07	27.64	27.58	76.03	0.22	0.22	0.42
Number of fruits per cluster	0.09	0.08	0.10	0.09	0.09	0.14	31.52	30.11	61.85	0.34	0.32	0.51
Number of fruits per plant	15.77	15.77	15.87	8.74	8.74	9.07	62.41	62.41	65.36	6.46	6.46	6.63
Average fruit weight (gm)	16.72	16.77	16.90	47.10	47.06	47.63	25.71	25.78	26.61	4.27	4.28	4.37
Fruit length (cm)	0.02	0.02	0.04	0.18	0.18	0.23	7.70	7.70	21.18	0.09	0.09	0.19
Fruit girth (cm)	0.11	0.11	0.18	0.34	0.34	0.59	11.42	12.15	43.41	0.23	0.24	0.58
Number of locules per fruit	0.09	0.09	0.11	0.23	0.23	0.29	20.53	20.53	35.64	0.28	0.28	0.40
Pericarp thickness (mm)	0.03	0.03	0.05	0.01	0.00	0.05	28.36	28.30	98.52	0.20	0.20	0.44
Total soluble solid (TSS)	0.02	0.02	0.04	0.22	0.22	0.26	6.75	6.75	16.12	0.08	0.08	0.16
Ascorbic acid (mg/100 g fresh fruit)	59.53	57.33	58.04	16.02	22.37	17.82	76.81	69.93	72.24	13.93	13.04	13.34
Total fruit yield per plant (kg)	0.05	0.05	0.05	0.04	0.03	0.05	40.64	44.69	68.89	0.28	0.31	0.39

Y_1=2016-17 and Y_2=2017-18

indicating partial dominance. The general predictability ratio was less than one for all the characters. σ^2A greter then σ^2D in plant height (737.95), number of fruits per plant (15.87) and ascorbic acid (58.04) then it repregent the preponderance of recessive effect and σ^2D greter then σ^2A in all traits except plant height (59.64), number of fruits per plant (9.07) and ascorbic acid (17.82) then it repregent the preponderance of dominance effect.

4.4.4.5 Heritability and genetic advance

The estimates of heritability and genetic advance in per cent of mean had given in Table 4.10.

Estimates of heritability in narrow-sense (h^2_{ns}) have been classified by **Kempthorne and Curnow (1961)** into three categories *viz*., high (> 30%), medium (10-30%) and low (<10%). In the year Y_1, high estimate of heritability in narrow-sense was recorded for plant hieght (92.32%) followed by ascorbic acid (76.81%), number of fruits per plant (62.41%), total fruit yield per plant (40.64%) and number of fruits per cluster (31.52%) while, moderate estimate of heritability in narrow sense was observed for pericarp thickness (28.36%) followed by number of primary branches per plant (27.64%), average fruit weight (25.71%), number of locules per fruit (20.53%), days to first fruit harvest (13.11%) and fruit girth (11.42%) while, remaining characters showed low estimate of heritability in narrow-sense (h^2_{ns}).

In the year Y_2, high estimate of heritability in narrow-sense was recorded for plant hieght (91.89%) followed by ascorbic acid (69.93%), number of fruits per plant (62.41%), total fruit yield per plant (44.69%) and number of fruits per cluster (30.11%) while, moderate estimate of heritability in narrow sense was observed for pericarp thickness (28.36%) followed by number of primary branches per plant (27.58%), average fruit weight (25.78%), number of locules per fruit (20.53%), days to 50 % flowering

(14.42), days to first fruit harvest (13.11%) and fruit girth (12.15%) while, remaining characters showed low estimate of heritability in narrow-sense (h^2_{ns}).

In case of pooled, high estimate of heritability in narrow-sense was recorded for pericarp thickness (98.52%) followed by plant height (92.43%), number of primary branches per plant (76.03%), ascorbic acid (72.24%), total fruit yield per plant (68.89%), number of fruits per plant (65.36%), number of fruits per cluster (61.85%), days to first fruit harvest (46.34%), fruit girth (43.41%) and number of locules per fruit (35.64%) while, moderate estimate of heritability in narrow sense was observed for average fruit weight (26.61%) followed by days to 50 % flowering (22.44%), days to first fruit set (22.38%), fruit length (21.18%) and total soluble solids (16.12%) while, none of the characters showed low estimate of heritability in narrow-sense (h^2_{ns}).

In Y_1, high estimate of genetic advance in per cent of mean (>20%) was observed for plant hieght (53.17%). Moderate estimate of genetic advance in percent of mean (10-20%) was observed for ascorbic acid (13.93%) while, remaining characters showed low estimate of genetic advance in per cent of mean.

In Y_2, high estimate of genetic advance in per cent of mean (>20%) was observed for plant hieght (54.22%). Moderate estimate of genetic advance in percent of mean (10-20%) was observed for ascorbic acid (13.04%) while, remaining characters showed low estimate of genetic advance in per cent of mean.

In pooled, high estimate of genetic advance in per cent of mean (>20%) was observed for plant hieght (53.80%). Moderate estimate of genetic advance in percent of mean (10-20%) was observed for ascorbic acid (13.34%) while, remaining characters showed low estimate of genetic advance in per cent of mean.

4.4.4.6 Estimation of genetic divergence (D^2)

The studies of genetic divergence among the 54 (10 lines, 4 testers and 40 F_1's) genotypes of tomato were carried out by using Mahalanobis D^2.

Fifty four genotypes were grouped into 8 different non over lapping clusters given in Table 4.11. In Y_1, cluster VII had highest number of genotypes (18) followed by cluster IV (12), Cluster I (8), cluster V (5), cluster III and cluster IV (4), cluster VI (2) and cluster VIII (1). In Y_2, cluster I had highest number of genotypes (12) followed by cluster II and cluster III (11), Cluster V (9), cluster IV (7), cluster VI (2), cluster VII and cluster VIII (1). In pooled, cluster IV and cluster V had highest number of genotypes (19) followed by cluster III (5), Cluster II (4), cluster I (3), cluster VI (2), cluster VII and cluster VIII (1).

The estimates of intra and inter-cluster distance represented by D^2 values had given in Table 4.12.

In Y_1, the intra-cluster D^2 value ranged from 0.00 to 75.03 while, the inter-cluster value ranged from 39.49 to 763.35 indicated that the selected breeding lines were highly divergent. The highest intra-cluster distance was shown by cluster VII (75.03) followed by cluster IV (43.82), cluster V (42.72), cluster III (29.65), cluster II (24.42), cluster I (24.16) cluster VI (15.78) while, the minimum intra-cluster distance was shown by cluster VIII (0.00) it was monogenotypic. The maximum inter-cluster distance was observed between cluster III and cluster VI (763.35), followed by cluster VI and cluster VII (507.11), cluster IV and cluster VI (502.55), cluster V and cluster VI (488.57)

Table -4.11 Clustering pattern of fifty four genotypes of tomato on the basis of Mahalnobis 'D^2' statistics over two years and Pooled

Cluster number	Years	No. of genotypes	Genotypes
I	Y_1	8	NDT-3×Punjab Chhuhara, NDT-3×Arka Vikas, Arka Saurabh, NDT-2×Arka Vikas, Arka Saurabh×Arka Meghali, NDT-2×Arka Meghali, NDT-3×Arka Meghali, Punjab Chhuhara
	Y_2	12	NDT-3×Punjab Chhuhara, NDT-3×Arka Vikas, Arka Saurabh, Arka Saurabh×Arka Meghali, NDT-2×Arka Vikas, NDT-2×Arka Meghali, Punjab Chhuhara, NDT-3×Arka Meghali, NDT-8, Arka Saurabh×Punjab Chhuhara, Arka Saurabh×Arka Vikas, NDT-1×Punjab Chhuhara
	Pooled	3	NDT-3×Punjab Chhuhara, NDT-3×Arka Vikas, Arka Saurabh
II	Y_1	4	NDT-8×Punjab Chhuhara, NDT-8×Arka Vikas, NDT-2×Punjab Chhuhara, Arka Saura×Punjab Chhuhara
	Y_2	11	Azad T-6×Punjab Chhuhara, Azad T-6×Arka Vikas, Azad T-6×Arka Meghali, NDT-1, NDT-4×Arka Vikas, NDT-6×Pusa Ruby, Pusa Ruby, NDT-8×Pusa Ruby, NDT-7×Pusa Ruby, NDT-4×Punjab Chhuhara, NDT-4×Arka Meghali
	Pooled	4	NDT-8×Punjab Chhuhara, NDT-8×Arka Vikas, NDT-2×Punjab Chhuhara, Arka Saurabh×Punjab Chhuhara
III	Y_1	4	Azad T-6×Punjab Chhuhara, Azad T-6×Arka Vikas, Azad T-6×Arka Meghali, Azad T-6×Pusa Ruby
	Y_2	11	NDT-8×Punjab Chhuhara, NDT-8×Arka Vikas, NDT-2×Punjab Chhuhara, NDT-8×Arka Meghali, NDT-6×Arka Meghali, NDT-6×Arka Vikas, NDT-7×Arka Vikas, NDT-7×Punjab Chhuhara, NDT-3, NDT-6×Punjab Chhuhara, NDT-7×Arka Meghali
	Pooled	5	Azad T-6×Punjab Chhuhara, Azad T-6×Arka Vikas, Azad T-6×Arka Meghali, Azad T-6×Pusa Ruby, NDT-1
IV	Y_1	12	NDT-4×Arka Meghali, Pusa Ruby, NDT-6×Pusa Ruby, NDT-4×Punjab Chhuhara, NDT-1×Pusa Ruby, NDT-7×Pusa Ruby, NDT-8×Pusa Ruby, NDT-4×Arka Vikas, NDT-4, NDT-5, NDT-4×Pusa Ruby, NDT-2×Pusa Ruby
	Y_2	7	NDT-2, Arka Vikas, NDT-1×Arka Vikas, NDT-2×Pusa Ruby, Arka Meghali, NDT-1×Arka Meghali, Azad T-6
	Pooled	19	NDT-4×Arka Meghali, Pusa Ruby, NDT-6×Pusa Ruby, NDT-4×Punjab Chhuhara, NDT-1×Pusa Ruby, NDT-7×Pusa Ruby, NDT-8×Pusa Ruby, NDT-4×Arka Vikas, NDT-4×Pusa Ruby, NDT-5×Arka Meghali, NDT-5×Punjab Chhuhara, NDT-5×Arka Vikas, NDT-5×Pusa Ruby, NDT-5, NDT-4, Azad T-6, NDT-2×Pusa Ruby, NDT-1×Punjab Chhuhara, NDT-3×Pusa Ruby
V	Y_1	5	NDT-5×Punjab Chhuhara, NDT-5×Arka Vikas, NDT-5×Arka Meghali, NDT-5×Pusa Ruby, Azad T-6
	Y_2	9	NDT-5×Arka Vikas, NDT-5×Arka Meghali, NDT-5×Punjab Chhuhara, NDT-5×Pusa Ruby, NDT-4×Pusa Ruby, NDT-1×Pusa Ruby, NDT-5, NDT-4, NDT-3×Pusa Ruby
	Pooled	19	NDT-2×Arka Vikas, Arka Saurabh×Arka Meghali, NDT-2×Arka Meghali, NDT-3×Arka Meghali, Punjab Chhuhara, Arka Saurabh×Arka Vikas, NDT-6×Punjab Chhuhara, NDT-8, NDT-7×Arka Meghali, NDT-7×Punjab Chhuhara, NDT-3, NDT-1×Arka Vikas, Arka Vikas, Arka Meghali, NDT-6×Arka Meghali, NDT-6×Arka Vikas, NDT-7×Arka Vikas, NDT-8×Arka Meghali, NDT-2
VI	Y_1	2	NDT-6, NDT-7
	Y_2	2	NDT-6, NDT-7
	Pooled	2	NDT-6, NDT-7
VII	Y_1	18	NDT-6×Arka Vikas, NDT-7×Arka Vikas, NDT-6×Arka Meghali, NDT-7×Punjab Chhuhara, NDT-3, NDT-6×Punjab Chhuhara, NDT-7×Arka Meghali, Arka Saurabh×Arka Vikas, NDT-1×Punjab Chhuhara, NDT-1×Arka Vikas, NDT-8×Arka Meghali, NDT-2, Arka Vikas, NDT-1, NDT-1×Arka Meghali, Arka Meghali, NDT-3×Pusa Ruby, Arka Saurabh×Pusa Ruby
	Y_2	1	Arka Saurabh×Pusa Ruby
	Pooled	1	Arka Saurabh×Pusa Ruby
VIII	Y_1	1	NDT-8
	Y_2	1	Azad T-6×Pusa Ruby
	Pooled	1	NDT-1×Arka Meghali

Y_1=2016-17 and Y_2=2017-18

Table-4.12 Intra and inter clusters D^2 values for eight clusters in tomato over two years and Pooled

	Years	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII
Cluster I	Y_1	**24.16**	56.89	233.36	112.43	163.56	279.73	87.65	39.49
	Y_2	**28.78**	118.84	71.66	76.56	131.96	267.88	181.04	275.22
	Pooled	**7.72**	33.31	91.96	53.97	32.46	168.95	86.09	48.57
Cluster II	Y_1		**24.42**	232.49	150.44	216.49	457.15	79.03	98.87
	Y_2		**43.29**	105.54	96.64	68.63	555.01	75.60	69.95
	Pooled		**13.44**	92.72	77.79	34.10	266.39	104.41	80.82
Cluster III	Y_1			**29.65**	91.43	80.11	763.35	168.38	276.99
	Y_2			**42.96**	98.83	173.07	488.76	167.51	230.30
	Pooled			**21.41**	49.98	87.62	418.45	39.48	62.56
Cluster IV	Y_1				**43.82**	72.54	502.55	109.75	154.17
	Y_2				**46.50**	135.36	404.37	78.57	194.73
	Pooled				**29.76**	67.35	272.17	64.36	62.78
Cluster V	Y_1					**42.72**	488.57	176.06	165.55
	Y_2					**50.28**	444.31	123.39	103.77
	Pooled					**33.43**	246.88	88.78	65.07
Cluster VI	Y_1						**15.78**	507.11	184.21
	Y_2						**16.31**	645.17	833.19
	Pooled						**9.78**	392.08	279.21
Cluster VII	Y_1							**75.03**	133.25
	Y_2							**0.00**	80.95
	Pooled							**0.00**	25.08
Cluster VIII	Y_1								**0.00**
	Y_2								**0.00**
	Pooled								**0.00**

Y_1=2016-17 and Y_2=2017-18

Table 4.13 Intra-cluster group mean for 15 characters in tomato over two years and pooled

Cluster number	Years	Days to 50 % flowering	Days to first fruit set	Days to first fruit harvest	Plant height (cm)	Number of primary branches per plant	Number of fruits per cluster	Number of fruits per plant	Average fruit weight (g)
I	Y_1	30.51	37.79	61.61	80.68	3.29	5.04	44.85	33.43
	Y_2	33.58	38.81	62.51	82.57	3.76	5.76	45.70	35.53
	Pooled	32.97	38.67	62.83	84.69	3.81	5.03	47.15	39.12
II	Y_1	29.49	36.94	60.87	69.66	3.55	5.76	36.21	38.03
	Y_2	32.57	37.85	61.66	124.71	4.08	5.96	35.01	37.80
	Pooled	31.11	37.56	61.50	70.29	3.78	5.97	36.84	38.66
III	Y_1	29.49	37.33	60.95	135.18	4.08	5.25	29.33	41.19
	Y_2	32.86	38.41	62.29	80.34	4.09	5.84	34.80	38.99
	Pooled	31.13	37.71	61.41	133.04	4.23	5.67	30.76	43.71
IV	Y_1	29.03	36.19	60.06	123.94	3.52	5.43	38.39	32.25
	Y_2	32.35	37.48	61.18	99.71	4.01	6.04	44.09	52.43
	Pooled	30.74	37.08	60.89	124.86	3.77	5.69	39.97	32.50
V	Y_1	29.38	36.69	60.37	132.91	3.49	5.27	39.49	30.23
	Y_2	32.20	37.82	61.61	134.74	4.04	5.77	42.28	30.10
	Pooled	31.50	37.90	61.59	83.63	3.64	5.56	39.77	39.63
VI	Y_1	30.23	37.66	61.39	67.25	3.44	5.52	70.08	25.21
	Y_2	33.44	38.91	62.65	68.51	3.91	6.03	71.34	26.47
	Pooled	31.83	38.28	62.03	67.88	3.67	5.77	70.71	25.84
VII	Y_1	29.55	37.01	60.72	92.14	3.48	5.46	37.56	43.49
	Y_2	32.97	39.03	62.60	131.75	3.16	6.44	37.39	57.94
	Pooled	31.14	38.41	61.97	129.45	2.93	6.19	36.76	57.31
VIII	Y_1	29.91	37.43	61.01	79.03	3.39	5.70	51.23	37.23
	Y_2	33.40	39.30	63.18	160.02	4.46	6.04	29.03	40.59
	Pooled	28.67	35.26	58.79	110.43	3.26	5.59	44.52	56.71

Table-4.13 contd….

