COMBINING ABILITY AND HETEROSIS FOR YIELD AND QUALITY TRAITS OF F_1 HYBRIDS IN TOMATO (*Solanum lycopersicum* L.)

ASMAUL HUSNA

DEPARTMENT OF GENETICS AND PLANT BREEDING
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

JUNE 2019

COMBINING ABILITY AND HETEROSIS FOR YIELD AND QUALITY TRAITS OF F_1 HYBRIDS IN TOMATO (*Solanum lycopersicum* L.)

BY

ASMAUL HUSNA

REGISTRATION NO.: 12-04827

A thesis
submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
IN
GENETICS AND PLANT BREEDING
SEMESTER: JANUARY-JUNE, 2019

Approved by:

Prof. Dr. Naheed Zeba
Supervisor

Prof. Dr. Jamilur Rahman
Co-Suervisor

Prof. Dr. Kazi Md. Kamrul Huda
Chairman
Examination Committee

Prof. Dr. Naheed Zeba
Department of Genetics and Plant Breeding
Sher-e-Bangla Agricultural University
Dhaka-1207, Bangladesh

Phone: +8802-9180921-167 (Office), +8802-44814079 (Res.)
Mobile: +88 01913-091772
E-mail: zeban@sau.edu.bd

CERTIFICATE

*This is to certify that the thesis entitled, ''Combining ability and heterosis for yield and quality traits of F_1 hybrids in tomato (Solanum lycopersicum L.)'' submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN GENETICS AND PLANT BREEDING**, embodies the result of a piece of bona fide research work carried out by Asmaul Husna, Registration number 12-04827 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has duly been acknowledged.

Dated: June, 2019
Dhaka, Bangladesh

(Prof. Dr. Naheed Zeba)

Supervisor

DEDICATED TO

MY

BELOVED PARENTS

Some commonly used abbreviations

Full word	Abbreviations	Full word	Abbreviations
Abstract	*Abstr*	International	*Intl.*
Advances/Advanced	*Adv.*	International Journal	*Intl. J.*
Agriculture	*Agric.*	Journal	*J.*
Agricultural	*Agril.*	Kilogram	Kg
Agronomy	*Agron.*	Limited	Ltd.
And others	*et al.*	Ministry	*Min.*
Analysis of Variance	ANOVA	Muriate of Potash	MP
Applied	*App.*	Negative logarithm of hydrogen ion concentration (-log $[H^+]$)	pH
Archives	*Arch.*		
Bangladesh Bareau of Statistics	BBS		
Biology	*Biol.*	Non-significant	^{ns}
Botany	*Bot.*	New South Wales	*NSW.*
Better parent	BP	Mid parent	MP
Breeding	*Breed.*	Parts per million	ppm
Centimeter	cm	Percentage	%
Component variance	CV	Plant	*PI.*
Cross between two dissimilar parents	X	Proceedings	*Proc.*
		Randomized Complete Block Design	RCBD
Degree celcious	°C		
Division	*Div.*	Research	*Res.*
Economic	*Econ.*	Review	*Rev.*
Environment	*Environ.*	Science	*Sci.*
Etcetera	etc.	Serial	Sl.
Experimental	*Expt.*	Society	*Soc.*
Food and Agricultural Organization	FAO	Specific combining ability	SCA
Gazette	*Gaz.*	Statistics	*Stat.*
General	*Gen.*	That is	i.e.
General combining ability (GCA)	GCA	The First Generation of a cross between two dissimilar parents	F_1
Genetics	*Genet.*		
Gram	G	Triple Super Phosphate	TSP
Heredity	*Hered.*	University	*Univ.*
Horticulture/ Horticultural	*Hort.*	Variety	*var.*
		Vegetable	*Veg.*
Incorporated	*Inc.*	Videlicet (namely)	*viz.*
Information	*Inf.*	Weight	wt.

ACKNOWLEDGEMENTS

At first the author expresses her profound gratitude to Almighty Allah for her never-ending blessings to complete this research work successfully. It is a great pleasure to express his reflective gratitude to his respected and beloved parents and teachers who entiled much hardship inspiring for prosecuting her studies, thiseby receiving proper education.

The author would like to express her earnest respect, sincere appreciation and enormous thankfulness to her reverend, heartedly respected and beloved supervisor, Prof. Dr. Naheed Zeba, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka, for her scholastic supervision, constructive, knowledgeable and insightful suggestions, continuous encouragement and unvarying inspiration throughout the research work and for taking immense care just like a family during study and the preparation of this manuscript.

The author wishes to express her gratitude and best regards to her respected Co-Supervisor, Prof. Dr. Jamilur Rahman, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka, for his cooperation, guidance, suggestions, comments, encouragement and valuable teaching which was very helpful during the final stretch of his thesis writing.

The author is highly grateful to her honorable teacher Prof. Dr. Kazi Md. Kamrul Huda, Chairman, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka, for his valuable and knowledgeable teaching and guidance during his study as well as constructive suggestions, encouragement and heartedly cooperation during the whole research period.

The author is highly grateful to Prof. Dr. Kamal Uddin Ahamed, Honourable Vice-chancellor, Sher-e-Bangla Agricultural University, Dhaka, and Professor Dr. Parimal Kanti Biswas, Dean, Post Gratuate Studies for providing all kind of logistic support, valuable suggestions and cooperation during the whole study period.

The author feels to express her heartfelt thanks and deepest gratitudes to her all respectable teachers, specially honourable Prof. Dr. Md. Shahidur Rashid Bhuiyan, Prof. Dr. Md. Sarowar Hossain, Prof. Dr. Firoz Mahmud, Dr. Md. Ashaduzzaman Siddikee, Dr. Md. Harun Ur Rashid, Dr. Md. Abdur Rahim, Dr. Ms. Shahanaz Parvin, Ms. Kamrunnahar and all other honourable course instructors of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka, for their valuable teaching, direct and indirect advices, encouragement and continuous warm cooperation during the period of her study.

The author had many good memories and she is very grateful to Mosammat Rexona Parvin and Shyamol Kumar Roy, academic officers and giving thanks to all the staff members of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka, for their continuous cooperation throughout the study period. It was also a great pleasure to work with Md. Ahsan-Wz-Zaman and Md. Zubaer Islam Talukder, Ms. Masuma Rahman, Ph.D students and her seniors, Nabila Narzis, Md. Mahmudul Hasan and Tanjina Rahman of the Department of Genetics and Plant Breeding and many of her senior and junior fellow MS students to whom the author was close throughout her institutional study and research period. It was an amazing experience to work with all of them. The author would like to thank all her fellows, specially Abu Bakar Siddique and Munni Akter for their cooperation.

Over and above, the author feels much pleasure and heartfelt appreciation to convey her profound thanks and gratefulness to her father and mother for their continuous encouragement and inspiration, who sacrificed much for her education. She can never repay their debt.

There are many others who helped, supported, assisted and inspired the author in various ways with their valuable suggestions and directions to achieve her dream of higher education. She is sincerely thankful and expresses her immense gratefulness to all of them as well as she regrets her inability for not to mention every one by name and heartedly requests for their forgiveness.

The Author

LIST OF CONTENTS

LIST OF CONTENTS (CONT'D)

LIST OF CONTENTS (CONT'D)

LIST OF CONTENTS (CONT'D)

LIST OF CONTENTS (CONT'D)

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDICES

COMBINING ABILITY AND HETEROSIS FOR YIELD AND QUALITY TRAITS OF F1 HYBRIDS IN TOMATO (*Solanum lycopersicum* L.)

By

ASMAUL HUSNA

ABSTRACT

The experiment was carried out at Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during the period of October, 2017 to March, 2018 and November 2018 to March 2019 to study combining ability and heterosis in intraspecific hybrids of some tomato genotypes. With eight tomato genotypes *viz*. G1 (SL-006), G2 (SL-007), G3 (SL-008), G4 (SL-009), G5 (SL-0010), G6 (SL-0011), G7 (SL-0012) and G8 (SL-0013) the experimental field was organized in Randomized Complete Block Design (RCBD) in three replications. In this study nineteen characters including both agromorphogenic, nutritional and physiological were taken under consideration. High general combining ability observed in parents G1, G3, G5 and G6 for one or more yield contributing traits. Characters like days to 1^{st} and 50% flowering, number of cluster per plant, fruit per cluster, fruit per plant, fruit wt, fruit area, relative water content, fruit pH and yield were governed by non-additive gene action. The maximum SCA effects was observed in the cross combinations G2×G1for higher yield and lowest in G2×G7 for days to first and 50% flowering and G2×G1 for early maturity. Highest desirable significant heterobeltiosis for yield related characters was expressed by the F_1 hybrids G2×G6 (Plant height), G3×G6 (branch number), G2×G8 (cluster number), G4×G3 (average fruit in one cluster), G2×G8 (fruit per plant), G1×G6 (fruit wt.), G5×G2 (fruit area) whereas, negative heterosis was highest in the crosses G3×G5 (1^{st} flowering), G3×G5 (50% flowering) and G1×G8 (maturity days). Most of the chemical traits showed significant heterosis. Thus, these three combinations could be feasible for further selection to obtain high yielding, short duration and longer shelf life.

INTRODUCTION

INTRODUCTION

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the important Solanaceous vegetables with the chromosome number 2n = 24 that grows extensively throughout the world (Jenkins, 1948). The genus '*Lycopersicum*' includes nine species, among them only two are cultivated- *Solanum lycopersicum* L. (common tomato) and *Solanum pimpinellifolium* L. (currant tomato) (Rashid, 1999).

Once tomato was considered poisonous and inedible, however, gradually it has become one of the most popular and worldwide consumed vegetable at present. In Bangladesh tomato is an exogenous crop. It was originated is Peru, Equador region (Rick, 1969). Some scientists opt that the native of tomato is the new world (The America) *i.e*., the Andean region which includes part of Bolivia, Colombia, Chili, Ecuador and Peru. According to Heisar (1969), tomato gradually spread from its native land to European countries and rest of the world. Wild cultivars of tomato were found in the tropical rain forests of South America. At present tomato is grown in almost all countries around the world except the colder 15 regions (Hannan *et al*., 2007).

Although tomato is a tropical day neutral nightshade plant, it is well grown in sub-tropical region in Bangladesh. The area and production is increasing day by day while the national average yield of tomato is 10 tons per ha (Anonymous, 2014). It grows in 68,366 acres of land with a production of 388725 M. Ton in Bangladesh, (BBS, 2018). Tomato grows well at much latitude and under a wide range of soil types and different methods of cultivation (Villareal, 1980). Fruit setting is optimum at 15 to 20°C night temperature (Charles and Harris, 1972; Schiable, 1962). So, winter season is the most preferable for tomato cultivation in Bangladesh. It is a self-pollinate crop but a certain extent of cross pollination may also take place.

Tomatoes are also known as "Poor man's apple" for their low price and availability. It is second most important vegetable crop after potato. It has become one of the most important and popular vegetable in Bangladesh because of its diverse use, nutritional value and good taste. It is consumed either fresh or cooked like juice, sauce and many more. It is an important source of Vitamin A, Vitamin C and some minerals. Tomato has some medicinal values like tomato pulp and juice are digestion, blood purification and is mild aperients. Tomato contains antiseptic properties against intestinal infestations and antioxidant property as it has ascorbic acid and lycopene content in it. It is an important source of β-carotene. At present, tomato is one of the most important raw materials for different food industries.

A genotype promising for a particular trait will not always transfer its favorable alleles naturally to its progenies successfully. Diallel crosses are used to estimate the allele transfer capacity, which is genetically designed and widely exploited in breeding programs for numerous species and purposes, including for tomato (Maluf, 2001). Diallels are genetic designs that partition the sum of square of treatments in combining ability effects of the parents, providing researchers with important information, e.g., about the predominant gene action in trait expression, heterosis of hybrid combinations and also which breeding strategy is the most indicated (Cruz *et al*., 2012).

Combining ability is one of the most effective tools to understand the genetic capability of parents and their hybrids to identify the best combiner that may be further used in crosses either to exploit heterosis or to accumulate fixable genes. It helps to know the genetic architecture of various characters that enable the breeder to design effective breeding plan for future up through gradation of the existing materials. This information also assists the breeders to select diversified parents and hybrid combinations. The performance of hybrid combinations helps to access the genetic advancement of the existing tomato genotypes.

Heterosis is considered more and more as a basic, highly effective breeding method applied in an ever-growing number of agricultural crops for developing early, high-yielding, uniform cultivars, which combine additionally a number of other valuable economic characters. It is well known that the use of heterosis effect in F_1 after crossing different species, cultivars or inbred lines, has opened wide new vistas for the breeding of cultivated crops. At the beginning of the twentieth Century Hedrick and Booth (1907) observed heterosis effect in tomatoes. Somewhat later East and Hayes (1912) pointed out that tomato F_1 crosses could have considerable practical value because crossing is relatively easy.

In Bangladesh open pollinated tomato varieties are mostly cultivated and recently exotic hybrid varieties are being introduced due to their high yielding potential. Seed of those hybrid varieties are very costly and due to unique nature of hybrid variety, tomato growers need to buy seed every season. To increase the production of tomato in the country, exploitation of hybrid technology might be a fruitful alternative. Considering necessity, demand and scope the present investigation was undertaken with the following objectives:

1. To analyse combining ability in F_1 and their parental lines
2. To determine the heterosis over mid parent and better parent and
3. To identify cross combinations for further investigation and regional yield trial.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Tomato always grows attention of the researchers as an important vegetable crop because of its nutritional value, growth habit, adoptively, productivity and availability everywhere in tropical, sub-tropical and temperate regions. Also the breeding of this crop is comparatively easy going and a lot of variation can be occurred through different breeding techniques. In this chapter, literature related to the combining ability, mode of gene action and heterosis have been reviewed and presented chronologically.

2.1 Combining Ability

In quantitative genetics two types of combining ability-general and specific, are studied. The genetic values of parents are expressed in terms of combining ability. Sprague and Tatum (1942) introduced these two combining ability and defined as the term 'general combining ability' is used to designate the average performance of a line in hybrid combination and 'specific combining ability' is used to designate those cases in which certain combinations do relatively better or worse than would be expected on the basis of the average performance of the lines involved. General combining ability is due to genes, which are largely additive in their effects and specific combining ability is due to the genes with dominance or epistatic effect. Here, in this part, an attempt has been made to review those early studies on combining ability of tomato are directly related to the present investigation.

Reddy *et al*. (2017) used forty hybrids generated from crossing ten lines with four testers for combining ability analysis in tomato. The general combining ability (GCA) and specific combining ability (SCA) were significant for all the characters, indicating the importance of both additive and non-additive genetic components. But it is found that there was predominance of non-additive genetic components for expression of different traits in the present set of materials. Amongst the lines, CO-3, Pant T-3 and Flawery were best general combiners for yield along with other traits, whereas among the testers H-24 and H86 were best general combiner for yield along with other traits. The most promising specific combiners for yield and other traits were Flawery × Sel-7, Fla-7171 × Azad T-5, GT-20 × Azad T-5, C0-3 × Sel-7, B-S-31-3 × H-24. Hence, the present study was carried out to obtain information on combining ability involved in expressing the different characters in tomato. High GCA effect of variety CO-3 was associated with its high GCA effect for primary branches per plant, fruits per plant, average fruit weight and yield per plant. The good combining ability of line T-3 was due to high fruits per cluster, fruits per plant and yield per plant. Among the female parents, H-24 and H-86 were the best general combiners for yield per plant along with high GCA for fruits per plant and average fruit weight. It was followed by for number of fruits per plant 'B-S-31-3', 'Sel-7' and 'Pant T-3', and for average fruit weight 'H-24', 'CO-3' and 'Punjab Upama' were good general combiners in desired directions. It is observed that a total of 16 crosses exhibited positive and significant SCA for yield per plant. The promising combinations for yield were 'Flawery × Sel-7' followed by 'Fla-7171 × Azad T-5' and 'GT20 × Azad T-5'. It is observed that majority of the crosses with high SCA for yields were involved with high/low or average/low combining parents. But very few crosses showing low/low general combiners showed high SCA. The cross combinations showing high negative SCA for days to flowering (earliness) were Pant T-3 × Sel-7, 'EC521087 × H-24', 'Flawery × H-86' and 'B-S-31-3 × H-86'. For plant height, estimates of SCA are desirable and the good specific combiners were B-S-31-3 × Azad T-5, Flawery × Sel7, Fla-7171 × Azad T-5 and Kashi sharad × H-86. The cross combinations viz., 'GT-20 × H-86' and 'T-Local × H-86' were good specific combiners for primary branches per plant. The best specific combiners for flowers per cluster were Flawery × Azad T-5, Punjab Upama × H-24, Kashi sharad × Azad T-5 and T-Local × H-24. The cross combinations *viz.*, T-Local × H24, Kashi

Sharad × Azad T-5 and Flawery × Azad T-5 showed higher SCA for fruits per cluster. For number of fruits per plant, the cross of Pant T-3 × H-24, Fla-7171 × Azad T-5, Punjab Upama ×H-86 and B-S-31-3 ×H-24 exhibited high specific combining ability for the trait. Cross GT-20 × Azad T-5 and Fla-7171 × H-86 showed high SCA for average fruit weight.

Panchal *et al.* (2016) carried out combining ability analysis in a field experiment through line × tester method using a set of 40 genotypes of tomato including seven females, four males, their 28 single F_1 hybrids and one standard check (Abhinav) for ten characters. Among the female parents, JTL-12-04, JTL-12-10 and JTL12-12 are identified as the best general combiners for fruit yield per plant. It also exhibited significant and desirable GCA effects for primary branches per plant, plant height, number of primary branches per plant, average fruit weight and some of its direct components. Among the testers, JT-3 and AT-3 exhibited significant and high positive GCA effects for fruit yield per plant and also other characters like, number of primary branches per plant, number of fruits per plant, first flowering node and other important traits. Parents, JTL-12-14 and GT-1 were proved to be poor general combiners for majority of the traits under study. High GCA effects for such characters have been also been reported in tomato by Yadav *et al.* (2013), Angadi *et al.* (2012), Kumari and Sharma (2012), Shende *et al.* (2012), Souza *et al.* (2012) and Singh *et al.* (2011). None of the parents was best general combiner for all the traits indicating differences in genetic variability for different characters among the parents.

In the similar study, SCA effect in 13 hybrids was highly significant for fruit yield per plant. The good general combining parents when crossed do not always produce high SCA effects. In the same way, poor general combiner parents do not always produce exhibit lower SCA effects. Shankar *et al.* (2013a, b), Yadav *et al.* (2013), Angadi *et al.* (2012), Angadi and Dharmatti (2012), Kumari and Sharma, (2012), Shende *et al.* (2012), Souza *et al.* (2012), Singh *et al.* (2011), Singh and

Asati (2011), Singh *et al*. (2010) and Virupannavar *et al*. (2010) also reported positive and significant SCA effects for fruit yield per plant in tomatoes. Again, Chandrasekhar and Rao (1989) evaluated progenies and parental genotypes reported significant variations of GCA and SCA. SCA effects were significant and 29 positive in 6 crosses for plant height fruit weight and yield. 'Pusa Early Dwarf' was the best general combiner. Bhutan *et al.* (1988) reported the non-additive type of gene action for the control of number of fruits in tomato and yield per plant in tomato.

In 2014, Bhavna *et al.* experimented on diallel analysis to study the combining ability in tomato for fourteen characters including fruit yield and its component characters and found that both additive and non-additive variances were significant for fruit yield and its related traits indicating their improvements in the expression of various traits. The magnitude of non-additive variance was higher for fruit yield and its contributing traits indicating predominant role of non-additive gene action in the inheritance of the traits. Similarly, Farzane *et al.* (2012) conducted a study on 10 × 10 diallel cross set of tomato including reciprocals to find out the combining ability for yield per plant (kg) and yield components (number of fruits per plant, individual fruit weight (g)) and locule number. Significant differences among genotypes were obtained for all of 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 number of fruits per plant and relative magnitude of these variances indicated that additive gene effects were more prominent for all of the traits. The tomato genotype 'Mb3' proved to be the best general combiner for yield and number of fruits per plant.

Sharma (2014) found the most promising general combiners were PT-2009-02 for fruit yield per hectare, fruit yield per plant, average fruit weight, number of locules and pericarp thickness, S-816 for plant height, branches per plant and number of locules, PT-1 exhibited the highest general combining ability for days to first harvest and days to last harvest. PT-20 for plant height, fruit length and fruit width, PT-09-06 for number of seeds per gram and number of fruit per plant, S-06-1 for TSS at immature stage, turning stage and red ripe stage. Most promising hybrids exhibiting significant sca effects were, PT-19 x Punjab Chhuharafor fruit yield per hectare, fruit yield per plant and average fruit weight, PT-41 x Punjab Chhuhara for dwarfness and number of locules, PT-19 x PT-3 and PT-11 x PT-3 for earliness, PT-41 x Roma for number of fruit per plant and tallness, PT-20 x Pumjab Chhuhara for fruit length ripe stage, fruit width for higher number of seeds per gram, PT-1 x Punjab Chhuhara for fruit width and PT-09-06 x Punjab Chhuhara for pericarp thickness. The combining ability analysis indicated the importance of both additive and non-additive gene action for different growth, yield and fruit quality characters.

In an experiment by Al-Daej (2014) the cross 1×4 proved the best for fruit length, diameter, firmness and weight; 1×7 for number of locales; 2×4 for TSS and the lowest fruit thickness over mid-parents. The variance values of general combining ability (GCA) were higher than the specific combining ability (SCA) for all the traits except the fruit thickness. While, additive and none additive components were similar in fruit thickness. Conclusion: The SCA effects showed that the cross 1×4 was the best in fruit weight, 1×6 in firmness, 2×3 in fruit diameter and weight, 2×5 in number of locales, 2×6 in fruit thickness and 2×7 in TSS. The magnitude of additive variance was more pronounced for all the seven characters of interest of fruit quality both when F = 0 and F = 1 except for fruit thickness. The presence of excess additive variance was confirmed by the study results for most of the investigated traits of tomato crop. The study findings indicated the improved lines and testers for histerosis analysis for cross pollination to obtain improved tomato high quality and high yielding cultivars. The cross 1×4 proved the best for fruit length, diameter, firmness and weight; 1×7 for number of locales; 2×4 for TSS and the lowest fruit thickness over mid-parents. The variance values of general combining ability (GCA) were higher than the specific combining ability (SCA) for all the traits except the fruit thickness. While, additive and none additive components were similar in fruit thickness. The SCA effects showed that the cross 1×4 was the best in fruit weight, 1×6 in firmness, 2×3 in fruit diameter and weight, 2×5 in number of locales, 2×6 in fruit thickness and 2×7 in TSS. The magnitude of additive variance was more pronounced for all the seven characters of interest of fruit quality both when F = 0 and F = 1 except for fruit thickness. The presence of excess additive variance was confirmed by the study results for most of the investigated traits of tomato crop. The study findings indicated the improved lines and testers for histerosis analysis for cross pollination to obtain improved tomato high quality and high yielding cultivars.

In a study with thirteen parental lines were crossed in line X tester fashion comprising 10 lines and 3 testers by Kumar *et al.* in 2013. 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 combinations. An overall appraisal of gca effects revealed that among parents H24 emerged out as good general combiner for plant height, days to 50% flowering, fruits per cluster and total yield per plant whereas, line DT-2 traced out good general combiner for days to 50% flowering, average fruit weight and TSS and CO-3 for days to 50% flowering and total yield per plant. Among the parents Punjab Upma was found to be good general combiner for plant height, days to 50% flowering, and total yield per plant. Pant T-3 for days to 50% flowering and total yield per plant, whereas H-86 for plant height TSS, titratable acidity and lycopene. Selection -7 for number of fruits per plant, average fruit weight, fruits per cluster, ascorbic acid, titratable acidity and lycopene, while NDTVR-60 for days to 50% flowering, average fruit weight, TSS, titratable acidity and lycopene. Fla-7171 good general combiner for plant height, fruits per cluster and lycopene whereas, Kashi Amrit only for lycopene. Male parent Floradade for plant height and days to 50% flowering while Kashi Sharad good general combiner for average fruit weight, total yield per plant and lycopene as well as Azad T-5 for plant height, days to 50% flowering, fruits per cluster, TSS and Lycopene. Significant SCA effects in favourable direction as observed in many crosses for Plant Height, Days of 50% flowering, No. of primary branches, No. of fruits per plant, Average fruit weight, Fruit per cluster, Total yield per plant, TSS, Ascorbic Acid, Titratable Acidity and Lycopene. This result getting support from the findings of Singh *et al.* (2010), Saleem *et al.* (2009), Hannan *et al.* (2007), Premalakshme *et al.* (2006), Duhan *et al.* (2005) and Dhaliwal *et al.* (2004).

Izge *et al.* (2012) performed combining ability studies for yield and yield components of tomato in a set of 6 lines and 2 testers during the 2009 and 2010 dry season under irrigation results showed that both general combining ability (GCA) and specific 20 combining ability (SCA) were influenced by the environment. Out of the 12 hybrids studied, 4 each were found to be good specific combiners for number of flower clusters and plant height, and 5 for number of fruits per plant over both the environment combined. Cherry × Hong Large and Cherry × Roma 'VF' were the best specific combiners for number of fruits per plant and incidentally having high number of trichome count. Souza *et al.* (2012), also studied the general combining ability (GCA), specific combining ability (SCA) in a complete diallel cross of fifteen genotypes (five parents and ten hybrids) tomato breeding lines for plant fruit yield, 'IAC-2' was the best parental line with the highest GCA followed by IAC-4 and IAC-1 lines. The hybrids IAC-1 × IAC-2, IAC-1 × IAC-4 and IAC-2 × IAC-4 showed the highest effects of SCA.

From twenty-five varieties of tomato Peter *et al.* (2012) in the same way reported that the component characters locules per fruit and plant height were found to be important for the expression of genetic divergence.

In 1997 Chadha *et al.* reported the lines ‘BWR-5 (HR)’, ‘LB79-5 (W)’ and ‘EC 129156’ as good general combiners for marketable fruits per plant. They also found that four Fruits showed significant positive SCA effects and lines ‘BT-1Q’, ‘BWR-5 (HR)’ and ‘EC 191540’ as food general combiners for average fruit weight. Five F1 showed significant positive SCA effects for average fruit weight. Similarly, Vidyasagar *et al.* (1997) in a line (8) × tester (3) analysis observed superiority of 3 F1S to their respective better parents for fruit weight. Ghosh *et al.* (1996) from a 9 × 9 diallel cross and graphical analysis of tomato reported the partial dominance for days to first flowering, plant height, equatorial fruit diameter and polar fruit diameter, number of locules per fruit and yield per plant. From graphical analysis they reported the over dominance for total soluble solids (TSS). Dod *et al.* (1995) also studied combining ability of tomato in a 12 parent’s diallel (excluding reciprocals) for number of locules per fruit, TSS% and reported the importance of both additive and non-additive genetic components. They also found a predominant role for additive gene action. ‘AC238’, ‘Punjab Chhuhara’ and ‘Pusa Ruby’ were the best general combiners. Perera and Liyanaarachchi (1993) from a 13 × 13 half diallel cross analysis found complete dominance for flowering time and fruit weight.

E-Mahdy *et al.* (1990) in a study of complete diallel set of 6 lines under heat stress reported that additive gene effect appeared more important than non-additive gene effects for early yield, fruit weight, TSS % and Zhou and Xu (1990) studied Soluble Solids Content (SSC) in fruits from 20 hybrid combinations from a 5 × 4 diallel without reciprocals and observed 74.15 % GCA and 25.85 % SCA variance.

2.2 Heterosis

When two pure or inbred lines are mated, the performance of F_1 may be superior or inferior to mid parental value. This superiority or inferiority over mean is called heterosis. The magnitude of heterosis varies upon accumulation of favorable dominant alleles of F_1 offspring. The more the parental populations differ from each other for useful dominant alleles, the higher will be the magnitude of heterosis. This relationship is proved by Falconer (1981) and his formula for heterosis is- Heterosis in F_1 = dy^2, Where, d = Magnitude of dominance, y = Difference between the parental population for allelic frequencies at the locus. Though tomato is a self-fertilized crop where degree of heterosis was theoretically noticed that it has been attributed to the fact that tomato was basically a highly out crossing genus which was later evolved into a self-fertilized one (Rick, 1965). Heterosis is estimated in three different ways- 1. Mid parent heterosis, 2. Better parent heterosis and 3. Standard heterosis.

2.2.1 Heterosis in crop plants

Heterosis is defined as the superior performance of heterozygous hybrid individual over its homozygous parental inbred line. Hybrid often possesses comparatively increased vigor than their parents (Sprague, 1983). In 1900, when Mendel's laws were rediscovered and drew the attention of the biological world on problems of heredity, led to introduce interest in hybrid vigour as one aspect of quantitative inheritance. Widespread understanding of heterosis was laid by Shull in 1908. He established that a variety was a complex mixture of genotypes. The variability among strains undergoing inbreeding, including loss of vigour, was a consequence of segregation and the eventual homozygosity of desired and deleterious alleles. He also revealed that when certain lines were combined, F_1 yields exceeded those of the parental varieties. The word heterosis was coined by Shull and first proposed in 1914. In 1876, Darwin reconsidered earlier literature and also his own experiments in several crop species. Most of these studies point out that the offspring arising from cross-fertilization were more vigorous than those obtained by selfing. He also decided that self-fertilization is 'harmful' (Allard, 1960).

A study on tomato was conducted by Bhatt *et al*. (2001) to find out the degree of heterosis for yield with two important quality characters, ascorbic acid and total soluble solids. Significant differences among genotypes were noticed for all the three characters. Similarly, in 2001 Kurian and Peter conducted an experiment with tomato hybrids and the obtained F_1 hybrids showed highest significant heterobeltiosis for TSS and lycopene. The F_1 hybrids usually performed better in fruit quality, i.e. uniform ripening, high lycopene and total solids. Premalakshme *et al.* (2005) presented a study for development of F_1 hybrids with high yield and quality in tomato through diallel crossing comprising six parents. The studies exposed remarkable heterosis over the better parent for earliness, plant height, and laterals per plant. In order of merit, the three best performing F_1 hybrids showed heterosis percentage of 14.43 and 13.90 for marketable fruit weight and fruit yield over the standard check, respectively.

From 20th century heterosis began to utilize commercially in agriculture. Heterosis played a vital role in the breeding and development of crop hybrids, although the genetic basis of the phenomenon remained imprecise (Me Daniel, 1986; Rood *et al.*, 1988). Maybe Hayes and Jones in 1916 first suggested that hybrid vigor be exploited in vegetables (Hayes, 1952). However, the commercial exploitation of heterosis was first raised in 1930's. Nowadays, most of the world's sugar is produced by hybrid sugarcane or hybrid sugar beets. In Japan, F_1 hybrid eggplants were economically used before 1952 (Kakizaki, 1930). Hybrid rice is now being produced on an increasing area in China. In short, the economic importance of hybrid varieties can be grasped in Gardner's (1968) statement. Development and utilization of heterosis has been the most important practical accomplishment of genetics so far.

2.2.2 Heterosis in tomato

Heterosis effect was first introduced in tomatoes by Hedrick and Booth in 1907. Then, heterosis for yield and its component has been demonstrated by many researchers (Singh and Singh, 1993; Daskalof *et al*., 1967; Burdick, 1954).

In 2014, Sharma used thirty crosses were evolved in a line x tester mating design with 10 genotypes as female parents (lines) and 3 genotypes as male parents (testers). The hybrids, PT-11 x PT-3 and PT-20 x Punjab Chhuhara were most promising for earliness exhibiting highest negative heterosis. With respect to plant height, hybrids, PT-09-06 x PT-3 and PT-20 x Roma were most promising for tallness and dwarfness, respectively. Hybrid combination, PT-09-06 x PT-3 exhibited most promising results with respect to heterosis for fruit yield per plant and total fruit yield per hectare. Most promising hybrid for number of locules was PT-20 x Roma which exhibited negative heterosis. The best hybrids with respect to heterosis were PT-2009-02 x PT-3 for average fruit weight, PT-09-06 x Punjab Chhuhara for number of fruits per plant, PT-1 x Punjab Chhuhara for number of seeds per gram, PT-20 x Punjab Chhuhara for pericarp thickness, PT-20 x Roma for number of locules, PT-20 x Punjab Chhuhara for pericarp thickness and fruit width, PT-09-06 x Punjab Chhuhara for fruit shape index, S-06-1 x Punjab Chhuhara for TSS at turning and red ripe stage.

Saeed *et al.* (2014), used Line × Tester analysis to identify the potential parents and their hybrids from a set of 12 crosses derived from three lines used as females 'LA-2661', 'LA-2662' and '017899' and four testers, including 'BL-1078', 'BL-1079', 'CLN-2413' and 'CLN-2418-A'. Results showed that heterosis and heterobeltiosis in desired direction were recorded in two crosses viz. LA-2662 × CLN-2418A and LA-2662 × BL-1078. F1 hybrid LA-2662 × CLN-2418A proved to be the best cross in overall performance. Again Singh *et al.* (2014) studied the heterosis for yield components and yield per plant using 7 × 7 half diallel cross between bacterial wilt-resistant per tolerant genotypes and high yielding varieties.

The heterosis over better parent (BP) was up to the extent of -38.14%, 42.04%,36.14, -5.70%, -5.65%, 26.32%, 63.44%, 4.83%, 16.50%, 38.88%, 62.70% and 45.89% was recorded for plant height, number of primary branches per plant, number of secondary branches per plant, days to 50% flowering, days to maturity, fruit set, fruit length, fruit width, number of locules per fruit, number of fruits per plant, fruit weight and fruit yield per plant, respectively. The extent of heterosis was not as high as we are also looking for resistant to the bacterial wilt disease. The crosses showing heterosis for fruit yield per plant were not heterotic for all the characters under study. The heterosis for yield was generally accompanied by heterosis for yield components. Five promising crosses viz., Arka Ahuti × LO-5973, Arka Vikas × TWC 4, Arka Ahuti × TWC-4, BRH-2 × LO-5973 and CAU-TS-9 × LO-5973 were identified for developing high-yielding F1 hybrids/varieties of tomato with many desirable traits.