Cluster number	Years	Fruit length (cm)	Fruit girth (cm)	Number of locules per fruit	Pericarp thickness (mm)	Total soluble solid (TSS)	Ascorbic acid (mg/100 g fresh fruit)	Total fruit yield per plant (kg)
I	Y_1	6.68	12.48	4.07	4.59	5.90	35.78	2.81
	Y_2	7.31	14.15	4.57	4.91	6.11	36.79	3.11
	Pooled	7.61	13.80	3.83	4.79	5.69	38.69	3.19
II	Y_1	6.54	13.49	4.18	4.95	5.22	36.81	2.62
	Y_2	7.25	13.94	4.84	4.89	5.80	43.96	2.86
	Pooled	6.81	14.10	4.35	5.15	5.41	37.17	2.79
III	Y_1	6.83	12.45	4.70	4.54	5.60	54.13	2.46
	Y_2	7.30	14.10	4.69	5.21	5.67	34.95	2.70
	Pooled	7.15	13.28	4.90	4.94	5.86	52.54	2.70
IV	Y_1	6.78	12.91	4.45	4.29	5.30	36.04	2.53
	Y_2	7.71	14.08	4.97	5.10	6.04	41.67	3.41
	Pooled	6.92	13.42	4.39	4.65	5.55	41.36	2.64
V	Y_1	6.32	12.67	4.04	4.84	5.42	55.32	2.19
	Y_2	7.11	14.06	4.30	4.80	5.76	45.62	2.69
	Pooled	7.08	13.36	4.61	4.82	5.83	34.73	2.79
VI	Y_1	6.35	11.98	4.31	4.29	5.55	41.36	2.76
	Y_2	6.89	13.19	4.68	4.70	5.94	42.91	3.08
	Pooled	6.62	12.59	4.49	4.50	5.75	42.13	2.92
VII	Y_1	7.03	13.07	4.39	4.60	5.44	32.77	2.61
	Y_2	7.72	14.22	4.66	4.70	6.31	40.69	3.22
	Pooled	7.45	13.62	4.48	4.50	6.12	34.58	3.04
VIII	Y_1	6.50	12.16	3.77	4.49	6.12	47.13	2.98
	Y_2	7.36	14.01	5.36	5.10	5.65	51.61	2.94
	Pooled	7.41	13.68	4.95	4.14	5.18	42.37	2.82

Y_1=2016-17 and Y_2=2017-18

and cluster II and cluster VI (457.15) while, the minimum inter-cluster distance was observed between cluster I and cluster VIII (39.49).

In Y_2, the intra-cluster D^2 value ranged from 0.00 to 50.28 while, the inter-cluster value ranged from 68.63 to 833.19 indicated that the selected breeding lines were highly divergent. The highest intra-cluster distance was shown by cluster V (50.28) followed by cluster IV (46.50), cluster II (43.29), cluster III (42.96), cluster I (28.78) and cluster VI (16.31) while, the minimum intra-cluster distance was shown by cluster VII and cluster VIII (0.00) it was monogenotypic. The maximum inter-cluster distance was observed between cluster VI and cluster VIII (833.19), followed by cluster VI and cluster VII (645.17), cluster II and cluster VI (555.01), cluster III and cluster VI (488.76) and cluster V and cluster VI (444.31) while, the minimum inter-cluster distance was observed between cluster II and cluster V (68.63).

In pooled, the intra-cluster D^2 value ranged from 0.00 to 33.43 while, the inter-cluster value ranged from 25.08 to 418.45 indicated that the selected breeding lines were highly divergent. The highest intra-cluster distance was shown by cluster V (33.43) followed by cluster IV (29.76), cluster III (21.41), cluster II (13.44), cluster VI (9.78) and cluster I (7.72) while, the minimum intra-cluster distance was shown by cluster VII and cluster VIII (0.00) it was monogenotypic. The maximum inter-cluster distance was observed between cluster III and cluster VI (418.45), followed by cluster VI and cluster VII (392.08), cluster VI and cluster VIII (279.21), cluster IV and cluster VI (272.17) and cluster II and cluster VI (266.39) while, the minimum inter-cluster distance was observed between cluster VII and cluster VIII (25.08).

The comparison of clusters means revealed considerable differences among the clusters of different quantitative and quality characters given in Table 4.13.

In Y_1, Cluster I showed high mean value for days to 50% flowring (30.51 days), days to first fruit set (37.79 days) and days to first fruit harvest (61.61 days). Cluster II showed high mean value for number of fruits per cluster (5.76), fruit girth (13.49 cm) and pericarp thickness (4.95 mm). Cluster III showed high mean value for plant height (135.18 cm), number of primary branches per plant (4.08), number of locules per fruit (4.70) and pericarp thickness (4.54 mm). Cluster V showed high mean value for ascorbic acid (55.32 mg). Cluster VI showed high mean value for number of fruits per plant (70.08). Cluster VII showed high mean value for average fruit weight (43.49 g) and fruit length (7.03 cm). Cluster VIII showed high mean value for total soluble solids (6.12 ^{0}B) and total fruit yield per plant (2.98 kg).

In Y_2, Cluster I showed high mean value for days to 50% flowring (33.58 days). Cluster III showed high mean value for pericarp thickness (5.21mm). Cluster IV showed high mean value for total fruit yield per plant (3.41 kg). Cluster VI showed high mean value for number of fruits per plant (71.34). Cluster VII showed high mean value for number of fruits per cluster (66.44) average fruit weight (57.94 g), fruit length (7.72 cm), fruit girth (14.22 cm) and total soluble solids (6.31 ^{0}B). Cluster VIII showed high mean value for days to first fruit set (39.30 days), days to first fruit harvest (63.18 days), plant height (160.02 cm), number of primary branches per plant (4.46), number of locules per fruit (5.36) and ascorbic acid (51.61 mg).

In pooled, Cluster I showed high mean value for days to 50% flowring (32.97 days), days to first fruit set (38.67 days), days to first fruit harvest (62.83 days) and total fruit yield per plant (3.19 kg). Cluster II showed high mean value for fruit girth (14.10 cm). Cluster III showed high mean value for plant height (133.04 cm), number of primary branches per plant (4.23) and ascorbic acid (52.54 mg). Cluster VI showed high mean value for number of fruits per plant (70.71). Cluster VII showed high mean value for number of fruits per cluster (6.19), average fruit weight (57.31 g), fruit length (7.45 cm)

and total soluble solids (6.12 ^{0}B). Cluster VIII showed high mean value for number of locules per fruit (4.95).

In Y_1, highest per cent contribution towards total genetic divergence given in Table 4.14 was exhibited by plant hieght (42.42%) followed by number of fruits per plant (24.60 %), average fruit weight (12.51 %) and ascorbic acid (11.25 %). Rest of the characters exhibited low contribution towards total genetic divergence.

In Y_2, highest per cent contribution towards total genetic divergence was exhibited by plant hieght (46.96 %) followed by number of fruits per plant (24.11 %) and average fruit weight (12.30 %). Rest of the characters exhibited low contribution towards total genetic divergence.

In pooled, highest per cent contribution towards total genetic divergence was exhibited by plant hieght (44.03 %) followed by number of fruits per plant (26.83 %) and average fruit weight (14.26 %). Rest of the characters exhibited low contribution towards total genetic divergence.

Table-4.14 Per cent contribution of 15 characters towards total genetic divergence in tomato over two years and pooled

Characters	Contribution (%)		
	Y_1	Y_2	Pooled
Days to 50 % flowering	0.01	0.01	0.07
Days to first fruit set	0.01	0.01	0.01
Days to first fruit harvest	0.01	0.01	0.01
Plant height (cm)	42.42	46.96	44.03
Number of primary branches per plant	0.01	0.01	0.01
Number of fruits per cluster	0.49	0.63	0.70
Number of fruits per plant	24.60	24.11	26.83
Average fruit weight (g)	12.51	12.30	14.26
Fruit length (cm)	0.49	0.77	0.84
Fruit girth (cm)	0.70	0.84	0.84
Number of locules per fruit	3.14	2.66	2.87
Pericarp thickness (mm)	1.19	1.26	1.12
Total soluble solid (TSS)	0.91	0.84	1.05
Ascorbic acid (mg/100 g fresh fruit)	11.25	7.62	5.38
Total fruit yield per plant (kg)	0.21	0.14	0.14

Y_1=2016-17 and Y_2=2017-18

DISCUSSION

Tomato belongs to nightshade or solanaceae family with primary center of origin in Mexico-Peru-Equador region was once considered in edible but has evolved into globally leading popular vegetable. It is extensively studied by the horticulturists and breeders. It has wide range of variation in terms of growth habit, morphological traits and uses making it a repository of glowing traits in its armory. It has determinate *vs* indeterminate types plant, fruits canning to juice type, smooth to ridged, acidic to sweet type, red to orange, yellow to striped colour fruits etc. But whatever may be the type botanically it is same and they are crossable. Botanical nomenclature of tomato has seen a lot of debate, research work and change. The success in breeding depends mainly on the choice of superior parents for hybridization and the information on nature and magnitude of gene action and combining ability of the parents. These genetic parameters help in deciding the most appropriate method for further improvement.

Among the various mating designs, line × tester cross techniques has been most frequently used to determine the nature and magnitude of gene action by the estimates of genetic components, gca and sca variances and their effects in many cross pollinated vegetable crops.

In tomato **(Kurion *et al.*, 1995; Kumar *et al.*, 2017; Srivastava *et al.*, 1998 and Dhaliwal *et al.*, 2000)** have also used this technique for estimating heterosis, combining ability and gene action but most of them based on one season data and can not universally be extrapolated to every kind of materials and environments. It is therefore imperative to evaluate the newer strains over seasons for gathering stable information on their genetic makeup by incorporating them in hybridization programme.

The present investigation entitled **"Heterosis, combining ability and gene action involved for yield and quality attributing traits in tomato (*Solanum lycopersicum* L.)"** was under taken (i) to estimate heterosis over better-parent and standard variety, (ii) to study the combining ability, variances and their effects, (iii) to find out gene action involved in the inheritance of various characters, (iv) to estimate the heritability in narrow sense and genetic advance in per cent of mean and (v) to examine genetic divergence among the parents and their crosses among various quantitative traits. In the present study 54 genotypes (10 lines, 4 testers and 40 F_1's) were evaluated in RBD with three replications at the Main Experiment Station (MES) of the Department of Vegetable Science, N. D. University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.), India for two *Rabi* seasons during 2016-17 and 2017-18. Observations were recorded for days to 50 % flowering, days to first fruit set, days to first fruit harvest, plant height (cm), number of primary branches per plant, number of fruits per cluster, number of fruits per plant, average fruit weight (g), fruit length (cm), fruit girth (cm), number of locules per fruit, pericarp thickness (mm), total soluble solids (TSS), ascorbic acid (mg/100 g fresh fruit) and total fruit yield per plant (kg).The observations were also recorded for some ancillary traits as well.

The results obtained on various aspects of the present investigation are discussed in the light of available literature in this chapter under following sections:

5.1 Analysis of variance

5.2 Mean performance of parents for different characters

5.3 Estimates of heterosis over better parent and standard variety

5.4 Combining ability variances and their effects

5.4.1 Analysis of variance for combining ability

5.4.2 General combining ability effects

5.4.3 Specific combining ability effects

5.5 Proportional contribution of lines, testers and lines × testers

5.6 Components of variation

5.7 Heritability and genetic advance

5.8 Genetic divergence analysis

5.1 Analysis of variance

Analysis of variance for line × tester mating design for both the years (Y_1 and Y_2) had been presented in Table 4.1.1. Analysis of variance revealed that the differences among treatments were highly significant for all the characters studied during both the years. Further partitioning of treatment variances into parents, crosses, lines and testers revealed highly significant differences among parents as well as crosses for all the fifteen characters. Variances due to parents was highly significant for all the characters during both the years and significant for days to 50 % flowering in scound year except days to 50 % flowering in first year while, for days to first fruit set, days to first fruit harvest, number of primary branches per plant and number of locules per fruit in both the year. Variances due to parents *vs.* crosses were highly significant for days to 50 % flowering, days to first fruit set, days to first fruit harvest, plant height, number of fruits per plant, average fruit weight (g), pericarp thickness (mm) and total fruit yield per plant (kg) in both the years and ascorbic acid in second year while, significant for number of fruits per cluster and fruit length (cm) in both the years. Variances due to lines *vs*. testers were highly significant for the characters like plant height, number of fruits per plant, average fruit weight (g) and fruit girth (cm) while, significant for number of primary branches per plant and number of locules per fruit in both the years.