Kumar *et al.* (2013) used six diverse parental lines of tomato were crossed in a 6 × 6 diallel mating design excluding reciprocals. The 15 F1 hybrids and two standard checks (HYB-Roop-666 and TS-15) along with their parents Top three cross combinations for fruit yield per plant as per their per se performance, ArkaAbha x Punjab Chhuhara, ArkaMeghali x Punjab Chhuhara, Punjab Chhuhara x Best of All came out to be expressing significantly positive standard heterosis. Most of the crosses manifested highly significant heterosis over bothchecks, for fruit length and Fruit breadth that reflect that hybrids have better chance of having bigger fruits in case of tomato. For average fruit weight, ArkaAbha x ArkaMeghali, ArkaMeghali x Punjab Chhuhara proved to be the best hybrids which has expressed significant positive results for all types of heterosis including over checks.Overall, hybrids have reported greater plant heights as compared to check and mid parents which indicate that heterosis can be exploited for further improving the plant heights.ArkaMeghali x Punjab Chhuhara found to be the best cross combination which have significant favourable heterosis, of all three types, for vitals yield attributing traits i.e. number of fruits per cluster and number of fruit clusters per plant. This study was same as the findings of Ahmed *et al*. (2011), Singh and Sastry (2011), Kumari and Sharma (2011), Kumari *et al*. (2010), Kumar *et al*. (2009), Hannan *et al*. (2007), Mirshamssi *et al*. (2006), Premalakshme *et al*. (2005), Anita *et al*. (2005), Singh *et al*. (2005), Tiwri and Lal (2004), Gunasekera and Parera (1999), Singh *et al*. (1995) and Ahmed *et al*. (1988).

Chattopadhyay *et al*. (2012) a total of 25 entries consisting of 13 diversified genotypes of tomato along with their 12 F1 hybrids were evaluated during two consecutive rabi seasons which showed that Pronounced heterosis over better-parent was observed for number of locules per fruit, fruit length etc. Heterosis over mid parent and better parent, however, for most of the characters were in negative direction. Some of the parents having good potentiality for generating high cross combination for most of the quality traits under study were identified. Singh *et al*. (2012) in a complete 7 × 7 half diallel cross of tomato evaluate with parents for heterotic manifestation of yield and yield attributing characters. The crosses showing heterosis for yield per plant were not heterotic for all the characters under study. Five promising crosses viz., Ox-heart × Sutton Roma, Marglobe Supreme × Sutton Roma, Money Maker × Pusa Early Dwarf, Marglobe Supreme × Money Maker and Sutton Roma × Pusa Early Dwarf were identified for developing high yielding F1 hybrids/varieties of tomato with many desirable traits.

A trial comprising 15 hybrids and 8 parental lines was in conducted by Kumar *et al*. in 2012 and heterosis was estimated in fifteen single experimental cross hybrids, obtained by five parental lines namely H-24, DT-2, CO-3, Punjab Upma, Pant T-3 and three testers of tomato *viz*. Floradade, Kashi Sharad, Azad T-5 for yield and yield related traits; plant height, days to 50% flowering, number of fruits per plant, average fruit weight, fruit diameter, number of fruits per cluster and total yield per plant. Significant differences among genotypes were observed for all the traits. Positive and highly significant heterosis was found for number of fruits per plant 25.27%, 25.13% and 21.13% over better parent and 29.95%, 25.27% and 24.46% over standard parent and for total yield per plant 32.06%, 18.34%, 13.36% and 11.27% over better parent and 31.83%, 31.14%, 30.10% and 25.26% over standard check 'Azad T-5'. The hybrid also showed significantly high percentage of positive heterosis over better and standard parent for number of fruits per cluster, average fruit weight and the hybrids showed negative heterosis for plant height and day to 50% flowering which are desirable characters. Similarly, in an experiment conducted by Ramana *et al.* in 2011 ten parents (EC-165749, EC-157568, EC-164838, LE-56, LE-62, LE-64, LE-65, LE-66, LE-67 and LE-68) were crossed in diallele mating design (without reciprocals). The resultant 45 F1's were evaluated along with their parents and two standard checks (Siri and US-618) for six characters viz., plant height (cm), number of primary branches per plant, days to 50% flowering, number of fruits per cluster, average fruit weight (g) and fruit yield per plant (kg). Studies on heterosis revealed that majority of the hybrids exhibited relative heterosis, heterobeltiosis and standard heterosis in desirable direction. The potential crosses viz., LE-64 × LE-66, LE-56 x LE-68, EC-157568 x LE-68 and EC-164838 x LE-66, exhibited high standard heterosis and high per se performance for fruit yield per plant, which offers scope for commercial exploitation through heterosis breeding.

Souza *et al*. (2012) evaluated the yield and its components traits, *viz*., fruit yield per plant, fruit number per plant, average fruit weight, no. of cluster per plant, fruit number per cluster, fruit wall thickness and number of locules per fruit including some quality components, namely, total soluble solids, total titratable acidity, fruit length, fruit width, length to width ratio by studying heterosis in tomato. Again, Sharma and Sharma (2013) estimated the heterosis on the basis of mean performance and reported 43.67 percent heterosis over better parent for yield. The heterobeltiotic effect for number of fruits per cluster ranged from -34.39 to 33.0

percent. The fruit yield among the crosses varied from 764.33 to 1808.23 (g). Significant heterobeltiosis was observed in desirable direction for all the traits except days to first picking and total soluble solids. Maximum and significant heterosis in favorable direction was observed for yield, plant height, fruit number and fruits per cluster reported by Kumari and Sharma (2011). Heterosis was considerable in all hybrids. Resende *et al*. (2000) examined heterosis of tomato for number of fruits in 1st, 2nd and 3rd trusses, found higher heterosis values in the hybrids than the standard cultivar Santa Clara for number of fruits per truss. Ninety-one F_1 crosses of tomato in a diallel set involving 13 percents (excluding reciprocals) to study heterosis for number of fruit/truss and found appreciable heterosis over best parental lines evaluated by Bhatt *et al*. (1999). Again, Hannan *et al*. (2007a) determined the heterosis in tomato for yield and yield component characters, *viz*., plant height at 60 days after transplantation, days to first flowering, number of flower per cluster, number of fruits per plant, fruit weight per plant, days to first fruit ripening. Gul *et al*. (2010) studied in tomato for degree of heterosis in yield and its five yield attributing components, *viz*., number of flowers per cluster, number of fruits set per cluster, fruit length, fruit width, fruit weight and fruit yield per plant. The degree of heterosis for plant height, fruit weight, bacterial wilt incidence and yield per plant were determined by Singh and Asati (2011). Ahmad (2002) found that highest heterosis over better parent in the cross TM041 X TM044 which were 159.70 and 181.36 percent respectively for May and July sowing.

Ahmad (2002) conducted a crosse 8 X 8 diallel set of tomato without reciprocal in May and July sowing and found highest heterobeltiotic effects in both the sowing in the hybrid TM051 X TM017 (-21.76% and -13.43% respectively). Again, heterosis was estimated for yield and yield related characters, plant height, days to 50% flowering, number of fruits per plant, average fruit weight, average fruit diameter, number of fruits per cluster and total yield per plant (Kumar *et al*., 1988). Vedyasagar *et al*. (1997) also studied a line (8) X tester (3) of tomatoes involving bacterial wilt (*Ralstonia Solanacearum*) resistant parents and observed that 12 F_1s each demonstrated superiority to their respective better parents for days to 50% (early) flowering. Again, significant differences among genotypes were noticed for all the traits such as, for fruit yield per plant, i.e. 29.95% over better parent and 32.36% over standard check. The hybrid also revealed significantly high percentage of positive heterosis over better and standard parent for number of fruits per cluster, average fruit weight but revealed negative heterosis for plant height and day to 50% flowering which are desirable traits. Heterosis over better parent and negative heterosis for days to flowering over the better parent in many of the hybrids vigor in their diallel progenies reported by Singh (1993) and Ahmed *et al*., (1988).

Ahmad (2002) and Ahmed *et al*. (1988) reported highest heterosis over better parent in the cross TM026 X TM025 which were 32.24% and 26.90% respectively for May and July sowing. Mid-parent heterosis and better parent heterosis were observed for various quantitative characters in tomato (Chattopadhya *et al*., 2012). Obvious heterosis over better-parent was observed for fruit yield per plant (148.82%), fruiting clusters per plant (111.64%), number of fruits per plant (103.33%), fruit weight (62.79%) and plant height (50.57%). Kumar *et al*. (1995b) examined on seven tomato lines, their 21 F_1s and three saleable hybrids showed greatest heterosis (%) over superior parents for plant height. Heterosis of tomato in a 7X7 diallel set (without reciprocal) and found maximum -45.40 per cent heterosis for plant height in the cross Japanese X Anobik over parental value studied by Bhuiyan (1982). Heterosis for plant height was also studied by Dod *et al*. (1992) from diallel cross.

Vidyasagar *et al*. (1997) studied in a line (8) X tester (3) analysis perceived better parents heterosis in 5 F_1s for marketable fruits/Plant. Similarly, Sekar (2001) observed that more than 10% heterosis over the best parent for the number of fruits per plant and yield per plant. In a study of line X tester analysis Dev *et al*. (1994) observed heterosis over the better parent 115.7% for the number of fruits per plant. Jamwal *et al*. (1984) crossed among 10 foreign lines and 3 local testers and observed that heterois for fruit number per plant. Bhuiyan (1982) also observed that maximum better parent heterosis (113.92 percent) for number of fruits per plant in the cross Fujuki X CL. 8d-0-7-l-0-0. In the same way, Chaudhury and Khanna (1972) reported that heterosis in 17 hybrids out of 28 hybrids for fruit number and with maximum increases over the better parent of 49.93% under high temperature growing environment.

Kumar *et al*. (1995a) researches on seven tomato lines, their 21 F_1s and three commercial hybrid standards and observed more heterosis over superior parents for early yield (41.6%). Jamwal *et al*. (1984) also crossed 10 foreign lines and 3 local testers and studied heterosis. In 2013 Shankar *et al*. studied heterosis for quality and yield characters in tomato. The study revealed that majority of the hybrids exhibited significant qualified heterosis, heterobeltiosis, standard heterosis in desired direction. The hybrids showed higher performance and also showed high standard heterosis. The crosses recorded high negative standard heterosis for earliness and days to 50 percent flowering. Negative heterosis was observed over mid and superior parent for marketable maturity (Kumari *et al*., 2010). Negative heterobeltiosis for this trait also reported by Singh and Sastry (2011), whereas, positive heterosis for this character had been reported by Hannan *et al*. (2007) and Mirshamssi *et al*. (2006). Negative heterobeltiosis and standard heterosis were seen for this trait (Kumar *et al*., 2009).

Heterosis for the trait fruit weight was reported by many authors as Scott *et al*. (1986). Islam *et al*. (2012) studied the heterotic performance in F_1 generation of tomato. The hybrids showed that significant variation in heterosis. Chattopadhyay *et al*. (2012) reported that mid-parent heterosis and better parent heterosis for various quantitative traits in tomato. Prominent heterosis over better-parent was observed for fruit yield per plant (148.82%), fruiting clusters per plant (111.64%), number of fruits per plant (103.33%), fruit weight (62.79%) and plant height (50.57%). Better parent heterosis for average fruit weight in the cross TM051 X TM017 reported by Ahmad (2002). Greatest heterosis over superior parents for average fruit weight (30.8% and 32.27%) respectively, reported by Kumar *et al*. (1995a) and Kumar *et al.* (1995b). A line (8) X tester (3) analysis observed superiority of 3 F_1S to their respective better parents for fruit weight (Vidyasager *et al*., 1997). Ahmed *et al*. (1988) also reported that heterosis over the better parent for fruit weight (Singh *et al.*, 1995). Heterosis for the trait fruit weight under high temperature environments was reported by Scott *et al.* (1986). Again, Alvarez (1985) studied that hybrid INCA 21X INCA 3 was superior to the better parent for average weight in summer. Maximum better parent heterosis (8.45 percent) for individual fruit weight in the cross Fujuki X World champion was observed by Bhuiyan (1982).

Heterosis over better parent for fruit size in few cases in tomato was reported by Scott *et al.* (1986). Highest better parent heterosis in the cross TM051 X TM025 (22.25 percent in May sowing and 2.87 percent in July sowing) for fruit length (Ahmad, 2002). A full diallel without backcrosses concerning seven parents recorded maximum heterosis for fruit length (4.62%) in the hybrid VI00 X 93/10 (Susie, 1998).Again, five new processing tomato lines as female parents to cultivars Meidong and Jiazhouzhiyong were crossed and perceived higher heterosis for fruit length (Wang *et al.*, 1998). Singh *et al*. (1995) reported that heterosis in some crosses for length of fruit. Also Scott *et al*. (1986) and Chaudhury and Khanna (1972) reported that heterosis over better parent for fruit size in few cases in tomato. Evaluation trial of tomato hybrids in summer where also found that heterosis in equatorial diameter in the majority of cases (Alverez, 1985). Highest better parent heterosis in the cross TM051 X TM017 (22.65% in May sowing and 15.97% in July sowing) for fruit breadth (Ahmad, 2002). Susie

(1998) studied on full diallel without backcrosses concerning seven parents and recorded maximum heterosis for fruit width (4.56%) in the hybrid D150 X NO-IO. Wang *et al*. (1998) studied on using five lines and two cultivars observed that higher heterosis for fruit length. Chaudhruy and Khanna (1972) also reported that heterosis for fruit size, with maximum increases over the better parent of 6.82% (Chaudhury and Khanna, 1972). Heterosis for equatorial diameter in tomato was reported by Alvarez (1985).

Lower number of locules in oval and pear shaped variations like Roma and Italian Red Pear (Roy and Choudhary, 1972). The locule number ranged between 4 or 5 among F_1 hybrids like Mangla, Rupali and Vaishali (Sethi and Anand, 1986). Heterosis for locule number is also studied by Dod and Kale (1992), Ghosh *et al*. (1997), Srivastava *et al*. (1998a), Premalakmhme *et al*. (2002), Anita *et al*. (2005) and Ahmed *et al*. (2011). Singh *et al*. (2005) and Kumar *et al*. (2009) reported that significant negative heterosis for number of locules per fruit. Heterosis using line x tester analysis between bacterial wilt (*Ralstonia solanaccarxm*) resistant/tolerant compliances (Sakthi, LE 214 and LE 206) and processing cultivars (HW 208F, St 64, Ohio 8129, Fresh Market 9 and TH 318) and identified heterotic hybrids for locule number (LE 206 X Ohio 8129 and LE214XSt 64) (Kurian and Peter, 2001). Sherif and Hussein (1992) also observed significant heterosis for fruit yield per plant, as reflected by differences in the highest yields of parents and F1 hybrids: 845.6 and 2084.7 g per plant for ‘Yellow Pear’ and Sweet 100 × Yellow Pear, respectively.

MATERIALS AND METHOD

CHAPTER III

MATERIALS AND METHODS

The experiment entitled "Manifestation of heterosis and combining ability for yield and quality traits of F_1 hybrids from 8×8 diallel analysis in tomato (*Solanum lycopersicum* L.)" was carried out in the experimental farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, during Robi season 2018 and 2019. The details of materials used for this study and methodologies followed for the experiment have been described in this chapter. This discussion emphasizes on methodologies related to the location of experimental site, planting materials, climate and soil, preparation of seed bed, experimental design and layout, pot preparation, transplantation of seedlings, fertilizing, intercultural operations, harvesting, data recording procedure, physiological, nutritional and statistical analyzing procedure.

3.1. Experimental site

The study was conducted in the research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla nagar, Dhaka-1207, during the Robi season of 2018-2019 and 2019-2020. The geographical location of the site is in Agro-ecological zone of "Madhupur Tract" (AEZ-28) with 23°74' N latitude and 90°35' E longitudes (Anonymous, 2014) and 8 meters of elevation from sea level. The experimental site is shown in Appendix I.

3.2 Planting materials

A total of eight parental genotypes of tomato with 56 F_1 hybrids of these 8 parents was used in the study. The eight parents used in this study are listed in Table 1. The seeds of eight parents were obtained from the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. Fifty-six crosses including reciprocal crosses made from these eight

Table 1. Name and source of tomato genotypes used in the present study

Sl. No.	Genotypes	Name/Accession No.	Source
1	G1	SL-006	GEPB, SAU
2	G2	SL-007	
3	G3	SL-008	
4	G4	SL-009	
5	G5	SL-010	
6	G6	SL-011	
7	G7	SL-012	
8	G8	SL-013	

GEPB = Department of Genetics and Plant Breeding, SAU= Sher-e-Bangla Agricultural University

Table 2. Pattern of diallel crosses among the parents

	G1	G2	G3	G4	G5	G6	G7	G8
G1		G1×G2	G1×G3	G1×G4	G1×G5	G1×G6	G1×G7	G1×G8
G2	G2×G1		G2×G3	G2×G4	G2×G5	G2×G6	G2×G7	G2×G8
G3	G3×G1	G3×G2		G3×G4	G3×G5	G3×G6	G3×G7	G3×G8
G4	G4×G1	G4×G2	G4×G3		G4×G5	G4×G6	G4×G7	G4×G8
G5	G5×G1	G5×G2	G5×G3	G5×G4		G5G6	G5×G7	G5×G8
G6	G6×G1	G6×G2	G6×G3	G6×G4	G6×G5		G6×G7	G6×G8
G7	G7×G1	G7×G2	G7×G3	G7×G4	G7×G5	G7×G6		G7×G8
G8	G8×G1	G8×G2	G8×G3	G8×G4	G8×G5	G8×G6	G8×G7	

parents are shown in Table 2. The seeds of these fifty-six crosses and eight parents were sown in the next season to analyze the heterosis and combing ability. Eight tomato parents used in this experiment are shown in plate 1.