The pooled analysis of variance given in Table 4.1.2 also divided the source of variance into environments found highly significant for all the traits under study. Variances due to treatments and parents were found

highly significant for all the traits under study as well as crosses for all the fifteen characters. Variances due to parent vs crosses were found highly significant for all the traits under study except for number of locules per fruit and total soluble solids while, significant for fruit girth (cm) and ascorbic acid. Variances due to line vs testers were found highly significant for the characters like plant height, number of primary branches per plant, number of fruits per plant, average fruit weight (g), fruit girth (cm), number of locules per fruit while, significant for fruit length (cm) and total fruit yield per plant (kg). The similar results were also reported by **Kumar *et al.* (2004).**

5.2 Mean performance of parents for different characters

The mean performance of 14 parental genotypes of tomato for fifteen quantitative characters had been presented in Table 4.2 and the most desirable parents for different characters are listed in Table 5.1. The highest mean performance for total fruit yield per plant was exhibited by Arka Meghali (3.53 kg) followed by Arka Vikas (3.44 kg), NDT-2 (3.28 kg), Arka Saurabh (3.11 kg) and NDT-8 (2.98 kg) in Y_1, Arka Meghali (3.90 kg) followed by Arka Vikas (3.81 kg), NDT-2 (3.65 kg), Arka Saurabh (3.26 kg) and Azad T-6 (3.19 kg) in Y_2 and Arka Meghali (3.71 kg) followed by Arka Vikas (3.63 kg), NDT-2 (3.46 kg), Arka Saurabh (3.18 kg) and NDT-8 (3.05 kg) in pooled. The above mentioned genotypes may be used as donor parents in hybridization programme for developing high yielding varieties of respective groups. Some other genotypes exhibiting very high mean performance for characters other than fruit yield per plant are also listed in Table 5.1. These lines merits due consideration as promising parents for hybridization programme for bringing over all improvement in plant genetic architecture in a component breeding approach ultimately leading to high yielding tomato genotypes even if they have moderate or low fruit yield. In this context, the most desirable parents were Pusa Ruby (26.79 days)

showed earliest days to 50 % flowering among the parents followed by NDT-4 (27.77 days), NDT-5 (27.79 days), NDT-2 (27.97 days) and Azad T-6 (27.99 days) in $Y_{1,}$ Parent Pusa Ruby (30.00 days) followed by NDT-4 (30.32 days), NDT-5 (31.00 days), NDT-2 (31.18 days) and Azad T-6 (31.20 days) in Y_2 and Parent Pusa Ruby (28.40 days) followed by NDT-4 (29.05 days), NDT-5 (29.40 days), NDT-2 (29.58 days) and Azad T-6 (29.59 days) in pooled; Parent Pusa Ruby (34.09 days) showed earliest days to first fruit set among the parents which was followed by NDT-4 (34.62 days), Arka Vikas (35.09 days), NDT-5 (35.20 days) and NDT-2 (35.34 days) in Y_1, Parent Pusa Ruby (35.34 days) followed by NDT-4 (35.87 days), Arka Vikas (36.34 days), NDT-5 (36.45 days) and NDT-2 (36.49 days) in Y_2 and Parent Pusa Ruby (34.72 days) followed by NDT-4 (35.24 days), Arka Vikas (35.71 days), NDT-5 (35.83 days) and NDT-2 (35.87 days) in pooled; Parent Pusa Ruby (58.06 days) showed earliest days to first fruit harvest among the parents which was followed by NDT-4 (58.27 days), NDT-2 (58.90 days), Azad T-6 (59.08 days) and Arka Vikas (59.22 days) in Y_1 Parent Pusa Ruby (59.32 days) followed by NDT-4 (59.53 days), NDT-2 (60.16 days), Azad T-6 (60.34 days) and Arka Vikas (60.48 days) in Y_2 and Parent Pusa Ruby (58.69 days) followed by NDT-4 (58.90 days), NDT-2 (59.53 days), Azad T-6 (59.71 days) and Arka Vikas (59.85 days) in pooled.

Among the parents maximum plant height was recorded in NDT-4 (125.40 cm) followed by NDT-5 (121.67 cm), NDT-1 (120.85 cm), Pusa Ruby (111.01 cm) and Azad T-6 (110.16 cm) in Y_1, NDT-4 (126.66 cm) followed by NDT-5 (122.67 cm), NDT-1 (122.04 cm), Pusa Ruby (111.69 cm) and Azad T-6 (110.82 cm) in Y_2 and NDT-4 (126.66 cm) followed by NDT-5 (122.67 cm), NDT-1 (122.04 cm), Pusa Ruby (111.69 cm) and Azad T-6 (110.82 cm) in pooled; The parental line NDT-5 (4.19) had maximum number of primary branches per plant, which was followed by NDT-2 and Arka Saurabh (4.15), NDT-4 (3.95), NDT-1 (3.69) and Azad T-6 (3.62)

inY_1, NDT-5 (4.66) followed by NDT-2 and Arka Saurabh (4.62), NDT-4 (4.42), NDT-1 (4.16) and Azad T-6 (4.09) in Y_2 and NDT-5 (4.43) followed by NDT-2 and Arka Saurabh (4.39), NDT-4 (4.19), NDT-1 (3.93) and Azad T-6 (3.86) in pooled; highest number of fruits per cluster was recorded in parent NDT-1 (6.10) followed by NDT-5 and NDT-8 (5.70), NDT-7 (5.63), NDT-6 (5.40) and NDT-2 and Arka Meghali (5.36) in Y_1, parent NDT-1 (6.61) followed by NDT-5 and NDT-8 (6.21), NDT-7 (6.14), NDT-6 (5.91) and NDT-2 and Arka Meghali (5.87) in Y_2 and parent NDT-1 (6.36) followed by NDT-5 and NDT-8 (5.96), NDT-7 (5.89), NDT-6 (5.66) and NDT-2 and Arka Meghali (5.62) in pooled; highest number of fruits per plant was recorded in parent NDT-6 (73.56) followed by NDT-7 (66.61), NDT-8 (51.23), Arka Saurabh (49.88) and Arka Meghali (49.54) in Y_1, parent NDT-6 (74.82) followed by NDT-7 (67.87), NDT-8 (52.49), Arka Saurabh (51.14) and Arka Meghali (50.80) in Y_2 and parent NDT-6 (74.19) followed by NDT-7 (67.24), NDT-8 (51.86), Arka Saurabh (50.51) and Arka Meghali (50.17) in pooled; parent NDT-2 (59.32 g) produced heaviest fruit followed by Arka Vikas (56.01 g), Arka Meghali (53.35 g), NDT-1 (50.68 g) and Arka Saurabh (40.69 g) in Y_1, parent NDT-2 (60.58 g) followed by Arka Vikas (57.27 g), Arka Meghali (54.61 g), NDT-1 (51.94 g) and

Arka Saurabh (41.95 g) in Y_2 and parent NDT-2 (59.95 g) followed by Arka Vikas (56.64 g), Arka Meghali (53.98 g), NDT-1 (51.31 g) and Arka Saurabh (41.32 g) in pooled; Largest fruit length were recorded in parent Arka Saurabh (8.30 cm) followed by NDT-4 (7.93 cm), NDT-2 and Arka Vikas (7.70 cm), NDT-1 (7.09 cm) and Arka Meghali (6.76 cm) in Y_1, parent Arka Saurabh (8.84 cm) followed by NDT-4 (8.47 cm), NDT-2 and Arka Vikas (8.24 cm), NDT-1 (7.63 cm) and Azad T-6 (7.47 cm) in Y_2 and

Table-5.1 Mean performance of 14 parents for 16 characters Y_1=2016-17 and Y_2=2017-18 and pooled

Genotypes	Days to 50 % flowering			Days to first fruit set			Days to first fruit harvest			Plant height (cm)		
Lines	**Y_1**	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**
NDT-1	28.62	32.17	30.40	36.14	37.39	36.77	60.09	61.35	60.72	120.85	122.04	121.44
NDT-2	27.97	31.18	29.58	35.24	36.49	35.87	58.90	60.16	59.53	86.04	87.30	86.67
NDT-3	30.05	33.26	31.66	37.63	38.88	38.26	61.23	62.49	61.86	95.03	96.29	95.66
NDT-4	27.77	30.32	29.05	34.62	35.87	35.24	58.27	59.53	58.90	125.40	126.66	126.03
NDT-5	27.79	31.00	29.40	35.20	36.45	35.83	59.43	60.69	60.06	121.67	122.67	122.17
NDT-6	30.01	33.22	31.61	37.46	38.71	38.08	61.30	62.56	61.93	68.14	69.40	68.77
NDT-7	30.45	33.66	32.06	37.86	39.11	38.49	61.49	62.75	62.12	66.37	67.63	67.00
NDT-8	29.91	33.12	31.52	37.43	38.68	38.05	61.01	62.27	61.64	79.03	80.75	79.89
Azad T-6	27.99	31.20	29.59	35.49	36.74	36.12	59.08	60.34	59.71	110.16	110.82	110.49
Arka Saurabh	30.26	33.14	31.70	36.74	37.99	37.37	60.37	61.63	61.00	85.62	86.88	86.25
Testers												
Pusa Ruby	26.79	30.00	28.40	34.09	35.34	34.72	58.06	59.32	58.69	111.01	111.69	111.35
Punjab Chhuhara	28.12	32.69	30.41	35.68	36.93	36.31	59.31	60.57	59.94	87.20	87.30	87.25
Arka Vikas	28.49	31.70	30.09	35.09	36.34	35.71	59.22	60.48	59.85	82.37	83.63	83.00
Arka Meghali	30.45	34.32	32.39	37.86	39.11	38.49	61.57	62.83	62.20	87.03	88.29	87.66
Mean	**28.91**	**32.21**	**30.56**	**36.18**	**37.43**	**36.81**	**59.95**	**61.21**	**60.58**	**94.71**	**95.21**	**95.26**
Lowest	26.79	30.00	28.40	34.09	35.34	34.72	58.06	59.32	58.69	66.37	67.63	67.00
Highest	30.45	34.32	32.39	37.86	39.11	38.49	61.57	62.83	62.20	125.40	126.66	126.03

Table 5.1 Contd….

Genotypes	Number of primary branches per plant			Number of fruits per cluster			Number of fruits per plant			Average fruit weight (g)		
Lines	**Y_1**	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**
NDT-1	3.69	4.16	3.93	6.10	6.61	6.36	33.36	34.62	33.99	50.68	51.94	51.31
NDT-2	4.15	4.62	4.39	5.36	5.87	5.62	37.37	38.63	38.00	59.32	60.58	59.95
NDT-3	3.52	3.99	3.76	4.43	4.94	4.69	35.24	36.50	35.87	36.37	37.63	37.00
NDT-4	3.95	4.42	4.19	4.20	4.71	4.46	45.26	46.52	45.89	30.03	31.29	30.66
NDT-5	4.19	4.66	4.43	5.70	6.21	5.96	45.23	46.49	45.86	31.08	32.34	31.71
NDT-6	3.45	3.92	3.69	5.40	5.91	5.66	73.56	74.82	74.19	25.35	26.61	25.98
NDT-7	3.42	3.89	3.66	5.63	6.14	5.89	66.61	67.87	67.24	25.07	26.33	25.70
NDT-8	3.39	3.86	3.63	5.70	6.21	5.96	51.23	52.49	51.86	37.23	38.49	37.86
Azad T-6	3.62	4.09	3.86	5.13	5.64	5.39	44.58	45.84	45.21	39.26	40.52	39.89
Arka Saurabh	4.15	4.62	4.39	5.10	5.61	5.36	49.88	51.14	50.51	40.69	41.95	41.32
Testers												
Pusa Ruby	3.49	3.96	3.73	4.83	5.34	5.09	37.96	39.22	38.59	36.33	37.59	36.96
Punjab Chhuhara	3.15	3.62	3.39	4.73	5.24	4.99	40.88	42.14	41.51	29.67	30.93	30.30
Arka Vikas	3.49	3.96	3.73	5.26	5.77	5.52	42.23	43.49	42.86	56.01	57.27	56.64
Arka Meghali	3.22	3.69	3.46	5.36	5.87	5.62	49.54	50.80	50.17	53.35	54.61	53.98
Mean	**3.64**	**4.11**	**3.87**	**5.21**	**5.72**	**5.47**	**46.64**	**47.90**	**47.27**	**39.32**	**40.58**	**39.95**
Lowest	3.15	3.62	3.39	4.20	4.71	4.46	33.36	34.62	33.99	25.07	26.33	25.70
Highest	4.19	4.66	4.43	6.10	6.61	6.36	73.56	74.82	74.19	59.32	60.58	59.95

Table 5.1 Contd....

Lines	Fruit length (cm)			Fruit girth (cm)			Number of locules per fruit			Pericarp thickness (mm)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1	7.09	7.63	7.36	13.56	14.77	14.17	4.77	5.13	4.95	5.52	5.93	5.73
NDT-2	7.70	8.24	7.97	13.36	14.57	13.97	5.17	5.53	5.35	4.92	5.33	5.13
NDT-3	6.53	7.07	6.80	14.50	15.71	15.11	4.67	5.03	4.85	4.89	5.30	5.10
NDT-4	7.93	8.47	8.20	15.47	16.68	16.08	4.50	4.86	4.68	4.22	4.63	4.43
NDT-5	6.53	7.07	6.80	12.49	13.70	13.09	4.37	4.73	4.55	4.45	4.86	4.66
NDT-6	6.29	6.83	6.56	12.46	13.67	13.07	4.23	4.59	4.41	4.29	4.70	4.50
NDT-7	6.41	6.95	6.68	11.50	12.71	12.11	4.40	4.76	4.58	4.29	4.70	4.50
NDT-8	6.50	7.04	6.77	12.16	13.37	12.77	3.77	4.13	3.95	4.49	4.90	4.70
Azad T-6	6.93	7.47	7.20	13.53	14.74	14.14	4.60	4.96	4.78	5.79	6.20	6.00
Arka Saurabh	8.30	8.84	8.57	15.20	16.41	15.81	4.03	4.39	4.21	4.85	5.26	5.06
Testers												
Pusa Ruby	6.40	6.94	6.67	12.30	13.51	12.91	3.90	4.26	4.08	4.39	4.80	4.60
Punjab Chhuhara	5.90	6.44	6.17	11.06	12.27	11.67	3.53	3.89	3.71	4.85	5.26	5.06
Arka Vikas	7.70	8.24	7.97	13.36	14.57	13.97	4.07	4.43	4.25	5.15	5.56	5.36
Arka Meghali	6.76	7.30	7.03	12.16	13.37	12.77	4.50	4.86	4.68	4.42	4.83	4.63
Mean	**6.92**	**7.46**	**7.19**	**13.08**	**14.29**	**13.69**	**4.32**	**4.68**	**5.50**	**4.75**	**5.16**	**4.96**
Lowest	5.90	6.44	6.17	11.06	12.27	11.67	3.53	3.89	3.71	4.22	4.63	4.43
Highest	8.30	8.84	8.57	15.47	16.68	16.08	5.17	5.53	5.35	5.79	6.20	6.00

Table 5.1 Contd....

Genotypes	Total soluble solid (TSS)			Ascorbic acid (mg/100 g fresh fruit)			Total fruit yield per plant (kg)		
Lines	**Y_1**	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**
NDT-1	5.92	6.31	6.12	40.78	42.00	41.39	2.76	3.13	2.94
NDT-2	5.42	5.81	5.62	31.87	40.09	35.98	3.28	3.65	3.46
NDT-3	4.92	5.31	5.12	27.24	28.46	27.85	2.63	3.00	2.82
NDT-4	4.45	4.84	4.65	28.78	30.00	29.39	2.46	2.83	2.64
NDT-5	6.42	6.81	6.62	32.76	33.98	33.37	2.51	2.88	2.69
NDT-6	5.72	6.11	5.92	39.31	41.20	40.26	2.76	3.13	2.94
NDT-7	5.38	5.77	5.58	43.40	44.62	44.01	2.76	3.03	2.89
NDT-8	6.12	6.51	6.32	47.13	48.35	47.74	2.98	3.12	3.05
Azad T-6	5.92	6.31	6.12	49.62	50.84	50.23	2.82	3.19	3.01
Arka Saurabh	5.38	5.77	5.58	41.46	40.02	40.74	3.11	3.26	3.18
Testers									
Pusa Ruby	4.95	5.34	5.15	34.14	35.36	34.75	2.47	2.84	2.65
Punjab Chhuhara	5.55	5.94	5.75	37.55	38.77	38.16	2.26	2.63	2.44
Arka Vikas	5.98	6.37	6.18	38.03	39.25	38.64	3.44	3.81	3.63
Arka Meghali	5.41	5.80	5.61	40.82	42.04	41.43	3.53	3.90	3.71
Mean	**5.54**	**5.93**	**5.74**	**38.06**	**39.64**	**38.85**	**2.84**	**3.17**	**3.01**
Lowest	4.45	4.84	4.65	27.24	28.46	27.85	2.26	2.63	2.44
Highest	6.42	6.81	6.62	49.62	50.84	50.23	3.53	3.90	3.71

parent Arka Saurabh (8.57 cm) followed by NDT-4 (8.20 cm), NDT-2 and Arka Vikas (7.97 cm), NDT-1 (7.36 cm) and Azad T-6 (7.20 cm) in pooled; parental line NDT-4 (15.47 cm) is maximum fruit girth followed by Arka Saurabh (15.20 cm), NDT-3 (14.50 cm), NDT-1 (13.56 cm) and Azad T-6 (13.53 cm) in Y_1, parental line NDT-4 (16.68 cm) followed by Arka Saurabh (16.41 cm), NDT-3 (15.71 cm), NDT-1 (14.77 cm) and Azad T-6 (14.74 cm)in Y_2 and parental line NDT-4 (16.08 cm) followed by Arka Saurabh (15.81 cm), NDT-3 (15.11 cm), NDT-1 (14.17 cm) and Azad T-6 (14.14 cm) in pooled; parents, NDT-2 (5.17) recorded maximum number of locules per fruit followed by NDT-1 (4.77), NDT-3 (4.67), Azad T-6 (4.60) and NDT-4 and Arka Meghali (4.50) in Y_1, NDT-2 (5.53) followed by NDT-1 (5.13), NDT-3 (5.03), Azad T-6 (4.96) and NDT-4 and Arka Meghali (4.86) in Y_2 and NDT-2 (5.35) followed by NDT-1 (4.95), NDT-3 (4.85), Azad T-6 (4.78) and NDT-4 and Arka Meghali (4.68) in pooled; Azad T-6 (5.79 mm) recorded maximum pericarp thickness followed by NDT-1 (5.52 mm), Arka Vikas (5.15 mm), NDT-2 (4.92 mm) and NDT-3 (4.89 mm) in Y_1, Azad T-6 (6.20 mm) followed by NDT-1 (5.93 mm), Arka Vikas (5.56 mm), NDT-2 (5.33 mm) and NDT-3 (5.30 mm) inY_2 and Azad T-6 (6.00 mm) followed by NDT-1 (5.73 mm), Arka Vikas (5.36 mm), NDT-2 (5.13 mm) and NDT-3 (5.10 mm) in pooled; parental line NDT-5 (6.42 °B) had maximum total soluble solids which were followed by NDT-8 (6.12 °B), Arka Vikas (5.98 °B), NDT-1 and Azad T-6 (5.92 °B) and NDT-6 (5.72 °B) in Y_1, NDT-5 (6.81 °B) followed by NDT-8 (6.51 °B), Arka Vikas (6.37 °B), NDT-1 and Azad T-6 (6.31 °B) and NDT-6 (6.11 °B) in Y_2 and NDT-5 (6.62 °B) followed by NDT-8 (6.32 °B), Arka Vikas (6.18 °B), NDT-1 and Azad T-6 (6.12 °B) and NDT-6 (5.92 °B) in pooled; Azad T-6 (49.62 mg) recorded maximum ascorbic acid followed by NDT-8 (47.13 mg), NDT-7 (43.40 mg), Arka Saurabh (41.46 mg) and Arka Meghali (40.82 mg) in Y_1, Azad T-6 (50.84 mg) followed by NDT-8 (48.35 mg), NDT-7

(44.62 mg), Arka Meghali (42.04 mg) and NDT-1 (42.00 mg) in Y_2 and Azad T-6 (50.23 mg) followed by NDT-8 (47.74 mg), NDT-7 (44.01 mg), Arka Meghali (41.43 mg) and NDT-1 (41.39 mg) in pooled.

5.3 Estimates of heterosis over better parent and standard variety

The exploitation of heterosis refers as the superiority of F_1 hybrid over its parent in terms of yield and its attributing traits. The exploitation of heterosis requires an intensive evaluation of germplasm to find out diverse donors with high nicking of genes and further identification of heterotic crosses. In present study, the estimates of heterosis over better-parent and standard variety (Arka Vikas) over two years and pooled were calculated for 40 F_1's to assess their genetic potential as breeding material and presented in Table 4.5 and summarized in Table 5.2.

Perusal of Table-4.5 revealed that nature and magnitude of heterosis differed for different traits and over seasons in various hybrid combinations. In case of total fruit yield per plant, in Y_1 the heterobeltiosis ranged from -49.42 to 8.49 per cent and standard heterosis from -54.36 to -7.85 per cent, in Y_2, over better parent from -44.62 to 7.44 per cent and standard parent from -49.08 to -7.09 per cent and in pooled, over better parent from -46.90 to 7.93 per cent and standard parent from -51.59 to -7.45 per cent. Out of 40 crosses, none of the F_1's showed significant and positive heterosis over better and standard parent in Y_1, Y_2 and pooled. A perusal of Table-5.2 revealed that crosses exhibiting significant and negative estimates of heterosis for one or both types of heterosis for total fruit yield also exhibited significant an positive estimates heterosis for other important yield and yield attributing traits. In contrast, none of the crosses showed significant and desirable heterosis for all the traits. The above results are in conformity with the findings of **Indrajyoti *et al.* (2001), Mahendrakar *et al.* (2005), Dharmatti *et al.* (2006), Singh *et al.* (2006), Seeja *et al.* (2007), Yadav *et al.* (2013) and Sherpa *et al.* (2014).**

Table-5.2 Lists of crosses with desirable and significant heterosis for 15 characters in tomato Y_1=2016-17, Y_2=2017-18 and pooled

Characters	Y_1		Y_2		Pooled	
	BP	**SV**	**BP**	**SV**	**BP**	**SV**
Days to 50 % flowering	NDT-4 × Arka Meghali (-19.69 %) and NDT-1 × Arka Meghali (-11.12 %)	NDT-4 × Arka Meghali (-14.16%)	NDT-4 × Arka Meghali (-17.46%), NDT-1 × Arka Meghali (-11.80%) and NDT-7 × Arka Vikas (-8.83%)	NDT-4 × Arka Meghali (-10.62%)	NDT-4 × Arka Meghali (-18.51%), NDT-1 × Arka Meghali (-11.48%) and NDT-6 × Pb. Chhuhara (-8.38%)	NDT-4 × Arka Meghali (-12.30%)
Days to first fruit set	NDT-4 × Arka Meghali (-13.90%) and NDT-1 × Arka Meghali (-8.51 %)	-	NDT-4 × Arka Meghali (-13.46%) and NDT-1 × Arka Meghali (-8.24 %)	-	NDT-4 × Arka Meghali (-13.68%), NDT-1 × Arka Meghali (-8.38 %) and NDT-7 × Arka Vikas (-6.63%)	-
Days to first fruit harvest	NDT-4 × Arka Meghali (-8.43%) and NDT-1 × Arka Meghali (-5.54 %)	-	NDT-4 × Arka Meghali (-8.26%) and NDT-1 × Arka Meghali (-5.43%)	-	NDT-4 × Arka Meghali (-8.34%), NDT-1 × Arka Meghali (-5.48%) and NDT-7 × Arka Vikas (-3.70%)	NDT-4 × Arka Meghali (-4.74%)
Plant height (cm)	Azad T-6 × Pusa Ruby (42.11%), NDT-5 × Pusa Ruby (23.62%), NDT-7 × Pusa Ruby (21.87%), Azad T-6 × Arka Meghali (19.40%) and NDT-4 × Pusa Ruby (18.15%)	Azad T-6 × Pusa Ruby (91.54%), NDT-5 × Pusa Ruby (82.61%), NDT-4 × Pusa Ruby (79.88%), NDT-5 × Pb. Chhuhara (67.66%) and NDT-7 × Pusa Ruby (64.26%)	Azad T-6 × Pusa Ruby (43.27%), NDT-5 × Pusa Ruby (26.35%), NDT-7 × Pusa Ruby (22.26%), Azad T-6 × Arka Meghali (19.83%) and NDT-4 × Pusa Ruby (17.97%)	Azad T-6 × Pusa Ruby (91.35%), NDT-5 × Pusa Ruby (85.35%), NDT-4 × Pusa Ruby (78.68%), NDT-5 × Pb. Chhuhara (66.65%) and NDT-7 × Pusa Ruby (63.29%)	Azad T-6 × Pusa Ruby (42.70%), NDT-5 × Pusa Ruby (24.99%), NDT-7 × Pusa Ruby (22.07%), Azad T-6 × Arka Meghali (19.61%) and NDT-4 × Pusa Ruby (18.06%)	Azad T-6 × Pusa Ruby (91.45%), NDT-5 × Pusa Ruby (83.99%), NDT-4 × Pusa Ruby (79.27%), NDT-5 × Pb. Chhuhara (67.15%) and NDT-7 × Pusa Ruby (63.77%)
Number of primary branches per plant	Azad T-6 × Arka Meghali (24.01%)	Azad T-6 × Arka Meghali (28.63%)	Azad T-6 × Arka Meghali (21.25%)	Azad T-6 × Arka Meghali (25.23%)	Azad T-6 × Arka Meghali (21.25%) and NDT-6 × Arka Meghali (14.46%)	Azad T-6 × Arka Meghali (26.82%)
Number of fruits per cluster	-	NDT-8 × Arka Vikas (21.28%), NDT-8 × Pusa Ruby (17.10%) and NDT-1 × Pb. Chhuhara and NDT-2 × Pusa Ruby (17.10%)	-	-	NDT-3 × Pusa Ruby (15.72%), Arka Saurabh × Pusa Ruby (15.49%), NDT-4 × Arka Vikas (15.22%), NDT-2 × Pusa Ruby (14.24%) and NDT-4 × Pb. Chhuhara (13.43%)	NDT-8 × Arka Vikas (17.28%), NDT-1 × Pb. Chhuhara, NDT-2 × Pusa Ruby and NDT-8 × Pusa Ruby (16.31%), NDT-1 × Arka Vikas and NDT-4 × Arka Vikas (15.22%), NDT-7 × Arka Vikas (13.95%) and NDT-8 × Pb. Chhuhara (12.20%)

Number of fruits per plant	NDT-3 × Pusa Ruby (20.71%), NDT-2 × Arka Vikas (11.01%), NDT-2 × Pusa Ruby (10.28%), NDT-3 × Pb. Chhuhara (9.80%) and NDT-1 × Pusa Ruby (9.29%)	NDT-2 × Arka Vikas (11.01%), NDT-3 × Pusa Ruby (8.50%), Arka Saurabh × Arka Meghali (7.55%), NDT-3 × Pb. Chhuhara (6.29%) and NDT-3 × Arka Vikas (6.10%)	NDT-3 × Pusa Ruby (20.04%), NDT-2 × Arka Vikas (10.69%), NDT-2 × Pusa Ruby (9.95%), NDT-3 × Pb. Chhuhara (9.51%) and NDT-1 × Pusa Ruby (8.99%)	NDT-2 × Arka Vikas (10.69%), NDT-3 × Pusa Ruby (8.26%), Arka Saurabh × Arka Meghali (7.33%), NDT-3 × Pb. Chhuhara (6.11%) and NDT-3 × Arka Vikas (5.93%)	NDT-3 × Pusa Ruby (20.37%), NDT-2 × Arka Vikas (10.85%), NDT-2 × Pusa Ruby (10.12%), NDT-3 × Pb. Chhuhara (9.65%) and NDT-1 × Pusa Ruby (9.14%)	NDT-2 × Arka Vikas (10.85%), NDT-3 × Pusa Ruby (8.38%), Arka Saurabh × Arka Meghali (7.44%), NDT-3 × Pb. Chhuhara (6.20%) and NDT-3 × Arka Vikas (6.01%)
Average fruit weight (g)	Arka Saurabh × Pusa Ruby (39.31%) and NDT-7 × Pb. Chhuhara (22.40%)	-	Arka Saurabh × Pusa Ruby (38.13%) and NDT-7 × Pb. Chhuhara (21.49%)	-	Arka Saurabh × Pusa Ruby (38.711%), NDT-7 × Pb. Chhuhara (21.94%) and NDT-1 × Arka Meghali (5.07%)	-
Fruit length (cm)	NDT-7 × Pb. Chhuhara (21.12%)	-	NDT-7 × Pb. Chhuhara (19.48%)	-	NDT-7 × Pb. Chhuhara (20.27%) and NDT-8 × Pusa Ruby (10.30%)	-
Fruit girth (cm)	-	-	-	-	NDT-5 × Arka Meghali (14.72%)	Arka Saurabh × Arka Vikas (13.75%) and Arka Saurabh × Pb. Chhuhara (10.31%)
Number of locules per fruit	NDT-6 × Pusa Ruby (34.75%)	NDT-6 × Pusa Ruby (40.05%), NDT-6 × Pb. Chhuhara (27.03%) and NDT-2 × Arka Vikas and NDT-8 × Arka Meghali (26.04%)	NDT-6 × Pusa Ruby (34.75%)	NDT-6 × Pusa Ruby (36.79%), NDT-6 × Pb. Chhuhara (24.83%) and NDT-2 × Arka Vikas and NDT-8 × Arka Meghali (23.93%)	NDT-6 × Pusa Ruby (33.33%), NDT-6 × Pb. Chhuhara (21.32%), Arka Saurabh × Pb. Chhuhara (19.95%) and Arka Saurabh × Arka Vikas (16.47%)	NDT-6 × Pusa Ruby (38.35%), NDT-6 × Pb. Chhuhara (25.88%), NDT-2 × Arka Vikas and NDT-8 × Arka Meghali (24.94%), Azad T-6 × Pusa Ruby (21.88%) and NDT-4 × Pb. Chhuhara (21.18%)
Pericarp thickness (mm)	-	-	-	-	NDT-6 × Arka Meghali (15.12%)	-
Total soluble solid (TSS)	Arka Saurabh × Arka Meghali (27.89%) and NDT-3 × Pusa Ruby (19.58%)	Arka Saurabh × Arka Meghali (15.71%)	Arka Saurabh × Arka Meghali (26.02%) and NDT-3 × Pusa Ruby (18.15%)	Arka Saurabh × Arka Meghali (14.75%)	Arka Saurabh × Arka Meghali (26.92%), NDT-3 × Pusa Ruby (18.84%), NDT-7 × Pb. Chhuhara (14.79%) and NDT-2 × Arka Meghali (12.46%)	Arka Saurabh × Arka Meghali (15.21%)
Ascorbic acid (mg/100 g fresh fruit)	NDT-5 × Pb. Chhuhara (62.68%), NDT-5 × Arka Vikas (54.35%), NDT-5	NDT-5 × Pb. Chhuhara (60.64%), NDT-5 × Arka Meghali (58.59%), NDT-	NDT-5 × Pb. Chhuhara (58.12%), NDT-5 × Pusa Ruby (57.67%), NDT-5	NDT-5 × Arka Meghali (56.76%), NDT-5 × Pb. Chhuhara (56.20%),	NDT-5 × Pb. Chhuhara (60.36%), NDT-5 × Arka Vikas (52.20%), NDT-5	NDT-5 × Pb. Chhuhara (58.39%), NDT-5 × Arka Meghali (57.66%), NDT-

	× Arka Meghali (47.75%), NDT-5 × Pusa Ruby (37.28%) and NDT-2 × Pusa Ruby (26.60%)	5 × Arka Vikas (54.35%), Azad T-6 × Arka Meghali (51.38%) and Azad T-6 × Arka Vikas (45.80%)	× Arka Vikas (50.11%), NDT-5 × Arka Meghali (46.36%) and NDT-4 × Pusa Ruby (17.46%)	NDT-5 × Arka Vikas (50.11%), Azad T-6 × Arka Meghali (49.78%) and Azad T-6 × Arka Vikas (47.77%)	× Pusa Ruby (47.65%), NDT-5 × Arka Meghali (47.04%) and NDT-2 × Pusa Ruby (21.37%)	5 × Arka Vikas (52.20%), Azad T-6 × Arka Meghali (50.57%) and Azad T-6 × Arka Vikas (46.80%)
Total fruit yield per plant (kg)	-	-	-	-	-	-

For maturity traits negative heterosis is desirable. Since hybrids with heterosis for earliness produce first fruit earlier as compared to parents, thereby increasing their productivity per day per unit area and as a consequence fetch good prices in the market by early supply of produce. A close examination of heterosis value of days to 50% flowering revealed that two, eight and one hybrids exhibited significant and desirable heterosis in respect to better and standard parent Y_1, Y_2 and pooled respectively.