3.3 Soil

The experimental plot was situated in the subtropical zone. The soil was clay loam in texture and olive gray with common fine to medium distinct dark yellowish brown mottles that belongs to Agroecological region of "Madhupur Tract" (AEZ No. 28) with pH 5.47 to 5.63 and 0.82% organic carbon content (Appendix II).

3.4 Climate

The experiment was held in the month of November to April. The monthly average minimum and maximum temperature and relative humidity during the crop period was 12.00°C to 26.00°C and 57% to 79%, respectively. The monthly average rainfall was 17.59 mm. Details of the metrological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was noted from the Weather Station of Bangladesh, Sher-e- Bangla Nagar, Dhaka-1207 and presented in Appendix III.

3.5 Seedbed preparation and raising of seedling

In November 15, 2018 in 1st season and in 14th October, 2019 in 2nd season the seeds were sown in the seedbed of Sher-e-Bangla Agricultural University farm unit in rows spaced at 10 cm apart. Before sowing, seeds were treated with Autostin 50 WDG for 5 minutes. Seedlings were raised using regular nursery practices. Watering was done regularly. Cultural practices required for seedling preparation were done before and after seed sowing. When the seedlings were 32 days old, they were transplanted in the main field with proper labeling.

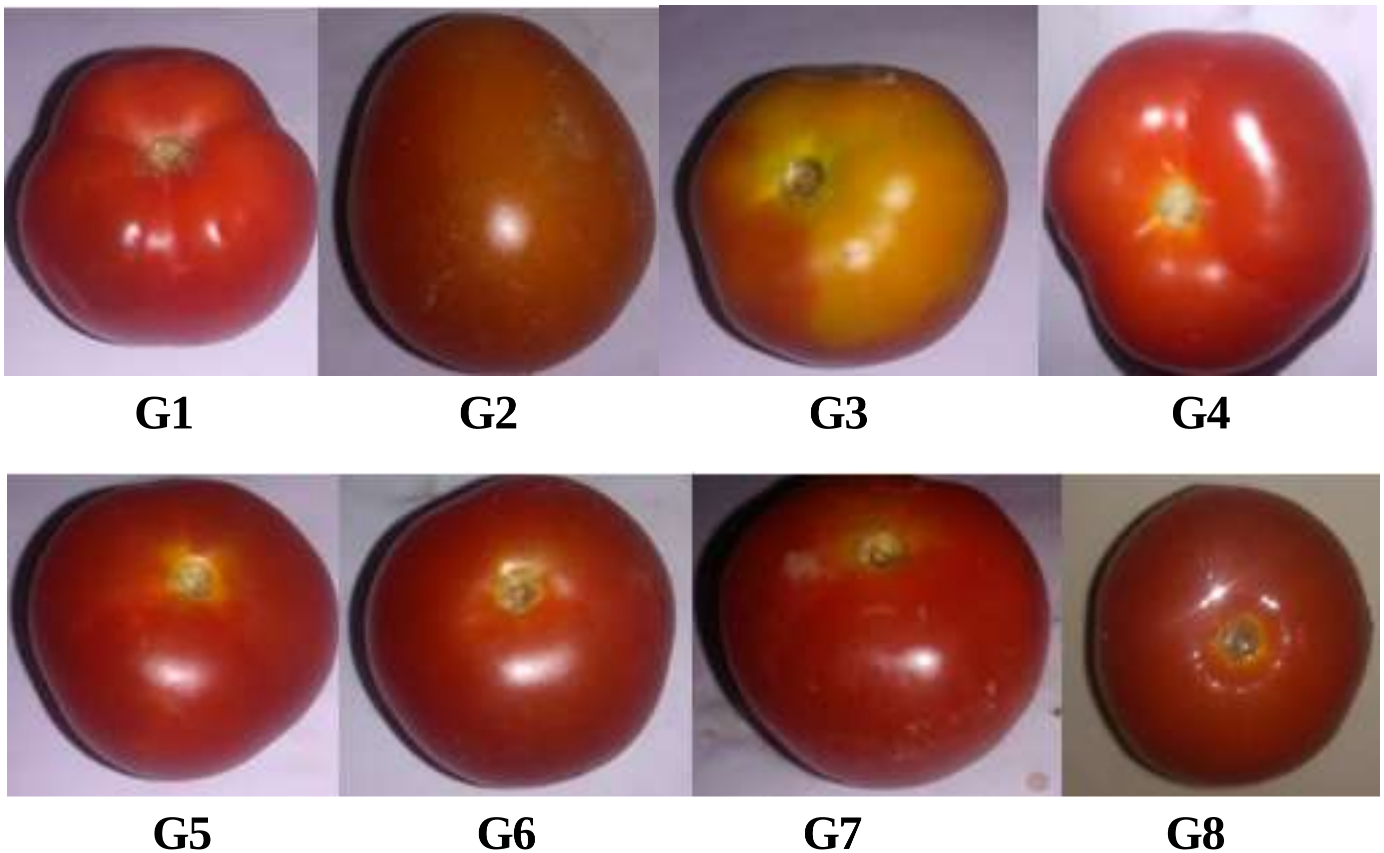


Plate 1. Eight tomato genotypes used as parent

3.6 Design and layout of the experiment

The research was laid out and evaluated under field condition during the Rabi season of 2017-2018 for hybridization and 2018-2019 for evaluation of combining ability and heterosis in Randomized Complete Block Design (RCBD). The number of parental genotypes were eight. Fifty-six crosses including reciprocal crosses were made using these parents. Replications in first season was three and in the second season it was two. Spacing was 40 cm × 60 cm. Plot size was 10× 20 m and 11× 24 m in first season and second season respectively. Date of transplanting in first season was 17th December 2018 and 16th November 2019 in second season.

3.7 Land preparation

In each season, the land was ploughed and cross ploughed followed by laddering to ensure good tillage seven days before transplanting. Weeds and other unwanted plants were removed thoroughly. Cow dung and fertilizer of required doses were applied in the field. Slight watering was done frequently to keep the soil moist. Pits were prepared for transplanting the seedlings.

3.8 Manure and fertilizers application

Table 3 shows the quantities of manure and fertilizer as per recommendation guide (BARI, 2018). At the time of final land preparation half cow dung and all TSP were applied thoroughly. The remaining cow dung and half MP were applied before three days of planting. The whole Urea and half MP were applied in three equal splits as top dressing after 15, 30 and 45 days of transplanting respectively.

Table 3. Doses of manures and fertilizers used in the experiment

Sl. No.	Fertilizers/ Manures	Doses	
		Applied in the plot	Quantity/ha
1	Urea	10.5 kg	550 kg
2	TSP	08 kg	450 kg
3	MOP	4.5 kg	250 kg
4	Cow dung	200 kg	10 ton

3.9 Transplanting of seedlings

Thirty-two days old seedlings were transplanted in the main field in the afternoon. The transplanted seedlings were watered regularly so that there becomes a firm relation with roots and soil to stand along. Transplanting of seedling is shown in Plate 2A.

3.10 Intercultural operations

After seedlings establishment, first weeding was done uniformly in all the plots. After 20 days of first weeding second one was done. Thinning and gap filling was done. Bamboo sticks as mechanical support was provided to grow the plants straight. During early stages of growth, pruning by removing some of the lateral branches and leaves was done to ensure proper sunlight and to reduce the self-shading and insect infestation. Staking, pesticide application, irrigation and after-care were also done as and when required. Different intercultural operations are shown in Plate 2 (B-D).

3.11 Emasculation and Hybridization

In January 2018 hybridization was performed at the flowering stage of all the eight parents. Day before hybridization selected flowers were emasculated and then bagged with polythene bag in the evening. The next day at the very morning pollen from each genotype were collected. These pollens were then dusted in the

Plate 2. Transplanting and intercultural operation A. Transplanting of seedling B. Land preparation C. Staking of the plant D. Watering of the plant

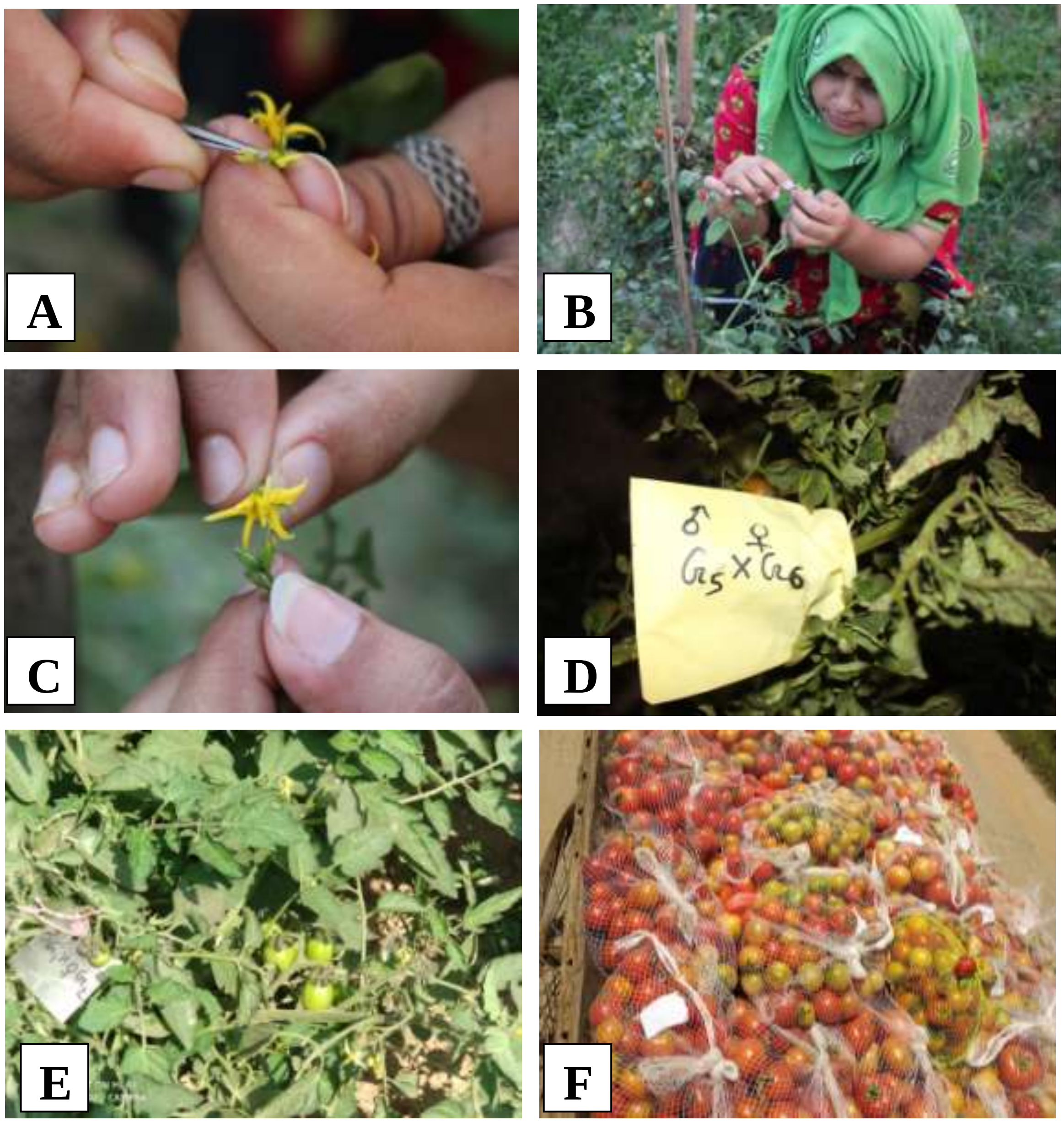


Plate 3. Hybridization procedure and harvesting A-B. Emasculation of female flower C. Dusting of pollen in emasculated flower D. Tagging of the crosses E. Fruit setting in the crossed flower F. Harvested fruits

emasculated flowers reciprocally. Each genotype was once counted as female parent and then male parent respectively. Thus diallel crosses were made. To ensure 100% success in cross product same crossing was done several times in several flowers. In a single cluster all the flowers were hybridized with the pollen of same genotype. After crossing, the flowers were bagged with paper envelop with proper labeling. After fruit setting envelops were removed and the fruit cluster were tagged carefully to ensure correct selection of crosses. Whole hybridization processes are shown in Plate 3 (A-E).

3.12 Harvesting and processing

Fruits were harvested in the maturity stage when fruits started ripening. Harvesting continued for about one and a half month as all the genotypes used in this experiment were indeterminate type and matured progressively at different dates and over a long period. After collection some fruits were used for chemical analysis and from some fruits seeds were collected and stored in 4^oC for 2^{nd} season and future use. Harvested fruits are shown in Plate 3F.

3.13 Data recording

Data were recorded from each pot based on different yield and yield contributing, physiological and nutritional traits. A view of data collection in the experimental site is shown in Plate 4A.

3.13.1 Agromorphogenic traits

Data for some physical parameters related to yield and yield contributing characters were recorded during the experiment. These traits are as following:

3.13.1.1 Plant Height (cm)

Five plants from each genotype from each plot were selected at random and plant height was measured at maturity stage after 75 days of transplanting.

Plate 4. Data collection for agromorphogenic and physiological traits. A. Yield related data collection B. Determination of chlorophyll content in leaf

3.13.1.2 Days to first flowering

Number of days required for first flower formation was recorded as the days passed from seedling transplanting to first flowering.

3.13.1.3 Days to 50% flowering

Number of days when flower at 50% plant of each genotype was formed was counted as the days passed from seedling transplanting to flowering in half of the plants.

3.13.1.4 Days to Maturity

The number of days needed for the plant to mature for fruit ripening was counted from the date of transplanting to date of first harvesting.

3.13.1.5 Number of branches per plant

Number of branches per plant was counted from each of the selected plant during maturity stage.

3.13.1.6 Number of clusters per plant

At the time of harvesting number of clusters per plant was recorded.

3.13.1.7 Number of fruits per cluster

All fruits in one cluster were recorded by randomly selecting five clusters in every selected plant.

3.13.1.8 Number of fruits per plants

Number of fruits per plant was recorded during maturity stage of plants from five plants from each genotype from each plot at random.

3.13.1.9 Average fruit weight (g)

Weight of randomly selected ten fruits from each selected plant was measured by electric precision balance and their mean value was calculated.

3.13.1.10 Fruit area index (cm^2)

Fruit length and diameter of five fruits from each selected plants were measured using Digital Caliper-515 (DC-515) in millimeter (mm), multiplying them fruit area was calculated and average of it were calculated and then converted it to centimeter (cm).

3.13.1.11 Number of locules per fruit

Five fruits of each replication of every genotype were cut into equal part horizontally and number of locules per fruit was recorded.

3.13.1.12 Skin diameter of fruit (mm)

Five fruits of each replication of every genotype were cut into equal part horizontally and their skin diameter was measured by using Digital Caliper-515 (DC-515).

3.13.1.13 Yield per plant

As all the genotypes were indeterminate type, fruits ripped at different times in the same plant of same genotype. So, when harvested every time number of fruits harvested from each plant and their weight were recorded and finally after final harvest their average weight were calculated as yield per plant.

3.13.2 Physiological traits

Physiological traits *viz*. leaf chlorophyll content, relative water content (RWC), moisture percentage in fruit was noted.

3.13.2.1 Leaf chlorophyll content

By using SPAD-502 plus Portable Chlorophyll meter leaf chlorophyll content was counted. The chlorophyll content was measured from the leaves of different genotype from three different portion of the leaf and then average was calculated. Determination of chlorophyll content in leaf is shown in Plate 4B.

3.13.2.2 Relative Water Content (RWC)

Barrs and Weatherly (1962) method was followed to measure relative water content (RWC). Whole fresh plant was weighted. Then the plant was kept in emerged water under light until the weight stayed constant to attain full turgid and then turgid weight was recorded. Then the plant was kept in hot air oven at 60°C for 72 hours and the dry weight was recorded. Finally, the following formula was used to calculate relative water content (RWC),

$$\text{Relative water content (\%)} = \frac{(\text{Fresh weight} - \text{Dry weight})}{(\text{Turgid weight} - \text{Dry weight})} \text{x } 100$$

After that dry weight of fruit was measured and moisture percentage was calculated by the following formula;

$$\text{Moisture Percent (\%)} = \frac{(\text{Weight of freash fruit} - \text{Weight of oven dry fruit})}{\text{Weight of freash fruit}} \times 100$$

3.13.3 Nutritional traits

Some nutritional parameters of tomato named Brix (%), Vitamin-C content (mg/100 g), pH of fruit and titrable acidity (%) were measured from ripe fruits.

3.13.3.1 Brix percentage (%)

With the help of portable Refractometer (ERMA, Tokyo, Japan) Brix percentages were measured at room temperature. Fruit juice was collected from a single fruit of each genotype by blending it to measure Brix percentage (%). Determination of Brix % is shown in Plate 5 (A-B).

3.13.3.2 Vitamin C content (mg/100 g fruit)

Through oxidation reduction titration method (Tee *et al*., 1988) Vitamin-C was determined by following formula;

$$\text{Vitamin C} = \frac{(0.5 \times \text{dye required for tomato juice} \times 100 \times 100)}{(\text{dye required for L}-\text{ascorbic acid} \times 5 \times \text{weight of fruit})}$$

The reagents and their preparation procedure are described in the following;

3.13.3.2.1 Dye preparation

260 mg 2, 6-dichloro indophenols and 210 mg sodium bicarbonate were mixed in one litter of distilled water. It was kept in the burette.