Out of significant crosses for fruit yield, only two and one cross in both years and four and one in pooled showed positive and significant heterobeltiosis over better and standard parent for TSS respectively. For instance, none of the crosses exhibited significant heterobeltiosis over better and standard parent for fruit yield in both the years and pooled. However, out of forty crosses, eleven and fourteen cross in both years and eleven and fifteen in pooled combinations showed positive and significant heterosis over better and standard parent respectively. However, the number of crosses which showed significant standard heterosis for quality traits along with fruit yield were generally more in number than the crosses for significant better parent heterosis. This showed negative association for heterosis between fruit yield and quality traits.

A perusal of Table 5.2 which showed best five crosses on the basis of desirable and significant heterobeltiosis for fifteen traits in both the years and over pooled revealed that common crosses on the basis of *per se* performance (Table 4.3) since, earliness, desirable fruit shape, size, colour, number of fruits and fruit yield are important consideration for choice of elite high yielding F_1 hybrids. The decision for final selection of a hybrid for commercial cultivation should also be taken into account the earlier mentioned features. Out of 40 crosses none of the cross showed significant positive heterosis over better parent and standard variety in both the years

and pooled for fruit yield (Table-4.5). The general rating of fruits of line × tester set of present study had been given in Table-4.5 while, photographs of parents and F_1's had been shown in fig. 4.1 to 4.3.

Besides fruit yield per plant, substantial heterosis over better-parent and standard variety was also observed in negative as well as positive direction for remaining characters in both the years (Table-4.5). However, the number of crosses showing significant estimates and the range of heterosis varied from one character to another. In general, some crosses showed appreciable and high heterosis for various traits under study. The existence of wide spectrum of heterosis in either direction with expression of high degree of desirable heterosis by some crosses for number of traits observed in present study is in conformity with the earlier reports of high heterosis for such characters in tomato **(Indrajyoti *et al.*, 2001; Mahendrakar *et al*,. (2005); Dharmatti *et al.*, 2006; Singh *et al.*, 2006; Seeja *et al.*, 2007; Yadav *et al.*, 2013 and Sherpa *et al.*, 2014)**.

5.4 Combining ability variances and their effects

The understanding of inheritance of various characters and identification of superior parents are important pre-requisites for launching an effective and efficient breeding programme. It is not always necessary that parents with high mean performance for yield and other traits would produce desirable F_1's and/or segregants. The selection of a few parents having high genetic potential as per breeding objectives is essential because analyzing and handling of very large number of crosses resulting from numerous parents available in germplasm collections of a crop would be an impractical and perhaps impossible task. Combining ability analysis is useful technique for understanding of genetic worth of parents and their crosses for further exploitation in breeding programmes. In addition, it also provides the idea about gene effects involved in inheritance of different

characters which is essential for deciding suitable breeding strategy. Among the various techniques of combining ability analysis, line × tester analysis **(Kempthorne, 1957)** has been widely utilized for screening the germplasm to identify valuable donor parents and promising crosses in many crops including tomato by many workers **(Dod e*t al*., 1995; Cheema *et al*., 1996; Sharma *et al*., 1999; Dhaliwal *et al*., 2000; Janaki, 2011 and Sherpa *et al*., 2014).**

5.4.1 Analysis of variance for combining ability

Analysis of variances for combining ability in both the years (Y_1 and Y_2) is presented in Table 4.6.1. Analysis of variances for combining ability revealed that the partitioning of variances due to lines × testers showed highly significant for days to 50 % flowering, days to first fruit set, plant height, number of fruits per plant, average fruit weight, fruit length, number of locules per fruit, total soluble solids, ascorbic acid in both years and total fruit yield per plant in Y_1 whereas, significant for days to first fruit harvest, number of fruits per cluster, fruit girth in both years and total fruit yield per plant in Y_2, except number of primary branches per plant and pericarp thickness in both years. Variances due to lines were highly significant for plant height followed by ascorbic acid, number of fruits per plant, number of primary branches per plant and total fruit yield per plant in Y_1 and plant height followed by ascorbic acid, number of fruits per plant, number of primary branches per plant and total fruit yield per plant in Y_2, whereas, variances due to testers was also highly significant for plant height in both the years.

Analysis of variances for combining ability in pooled is presented in Table 4.6.2. Analysis of variances for combining ability revealed that the partitioning of variances due to envirоonments showed highly significant for all the charecters. Analysis of variances for combining ability revealed that

the partitioning of variances due to lines × testers showed highly significant for all the charecters. Variances due to lines were highly significant for plant height followed by ascorbic acid, number of fruits per plant, number of primary branches per plant and total fruit yield per plant whereas, variances due to testers was also highly significant for plant height. Similar finding was also reported by **Pandey (2006), Dharmatti *et al.* (1999), Singh *et al.* (2006 a) and Saidi *et al.* (2008).**

5.4.2 General combining ability effects

General combining ability study helps in making the choice of the parents and also helps in the isolation of suitable germplasm for further improvement. General combining ability is primarily a function of additive and additive × additive gene action.

For illustrating genetic worth of parents for hybridization programme, the general combining ability (gca) effects of 14 parents (10 lines and 4 testers) for fifteen characters in Y_1, Y_2 and pooled had been presented in Table 4.7 and consolidated in Table 5.3 and Table 5.4.

The significant and positive gca effects for fruit yield per plant were exhibited by fourteen parent. Among the parents NDT-2, NDT-3 were found good general combiners in both the years and pooled. On the basis of gca effects and mean performance; parents NDT-4 and NDT-1 were found good general combiner for days to 50 % flowering in both the years and pooled; parents NDT-4 was found good general combiner for days to first fruit set in both the years and pooled; parents NDT-4 and NDT-1 were found good general combiner for days to first fruit harvest in both the years and pooled; parents NDT-5, Azad T-6, NDT-4 and NDT-1 were found as the top four good general combiners for plant height at last picking stage in both the years and pooled; parents Azad T-6 was found good general combiner for number of primary branches per plant; parents, NDT-8 was found good

general combiners in both the years and pooled for number of fruits per cluster; parents, NDT- 3, NDT- 1, NDT-2, Arka Saurabh and NDT-5 were found good general combiners in both the years and pooled for number of fruits per plant; based on result both the years and pooled; NDT-1, Azad T-6, Arka Saurabh, NDT-7 and NDT-2 were found as the top good general combiners for average fruit weight; none of the parents was found as the good general combiners for fruit length over both the years and pooled; parents Arka Saurabh was found as good general combiners for fruit length over both the years and pooled; parents Azad T-6 and NDT-6 were found as the top two good general combiners for fruit length in both the years and pooled; parents NDT-8 were found as good general combiners for pericarp thickness in both the years and pooled; NDT-2 and Arka Saurabh were found as top two good general combiners for total soluble solids in both the years and pooled and parents NDT-5, Azad T-6 and NDT-4 were found good general combiners in both the years and pooled for ascorbic acid. Significant gca values indicated the importance of additive and additive × additive gene effect as earlier reported by **Griffing (1956)**. In view of this, these parents offered the best possibilities for the development of improved lines of tomato through hybridization programme. It is, therefore, recommended that to improve yield one should breed for superior combining ability for the component traits with an ultimate objective to improve the pace of its genetic improvement. On the basis of mean performance and gca effects it had been found that there is perfect relationship between *per se* performance and gca effect of the parents.

The above two parents (NDT-2 and NDT-3) in both the years and pooled showed positive and significant gca effects for fruit yield per plant and other important traits as mentioned in above paragraphs may serve as valuable parents for hybridization programme or multiple crossing

Table 5.3 List of good general combiner parents for various characters in tomato Y_1=2016-17, Y_2=2017-18 and pooled

Good general combiner parents	Characters		
Lines	**Y_1**	**Y_2**	**Pooled**
NDT-1	Days to 50 % flowering, Days to first fruit harvest, Plant height, Number of fruits per plant, Average fruit weight, Total fruit yield per plant	Days to 50 % flowering, Days to first fruit harvest, Plant height, Number of fruits per plant, Average fruit weight	Days to 50 % flowering, Days to first fruit set, Days to first fruit harvest, Plant height, Number of fruits per cluster, Number of fruits per plant, Average fruit weight, Total fruit yield per plant
NDT-2	Number of fruits per plant, Average fruit weight, Total soluble solids, Total fruit yield per plant	Number of fruits per plant, Average fruit weight, Total soluble solids, Total fruit yield per plant	Number of fruits per cluster, Number of fruits per plant, Average fruit weight, Number of locules per fruit, Pericarp thickness, Total soluble solids, Total fruit yield per plant
NDT-3	Number of fruits per plant, Total fruit yield per plant	Number of fruits per plant, Total fruit yield per plant	Number of fruits per plant, Total soluble solids, Total fruit yield per plant
NDT-4	Days to 50 % flowering, Days to first fruit set, Days to first fruit harvest, Plant height, Ascorbic acid	Days to 50 % flowering, Days to first fruit set, Days to first fruit harvest, Plant height, Ascorbic acid	Days to 50 % flowering, Days to first fruit set, Days to first fruit harvest, Plant height, Fruit length, Ascorbic acid
NDT-5	Plant height, Number of fruits per plant, Ascorbic acid	Plant height, Number of fruits per plant, Ascorbic acid	Plant height, Number of fruits per plant, Ascorbic acid
NDT-6	Number of locules per fruit	Number of locules per fruit	Number of locules per fruit
NDT-7	Average fruit weight	Average fruit weight	Average fruit weight
NDT-8	Number of fruits per cluster, Pericarp thickness	Number of fruits per cluster, Pericarp thickness	Number of fruits per cluster, Pericarp thickness
Azad T-6	Plant height, Number of primary branches per plant, Average fruit weight, Number of locules per fruit, Ascorbic acid	Plant height, Number of primary branches per plant, Average fruit weight, Number of locules per fruit, Ascorbic acid	Plant height, Number of primary branches per plant, Average fruit weight, Number of locules per fruit, Ascorbic acid
Arka Saurabh	Number of fruits per plant, Average fruit weight, Fruit girth, Total soluble solids	Number of fruits per plant, Average fruit weight, Fruit girth, Total soluble solids	Number of fruits per plant, Average fruit weight, Fruit length, Fruit girth, Total soluble solids, Total fruit yield per plant
Testers			
Pusa Ruby	Plant height	Plant height	Plant height
Punjab Chhuhara	-	-	-
Arka Vikas	Number of fruits per cluster, Total fruit yield per plant	Number of fruits per cluster	Number of fruits per cluster, Pericarp thickness, Total fruit yield per plant
Arka Meghali	Number of fruits per plant, Average fruit weight, Ascorbic acid	Number of fruits per plant, Average fruit weight, Ascorbic acid	Number of fruits per plant, Average fruit weight, Ascorbic acid

Table 5.4 Summary of general combining ability effects of parents for 15 characters in tomato Y_1=2016-17, Y_2=2017-18 and pooled

Traits / Lines	Total fruit yield per plant (kg)			Days to 50 % flowering			Days to first fruit set			Days to first fruit harvest		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1	0.19*	0.16	0.18**	G	G	G	A	A	G	G	G	G
NDT-2	0.39**	0.39**	0.39**	A	A	P	A	A	A	A	A	A
NDT-3	0.33**	0.33**	0.33**	P	P	P	A	A	P	P	P	P
NDT-4	0.04	0.04	0.04	G	G	G	G	G	G	G	G	G
NDT-5	-0.46**	-0.46**	-0.46**	A	A	A	A	A	A	A	A	A
NDT-6	-0.26**	-0.26**	-0.26**	A	A	A	A	A	A	A	A	A
NDT-7	-0.35**	-0.37**	-0.36**	A	A	A	A	A	A	A	A	A
NDT-8	0.04	0.07	0.05	A	A	A	A	A	A	A	A	A
Azad T-6	-0.03	-0.05	-0.04	A	A	A	A	A	A	A	A	A
Arka Saurabh	0.11	0.14	0.13*	A	A	A	A	A	A	A	A	A
Testers												
Pusa Ruby	0.01	0.01	0.01	A	A	A	A	A	A	A	A	A
Punjab Chhuhara	-0.09	-0.11*	-0.10*	A	A	G	A	A	A	A	A	A
Arka Vikas	0.10*	0.11	0.11*	A	A	A	A	A	A	A	A	A
Arka Meghali	-0.03	0.00	-0.02	A	A	A	A	A	A	A	A	A

Table-5.4 Contd.....

Traits / Lines	Total fruit yield per plant (kg)			Plant height (cm)			Number of primary branches per plant			Number of fruits per cluster		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1	0.19*	0.16	0.18**	G	G	G	A	A	G	A	A	G
NDT-2	0.39**	0.39**	0.39**	P	P	P	P	P	P	A	A	G
NDT-3	0.33**	0.33**	0.33**	P	P	P	P	P	P	P	P	P
NDT-4	0.04	0.04	0.04	G	G	G	P	P	P	A	A	A
NDT-5	-0.46**	-0.46**	-0.46**	G	G	G	A	A	A	P	P	P
NDT-6	-0.26**	-0.26**	-0.26**	P	P	P	A	A	A	P	P	P
NDT-7	-0.35**	-0.37**	-0.36**	P	P	P	A	A	A	P	P	P
NDT-8	0.04	0.07	0.05	P	P	P	A	A	A	G	G	G
Azad T-6	-0.03	-0.05	-0.04	G	G	G	G	G	G	P	P	P
Arka Saurabh	0.11	0.14	0.13*	P	P	P	P	P	P	A	A	A
Testers												
Pusa Ruby	0.01	0.01	0.01	G	G	G	P	P	P	A	A	A
Punjab Chhuhara	-0.09	-0.11*	-0.10*	P	P	P	A	A	A	P	P	P
Arka Vikas	0.10*	0.11	0.11*	P	P	P	A	A	A	G	A	G
Arka Meghali	-0.03	0.00	-0.02	P	P	P	P	P	P	P	P	P

Table-5.4 Contd.....