3.13.3.2.2 L-ascorbic acid preparation

10 mg granular L-ascorbic acid was taken in 100 ml volumetric flask and volume it with oxalic acid solution. Again 5 ml of the solution was taken in another volumetric flask and volume was made up to 100 ml. From this solution, 5 ml was titrated for 3 times against 2, 6-dichloro indophenols from burette. Their mean was recorded and this is the required amount of dye for titrating L-ascorbic acid.

3.13.3.2.3 5% oxalic acid preparation

50 mg oxalic acid was mixed in one litter of distilled water to clean the fruit and prepare fruit juice.

3.13.3.2.4 Preparation of tomato solution

After weighing a single fruit it was pressed and blended with few drops of oxalic acid solution. Through Whatman filter paper it was filtered to collect the juice. Volume was made up to 100 ml using oxalic acid solution.

From the mixture 5 ml was titrated against the dye solution kept in the burette. The amount of dye required was noted. Titration process is shown in Plate 5C.

3.13.3.3 Determination of Titrable acidity

4 gm NaOH pellet was mixed into 1000 ml distilled water and 0.1 N NaOH solution was prepared. It was poured in burette. After weighing a single fruit it was pressed and blended and fruit juice was collected by passing it through Whatman filter paper. Then adding distilled water volume was made up to 100 ml.

Plate 5. Data collection for nutritional traits A. Tomato juice preparation for chemical analysis B. Determination of brix% C. Titration for Vit-C and titrable acidity D. Determination of fruit pH.

10 ml solution was separated and 2 drops of Phenolphthalein was added in it. It was titrated against former prepared 0.1 N NaOH and the amount of NaOH required was noted. Titration process is shown in Plate 5C. Finally titrable acidity was determined by following formula;

$$\%\text{Acidity} = \frac{(titrate \times Normality\ of\ alkali \times volume\ madeup \times Equivalent\ wt.of\ acid \times 100)}{(Volume\ of\ sample\ taken \times weight\ of\ sample \times 1000)}$$

3.13.3.4 Determination of Fruit pH

Fruit juice was collected from a single fruit of each genotype by blending it to measure fruit pH using REX pH meter model –PHS-3C. The electrode was inserted into the juice to get pH value. pH determination is shown Plate 5D.

3.14 Statistical analysis

The data recorded for different characters were analyzed statistically to measure the significant difference among different tomato lines. Through 'F' test the mean values of all the characters were evaluated and analysis of variance was performed. The significant difference among the treatments means was measured by the least significant difference (LSD) test at 5% and 1% level. (Gomez and Gomez, 1984).

3.14.1 Analysis of variance (ANOVA)

The objective of the experiment was to evaluate the performance of the hybrids and their parents, so data were recorded from all the genotypes and F_1 hybrids. To find out the variation among the different genotypes the collected data for various different traits were analyzed statistically using MSTAT-C program for F-test as it was a single factor experiment (Table 4). Coefficient of variation (CV%) was calculated as of Gomez and Gomez (1984). From the ANOVA combining ability was estimated and heterosis was calculated from the mid values.

Table 4. The general form of ANOVA for combining ability

Source of variation	d.f.	Sum of squares	Mean sum squares	F-test	Expected mean squares
GCA	p − 1	Sg	Mg	MSg/MSe	σ_e^2+ (p+2)$\left\{\frac{1}{(p-1)}\right\}$ $\sum Gi^2$
SCA	$p(p-1)/2$	Ss	Ms	MSs/MSe	σ_e^2+$\left\{\frac{2}{p(p-1)}\right\}\sum_i\sum_j S_{ij}^2$ $i<j$
Error	$(r-1)(p-1)$	Se	Me		σ_e^2

3.14.2 Statistical procedure used for combining ability analysis

In 1956, Griffing proposed four methods of analysis of combining ability depending on the materials used. Griffing has also considered Eisenhart's model I (fixed effect) and model II (random effect) in the analysis. In this study combining ability analysis were calculated as method 1 (including reciprocals) and Model-I. The mathematical model for the analysis was as follows

Yij = m + gi + gj + Sij + 1/$bc \sum \sum kl\ eijkl$

Where, i, j=1, 2, ………………., p

K=l, 2, ………………., b

L=1, 2, ………………., c

P = Number of parents

b = Number of blocks or replications

c = Number of observation in each plot

Yi = the mean of i^{th} x j^{th} genotype over K and L

m = the population mean

gj= The general combining ability (GCA) effect to i^{th} parent

gj = The GCA of j^{th} parent

sij = The SCA effect such that sij = sji

$1/bc \sum \sum kl\ eijkl$ = the mean error effect

The restriction imposed: $\sum gi = 0$ and $\sum Sij + Sii = 0$

GCA = general combining ability

SCA = specific combining ability

p = Number of parents

r = Number of blocks or replications

Yi = Array total of the i^{th} parent

Yjj = Mean value of the i^{th} parent

Yg = Grand total of the p(p-l)/2 crosses and parental lines

Yij= Progeny mean values in the diallel table

Se = Sum of square due to error

Sg= $\frac{1}{(P+2)}\left[\sum_i (Yi + Yii)^2 - \frac{4}{p} Y..^2\right]$

$$Ss = \sum_i \sum_j Y_{ij}^2 \frac{1}{(p+2)} \sum(Yi + Yii)^2 + \frac{2}{(p+1)(p+2)} Y..^2$$

The GCA and SCA effects of each character were calculated as follows:

$$gi = \frac{1}{(p+2)} \left[\sum_i (Yi + Yii)^2 - \frac{2}{p} Y..^2 \right]$$

$$Sij = Yij - \frac{1}{(p+2)} \sum_i (yi + yii + yj + yji) + \frac{2}{(p+1)(p+2)} Y..$$

The variance of GCA and SCA were,

$$Var(gi) = \frac{(P-1)}{p(p+2)} \sigma_e^2$$

$$Var(Sij) = \frac{2(P-1)}{(P+1)(P+2)} \sigma_e^2 \ (i \neq j)$$

Standard error (SE) of an estimate was calculated the square root of the variance of concerned estimate eg.

j Var (g;) and j Var (s.)

$\sqrt{Var(gi)}$ and $\sqrt{Var(Sij)}$

3.14.3 Estimation of heterosis

The amount of heterosis of the F_1 s was calculated using the following formula:

Heterosis over better parent (%) = $\frac{(\overline{F_1} - \overline{BP})}{\overline{BP}} \times 100$

Here,

$\overline{F_1}$ = Mean of F_1 individuals

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

Heterosis over mid parent (%) = $\frac{(\overline{F_1} - \overline{MP})}{\overline{MP}} \times 100$

Here,

$\overline{F_1}$ = Mean of F1 individuals

$\overline{MP}$ = Mean of the mid parent values

CD (Critical Difference) values were used to test significance of heterotic effects.

Critical Differences (CD) = t × $\sqrt{\frac{2EMS}{r}}$

Here,

EMS= Error Mean Sum of square

r = No. of replication

t = Tabulated t value at error d.f.

CD values were compared with the values come from $(\overline{F_1} - \overline{BP})$ and $(\overline{F_1} - \overline{MP}$ to test significant effect of heterosis.

RESULT AND DISCUSSION

RESULT AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to perform the diallel analysis of different genotypes of tomato (*Solanum Lycopersicum* L.) using yield contributing traits. This chapter comprises the presentation and discussion of the findings obtained from the experiment. The fruits were harvested when the color of the fruit started to change from green to orange red. The data pertaining to ten characters have been presented and statistically analyzed with the possible interpretations. The fruits of F_1 generation are shown in Appendix V.

4.1. Mean performance and analysis of variance

Mean performance of 19 yield related agro-morphogenic traits of parents and cross combinations are presented in Table 5 and in Table 6. Significant genotypic variations were observed for all the characters under studied (Appendix VI).

4.1.1 Plant height

Among the eight parents G2 showed the lowest plant height where G6 showed the highest plant height. Among the 56 cross combinations G3×G6 (161.33) showed the highest plant height, and the lowest plant height was observed in G5×G2 (58.00) (Table 5).

4.1.2 Days to first flowering

Among the eight parents G6 took the shortest period for first flowering where G3 took the highest period (Table 5). Among the 56 cross combinations G7×G6 (56) took the longest time for days to 1^{st} flowering, and the lowest was observed in G7×G2 (37.00).

4.1.3 Days to 50% flowering

Out of eight parents G3 took the longest period for 50% flowering where G6 took the lowest period of Days to 50% flowering (Table 5). Among the 56 cross

Table 5. Mean performance for 9 different characters in eight parents and their 56 F_1s of *Solanum lycopersicum* L.

Genotype	Plant Height	Days to First Flowering	Days to 50% Flowering	Number of Branches per Plant	Number of Cluster per Plant	Number of Fruit per Cluster	Number of Fruit per Plant	Days to Maturity	Fruit Weight
G1	80.67	47.67	57.00	13.00	17.67	4.67	43.00	83.00	26.05
G2	41.67	50.00	59.67	10.33	15.67	4.33	40.67	80.33	20.59
G3	114.00	52.33	61.33	10.00	17.33	4.33	31.33	80.00	17.29
G4	104.67	40.33	50.33	11.67	18.67	4.00	34.67	81.67	28.36
G5	104.00	47.67	57.67	16.00	18.33	6.00	33.33	86.00	27.54
G6	147.33	38.67	48.33	10.33	15.67	5.00	37.33	80.33	45.21
G7	82.33	45.00	55.00	11.67	18.67	3.33	38.00	81.67	23.63
G8	60.33	47.00	56.67	13.00	16.00	4.67	39.67	83.00	25.03
G1 × G2	58.67	51.67	60.33	9.67	15.33	4.67	40.67	79.67	52.18
G1 × G3	133.33	51.67	62.33	13.33	20.00	4.67	44.67	83.33	24.76
G1 × G4	97.67	38.67	47.67	11.67	17.33	4.67	47.67	81.67	20.78
G1 × G5	117.67	42.67	53.33	15.33	20.33	4.67	23.33	85.33	27.86
G1 × G6	119.00	43.33	52.67	11.33	19.67	5.00	32.67	81.33	15.85
G1 × G7	80.67	46.33	55.67	14.00	19.33	4.33	45.00	84.00	24.67
G1 × G8	80.67	47.00	58.00	9.00	18.33	4.67	38.00	79.00	20.35
G2 × G1	88.33	49.00	58.33	17.00	20.00	4.00	45.33	87.00	19.17
G2 × G3	89.67	48.00	57.67	9.00	16.67	5.00	41.00	79.00	30.71
G2 × G4	79.33	50.00	61.00	12.67	17.00	4.33	41.00	82.67	22.37
G2 × G5	102.00	41.33	51.33	13.33	16.67	4.00	34.33	83.33	37.37
G2 × G6	117.33	47.67	58.00	13.00	19.00	4.33	31.33	83.00	35.12
G2 × G7	70.33	39.33	49.67	11.33	18.33	5.00	32.00	81.33	54.04
G2 × G8	70.00	45.33	55.33	9.67	20.33	4.67	39.67	79.67	26.17
G3 × G1	86.67	45.67	55.33	12.67	16.33	6.00	32.67	82.67	30.05
G3 × G2	58.67	50.67	61.00	12.00	19.67	3.67	46.33	82.00	35.03

Table 5. (Cont'd)

Genotype	Plant Height	Days to First Flowering	Days to 50% Flowering	Number of Branches per Plant	Number of Cluster per Plant	Number of Fruit per Cluster	Number of Fruit per Plant	Days to Maturity	Fruit Weight
G3×G4	110.33	52.33	62.67	9.33	15.33	3.33	44.67	79.33	40.49
G3×G5	122.33	37.00	46.67	16.33	22.00	4.00	40.67	86.33	36.45
G3×G6	161.33	49.00	59.00	14.67	20.67	5.00	42.67	84.67	33.03
G3×G7	125.00	46.00	56.00	11.00	16.33	4.67	42.33	81.00	22.14
G3×G8	76.00	43.33	53.67	12.00	18.33	4.67	36.33	82.00	27.44
G4×G1	91.00	45.67	55.67	15.00	21.67	5.33	36.00	85.00	47.22
G4×G2	72.33	51.00	61.00	9.67	15.67	4.00	42.00	79.67	22.26
G4×G3	101.67	38.67	48.33	7.33	13.33	5.67	37.33	77.33	27.31
G4×G5	114.00	52.67	63.00	12.67	18.00	3.00	40.00	82.67	25.55
G4×G6	154.00	44.00	50.33	9.00	18.33	5.00	35.00	79.00	38.64
G4×G7	115.67	44.33	56.33	10.00	15.00	5.00	44.00	80.00	34.65
G4×G8	85.67	51.67	61.00	9.33	15.67	5.67	39.33	79.33	40.73
G5×G1	90.33	46.33	53.00	16.67	22.33	3.33	32.00	86.67	40.17
G5×G2	58.00	47.67	60.67	12.67	18.67	5.33	38.00	82.67	25.39
G5×G3	90.33	51.67	61.67	11.33	19.33	5.00	43.00	81.33	30.20
G5×G4	97.00	41.67	49.33	9.00	15.00	4.00	38.67	79.00	17.99
G5×G6	130.33	53.00	62.67	12.33	17.67	5.00	41.33	82.33	21.27
G5×G7	110.33	48.00	60.67	10.33	16.33	4.33	38.33	80.33	21.99
G5×G8	91.67	49.00	54.33	11.33	17.67	5.00	38.00	81.33	40.09
G6×G1	116.67	53.00	65.00	8.33	14.33	4.00	38.67	78.33	31.31
G6×G2	70.00	39.33	49.00	12.00	18.33	4.33	45.33	82.00	25.64
G6×G3	87.33	45.67	59.00	11.00	18.33	5.00	39.33	81.00	29.20
G6×G4	126.00	40.67	52.33	12.00	17.67	4.67	39.33	82.00	26.25
G6×G5	137.67	51.33	59.67	9.67	18.00	5.00	41.67	79.67	22.35
G6×G7	113.00	47.00	57.00	13.33	16.67	4.67	38.33	83.33	32.47

Table 5. (Cont'd)

Genotype	Plant Height	Days to First Flowering	Days to 50% Flowering	Number of Branches per Plant	Number of Cluster per Plant	Number of Fruit per Cluster	Number of Fruit per Plant	Days to Maturity	Fruit Weight
G6×G8	133.33	44.00	53.33	13.00	18.00	3.33	37.67	83.00	26.98
G7×G1	96.33	45.00	54.67	8.00	14.00	4.67	43.00	78.00	27.76
G7×G2	81.67	37.00	47.33	8.67	14.67	4.33	42.33	78.67	24.45
G7×G3	86.67	43.00	52.67	11.67	17.33	5.00	45.33	81.67	26.90
G7×G4	97.33	48.00	58.33	14.33	20.33	4.00	42.67	84.33	38.86
G7×G5	82.33	47.33	57.00	15.33	20.67	4.67	41.67	85.33	27.65
G7×G6	138.33	56.00	65.33	14.33	21.00	4.67	35.00	84.33	20.00
G7×G8	79.33	47.67	58.33	12.67	18.33	4.00	38.67	82.67	32.80
G8×G1	99.00	42.00	50.33	12.33	18.00	4.00	31.33	82.33	45.88
G8×G2	112.67	42.33	51.33	13.00	18.67	5.00	33.33	83.00	23.49
G8×G3	89.33	44.33	54.33	10.67	16.33	3.67	40.33	80.67	42.72
G8×G4	104.67	45.00	55.00	10.67	17.33	4.67	38.67	80.67	34.17
G8×G5	86.00	47.67	56.33	9.00	15.33	4.00	40.67	79.00	21.97
G8×G6	132.00	46.67	56.00	8.67	15.00	4.33	31.33	78.67	25.96
G8×G7	123.67	52.67	63.00	10.67	16.67	3.67	32.33	80.67	27.92
Average	99.62	46.34	56.17	11.72	17.73	4.52	38.76	81.72	29.66
Maximum	161.33	56.00	65.33	17.00	22.33	6.00	47.67	87.00	54.04
Minimum	41.67	37.00	46.67	7.33	13.33	3.00	23.33	77.33	15.85

Table 6. Mean performance for 10 different characters in eight parents and their 56 F_1s of *Solanum lycopersicum* L.

Genotype	Fruit Skin Diameter (mm)	Number of locule per fruit	Fruit area index (cm^2)	Yield per Plant (kg)	Leaf Chlorophyll Content	Relative Water Content	Brix (%)	Vitamin C content	Titrable Acidity (%)	Fruit pH
G1	0.67	29.90	1389.67	1122.80	29.90	22.185	5.00	19.157	3.210	4.45
G2	0.40	46.80	1062.67	839.97	46.80	23.952	5.00	16.437	2.784	3.58
G3	0.40	47.90	1303.67	554.92	47.90	20.566	7.00	20.866	5.217	4.92
G4	0.53	69.90	1555.33	983.32	69.90	45.946	4.00	26.936	4.567	3.53
G5	0.53	42.20	979.33	942.32	42.20	55.432	4.00	31.008	3.362	3.83
G6	0.40	27.90	1942.67	1700.63	27.90	32.642	5.00	23.262	2.800	3.29
G7	0.43	36.30	1306.00	867.61	36.30	60.406	4.00	38.377	2.865	3.20
G8	0.40	35.30	990.00	988.47	35.30	44.000	5.00	50.236	2.210	3.42
G1×G2	0.53	36.40	2585.33	2073.15	36.40	38.188	3.50	36.651	1.926	3.13
G1×G3	0.50	34.80	1176.67	1117.44	34.80	50.633	4.00	37.303	3.712	3.48
G1×G4	0.47	34.30	1087.00	968.91	34.30	36.240	5.00	16.200	3.914	3.38
G1×G5	0.47	39.90	1508.00	653.41	39.90	61.825	4.10	37.900	3.369	3.24
G1×G6	0.43	40.70	995.33	529.46	40.70	46.918	5.00	16.500	3.220	3.03
G1×G7	0.40	21.50	838.00	1106.23	21.50	46.409	4.00	19.900	2.785	3.05
G1×G8	0.43	32.50	1147.33	766.13	32.50	72.184	5.00	34.800	4.751	3.27
G2×G1	0.40	26.30	1279.67	875.56	26.30	44.960	5.00	25.300	1.711	4.06
G2×G3	0.40	26.00	1532.33	1226.36	26.00	62.956	5.00	39.700	1.624	3.54
G2×G4	0.53	37.00	1953.00	915.12	37.00	58.392	4.00	28.500	2.707	3.39
G2×G5	0.40	35.20	1205.33	1288.46	35.20	50.099	4.50	29.800	3.699	3.81
G2×G6	0.43	28.60	1535.67	1107.11	28.60	93.462	4.00	43.900	2.984	3.17
G2×G7	0.57	34.60	1266.67	1734.19	34.60	67.925	3.90	28.900	1.110	4.52
G2×G8	0.63	37.00	1937.33	1024.29	37.00	53.002	5.00	27.800	2.083	3.71
G3×G1	0.40	27.00	1823.67	972.92	27.00	48.538	4.30	19.800	0.904	4.19
G3×G2	0.50	27.00	1148.00	1616.30	27.00	46.500	5.00	21.500	1.840	3.64

Table 6. (Cont'd)

Genotype	Fruit Skin Diameter (mm)	Number of locule per fruit	Fruit area index (cm^2)	Yield per Plant (kg)	Leaf Chlorophyll Content	Relative Water content	Brix (%)	Vitamin C content	Titrable Acidity (%)	Fruit pH
G3×G4	0.47	52.33	1408.33	1812.84	58.80	53.458	4.50	33.700	2.756	3.44
G3×G5	0.53	37.00	1896.00	1488.91	39.00	42.270	4.00	25.500	2.542	3.59
G3×G6	0.50	49.00	1642.33	1395.11	38.50	30.200	3.90	23.800	2.261	5.12
G3×G7	0.43	46.00	1593.33	924.20	33.30	16.700	4.50	20.900	3.057	3.06
G3×G8	0.50	43.33	1381.33	990.20	25.70	38.900	7.50	11.800	3.411	3.22
G4×G1	0.47	45.67	1517.00	1697.00	38.30	33.300	4.00	24.000	5.129	3.80
G4×G2	0.43	51.00	928.00	933.35	25.00	45.100	5.00	13.300	5.442	3.42
G4×G3	0.50	38.67	1087.33	977.20	37.00	19.300	4.00	33.200	4.628	3.29
G4×G5	0.60	52.67	2150.00	1039.49	38.60	39.400	4.00	13.700	2.986	3.26
G4×G6	0.63	44.00	1460.67	1346.75	51.70	47.500	4.00	16.800	2.077	3.08
G4×G7	0.47	44.33	2355.00	1517.52	30.90	30.900	5.00	31.400	4.335	3.60
G4×G8	0.50	51.67	1716.00	1611.47	49.70	47.400	4.80	22.300	6.288	3.87
G5×G1	0.43	46.33	2345.33	1273.09	32.70	36.700	3.00	34.500	2.860	4.17
G5×G2	0.43	47.67	2153.33	970.53	42.70	53.700	2.90	24.700	4.060	3.11
G5×G3	0.53	51.67	1753.67	1294.23	36.40	29.200	3.00	25.300	3.289	3.73
G5×G4	0.53	41.67	1284.00	696.90	45.50	36.200	4.00	38.600	3.240	3.30
G5×G6	0.37	53.00	1096.67	876.03	37.50	43.500	4.20	25.200	2.041	3.18
G5×G7	0.50	48.00	1220.00	845.82	35.30	49.600	3.00	25.600	1.104	3.93
G5×G8	0.53	49.00	1226.67	1525.97	39.30	54.800	3.20	16.600	1.270	3.50
G6×G1	0.40	53.00	1461.33	1217.92	39.40	42.300	5.00	18.600	5.070	3.26
G6×G2	0.47	39.33	1177.33	1161.79	48.20	50.500	3.00	28.600	2.453	3.56
G6×G3	0.40	45.67	1402.00	1132.38	37.20	41.300	3.90	21.600	7.823	3.31
G6×G4	0.33	40.67	2002.67	1032.46	44.00	37.100	4.50	30.200	4.420	3.43
G6×G5	0.43	51.33	1086.33	932.48	40.60	48.300	5.00	16.700	3.870	3.73
G6×G7	0.47	47.00	1521.33	1247.29	35.00	34.200	4.30	38.900	6.529	3.82

Table 6 (Cont'd)

Genotype	Fruit Skin Diameter (mm)	Number of locule per fruit	Fruit area index (cm^2)	Yield per Plant (kg)	Leaf Chlorophyll Content	Relative Water content	Brix (%)	Vitamin C content	Titrable Acidity (%)	Fruit pH
G6×G8	0.47	44.00	1842.67	1018.50	43.70	40.000	4.00	33.300	2.441	3.53
G7×G1	0.50	45.00	1656.33	1192.18	43.30	53.500	3.50	45.100	1.842	3.40
G7×G2	0.43	37.00	1177.33	1032.24	49.60	51.100	5.00	19.300	0.966	4.19
G7×G3	0.53	43.00	1168.67	1211.96	44.50	29.300	5.00	39.400	1.615	3.57
G7×G4	0.50	48.00	1060.33	1657.20	42.00	16.200	3.90	47.500	1.521	3.32
G7×G5	0.43	47.33	1844.67	1151.72	36.30	37.900	4.20	30.900	2.539	3.56
G7×G6	0.53	56.00	1055.00	707.62	49.30	16.500	3.90	47.400	2.329	3.34
G7×G8	0.67	47.67	1239.67	1320.56	37.80	19.900	4.00	36.700	3.751	3.38
G8×G1	0.43	42.00	1242.33	1398.49	46.60	34.800	3.60	53.700	2.333	4.11
G8×G2	0.40	42.33	1001.67	788.24	42.30	25.300	4.40	33.800	2.438	4.50
G8×G3	0.50	44.33	1730.67	1729.23	30.50	39.700	5.00	37.800	1.417	3.80
G8×G4	0.43	45.00	1811.00	1308.34	69.70	28.500	4.50	37.900	1.269	3.33
G8×G5	0.37	47.67	1069.67	889.79	35.40	29.800	5.20	46.700	2.338	4.30
G8×G6	0.50	46.67	1372.00	855.90	46.40	43.900	3.20	35.700	3.872	3.90
G8×G7	0.70	52.67	1263.67	925.10	36.30	28.900	3.60	42.500	3.342	3.12
Average	0.48	46.34	1452.35	1142.24	38.89	41.883	4.34	29.593	3.067	3.61
Maximum	0.70	56.00	2585.33	2073.15	69.90	93.462	7.50	53.700	7.823	5.12
Minimum	0.33	37.00	838.00	529.46	21.50	16.200	2.90	11.800	0.904	3.03

combinations G7×G6 (65.33) took the longest time for 50% flowering and the lowest was observed in G3×G5 (46.67) (Table 5).

4.1.4 Number of branches per plant

Among the parents G3 had the lowest Number of branches per plant where G5 was the highest (Table 5). Among the cross combinations G2×G1 (17.00) was the highest in Number of branches per plant and lowest was observed in G4×G3 (7.33).

4.1.5 Number of cluster per plant

G2 among the eight parents had the lowest cluster per plant where G7 was the highest. Among the 56 cross combinations G5×G1 (22.33) was the highest for in mean number of cluster and lowest was observed in G4×G3 (13.33) (Table 5).

4.1.6 Number of fruit per cluster

G7 among the eight parents had the lowest number of fruit per cluster where G5 was the highest. Out of the 56 cross combinations G3×G1 (6.00) was the highest for in number of fruit in each cluster and lowest was observed in G4×G5 (3.00).

4.1.7 Number of fruits per Plant

Among the eight parents lowest number of fruits per plant was in G3 and in G1 it was the highest. Among 56 cross combinations, in G1×G4 (47.67) number of fruit per plant was highest and in G1×G5 (23.33) it was observed the lowest (Table 5).

4.1.8 Days to maturity

Among the parents G3 was of the shortest period of Days to maturity where G5 was the longest. Among the 56 cross combinations G2×G1 (87.00) had the largest period of Days to maturity and the lowest was observed in G4×G3 (77.33) (Table 5).

4.1.9 Average fruit weight (g)

Average fruit weight (g) was highest in G5 and lowest in G3 among the eight parents and in the 56 cross combinations G2×G7 (54.04) was the highest and G1×G6 (15.85) showed the lowest (Table 5).

4.1.10 Fruit skin diameter (mm)

Out of the eight parents G2 had the smallest fruit skin diameter (mm) where as G1 had the largest. Among the 56 cross combinations G2×G1 (87) had the largest Fruit skin diameter (mm) and the lowest was found in G4×G3 (77.33) (Table 6).

4.1.11 Number of locule per fruit

Number of locule per fruit was highest in G4 and lowest in G6 among the eight parents and in the 56 cross combinations G7×G6 (56.00) was the highest and G1×G7 (21.5) showed the lowest number of locule per fruit (Table 6).

4.1.12 Fruit area index (cm^2)

Out of eight parents G6 took the largest Fruit area index where G5 took the lowest Fruit area index (Table 6). Among the 56 cross combinations G1×G2 (2585.33) took the largest Fruit area index (cm^2), and the lowest was observed in G1×G7 (838.00).

4.1.13 Fruit Yield per plant (kg)

Among the eight parents lowest Fruit Yield per plant was in G3 where G5 took the highest Fruit Yield per plant. Among the 56 cross combinations G2×G1 (17) had the highest Fruit Yield per plant (kg) and the lowest was observed in G4×G3 (7.33) (Table 6).

4.1.14 Leaf chlorophyll content

Leaf chlorophyll content was highest in G4 and lowest in G6 among the eight parents and in the 56 cross combinations G8×G4 (69.7) was the highest and G1×G7 (21.5) showed the lowest Leaf chlorophyll content.

4.1.15 Relative Water Content (RWC)

Out of the eight parents G3 was of the higher Relative Water Content (RWC) where G7 was the lower Relative Water Content (RWC). Among the 56 cross combinations G2×G6 (93.462) had the higher Relative Water Content (RWC) and the lowest was observed in G7×G4 (16.2) (Table 6).

4.1.16 Brix percentage (%)

The highest Brix percentage (%) was observed in G3 and lowest in G7 among the eight parents and in the 56 cross combinations G3×G8 (7.50) was the highest and G5×G2 (2.90) showed the lowest Brix percentage (%) in each fruit.

4.1.17 Vitamin C content (mg/100 g fruit)

Out of eight parents G8 took the higher Vitamin C content (mg/100 g fruit) where G2 took the lowest Vitamin C content (mg/100 g fruit). Among the 56 cross combinations G8×G1 (53.7) took the highest Vitamin C content (mg/100 g fruit) and the lowest was observed in G3×G8 (11.8).

4.1.18 Titrable acidity (%)

Among the eight parents lowest Titrable acidity (%) was in G3 where G5 took the highest (Table 6). Among the 56 cross combinations G2×G1 (17) had the highest Fruit Yield per plant (kg) and the lowest was observed in G4×G3 (7.33).

4.1.19 Fruit pH

Among the eight parents G7 showed the smallest fruit length where G3 showed the longest. Among the 56 cross combinations G3×G6 (5.12) had the largest Fruit pH and the lowest was observed in G1×G6 (3.03) (Table 6).

4.2 Combining Ability

The analysis of variances for general combining ability (GCA) and specific combining ability (SCA) were found significant for most of the traits studied (Table 7) indicating both additive and non-additive gene actions for the expression of these traits. The general combining ability (GCA) variances for most of the traits studied higher than the specific combining ability variances indicating the predominance of the additive effect for these traits. The GCA component is predominantly a function of the additive genetic variance and GCA variances with each parent plays significant role in the choice of parents.

A parent with higher positive significant GCA effects is considered as a good general combiner and the magnitude and direction of the significant effects for the eight parents provide meaningful comparisons and would give indications to the future breeding programme. The results of GCA effects for nineteen different characters were estimated and presented in Table 8. The SCA effects signify the role of non-additive gene action in the expression of the traits. It indicates the highly specific combining ability leading to highest performance of some specific cross combinations. That is why it is related to a particular cross. High GCA may arise not only in crosses involving high combiners but also in those involving low combiners. Thus in practice, some of the low combiners should also be accommodated in hybridization programme. The SCA effects of 56 F_1 crosses for the same characters are presented in Table 9.

4.2.1 Plant height

The mean square (MS values) for GCA and SCA were significant for this trait which suggests the presence of both additive and non-additive gene action for this character (Table 7). Among the eight parent studies the parent G6 (27.318**) showed the significant positive GCA effects. On the other hand, G2 (-23.849**) and G8 (-6.828**) showed the significant negative GCA effect. So the parent G6 was the best general combiner for plant height (Table 8).

Among the 56 cross combinations 8 crosses showed significant positive SCA effects (Table 9). The highest positive significant effect was G6×G3 (37.000**) and the lowest positive significant effect was G3×G2 (15.500*). Thus these 8

Table 7. Analysis of variances (MS values) for GCA and SCA

Source	d.f	Plant Height	Days to First Flowering	Days to 50% Flowering	Number of Branches per Plant	Number of Cluster per Plant	Number of Fruit per Cluster	Number of Fruit per Plant	Days to Maturity	Fruit Weight
GCA	7	3248.62**	4.76 ns	4.98 ns	7.47**	3.07ns	0.18 ns	21.90**	7.47**	10.95 ns
SCA	21	205.79*	32.06**	33.03**	5.51**	5.17*	0.59 ns	33.21**	5.51**	89.64**
Reciprocal	21	596.26**	25.93**	31.60**	7.38**	6.28**	0.55 ns	25.60**	7.38**	126.19**
Error	126	122.05	9.52	9.81	2.49	3.29	0.50	6.29	2.49	32.09
GCA:SCA		15.79	0.15	0.15	1.36	0.59	0.31	0.66	1.36	0.12
σ2g		190.27	-1.68	-1.73	0.13	-0.13	-0.03	-0.68	0.13	-4.85
σ2s		47.01	12.65	13.04	1.70	1.05	0.05	15.11	1.70	32.31

Table 7. (Cont'd)

Source	d.f	Fruit Skin Diameter (mm)	Number of Locule per fruit	Fruit area index (cm^2)	Yield per Plant (kg)	Leaf Chlorophyll content	Relative Water content	Brix (%)	Vitamin C Content	Titrable Acidity (%)	Fruit pH
GCA	7	0.01 ns	1.31**	61357.44**	38389.93 ns	198.43**	264.34**	1.31**	191.09**	2.87**	0.22**
SCA	21	0.01 ns	0.74**	173970.64**	147277.74**	111.66**	320.77**	0.92**	103.62**	1.86**	0.29**
Reciprocal	21	0.01 ns	1.51**	263833.92**	161730.55**	77.31**	214.82**	0.70**	140.44**	3.19**	0.25
Error	126	0.01	0.10	2087.30	48969.45	$1.23E^{-12}$	$6.16E^{-13}$	$6.02E^{-15}$	3.08E-13	$5.41E^{-15}$	$2.41E^{-15}$
GCA:SCA		0.59	1.77	0.35	0.26	1.78	0.82	1.42	1.84	1.54	0.76
σ2g		0.00	0.04	-6849.86	-6697.69	5.55	-3.18	0.03	5.58	0.07	0.00
σ2s		0.00	0.36	96495.91	55190.62	62.69	180.08	0.52	58.17	1.04	0.16

ns=Non-significant, *=Significant at 5% probability level, **= Significant at 1% probability level

Table 8. General combining ability (GCA) effects of parents in a Diallele cross of *Solanum lycopersicum* L.