Traits / Lines	Total fruit yield per plant (kg)			Number of fruits per plant			Average fruit weight (g)			Fruit length (cm)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1	0.19*	0.16	0.18**	G	G	G	G	G	G	A	A	A
NDT-2	0.39**	0.39**	0.39**	G	G	G	G	G	G	P	P	P
NDT-3	0.33**	0.33**	0.33**	G	G	G	P	P	P	P	P	P
NDT-4	0.04	0.04	0.04	P	P	P	P	P	P	A	A	G
NDT-5	-0.46**	-0.46**	-0.46**	G	G	G	P	P	P	P	P	P
NDT-6	-0.26**	-0.26**	-0.26**	P	P	P	P	P	P	P	P	P
NDT-7	-0.35**	-0.37**	-0.36**	P	P	P	G	G	G	A	A	A
NDT-8	0.04	0.07	0.05	P	P	P	A	A	A	P	P	P
Azad T-6	-0.03	-0.05	-0.04	P	P	P	G	G	G	A	A	A
Arka Saurabh	0.11	0.14	0.13*	G	G	G	G	G	G	A	A	G
Testers												
Pusa Ruby	0.01	0.01	0.01	P	P	P	P	P	P	P	P	P
Punjab Chhuhara	-0.09	-0.11*	-0.10*	A	A	A	P	P	P	A	A	A
Arka Vikas	0.10*	0.11	0.11*	P	P	P	A	A	A	A	A	A
Arka Meghali	-0.03	0.00	-0.02	G	G	G	G	G	G	P	P	P

Table-5.4 Contd.....

Traits / Lines	Total fruit yield per plant (kg)			Fruit girth (cm)			Number of locules per fruit			Pericarp thickness (mm)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1	0.19*	0.16	0.18**	P	A	P	A	A	A	P	P	P
NDT-2	0.39**	0.39**	0.39**	P	P	P	A	A	G	A	A	G
NDT-3	0.33**	0.33**	0.33**	P	P	P	P	P	P	P	P	P
NDT-4	0.04	0.04	0.04	A	A	A	A	A	A	P	P	P
NDT-5	-0.46**	-0.46**	-0.46**	P	P	P	P	P	P	A	A	A
NDT-6	-0.26**	-0.26**	-0.26**	P	P	P	G	G	G	A	A	A
NDT-7	-0.35**	-0.37**	-0.36**	A	A	A	P	P	P	P	P	P
NDT-8	0.04	0.07	0.05	A	A	A	P	P	P	G	G	G
Azad T-6	-0.03	-0.05	-0.04	P	P	P	G	G	G	A	A	A
Arka Saurabh	0.11	0.14	0.13*	G	G	G	A	A	A	P	P	P
Testers												
Pusa Ruby	0.01	0.01	0.01	P	P	P	P	P	P	P	P	P
Punjab Chhuhara	-0.09	-0.11*	-0.10*	A	A	A	A	A	A	A	A	A
Arka Vikas	0.10*	0.11	0.11*	A	A	A	P	P	P	A	A	G
Arka Meghali	-0.03	0.00	-0.02	A	A	A	A	A	A	A	A	A

Table-5.4 Contd.....

Traits / Lines	Total fruit yield per plant (kg)			Total soluble solid (TSS)			Ascorbic acid (mg/100 g fresh fruit)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
NDT-1	0.19*	0.16	0.18**	P	P	P	P	P	P
NDT-2	0.39**	0.39**	0.39**	G	G	G	P	P	P
NDT-3	0.33**	0.33**	0.33**	A	A	G	P	P	P
NDT-4	0.04	0.04	0.04	P	P	P	G	G	G
NDT-5	-0.46**	-0.46**	-0.46**	P	P	P	G	G	G
NDT-6	-0.26**	-0.26**	-0.26**	P	P	P	P	P	P
NDT-7	-0.35**	-0.37**	-0.36**	P	P	P	P	P	P
NDT-8	0.04	0.07	0.05	P	P	P	A	A	A
Azad T-6	-0.03	-0.05	-0.04	A	A	A	G	G	G
Arka Saurabh	0.11	0.14	0.13*	G	G	G	P	P	P
Testers									
Pusa Ruby	0.01	0.01	0.01	P	P	P	P	P	P
Punjab Chhuhara	-0.09	-0.11*	-0.10*	P	P	P	P	P	P
Arka Vikas	0.10*	0.11	0.11*	A	A	A	A	P	P
Arka Meghali	-0.03	0.00	-0.02	A	A	A	G	G	G

G=Good combiner, P=Poor combiner and A=Average combiner

programme for obtaining high yielding variety or transgressive segregants for developing varieties of tomato.

Some other parents identified as good general combiners in desirable direction for characters other than fruit yield per plant have been listed in Table-5.3.

Thus, lines NDT-2 and NDT-3 emerged as the most useful parent as these parents were found good general combiner along with high *per se* performance (Table-5.1) for most of the traits studied. Hence, these parents may also be recommended for exploitation in hybridization programme aimed at improving the yield components for which they were good general combiner. These results corroborated with the findings of **Singh *et al.* (2006 a), Veer *et al.* (2006), Hannan *et al.* (2007 a), Prabuddha *et al.* (2008) and Sherpa *et al.* (2014).**

5.4.3 Specific combining ability effects

The sca effects represent non-additive gene action which is non-fixable. Specific combining ability effects help in the identification of superior cross combinations for development of promising varieties/hybrids. The crosses showing high sca effects involving parents with high gca effects may give rise desirable segregants in future generation. The specific combining ability effects of the forty crosses for fifteen traits in both the years and over pooled have been presented in Table 4.8. Perusal of Table 4.8 revealed that significant positive and negative sca effects were observed for all the characters. However, none of the crosses showed significant sca effect for all the traits. Further, sca effects were found to vary in nature and magnitude for all the characters with the change of seasons. This varying magnitude of sca effects over seasons may be due to environmental effects and genotypes, respectively. **Hussun *et al.* (2014)** also reported similar results.

Out of forty crosses studied some crosses showed significant and positive sca effects for fruit yield per plant as well as some other yield components in both the years and in pooled (Table 5.5).

For total fruit yield per plant, two cross combinations among forty crosses showed significant and positive sca effects for this trait in Y_1. Amongst these, the notable crosses were NDT-5 × Pb. Chhuhara and NDT-6 × Pusa Ruby. On the other hand two cross combinations showed negative and significant sca effects for this traits.

In case of Y_2, two cross combinations showed positive and significant sca effects. The best positive and significant cross combinations were NDT-5 × Pb. Chhuhara and NDT-6 × Pusa Ruby. Two cross combinations showed negative sca effects for total fruit yield per plant.

In case of pooled, five cross combinations showed positive and significant sca effects. The best positive and significant cross combinations were NDT-5 × Pb. Chhuhara and NDT-6 × Pusa Ruby, NDT-4 × Arka Vikas, NDT-5 × Arka Meghali and NDT-7 × Arka Meghali. Three cross combinations showed negative sca effects for total fruit yield per plant.

The cross NDT-5 × Pb. Chhuhara and NDT-6 × Pusa Ruby (0.42) was found most promising as it had highly significant sca effects for fruit yield per plant along with average fruit weight during both the years and pooled; likewise cross NDT-5 × Pb. Chhuhara along with plant height, total soluble solids and ascorbic acid in both the years and pooled except plant height, and ascorbic acid in Y_2; NDT-6 × Pusa Ruby along with number of locules per fruit during both the years and pooled (Table-5.5).

The two crosses in both years and pooled mentioned above may be considered for utilization in breeding programme for yield enhancement.

In general, the crosses showing significant and desirable sca effects were associated with better *per se* performance for respective traits.

However, the crosses having high sca effects in desirable direction did not always have high mean performance for the characters in question. Thus, the sca effect of the crosses may not be directly related to their *per se* performance. This may be attributed to the fact that *per se* performance is a realized value whereas sca effect is an estimate of F_1 performance over parental one. Therefore, both and pooled *per se* performance along with sca effects should be considered for evaluating the superiority of a cross although the former may be more important if development of F_1 hybrids is the ultimate objective.

The critical examination of results revealed that the crosses exhibiting high order significant and desirable sca effects for different characters involved parents having all types of combinations of gca effects such as high × high (H × H), high × average (H × A), high × low (H × L), average × average (A × A), average × low (A × L) and low × low (L × L). The foregoing observations clearly indicated that there was no particular relationship between positive and significant sca effects of crosses with gca effects of their parents for the characters under study and also advocated by previous workers in tomato **(Joshi and Thakur, 2005; Mahendrakar *et al.*, 2005; Veer *et al.*, 2006; Srivastava *et al.*, 2013; Yadav *et al.*, 2013 and Sherpa *et al.*, 2014).**

5.5 Proportional contribution of lines, testers and lines × testers

Proportional contribution of line, tester and lines × testers for the fifteen characters in Y_1 and Y_2 had been presented in Table 4.9. The knowledge of proportional contribution of lines, testers and their interaction components towards the expression of different characters gives an idea of relative importance of the nature and magnitude of genetic variability present in the material studied. Fixable component of genetic variation is reflected by the contribution of lines and testers while non-fixable effects are shown by the lines × testers component. The relative contribution of

Table-5.5 Summary of Specific combining ability of promising crosses for fruit yield per plant in Y_1, Y_2 and pooled in tomato (Y_1=2016-17 and Y_2=2017-18)

Characters	Y_1		Y_2		Pooled	
	Cross with significant effects	gca effects of parents	Cross with significant effects	gca effects of parents	Cross with significant effects	gca effects of parents
Days to 50 % flowering	NDT-4 × Arka Meghali (-3.73), Azad T-6 × Arka Vikas (-2.68), NDT-6 × Pb. Chhuhara (-2.30), NDT-7 × Arka Vikas (-1.97) and NDT-3 × Arka Meghali (-1.95)	H × A A × A A × A A × A L × A	NDT-4 × Arka Meghali (-3.14), NDT-6 × Pb. Chhuhara (-2.55), NDT-7 × Arka Vikas (-2.34) and Azad T-6 × Arka Vikas (-2.16)	H × A A × A A × A A × A	NDT-4 × Arka Meghali (-3.44), NDT-6 × Pb. Chhuhara (-2.43), Azad T-6 × Arka Vikas (-2.42), NDT-7 × Arka Vikas (-2.15) and NDT-3 × Arka Meghali (-1.62)	H × A A × A A × A A × A L × A
Days to first fruit set	NDT-4 × Arka Meghali (-3.00) and Azad T-6 × Arka Vikas (-2.12)	H × A A × A	NDT-4 × Arka Meghali (-3.00) and Azad T-6 × Arka Vikas (-2.12)	H × A A × A	NDT-4 × Arka Meghali (-3.00), Azad T-6 × Arka Vikas (-2.12), NDT-3 × Arka Meghali (-1.93), NDT-6 × Pb. Chhuhara (-1.77) and NDT-7 × Arka Vikas (-1.66)	H × A A × A A × A A × A A × A
Days to first fruit harvest	NDT-4 × Arka Meghali (-2.82)	H × A	NDT-4 × Arka Meghali (-2.82)	H × A	NDT-4 × Arka Meghali (-2.82), Azad T-6 × Arka Vikas (-2.11), NDT-3 × Arka Meghali (-2.00), NDT-7 × Arka Vikas (-1.79) and NDT-6 × Pb. Chhuhara (-1.69)	H × A A × A L × A A × A A × A
Plant height (cm)	NDT-8 × Pusa Ruby (13.32), NDT-7 × Pusa Ruby (12.91), Arka Saurabh × Pusa Ruby (11.81), NDT-5 × Pb. Chhuhara (10.20) and NDT-4 × Pb. Chhuhara (9.78)	L × H L × H L × H H × L H × L	Arka Saurabh × Pusa Ruby (13.33), NDT-7 × Pusa Ruby (12.67), NDT-1 × Arka Meghali (12.63), NDT-8 × Pusa Ruby (12.34) and NDT-4 × Pb. Chhuhara (11.15)	L × H L × H H × L L × H H × L	NDT-8 × Pusa Ruby (12.83), NDT-7 × Pusa Ruby (12.79), Arka Saurabh × Pusa Ruby (12.57), NDT-4 × Pb. Chhuhara (10.47) and NDT-5 × Pb. Chhuhara (9.84)	L × H L × H L × H H × L H × L
Number of primary branches per plant	NDT-4 × Arka Vikas (0.63)	L × A	NDT-4 × Arka Vikas (0.63)	L × A	NDT-4 × Arka Vikas (0.63), Azad T-6 × Arka Meghali (0.48), NDT-6 × Arka Meghali (0.41), NDT-7 × Arka Meghali (0.39) and NDT-1 × Pb. Chhuhara and NDT-2 × Pusa Ruby (0.38)	L × A H × L A × L A × L H × A L × L
Number of fruits per cluster	Azad T-6 × Arka Meghali (0.75)	L × L	Azad T-6 × Arka Meghali (0.77) and NDT-7 × Arka Vikas (0.67)	L × L	Azad T-6 × Arka Meghali (0.76), NDT-7 × Arka Vikas (0.62), NDT-1 × Pb. Chhuhara and NDT-3 × Pusa Ruby (0.61) and	L × L L × H H × L L × A

					NDT-5 × Pb. Chhuhara (0.52)	L × L
Number of fruits per plant	NDT-2 × Arka Vikas (5.96), NDT-6 × Pb. Chhuhara (5.20), NDT-7 × Arka Meghali (4.61), Arka Saurabh × Arka Meghali (4.24) and NDT-8 × Arka Vikas (2.59)	H × L L × A L × H H × H L × L	NDT-2 × Arka Vikas (5.96), NDT-6 × Pb. Chhuhara (5.20), NDT-7 × Arka Meghali (4.61), Arka Saurabh × Arka Meghali (4.24) and NDT-8 × Arka Vikas (2.59)	H × L L × A L × H H × H L × L	NDT-2 × Arka Vikas (5.96), NDT-6 × Pb. Chhuhara (5.20), NDT-7 × Arka Meghali (4.61), Arka Saurabh × Arka Meghali (4.24) and NDT-8 × Arka Vikas (2.59)	H × L L × A L × H H × H L × L
Average fruit weight (g)	Arka Saurabh × Pusa Ruby (17.66), NDT-1 × Arka Meghali (11.41), NDT-2 × Pb. Chhuhara (8.73), NDT-2 × Pusa Ruby (6.58) and NDT-1 × Arka Vikas (6.52)	H × L H × H H × L H × L H × A	Arka Saurabh × Pusa Ruby (17.64), NDT-1 × Arka Meghali (11.39), NDT-2 × Pb. Chhuhara (8.72), NDT-1 × Arka Vikas (6.57) and NDT-2 × Pusa Ruby (6.56)	H × L H × H H × L H × A H × L	Arka Saurabh × Pusa Ruby (17.65), NDT-1 × Arka Meghali (11.40), NDT-2 × Pb. Chhuhara (8.73), NDT-2 × Pusa Ruby (6.57) and NDT-1 × Arka Vikas (6.55)	H × L H × H H × L H × L H × A
Fruit length (cm)	NDT-5 × Arka Meghali (0.91), NDT-7 × Pb. Chhuhara (0.84), NDT-6 × Arka Vikas (0.79) and NDT-4 × Pusa Ruby (0.76)	L × L A × A L × A A × L	NDT-5 × Arka Meghali (0.91), NDT-7 × Pb. Chhuhara (0.84), NDT-6 × Arka Vikas (0.79) and NDT-4 × Pusa Ruby (0.76)	L × L A × A L × A A × L	NDT-5 × Arka Meghali (0.91), NDT-7 × Pb. Chhuhara (0.84), NDT-6 × Arka Vikas (0.79), NDT-4 × Pusa Ruby (0.76) and NDT-8 × Pusa Ruby (0.64)	L × L A × A L × A H × L L × L
Fruit girth (cm)	NDT-5 × Arka Meghali (1.92)	L × A	NDT-5 × Arka Meghali (1.93)	L × A	NDT-5 × Arka Meghali (1.92), Arka Saurabh × Arka Vikas (1.33) and NDT-4 × Pusa Ruby (1.30)	L × A H × A A × L
Number of locules per fruit	NDT-6 × Pusa Ruby (1.10), NDT-3 × Arka Meghali (1.00), NDT-8 × Arka Meghali (0.78) and NDT-2 × Arka Vikas (0.70)	H × L L × A L × A A × L	NDT-6 × Pusa Ruby (1.10), NDT-3 × Arka Meghali (1.00), NDT-8 × Arka Meghali (0.78) and NDT-2 × Arka Vikas (0.70)	H × L L × A L × A A × L	NDT-6 × Pusa Ruby (1.10), NDT-3 × Arka Meghali (1.00), NDT-8 × Arka Meghali (0.78) and NDT-2 × Arka Vikas (0.70)	H × L L × A L × A H × L
Pericarp thickness (mm)	-		-		NDT-6 × Arka Meghali (0.50), NDT-4 × Arka Vikas (0.48), NDT-8 × Pb. Chhuhara (0.44) and NDT-3 × Pusa Ruby (0.36)	A × A L × H H × A L × L
Total soluble solid (TSS)	NDT-7 × Pb. Chhuhara and Arka Saurabh × Arka Meghali (1.08) and NDT-5 × Pb. Chhuhara (0.71)	L × L H × A L × L	NDT-7 × Pb. Chhuhara and Arka Saurabh × Arka Meghali (1.08) and NDT-5 × Pb. Chhuhara (0.71)	L × L H × A L × L	NDT-7 × Pb. Chhuhara and Arka Saurabh × Arka Meghali (1.08), NDT-5 × Pb. Chhuhara (0.71), NDT-1 × Arka Vikas (0.56), NDT-8 × Pusa Ruby (0.53) and NDT-6 × Arka Vikas (0.47)	L × L H × A L × L L × A L × L L × A