Parents	Plant Height	Days to First Flowering	Days to 50% Flowering	Number of Branches per Plant	Number of Cluster per Plant	Number of Fruit per Cluster	Number of Fruit per Plant	Days to Maturity	Fruit Weight
G1	-4.786 ^{ns}	0.120 ^{ns}	-0.151 ^{ns}	0.797 **	0.542 ^{ns}	0.068 ^{ns}	-0.193 ^{ns}	0.797 **	0.352 ^{ns}
G2	-23.849 **	-0.068 ^{ns}	0.161 ^{ns}	-0.203 ^{ns}	-0.208 ^{ns}	-0.057 ^{ns}	0.870 ^{ns}	-0.203 ^{ns}	0.005 ^{ns}
G3	3.297 ^{ns}	0.641 ^{ns}	0.891 ^{ns}	-0.328 ^{ns}	0.062 ^{ns}	0.109 ^{ns}	1.203 **	-0.328 ^{ns}	-0.217 ^{ns}
G4	3.880 ^{ns}	-1.026 ^{ns}	-1.005 ^{ns}	-0.724 ^{ns}	-0.542 ^{ns}	-0.057 ^{ns}	0.974 ^{ns}	-0.724 ^{ns}	1.219 ^{ns}
G5	2.755 ^{ns}	0.703 ^{ns}	0.391 ^{ns}	1.234 **	0.687 ^{ns}	0.068 ^{ns}	-1.359 **	1.234 **	-1.444 ^{ns}
G6	27.318 **	-0.214 ^{ns}	-0.172 ^{ns}	-0.266 ^{ns}	0.021 ^{ns}	0.130 ^{ns}	-0.984 ^{ns}	-0.266 ^{ns}	0.002 ^{ns}
G7	-1.786 ^{ns}	-0.234 ^{ns}	0.203 ^{ns}	0.089 ^{ns}	-0.083 ^{ns}	-0.161 ^{ns}	1.057 ^{ns}	0.089 ^{ns}	-0.681 ^{ns}
G8	-6.828 **	0.078 ^{ns}	-0.318 ^{ns}	-0.599 ^{ns}	-0.479 ^{ns}	-0.099 ^{ns}	-1.568 **	-0.599 ^{ns}	0.765 ^{ns}
Var (gi)	2.583	0.722	0.732	0.369	0.424	0.166	0.587	0.369	1.325
Var (gi-gj)	3.906	1.091	1.107	0.557	0.641	0.251	0.887	0.557	2.003

^{ns}=Non-significant, *=Significant at 5% probability level, **= Significant at 1% probability level

Table 8. (Cont'd)

Parents	Fruit Skin Diameter (mm)	Number of Locule per fruit	Fruit area index (cm^2)	Yield per Plant (kg)	Leaf Chlorophyll content	Relative Water Content	Brix (%)	Vitamin C Content	Titrable Acidity (%)	Fruit pH
G1	-0.002 ^{ns}	-0.208 **	12.818 ^{ns}	-11.767 ^{ns}	-4.297 **	1.296 **	-0.023 **	-0.932 **	0.054 **	0.046 **
G2	-0.017**	0.271 **	-14.453 ^{ns}	9.428 ^{ns}	-2.047 **	7.435 **	0.052 **	-2.429 **	-0.529 **	0.073 **
G3	-0.008 ^{ns}	0.003 ^{ns}	7.130 ^{ns}	45.210 *	-1.922 **	-5.002 **	0.514 **	-2.528 **	0.140 **	0.193 **
G4	0.019 **	0.313 **	105.839 **	75.339 **	7.503 **	-3.078 **	-0.011 **	-2.019 **	0.673 **	-0.173 **
G5	0.003 ^{ns}	0.250 **	35.047 ^{ns}	-91.519 **	-0.216 **	3.377 **	-0.442 **	-1.235 **	-0.197 **	0.021 **
G6	-0.029 ^{ns}	-0.063 ^{ns}	18.693 ^{ns}	-19.607 ^{ns}	0.897 **	0.678 **	-0.092 **	-1.860 **	0.495 **	-0.106 **
G7	0.023**	-0.021 ^{ns}	-85.349 **	2.080 ^{ns}	-1.247 **	-3.142 **	-0.223 **	4.854 **	-0.408 **	-0.093 **
G8	0.015 ^{ns}	-0.542 **	-79.724 **	-9.164 ^{ns}	1.328 **	-1.565 **	0.227 **	6.149 **	-0.228 **	0.040 **
Var (gi)	0.017	0.074024	114.149	51.74956	2.5956E^{-07}	1.84E^{-07}	1.81E^{-08}	1.3E^{-07}	1.72E^{-08}	1.15E^{-08}
Var (gi-gj)	0.026	0.111914	260.912	78.23798	3.9241E^{-07}	2.77E^{-07}	2.74E^{-08}	1.96E^{-07}	2.6E^{-08}	1.73E^{-08}

^{ns}=Non-significant, *=Significant at 5% probability level, **= Significant at 1% probability level

Table 9. Specific combining ability (SCA) effects of among the F_1 generation in a Diallele cross of *Solanum lycopersicum* L.

F_1 Generation	Plant Height	Days to First Flowering	Days to 50% Flowering	Number of Branches per Plant	Number of Cluster per Plant	Number of Fruit per Cluster	Number of Fruit per Plant	Days to Maturity	Fruit Weight
G1×G2	2.516 ^{ns}	3.943 *	3.151 ^{ns}	1.016 ^{ns}	-0.396 ^{ns}	-0.193 ^{ns}	3.568 *	1.016 ^{ns}	5.662 ^{ns}
G1×G3	11.870 ^{ns}	1.568 ^{ns}	1.922 ^{ns}	0.807 ^{ns}	-0.167 ^{ns}	0.641 ^{ns}	-1.099 ^{ns}	0.807 ^{ns}	-2.382 ^{ns}
G1×G4	-4.380 ^{ns}	-3.266 ^{ns}	-3.349 ^{ns}	1.536 ^{ns}	1.771 ^{ns}	0.474 ^{ns}	2.297 ^{ns}	1.536 ^{ns}	2.771 ^{ns}
G1×G5	6.411 ^{ns}	-2.661 ^{ns}	-3.245 ^{ns}	2.245 *	2.375 *	-0.651 ^{ns}	-9.536 **	2.245 *	5.451 ^{ns}
G1×G6	-4.318 ^{ns}	1.922 ^{ns}	2.984 ^{ns}	-2.422 *	-1.292 ^{ns}	-0.214 ^{ns}	-1.911 ^{ns}	-2.422 *	-6.429 ^{ns}
G1×G7	-4.547 ^{ns}	-0.557 ^{ns}	-1.057 ^{ns}	-1.609 ^{ns}	-1.521 ^{ns}	0.078 ^{ns}	4.380 **	-1.609 ^{ns}	-3.109 ^{ns}
G1×G8	1.828 ^{ns}	-2.036 ^{ns}	-1.536 ^{ns}	-1.255 ^{ns}	0.375 ^{ns}	-0.151 ^{ns}	-2.328 ^{ns}	-1.255 ^{ns}	2.343 ^{ns}
G2×G1	-14.833 ^{ns}	1.333 ^{ns}	1.000 ^{ns}	-3.667 **	-2.333 ^{ns}	0.333 ^{ns}	-2.333 ^{ns}	-3.667 **	16.502 **
G2×G3	-4.901 ^{ns}	2.422 ^{ns}	2.109 ^{ns}	-0.693 ^{ns}	0.583 ^{ns}	-0.234 ^{ns}	2.839 ^{ns}	-0.693 ^{ns}	3.424 ^{ns}
G2×G4	-3.818 ^{ns}	5.255 **	5.672 **	0.370 ^{ns}	-0.646 ^{ns}	-0.234 ^{ns}	0.901 ^{ns}	0.370 ^{ns}	-8.562 *
G2×G5	1.474 ^{ns}	-2.474 ^{ns}	-0.724 ^{ns}	0.245 ^{ns}	-0.542 ^{ns}	0.141 ^{ns}	-2.099 ^{ns}	0.245 ^{ns}	3.167 ^{ns}
G2×G6	-9.422 ^{ns}	-2.557 ^{ns}	-2.661 ^{ns}	1.245 ^{ns}	1.125 ^{ns}	-0.255 ^{ns}	-0.307 ^{ns}	1.245 ^{ns}	0.718 ^{ns}
G2×G7	2.016 ^{ns}	-7.870 **	-8.036 **	-1.609 ^{ns}	-0.938 ^{ns}	0.370 ^{ns}	-3.516 *	-1.609 ^{ns}	10.266 **
G2×G8	22.391 **	-2.516 ^{ns}	-2.682 ^{ns}	0.411 ^{ns}	2.458 *	0.474 ^{ns}	-1.557 ^{ns}	0.411 ^{ns}	-5.597 ^{ns}
G3×G1	23.333 **	3.000 ^{ns}	3.500 ^{ns}	0.333 ^{ns}	1.833 ^{ns}	-0.667 ^{ns}	6.000 **	0.333 ^{ns}	-2.645 ^{ns}
G3×G2	15.500 *	-1.333 ^{ns}	-1.667 ^{ns}	-1.500 ^{ns}	-1.500 ^{ns}	0.667 ^{ns}	-2.667 ^{ns}	-1.500 ^{ns}	-2.160 ^{ns}
G3×G4	-0.797 ^{ns}	-0.453 ^{ns}	-0.557 ^{ns}	-2.339 *	-2.917 *	-0.068 ^{ns}	0.068 ^{ns}	-2.339 *	3.243 ^{ns}
G3×G5	0.661 ^{ns}	-3.349 ^{ns}	-3.286 ^{ns}	1.203 ^{ns}	2.188 ^{ns}	-0.193 ^{ns}	3.234 *	1.203 ^{ns}	5.332 ^{ns}
G3×G6	-5.901 ^{ns}	0.568 ^{ns}	2.109 ^{ns}	1.703 ^{ns}	1.688 ^{ns}	0.245 ^{ns}	2.026 ^{ns}	1.703 ^{ns}	1.676 ^{ns}
G3×G7	4.703 ^{ns}	-2.245 ^{ns}	-2.932 ^{ns}	-0.151 ^{ns}	-0.875 ^{ns}	0.370 ^{ns}	2.818 ^{ns}	-0.151 ^{ns}	-4.235 ^{ns}
G3×G8	-13.422 ^{ns}	-3.224 ^{ns}	-2.745 ^{ns}	0.536 ^{ns}	0.021 ^{ns}	-0.359 ^{ns}	-0.057 ^{ns}	0.536 ^{ns}	4.876 ^{ns}
G4×G1	3.333 ^{ns}	-3.500 ^{ns}	-4.000 ^{ns}	-1.667 ^{ns}	-2.167 ^{ns}	-0.333 ^{ns}	5.833 **	-1.667 ^{ns}	-13.220 **

Table 9. (Cont'd)

F_1 Generation	Plant Height	Days to First Flowering	Days to 50% Flowering	Number of Branches per Plant	Number of Cluster per Plant	Number of Fruit per Cluster	Number of Fruit per Plant	Days to Maturity	Fruit Weight
G4×G2	3.500 ^{ns}	-0.500 ^{ns}	0.004^{ns}	1.500 ^{ns}	0.667 ^{ns}	0.167 ^{ns}	-0.500 ^{ns}	1.500 ^{ns}	0.057 ^{ns}
G4×G3	4.333 ^{ns}	6.833 **	7.167 **	1.000 ^{ns}	1.000 ^{ns}	-1.167 *	3.667 *	1.000 ^{ns}	6.593 ^{ns}
G4×G5	-0.755 ^{ns}	1.151 ^{ns}	0.609 ^{ns}	-1.401 ^{ns}	-1.375 ^{ns}	-1.026 *	0.964 ^{ns}	-1.401 ^{ns}	-7.662 *
G4×G6	9.182 ^{ns}	-2.766 ^{ns}	-3.661 ^{ns}	-0.234 ^{ns}	0.792 ^{ns}	0.245 ^{ns}	-1.578 ^{ns}	-0.234 ^{ns}	1.573 ^{ns}
G4×G7	4.786 ^{ns}	1.089 ^{ns}	1.964 ^{ns}	1.078 ^{ns}	0.562 ^{ns}	0.203 ^{ns}	2.547 ^{ns}	1.078 ^{ns}	6.564 ^{ns}
G4×G8	-1.505 ^{ns}	2.943 ^{ns}	3.151 ^{ns}	-0.401 ^{ns}	-0.208 ^{ns}	0.807 ^{ns}	0.839 ^{ns}	-0.401 ^{ns}	5.808 ^{ns}
G5×G1	13.667 ^{ns}	-1.833 ^{ns}	0.167 ^{ns}	-0.667 ^{ns}	-1.000 ^{ns}	0.667 ^{ns}	-4.333 *	-0.667 ^{ns}	-6.158 ^{ns}
G5×G2	22.000 **	-3.167 ^{ns}	-4.667 *	0.333 ^{ns}	-1.000 ^{ns}	-0.667 ^{ns}	-1.833 ^{ns}	0.333 ^{ns}	5.990 ^{ns}
G5×G3	16.000 *	-7.333 **	-7.500 **	2.500 *	1.333 ^{ns}	-0.500 ^{ns}	-1.167 ^{ns}	2.500 *	3.127 ^{ns}
G5×G4	8.500 ^{ns}	5.500 *	6.833 **	1.833 ^{ns}	1.500 ^{ns}	-0.500 ^{ns}	0.667 ^{ns}	1.833 ^{ns}	3.782 ^{ns}
G5×G6	4.307 ^{ns}	5.339 **	4.776 *	-1.693 ^{ns}	-0.604 ^{ns}	0.286 ^{ns}	5.089 **	-1.693 ^{ns}	-6.403 ^{ns}
G5×G7	-4.255 ^{ns}	0.859 ^{ns}	2.068 ^{ns}	-0.214 ^{ns}	0.167 ^{ns}	0.078 ^{ns}	1.547 ^{ns}	-0.214 ^{ns}	-2.707 ^{ns}
G5×G8	-6.714 ^{ns}	1.214 ^{ns}	-0.911 ^{ns}	-2.193 *	-1.438 ^{ns}	0.016 ^{ns}	3.505 *	-2.193 *	2.052 ^{ns}
G6×G1	1.167 ^{ns}	-4.833 *	-6.167 **	1.500 ^{ns}	2.667 **	0.500 ^{ns}	-3.000 ^{ns}	1.500 ^{ns}	-7.727 ^{ns}
G6×G2	23.667 **	4.167 ^{ns}	4.500 *	0.500 ^{ns}	0.333 ^{ns}	0.004^{ns}	-7.000 **	0.500 ^{ns}	4.740 ^{ns}
G6×G3	37.000 **	1.667 ^{ns}	0.004^{ns}	1.833 ^{ns}	1.167 ^{ns}	0.004^{ns}	1.667 ^{ns}	1.833 ^{ns}	1.912 ^{ns}
G6×G4	14.000 ^{ns}	1.667 ^{ns}	-1.000 ^{ns}	-1.500 ^{ns}	0.333 ^{ns}	0.167 ^{ns}	-2.167 ^{ns}	-1.500 ^{ns}	6.195 ^{ns}
G6×G5	-3.667 ^{ns}	0.833 ^{ns}	1.500 ^{ns}	1.333 ^{ns}	-0.167 ^{ns}	0.004^{ns}	-0.167 ^{ns}	1.333 ^{ns}	-0.540 ^{ns}
G6×G7	0.516 ^{ns}	5.609 **	4.964 *	2.286 *	1.167 ^{ns}	0.182 ^{ns}	-2.161 ^{ns}	2.286 *	-2.737 ^{ns}
G6×G8	12.557 ^{ns}	-0.870 ^{ns}	-1.016 ^{ns}	-0.026 ^{ns}	-0.771 ^{ns}	-0.714 ^{ns}	-1.703 ^{ns}	-0.026 ^{ns}	-3.953 ^{ns}
G7×G1	-7.833 ^{ns}	0.667 ^{ns}	0.500 ^{ns}	3.000 **	2.667 **	-0.167 ^{ns}	1.000 ^{ns}	3.000 **	-1.547 ^{ns}
G7×G2	-5.667 ^{ns}	1.167 ^{ns}	1.167 ^{ns}	1.333 ^{ns}	1.833 ^{ns}	0.333 ^{ns}	-5.167 **	1.333 ^{ns}	14.792 **
G7×G3	19.167 *	1.500 ^{ns}	1.667 ^{ns}	-0.333 ^{ns}	-0.500 ^{ns}	-0.167 ^{ns}	-1.500 ^{ns}	-0.333 ^{ns}	-2.378 ^{ns}
G7×G4	9.167 ^{ns}	-1.833 ^{ns}	-1.000 ^{ns}	-2.167 ^{ns}	-2.667 **	0.500 ^{ns}	0.667 ^{ns}	-2.167 ^{ns}	-2.103 ^{ns}

Table 9. (Cont'd)

F_1 Generation	Plant Height	Days to First Flowering	Days to 50% Flowering	Number of Branches per Plant	Number of Cluster per Plant	Number of Fruit per Cluster	Number of Fruit per Plant	Days to Maturity	Fruit Weight
G7×G5	14.000 ns	0.333 ns	1.833 ns	-2.500 *	-2.167 ns	-0.167 ns	-1.667 ns	-2.500 *	-2.830 ns
G7×G6	-12.667 ns	-4.500 *	-4.167 ns	-0.500 ns	-2.167 ns	0.004ns	1.667 ns	-0.500 ns	6.235 ns
G7×G8	10.495 ns	3.984 *	4.609 *	0.453 ns	0.333 ns	-0.422 ns	-2.745 ns	0.453 ns	0.623 ns
G8×G1	-9.167 ns	2.500 ns	3.833 ns	-1.667 ns	0.167 ns	0.333 ns	3.333 ns	-1.667 ns	-12.768 **
G8×G2	-21.333 **	1.500 ns	2.000 ns	-1.667 ns	0.833 ns	-0.167 ns	3.167 ns	-1.667 ns	1.342 ns
G8×G3	-6.667 ns	-0.500 ns	-0.333 ns	0.667 ns	1.000 ns	0.500 ns	-2.000 ns	0.667 ns	-7.638 ns
G8×G4	-9.500 ns	3.333 ns	3.000 ns	-0.667 ns	-0.833 ns	0.500 ns	0.333 ns	-0.667 ns	3.280 ns
G8×G5	2.833 ns	0.667 ns	-1.000 ns	1.167 ns	1.167 ns	0.500 ns	-1.333 ns	1.167 ns	9.058 *
G8×G6	0.667 ns	-1.333 ns	-1.333 ns	2.167 ns	1.500 ns	-0.500 ns	3.167 ns	2.167 ns	0.512 ns
G8×G7	-22.167 **	-2.500 ns	-2.333 ns	1.000 ns	0.833 ns	0.167 ns	3.167 ns	1.000 ns	2.442 ns
Var (sij)	6.905	1.929	1.957	0.985	1.134	0.443	1.568	0.985	3.541
Var (sij-sik)	10.334	2.887	2.929	1.475	1.696	0.663	2.346	1.475	5.299
Var (sij-skl)	9.567	2.673	2.712	1.365	1.571	0.614	2.172	1.365	4.906