Ascorbic acid (mg/100 g fresh fruit)	NDT-2 × Pusa Ruby (9.79), NDT-8 × Arka Meghali (6.87), NDT-1 × Pusa Ruby (5.15), NDT-5 × Pb. Chhuhara (4.74) and NDT-1 × Arka Meghali (3.55)	L × L A × H L × L H × L L × L	NDT-1 × Arka Meghali (10.59), NDT-8 × Arka Meghali (7.89), NDT-2 × Pusa Ruby (7.87), Arka Saurabh × Pusa Ruby (6.65) and NDT-8 × Arka Vikas (5.33)	L × H A × H L × L L × L A × L	NDT-2 × Pusa Ruby (8.83), NDT-8 × Arka Meghali (7.38), NDT-1 × Arka Meghali (7.07), NDT-5 × Pb. Chhuhara (3.88) and NDT-8 × Arka Vikas (3.76)	L × L A × H L × H H × L A × L
Total fruit yield per plant (kg)	NDT-5 × Pb. Chhuhara and NDT-6 × Pusa Ruby (0.41)	L × L L × A	NDT-5 × Pb. Chhuhara (0.43) and NDT-6 × Pusa Ruby (0.42)	L × L L × A	NDT-5 × Pb. Chhuhara and NDT-6 × Pusa Ruby (0.42), NDT-4 × Arka Vikas (0.30), NDT-5 × Arka Meghali (0.28) and NDT-7 × Arka Meghali (0.27)	L × L L × A A × H L × L L × L

lines × testers component were higher than the lines for all the characters in both the years, except plant height, number of primary branches per plant, number of fruits per plant, ascorbic acid and total fruit yield per plant and lines × testers component were higher than the testers for all the characters in both the years except plant height which again confirmed predominant role of non-additive gene effects in the inheritance of these characters. The aforesaid results, thus, revealed the greater importance of non-fixable components of genetic variation in the expression of all the traits under study. Above findings were also supported by the relatively greater magnitude of sca variance than gca variance for most of the characters.

5.6 Components of variation

The estimates of general combining ability (gca) and specific combining ability (sca) variances, average degree of dominance, predictability ratio, additive and dominance variances for Y_1, Y_2 and pooled have been presented in Table 4.9. The combining ability analysis elucidated higher magnitude of variance due to sca (σ^2s) than variance due to gca (σ^2g) indicating preponderance of non-additive gene action for all the characters. Similar finding had also been reported by previous workers **(Chadda *et al.*, 1997;Dharmatti *et al.*, 1999; Dhaliwal *et al.*, 2000; Bhatt *et al.*, 2001; Mondal *et al.*, 2009; Janaki *et al.*, 2011 and Srivastava *et al.*, 2013)**.

Average degree of dominance were more than unity (1) for all the characters under study, except for plant height, number of primary branches per plant, number of fruits per plant and ascorbic acid in both the years and pooled and pericarp thickness and total fruit yield per plant in Y_1 and Y_2 which indicated existence of over dominance and controlled by a preponderance of non-additive gene effects suggesting thereby scope of development of F_1's as well as the recombinants within the segregating populations. Total soluble solids, days to first fruit set, fruit length, days to

50 % flowering, fruit girth, days to first fruit harvest, average fruit weight, number of locules per fruit and number of fruits per cluster which had less than one value of average degree of dominance suggested existence of partial dominance. The predictability ratio was lesser than (<1) for all the characters under study in both the years. The importance of additive as well as non-additive gene effects with predominance of non-additive gene effects in inheritance of fruit yield and yield components of tomato has also been reported by earlier workers **(Chadda *et al*., 1996; Dharmatti *et al*., 1999; Dhaliwal *et al*., 2000; Bhatt *et al*., 2001; Mondal *et al*., 2009 and Janaki *et al*., 2011).**

The predominance of non-additive gene effects representing non-fixable dominance and epistatic components of genetic variance indicated that maintenance of heterozygosity would be highly fruitful for improving the characters. Hence, the suitable breeding strategy for attaining high yield would be the full or partial exploitation of heterosis through development of hybrid, synthetic or composite cultivars **(Garg *et al.*, 2008)**. The non-additive gene effects may also be exploited upto some extent for improving the characters by resorting to breeding methods such as bi-parental mating followed by recurrent selection and population improvement methods as suggested.

The importance of additive gene effects of fixable nature for fruit yield per plant and most of other yield components in the present study suggested that these traits are amenable to improvement through selection even in early generations. This indicated that considerable improvement in status of fruit yield and important yield attributes in tomato can still be achieved by following conventional breeding procedures.

5.7 Heritability (narrow sense) and genetic advance

The knowledge of heritability of a character is important to the breeder since it indicates the possibility and extent to which improvement is

possible through selection **(Robinson *et al.*, 1949)**. Heritability, which denotes the proportion of additive genetic variance to the total variability, is a measure of genetic relationship between parents and progeny and has been widely used in determining the degree to which character may be transmitted from parent to offspring. **Singh *et al.* (2005)** pointed out that the heritability in combination with intensity of selection and amount of variability present in the population influences the gains to be obtained from selection. Since the genetic gain is yet another important selection parameter which is although independent and represents the expected genetic gain under selection. It measures the differences between the mean genotypic values of the selected lines and mean genotypic value of base population from which these lines were selected. Thus, it is necessary to utilize the heritability in conjunction with selection differential, which would indicate the expected genetic gain. The estimate of heritability with genetic advance as per cent of mean provides a better picture to the breeders during the process of selection.

In this study high estimate of heritability in narrow-sense was recorded for plant height followed by ascorbic acid, number of fruits per plant, total fruit yield per plant and number of fruits per cluster in Y_1, plant height followed by ascorbic acid, number of fruits per plant, total fruit yield per plant and number of fruits per cluster in Y_2 and pericarp thickness followed by plant height, number of primary branches per plant, ascorbic acid, total fruit yield per plant, number of fruits per plant, number of fruits per cluster, days to first fruit harvest, fruit girth and number of locules per fruit in pooled (Table-4.10), suggested that selection would be highly effective and efficient. Similar finding for high estimate of narrow sense heritability for different tomato traits have been also reported by **Lush (1947), Omora *et al*. (1988), Shahu and Mishra (1993) and Kumar *et al*. (2006).** Moderate estimate of heritability in narrow sense was observed for

pericarp thickness followed by number of primary branches per plant, average fruit weight, number of locules per fruit, days to first fruit harvest and fruit girth in Y_1, pericarp thickness followed by number of primary branches per plant, average fruit weight, number of locules per fruit, days to 50 % flowering, days to first fruit harvest and fruit girth in Y_2 and average fruit weight followed by days to 50 % flowering, days to first fruit set, fruit length and total soluble solids in pooled. Similar finding for moderate estimate of narrow sense heritability for different tomato traits have been also reported by previous workers **(Kumari *et al.*, 2007 and Meena *et al.*, 2014).**

High estimate of genetic advance in per cent of mean (>20%) was observed for plant height in both the years and pooled. Moderate estimate of genetic advance in per cent of mean was observed for ascorbic acid in both the years and pooled. Similar results had also been reported by earlier workers (**Pujari *et al.*, 1995**; **Kumar *et al.*, 2004 and Meena *et al.*, 2014)**

5.8 Genetic divergence analysis:

The studies of genetic divergence among the 54 (10 lines, 4 testers and 40 F_1's) genotypes of tomato were carried out by using Mahalanobis D^2.

Fifty four genotypes were grouped into 8 different non over lapping clusters given in Table 4.11. In Y_1, cluster VII had highest number of genotypes followed by cluster IV, Cluster I, cluster V, cluster III and cluster IV, cluster VI and cluster VIII. In Y_2, cluster I had highest number of genotypes followed by cluster II and cluster III, Cluster V, cluster IV, cluster VI, cluster VII and cluster VIII. In pooled, cluster IV and cluster V had highest number of genotypes followed by cluster III, Cluster II, cluster I, cluster VI, cluster VII and cluster VIII.

The estimates of intra and inter-cluster distance represented by D^2 values had given in Table 4.12. The intra-cluster and inter-cluster D^2 value ranged indicate the selected breeding lines were highly divergent.

In Y_1, the highest intra-cluster distance was shown by cluster VII followed by cluster IV, cluster V, cluster III, cluster II, cluster I cluster VI while, the minimum intra-cluster distance was shown by cluster VIII it was monogenotypic. The maximum inter-cluster distance was observed between cluster III and cluster VI, followed by cluster VI and cluster VII, cluster IV and cluster VI, cluster V and cluster VI and cluster II and cluster VI while, the minimum inter-cluster distance was observed between cluster I and cluster VIII.

In Y_2, the highest intra-cluster distance was shown by cluster V followed by cluster IV, cluster II, cluster III, cluster I and cluster VI while, the minimum intra-cluster distance was shown by cluster VII and cluster VIII it was monogenotypic. The maximum inter-cluster distance was observed between cluster VI and cluster VIII, followed by cluster VI and cluster VII, cluster II and cluster VI, cluster III and cluster VI and cluster V and cluster VI while, the minimum inter-cluster distance was observed between cluster II and cluster V.

In pooled, the highest intra-cluster distance was shown by cluster V followed by cluster IV, cluster III, cluster II, cluster VI and cluster I while, the minimum intra-cluster distance was shown by cluster VII and cluster VIII it was monogenotypic. The maximum inter-cluster distance was observed between cluster III and cluster VI, followed by cluster VI and cluster VII, cluster VI and cluster VIII, cluster IV and cluster VI and cluster II and cluster VI while, the minimum inter-cluster distance was observed between cluster VII and cluster VIII.

The comparison of clusters means revealed considerable differences among the clusters of different quantitative and quality characters given in Table 4.13.

In Y_1, Cluster I showed high mean value for days to 50% flowring, days to first fruit set and days to first fruit harvest. Cluster II showed high mean value for number of fruits per cluster, fruit girth and pericarp thickness. Cluster III showed high mean value for plant height, number of primary branches per plant, number of locules per fruit and pericarp thickness. Cluster V showed high mean value for ascorbic acid. Cluster VI showed high mean value for number of fruits per plant. Cluster VII showed high mean value for average fruit weight and fruit length. Cluster VIII showed high mean value for total soluble solids and total fruit yield per plant.

In Y_2, Cluster I showed high mean value for days to 50% flowring. Cluster III showed high mean value for pericarp thickness. Cluster IV showed high mean value for total fruit yield per plant. Cluster VI showed high mean value for number of fruits per plant. Cluster VII showed high mean value for number of fruits per cluster average fruit weight, fruit length, fruit girth and total soluble solids. Cluster VIII showed high mean value for days to first fruit set, days to first fruit harvest, plant height, number of primary branches per plant, number of locules per fruit and ascorbic acid.

In pooled, Cluster I showed high mean value for days to 50% flowring, days to first fruit set and days to first fruit harvest and total fruit yield per plant. Cluster II showed high mean value for fruit girth. Cluster III showed high mean value for plant height, number of primary branches per plant and ascorbic acid. Cluster VI showed high mean value for number of fruits per plant. Cluster VII showed high mean value for number of fruits per cluster, average fruit weight, fruit length and total soluble solids. Cluster

VIII showed high mean value for number of locules per fruit. The results are in conformity with findins of earlier researchers vs., **Mahesha *et al.* (2006), Jogi *et al.* (2008), Mehta and Asati (2008), Rana and Singh (2010) and Thapa *et al.* (2014).**

In Y_1, highest per cent contribution towards total genetic divergence given in Table 4.14 was exhibited by plant height followed by number of fruits per plant, average fruit weight and ascorbic acid. Rest of the characters exhibited low contribution towards total genetic divergence.

In Y_2, highest per cent contribution towards total genetic divergence was exhibited by plant height followed by number of fruits per plant and average fruit weight. Rest of the characters exhibited low contribution towards total genetic divergence.

In pooled, highest per cent contribution towards total genetic divergence was exhibited by plant height followed by number of fruits per plant and average fruit weight. Rest of the characters exhibited low contribution towards total genetic divergence.

SUMMARY AND CONCLUSION

The present investigation entitled **"Heterosis, combining ability and gene action involved for yield and quality attributing traits in tomato (*Solanum lycopersicum* L.)"** was under taken with the objectives (i) to estimate the general and specific combining ability variances and their effects, (ii) to workout gene action involved in inheritance for yield and its attributing traits, (iii) to estimate heterosis over better parent and standard variety, (iv) to estimate the heritability in narrow sense and expected genetic advance in per cent of mean and (v) to estimate genetic divergence among the parents and their crosses. .

The present study was carried out during *Rabi* seasons of 2016-17 and 2017-18 at Main Experiment Station of Department of Vegetable Science, Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Ayodhya (U.P.). The experimental materials of the study comprised 54 treatments of tomato [40 F_1's and 14 parental lines (10 lines *viz*., NDT-1, NDT-2, NDT-3, NDT-4, NDT-5, NDT-6, NDT-7, NDT-8, Azad T-6, Arka Saurabh and 4 testers *viz*., Pusa Ruby, Punjab Chhuhara, Arka Vikash and Arka Meghali]. The 14 parents were involved in a crossing programme to develop a line × tester set (10 lines + 4 testers + 40 F_1's). The fifty four genotypes (40 F_1's and 14 parental lines) were evaluated in Randomized Complete Block Design (RBD) with three replications. The observations were recorded on fifteen characters, *viz*., days to 50 % flowering, days to first fruit set, days to first fruit harvest, plant height (cm), number of primary branches per plant, number of fruits per cluster, number of fruits per plant, average fruit weight (g), fruit length (cm), fruit girth (cm), number of locules per fruit, pericarp thickness (mm), total soluble solids (TSS), ascorbic acid (mg/100g fresh fruit) total fruit yield per plant

(kg). The data were recorded from 40 F_1's and 14 parental lines on fifteen characters were subjected to analysis of variance, nature and magnitude of heterosis, combining ability variances and their effects, heritability in narrow sense, genetic advance in per cent of mean, and genetic divergence analysis**.** Observations were also recorded for some qualitative traits as well. The salient results of the study and conclusion drawn from them are summarized below:

1. Analysis of variance for line × tester mating design for both the years (Y_1 and Y_2) revealed that the differences among treatments were highly significant for all the characters studied in both the years. Further partitioning of treatment variances into parents, crosses, lines and testers revealed highly significant differences among parents as well as crosses for all the fifteen characters. Variances due to parents were highly significant for all the characters in both the years and significant for days to 50 % flowering in second year, except days to 50 % flowering in first year while, for days to first fruit set, days to first fruit harvest, number of primary branches per plant and number of locules per fruit in both the year. Variances due to parents *vs.* crosses were highly significant for days to 50 % flowering, days to first fruit set, days to first fruit harvest, plant height, number of fruits per plant, average fruit weight (g), pericarp thickness (mm) and total fruit yield per plant (kg) in both the years and ascorbic acid in second year while, significant for number of fruits per cluster and fruit length (cm) in both the years. Variances due to lines *vs*. testers were highly significant for the characters like plant height, number of fruits per plant, average fruit weight (g) and fruit girth (cm) while, significant for number of primary branches per plant and number of locules per fruit in both the years.

   The pooled analysis of variance also divided the source of variance into environments found highly significant for all the traits

under study. Variances due to treatments and parents were found highly significant for all the traits under study as well as crosses for all the fifteen characters. Variances due to parent *vs* crosses were found highly significant for all the traits under study except for number of locules per fruit and total soluble solids while, significant for fruit girth (cm) and ascorbic acid. Variances due to line *vs* testers were found highly significant for the characters like plant height, number of primary branches per plant, number of fruits per plant, average fruit weight (g), fruit girth (cm), number of locules per fruit while, significant for fruit length (cm) and total fruit yield per plant (kg).

2. Highest total fruit yield per plant was recorded in Arka Meghali followed by Arka Vikas, NDT-2 and Arka Saurabh among parents during both the year and in pooled analysis. The highest yielding hybrids were NDT-3 × Arka Vikas, NDT-2 × Arka Meghali, NDT-2 × Arka Vikas and NDT-4 × Arka Vikas during both the year, NDT-4 × Arka Meghali followed by NDT-2 × Arka Meghali, NDT-6 × Pb. Chhuhara and Azad T-6 × Arka in pooled. The above mentioned genotypes may be used as donor parents in hybridization programme for developing high yielding varieties of respective groups.

3. The based on the mean performence Pusa Ruby showed earliest days to 50 % flowering among the parents which was followed by NDT-4, NDT-5, NDT-2 and Azad T-6 in $Y_{1,}$ Parent Pusa Ruby followed by NDT-4, NDT-5, NDT-2 and Azad T-6 in Y_2 and pooled both, Parent Pusa Ruby showed earliest days to first fruit set among the parents which was followed by NDT-4, Arka Vikas, NDT-5 and NDT-2 in Y_1, Y_2 and pooled data also. Similarly Pusa Ruby also showed earliest days to first fruit harvest among the parents which was followed by NDT-4, NDT-2, Azad T-6 and Arka Vikas in Y_1,Y_2 and pooled; Among the parents maximum plant hieght was recorded in NDT-4 followed by NDT-5, NDT-1, Pusa Ruby and Azad T-6 in Y_1, Y_2 and pooled; highest

number of fruits per cluster were recorded in parent NDT-1 followed by NDT-5 and NDT-8, NDT-7, NDT-6 and NDT-2 and Arka Meghali in Y_1, Y_2 and pooled Similarly during Y_1, Y_2 and pooled analysis; highest number of fruits per plant was recorded in parent NDT-6 followed by NDT-7, NDT-8, Arka Saurabh and Arka Meghali; parent NDT-2 produced heaviest fruit followed by Arka Vikas, Arka Meghali, NDT-1 and Arka Saurabh in Y_1, Y_2 and pooled analysis; pericarp thickness which is good for transportations recorded maximum in Azad T-6 followed by NDT-1, Arka Vikas, NDT-2 and NDT-3 in Y_1, Y_2 and pooled data; TSS was recorded maximum in NDT-5 followed by NDT-8, Arka Vikas, NDT-1 and Azad T-6 and NDT-6 in Y_1, Y_2 and pooled; Azad T-6 recorded maximum ascorbic acid followed by NDT-8, NDT-7, Arka Saurabh and Arka Meghali in Y_1, Y_2 and pooled. These lines have merit as promising parents for hybridization programme for bringing over all improvement in plant architecture in a component breeding approach ultimately leading to high yielding tomato genotypes even if they have moderate or low total fruit yield per plant.

4. A wide range of variation in the estimates of heterobeltiosis and standard heterosis in positive and negative direction were observed for all the traits studied. In case of total fruit yield per plant, in Y_1 the heterobeltiosis ranged from -49.42 to 8.49 per cent and standard heterosis from -54.36 to -7.85 per cent. In Y_2, over better parent from -44.62 to 7.44 per cent and standard parent from -49.08 to -7.09 per cent and in pooled, over better parent from -46.90 to 7.93 per cent and standard parent from -51.59 to -7.45 per cent. Out of 40 crosses, none of the F_1's showed significant and positive heterosis over better and standard parent in Y_1, Y_2 and pooled.

5. Out of 40 crosses exhibiting significant and negative estimates of heterosis for one or both types of heterosis for total fruit yield also exhibited significant an positive estimates heterosis for other important

yield and yield attributing traits. In contrast, none of the crosses showed significant and desirable heterosis for all the traits.

6. Analysis of variances for combining ability revealed that the partitioning of variances due to lines × testers showed highly significant for days to 50 % flowering, days to first fruit set, plant height, number of fruits per plant, average fruit weight, fruit length, number of locules per fruit, total soluble solids, ascorbic acid in both years and total fruit yield per plant in Y_1 whereas, significant for days to first fruit harvest, number of fruits per cluster, fruit girth in both years and total fruit yield per plant in Y_2, except number of primary branches per plant and pericarp thickness in both years. Variances due to lines were highly significant for plant height followed by ascorbic acid, number of fruits per plant, number of primary branches per plant and total fruit yield per plant in Y_1 and plant height followed by ascorbic acid, number of fruits per plant, number of primary branches per plant and total fruit yield per plant in Y_2, whereas, variances due to testers was also highly significant for plant height in both the years.

   Analysis of variances for combining ability revealed that the partitioning of variances due to environments showed highly significant for all the characters; due to lines × testers showed highly significant for all the characters and variances due to lines were highly significant for plant height followed by ascorbic acid, number of fruits per plant, number of primary branches per plant and total fruit yield per plant whereas, variances due to testers was also highly significant for plant height.

7. The parents namely NDT-2 and NDT-3 should good general combining ability for number of fruits per plant and total fruit yield per plant during both the years (Y_1, Y_2) and in pooled. However, two crosses *viz*., NDT-5

× Pb. Chhuhara and NDT-6 × Pusa Ruby showed significant and positive sca effects for fruit yield per plant in both the year and pooled.

8. The relative contribution of lines × testers component were higher than the lines and testers for all the characters in both the years, except plant height, number of primary branches per plant, number fruits per plant, ascorbic acid and total fruit yield per plant in both years and pooled, testers were higher than the lines for all the characters except plant height.

9. Average degree of dominance were more than unity (>1) for the characters like plant height, number of fruits per plant and ascorbic acid in both year and pooled, for number of primary branches per plant, pericarp thickness and total fruit yield per plant in both years except pooled. The predictability ratio was lesser than (<1) for all the characters under study in both the years and pooled.

10. Estimate of high heritability in narrow-sense was recorded for plant height followed by ascorbic acid and number of fruits per plant in both years and pooled.

11. Estimate of high genetic advance in per cent of mean (>20%) was observed for plant height in both years and pooled.

12. Fifty four genotypes were grouped into 8 different non over lapping clusters. Maximum intra-cluster distance was found for cluster-VII in first year, cluster-V in second year and pooled followed by cluster-IV in both the years and pooled. The highest inter-cluster distance was observed between cluster-III and cluster-VI in first year and pooled, cluster-IV and cluster-VII in second year followed by cluster-VI and cluster-VII in both years and pooled.

13. Clustering pattern of the genotypes of heterogeneous origin, indicating no parallelism between genetic and geographical diversity. All the

parents and F_1's were grouped into eight clusters with different genotypes in both seasons which suggested that there were ample diversity within the experimental material.

14. Maximum contribution in genetic divergence showed by plant height followed by number of fruits per plant, ascorbic acid and average fruit weight and minimum contribution showed by days to first fruit set and days to first fruit harvest in both years and pooled.

Estimate of high heritability in narrow-sense was recorded for plant height followed by ascorbic acid and number of fruits per plant may give high response for yield improvement. Divergence analysis indicated that diverse crosses involving parents with different clusters reflects the chances of getting transgressive segregates either by making three way crosses and or double crosses between the members of diverse clusters.

Thus, there exists scope for development of desirable F_1/segregates as per consumer's choice to meet out the ever increasing demand of tomato in future.

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ABSTRACT

The present study was carried out during *Rabi* seasons of 2016-17 and 2017-18 at Main Experiment Station of Department of Vegetable Science, Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Ayodhya (U.P.) India. The experimental materials of the study comprised of 54 treatments of tomato [40 F_1's and 14 parental lines (10 lines *viz*., NDT-1, NDT-2, NDT-3, NDT-4, NDT-5, NDT-6, NDT-7, NDT-8, Azad T-6, Arka Saurabh and 4 testers *viz.*, Pusa Ruby, Punjab Chhuhara, Arka Vikash and Arka Meghali]. The 14 parents were involved in a crossing programme to develop a line × tester set (10 lines + 4 testers + 40 F_1's). The experimental materials (40 F_1's and 14 parental lines) were evaluated in Randomized Complete Block Design (RBD) with three replication having each experimental unit with spacing of 60cm × 50cm with plot size of 1.2m ×3.0m.

The observations were recorded on fifteen characters, *viz*., days to 50 % flowering, days to first fruit set, days to first fruit harvest, plant height (cm), number of primary branches per plant, number of fruits per cluster, number of fruits per plant, average fruit weight (g), fruit length (cm), fruit girth (cm), number of locules per fruit, pericarp thickness (mm), total soluble solids (TSS), ascorbic acid (mg/100g fresh fruit) and total fruit yield per plant (kg).

Analysis of variance revealed that the differences among treatments were highly significant for all the characters studied in both the years and pooled. Parent Pusa Ruby showed earliest days to 50 % flowering among the parents which was followed by NDT-4, NDT-5 and NDT-2 in both the year and pooled. The best F_1 hybrid regarding days to 50 % flowering was NDT-4 × Arka Meghali followed by Azad T-6 × Arka Vikas, NDT-1 × Arka Meghali and NDT-6 × Pb. Chhuhara in first year, NDT-4 × Arka Meghali followed by NDT-1 × Arka Meghali, NDT-6 × Pb. Chhuhara and NDT-7 × Arka Vikas in second year, NDT-4 × Arka Meghali followed by NDT-1 × Arka Meghali, NDT-6 × Pb. Chhuhara and Azad T-6 × Arka Vikas in pooled. In parents produced highest total fruit yield per plant was Arka Meghali followed by Arka Vikas, NDT-2 and Arka Saurabh in both the year and pooled. The highest yielding hybrid was NDT-3 × Arka Vikas followed by NDT-2 × Arka Meghali, NDT-2 × Arka Vikas and NDT-4 × Arka Vikas in both the year, NDT-4 × Arka Meghali followed by NDT-2 × Arka Meghali, NDT-6 × Pb. Chhuhara and Azad T-6 × Arka in pooled.

A wide range of variation in the estimates of heterobeltiosis and standard heterosis in positive and negative direction were observed for all the traits studied. In case of total fruit yield per plant, in Y_1 the heterobeltiosis ranged from -49.42 to 8.49 per cent and standard heterosis from -54.36 to -7.85 per cent. In Y_2, over better parent from -44.62 to 7.44 per cent and standard parent from -49.08 to -7.09 per cent and in pooled, over better parent from -46.90 to 7.93 per cent and standard parent from -51.59 to -7.45 per cent. Out of 40 crosses, none of the F_1's showed significant and positive heterosis over better and standard parent in Y_1, Y_2 and pooled. Out of 40 crosses exhibiting significant and negative estimates of heterosis for one or both types of heterosis for total fruit yield also exhibited significant an positive estimates heterosis for other important yield and yield attributing traits. In contrast, none of the crosses showed significant and desirable heterosis for all the traits.

The analysis of variance for combining ability revealed that there were significant line × tester for all the traits in Y_1, Y_2 and over pooled, except number of primary branches per plant and pericarp thickness in both year. The parent NDT-2 and NDT-3 had good general combining ability for number of fruits per plant and total fruit yield per plant in both years (Y_1, Y_2) and pooled. Two crosses *viz*., NDT-

5 × Pb. Chhuhara and NDT-6 × Pusa Ruby showed significant and positive sca effects for fruit yield per plant in both the year and pooled. The relative contribution of lines × testers component were higher than the lines and testers for all the characters in both the years, except plant height, number of primary branches per plant, number fruits per plant, ascorbic acid and total fruit yield per plant in both years and pooled, testers were higher than the lines for all the characters except plant height. Estimates of sca variance were higher than gca variances for most of the traits except plant height and ascorbic acid in both years and pooled. The value of sca variances were found significant and positive for all the characters except number of primary branches per plant and pericarp thickness in both years, total soluble solids in pooled. Likewise, positive and significant gca variances were also exhibited by almost all the characters except days to 50 % flowering, days to first fruit set, fruit length and total soluble solids in both the years and pooled. Average degree of dominance were more than unity (>1) for the characters like plant height, number of fruits per plant and ascorbic acid in both year and pooled, for number of primary branches per plant, pericarp thickness and total fruit yield per plant in both years except pooled. The predictability ratio was lesser than (<1) for all the characters under study in both the years and pooled. Estimate of high heritability in narrow-sense was recorded for plant height followed by ascorbic acid and number of fruits per plant in both years and pooled. Estimate of high genetic advance in per cent of mean (>20%) was observed for plant height in both years and pooled.

Fifty four genotypes were grouped into 8 different non over lapping clusters. Maximum intra-cluster distance was found for cluster-VII in first year, cluster-V in second year and pooled followed by cluster-IV in both the years and pooled. The highest inter-cluster distance was observed between cluster-III and cluster-VI in first year and pooled, cluster-IV and cluster-VII in second year followed by cluster-VI and cluster-VII in both years and pooled. Maximum contribution in genetic divergence showed by plant height and minimum contribution showed by days to first fruit set and days to first fruit harvest.

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