Table 9. (Cont'd)

F_1 Generation	Fruit Skin Diameter (mm)	Number of Locule per fruit	Fruit area index (cm^2)	Yield per Plant (kg)	Leaf Chlorophyll content	Relative Water content	Brix (%)	Vitamin C Content	Titrable Acidity (%)	Fruit pH
G1×G2	0.008 ns	0.750 **	481.786 **	334.457 *	-1.197 **	-9.041 **	-0.114 **	4.744 **	-0.774 **	-0.133 **
G1×G3	-3.017 **	-0.313 ns	27.870 ns	-130.498 ns	-1.772 **	11.409 **	-0.677 **	2.419 **	-0.954 **	-0.012 **
G1×G4	-0.027 ns	0.375 ns	-269.005 ns	127.149 ns	-5.797 **	-5.332 **	0.198 **	-6.541 **	0.727 **	0.109 **
G1×G5	-0.025 ns	-0.396 *	426.453 ns	-75.700 ns	1.922 **	2.706 **	-0.320 **	8.775 **	0.190 **	0.030 **
G1×G6	-0.029 ns	0.250 ns	-255.526 ns	-237.172 ns	4.559 **	0.752 **	0.780 **	-9.251 **	0.529 **	-0.403 **
G1×G7	-0.048 ns	-0.458 *	-132.651 ns	16.658 ns	-0.947 **	9.918 **	-0.339 **	-1.015 **	-0.400 **	-0.337 **
G1×G8	-0.056 ns	0.062 ns	-190.609 ns	-38.995 ns	3.628 **	11.878 **	-0.239 **	9.440 **	0.649 **	-0.004 **
G2×G1	0.067 ns	0.833 **	652.833 **	598.797 **	5.050 **	-3.386 **	-0.750 **	5.676 **	0.108 **	-0.465 **
G2×G3	-0.002 ns	0.375 ns	-104.859 ns	224.457 ns	-8.422 **	10.412 **	0.098 **	5.964 **	-0.946 **	-0.284 **
G2×G4	0.004 ns	0.229 ns	-103.234 ns	-302.767 *	-13.347 **	5.506 **	0.123 **	-4.245 **	0.863 **	-0.104 **
G2×G5	-0.044 ns	-0.208 ns	206.391 ns	69.349 ns	2.322 **	-0.796 **	-0.245 **	1.321 **	1.538 **	-0.242 **
G2×G6	0.019 ns	0.604 **	-100.089 ns	2.392 ns	0.659 **	21.986 **	-0.795 **	10.946 **	-0.314 **	-0.211 **
G2×G7	0.017 ns	-0.104 ns	-130.547 ns	229.470 ns	6.503 **	13.337 **	0.286 **	-7.918 **	-1.093 **	0.766 **
G2×G8	0.042 ns	-0.417 *	111.328 ns	-236.234 ns	1.478 **	-8.602 **	0.086 **	-2.513 **	-0.049 **	0.383 **
G3×G1	0.050 ns	0.167 ns	-323.500 ns	72.263 ns	3.900 **	1.047 **	-0.150 **	8.752 **	1.404 **	-0.355 **
G3×G2	-0.050 ns	1.333 **	192.167 ns	-194.970 ns	-0.500 **	8.228 **	0.004 ns	9.100 **	-0.108 **	-0.050 **
G3×G4	-0.004 ns	0.333 ns	-317.484 ns	132.236 ns	3.428 **	2.576 **	-0.589 **	8.405 **	-0.188 **	-0.263 **
G3×G5	0.065 ns	0.396 *	330.307 ns	295.643 *	0.947 **	-4.523 **	-0.908 **	-0.429 **	-0.095 **	-0.162 **
G3×G6	0.010 ns	0.375 ns	43.995 ns	95.910 ns	-0.016 **	-1.808 **	-0.858 **	-2.505 **	1.341 **	0.520 **
G3×G7	-0.008 ns	-0.667 **	6.870 ns	-121.445 ns	3.178 **	-10.738 **	0.123 **	-1.769 **	-0.463 **	-0.394 **
G3×G8	0.017 ns	0.521 **	176.245 ns	181.432 ns	-10.197 **	3.984 **	1.173 **	-8.414 **	-0.565 **	-0.331 **
G4×G1	0.016 ns	-1.167 **	-215.000 ns	-364.047 ns	-2.000 **	1.470 **	0.500 **	-3.900 **	-0.608 **	-0.210 **

Table 9. (Cont'd)

F_1 Generation	Fruit Skin Diameter (mm)	Number of Locule per fruit	Fruit area index (cm^2)	Yield per Plant (kg)	Leaf Chlorophyll content	Relative Water content	Brix (%)	Vitamin C Content	Titrable Acidity (%)	Fruit pH
G4×G2	1.500 ^{ns}	-0.167 ^{ns}	512.500 **	-9.112 ^{ns}	6.000 **	6.646 **	-0.500 **	7.600 **	-1.368 **	-0.015 **
G4×G3	1.000 ^{ns}	-1.000 **	160.500 ^{ns}	417.820 **	10.900 **	17.079 **	0.250 **	0.250 **	-0.936 **	0.075 **
G4×G5	-1.401 ^{ns}	0.083 ^{ns}	123.766 ^{ns}	-257.859 ^{ns}	-4.128 **	-4.382 **	0.117 **	-0.188 **	-0.430 **	-0.176 **
G4×G6	-0.234 ^{ns}	-0.271 ^{ns}	154.786 ^{ns}	-8.363 ^{ns}	0.559 **	2.817 **	0.017 **	-2.213 **	-0.986 **	-0.074 **
G4×G7	1.078 ^{ns}	0.687 **	234.828 *	367.706 **	-8.697 **	-12.113 **	0.348 **	7.022 **	-0.405 **	0.117 **
G4×G8	-0.401 ^{ns}	-0.125 ^{ns}	285.036 *	251.491 *	11.978 **	0.710 **	0.098 **	-3.623 **	0.266 **	0.124 **
G5×G1	-0.667 ^{ns}	0.004 ^{ns}	-418.667 **	-309.843 **	3.600 **	12.562 **	0.550 **	1.700 **	0.254 **	-0.465 **
G5×G2	0.333 ^{ns}	1.000 **	-474.000 **	158.963 *	-3.750 **	-1.800 **	0.800 **	2.550 **	-0.181 **	0.350 **
G5×G3	2.500 *	0.004 ^{ns}	71.167 ^{ns}	97.337 ^{ns}	1.300 **	6.535 **	0.500 **	0.100 **	-0.373 **	-0.070 **
G5×G4	1.833 ^{ns}	1.333 **	433.000 **	171.297*	-3.450 **	1.600 **	0.004 ^{ns}	-12.450 **	-0.127 **	-0.020 **
G5×G6	-1.693 ^{ns}	-0.042 ^{ns}	-414.589 **	-126.857 ^{ns}	-0.522 **	-0.038 **	0.798 **	-5.547 **	-0.410 **	-0.068 **
G5×G7	-0.214 ^{ns}	1.083 **	130.286 ^{ns}	-54.025 ^{ns}	-1.628 **	1.632 **	-0.070 **	-4.962 **	-0.642 **	0.208 **
G5×G8	-2.193 *	-0.396 *	-259.505 *	166.327 *	-2.653 **	-1.395 **	0.080 **	-2.857 **	-0.838 **	0.231 **
G6×G1	1.500 ^{ns}	-0.667 *	-233.000 *	-344.230 **	0.650 **	2.309 **	0.004 ^{ns}	-1.050 **	-0.925 **	-0.115 **
G6×G2	0.500 ^{ns}	-0.167 ^{ns}	179.167 ^{ns}	-27.342 ^{ns}	-9.800 **	21.481 **	0.500 **	7.650 **	0.265 **	-0.195 **
G6×G3	1.833 ^{ns}	0.333 ^{ns}	120.167 ^{ns}	131.365 ^{ns}	0.650 **	-5.550 **	0.004 ^{ns}	1.100 **	-2.781 **	0.905 **
G6×G4	-1.500 ^{ns}	-0.667 *	-271.000 ^{ns}	157.148*	3.850 **	5.200 **	-0.250 **	-6.700 **	-1.171 **	-0.175 **
G6×G5	1.333 ^{ns}	-0.833 **	5.167 ^{ns}	-28.223 ^{ns}	-1.550 **	-2.400 **	-0.400 **	4.250 **	-0.915 **	-0.275 **
G6×G7	2.286 *	-0.438 *	-97.526 ^{ns}	-147.254 ^{ns}	3.609 **	-14.068 **	0.080 **	10.563 **	1.275 **	0.170 **
G6×G8	-0.026 ^{ns}	0.083 ^{ns}	216.016 ^{ns}	-176.265 *	3.934 **	0.954 **	-0.870 **	0.618 **	-0.177 **	0.173 **
G7×G1	3.000 **	-0.333 ^{ns}	-409.167 **	-42.977 ^{ns}	-10.900 **	-3.546 **	0.250 **	-12.600 **	0.471 **	-0.175 **
G7×G2	1.333 ^{ns}	1.167 **	44.667 ^{ns}	350.973**	-7.500 **	8.412 **	-0.550 **	4.800 **	0.072 **	0.165 **
G7×G3	-0.333 ^{ns}	0.004 ^{ns}	212.333 ^{ns}	-143.880 ^{ns}	-5.600 **	-6.300 **	-0.250 **	-9.250 **	0.721 **	-0.255 **
G7×G4	-2.167 ^{ns}	1.000 **	647.333 **	-69.840 ^{ns}	-5.550 **	7.350 **	0.550 **	-8.050 **	1.407 **	0.140 **

Table 9 (Cont'd)

F_1 Generation	Fruit Skin Diameter (mm)	Number of Locule per fruit	Fruit area index (cm^2)	Yield per Plant (kg)	Leaf Chlorophyll content	Relative Water Content	Brix (%)	Vitamin C content	Titrable Acidity (%)	Fruit pH
G7×G5	-2.500 *	-1.667 **	-312.333 *	-152.952*	-0.500 **	5.850 **	-0.600 **	-2.650 **	-0.717 **	0.185 **
G7×G6	-0.500 ^{ns}	-0.167 ^{ns}	233.167 *	269.832 *	-7.150 **	8.850 **	0.200 **	-4.250 **	2.100 **	0.240 **
G7×G8	0.453 ^{ns}	0.208 ^{ns}	-35.609 ^{ns}	-12.322 ^{ns}	-1.922 **	-12.776 **	-0.539 **	-0.996 **	1.115 **	-0.306 **
G8×G1	-1.667 ^{ns}	0.004^{ns}	-47.500 ^{ns}	-316.183 **	-7.050 **	18.692 **	0.700 **	-9.450 **	1.209 **	-0.420 **
G8×G2	-1.667 ^{ns}	0.004^{ns}	467.833 **	118.025 ^{ns}	-2.650 **	13.851 **	0.300 **	-3.000 **	-0.177 **	-0.395 **
G8×G3	0.667 ^{ns}	-1.000 **	-174.667 ^{ns}	-369.513 **	-2.400 **	-0.400 **	1.250 **	-13.000 **	0.997 **	-0.290 **
G8×G4	-0.667 ^{ns}	0.004^{ns}	-47.500 ^{ns}	151.565 *	-10.004**	9.450 **	0.150 **	-7.800 **	2.509 **	0.270 **
G8×G5	1.167 ^{ns}	0.004^{ns}	78.500 ^{ns}	318.087**	1.950 **	12.500 **	-1.000 **	-15.050 **	-0.534 **	-0.400 **
G8×G6	2.167 ^{ns}	0.167 ^{ns}	235.333*	81.300 ^{ns}	-1.350 **	-1.950 **	0.400 **	-1.200 **	-0.715 **	-0.185 **
G8×G7	1.000 ^{ns}	0.333 ^{ns}	-12.000 ^{ns}	197.730 *	0.750 **	-4.500 **	0.200 **	-2.900 **	0.205 **	0.130 **
Var (sij)	0.985	0.197838	815.350	138.3065	$6.937E^{-07}$	$4.91E^{-07}$	$4.85E^{-08}$	$3.47E^{-07}$	$4.6E^{-08}$	$3.07E^{-08}$
Var (sij-sik)	1.475	0.296097	1826.384	206.9982	$1.0382E^{-06}$	$7.34E^{-07}$	$7.25E^{-08}$	$5.19E^{-07}$	$6.88E^{-08}$	$4.59E^{-08}$
Var (sij-skl)	1.365	-1.667 **	-312.333 *	-152.952 *	-0.500 **	5.850 **	-0.600 **	-2.650 **	-0.717 **	0.185 **

^{ns}=Non-significant, *=Significant at 5% probability level, **= Significant at 1% probability level

crosses were good specific combiner for plant height. The cross G6×G3 was the best specific combiner and 2 crosses showed significant negative SCA effects. The highest negative significant effect was G8×G7 (-22.167**) and the lowest negative significant effect was G8×G2 (-21.333**).

4.2.2 Days to first flowering

The mean square (MS values) for GCA was non-significant which suggests the absent of additive gene action and SCA was significant which suggests the present of non-additive gene action for this character. Among the eight parents no one showed significant positive and negative GCA effects for days to first flowering (Table 9).

Among the 56 cross combinations 7 crosses showed significant positive SCA effects (Table 9). The highest positive significant effect was G4×G3 (6.833**) and the lowest positive significant effect was G1×G2 (3.943*). Thus these 7 crosses were good specific combiner for Days to first flowering. The cross G4×G3 was the best specific combiner and 4 crosses showed significant negative SCA effects. The highest negative significant effect was G2×G7 (-7.870**) and the lowest negative significant effect was G7×G6(-4.500*).

4.2.3 Days to 50% flowering

The mean square (MS values) for GCA was non-significant which suggests the absent of additive gene action and SCA was significant which suggests the present of non-additive gene action for this character. Among the eight parents no one showed significant positive and negative GCA effects for Days to 50% flowering (Table 8).

Among the 56 cross combinations 7 crosses showed significant positive SCA effects (Table 9). The highest positive significant effect was G4×G3 (7.167**) and the lowest positive significant effect was G6×G2 (4.500*). Thus these 7 crosses were good specific combiner for Days to 50% flowering. The cross

G4×G3 was the best specific combiner and 4 crosses showed significant negative SCA effects. The highest negative significant effect was G2×G7(-8.036**) and the lowest negative significant effect was G5×G2(-4.667*).

4.2.4 Number of branches per plant

The mean square (MS values) for GCA and SCA were significant for this trait which suggests the presence of both additive and non-additive gene action for this character (Table 7). Among the eight parents studies the parent G1 and G5 showed the significant positive GCA effects. The GCA value of G5 (1.234**) was higher than G1 (0.797 **). On the other hand, no parents showed significant negative GCA effect. So the parent G1 and G5 were the best general combiner for Number of branches per plant (Table 8).

Among the 56 cross combinations 4 crosses showed significant positive SCA effects (Table 9). The highest positive significant effect was G7×G1 (3.000**) and the lowest positive significant effect was G1×G5 (2.245*). Thus these 4 crosses were good specific combiner for Number of branches per plant. The cross G7×G1 was the best specific combiner and 5 crosses showed significant negative SCA effects. The highest negative significant effect was G2×G1(-3.667**) and the lowest negative significant effect was G5×G8(-2.193*).

4.2.5 Number of cluster per plant

The mean square (MS values) for GCA was non-significant which suggests the absent of additive gene action and SCA was significant which suggests the present of non-additive gene action for this character. Among the eight parents studies no parents showed significant positive and negative GCA effects for Number of cluster per plant (Table 8).

Among the 56 cross combinations 4 crosses; showed significant positive SCA effects (Table 9). The highest positive significant effect were G6×G1 (2.667**) and G7×G1 (2.667**) and the lowest positive significant effect was G1×G5

(2.375*). Thus these 4 crosses were good specific combiner for Number of cluster per plant. The cross G6×G1 and G7×G1 was the best specific combiner and 2 crosses showed significant negative SCA effects. The highest negative significant effect was G3×G4 (-2.917*) and the lowest negative significant effect was G7×G4 (-2.667**).

4.2.6 Number of fruit per cluster

The mean square (MS values) for GCA and SCA were non-significant for this trait which suggests the absent of both additive and non-additive gene action for this character (Table 7). Among the eight parents no one showed significant positive and negative GCA effects for Number of fruit per cluster (Table 8).

Among the 56 cross combinations there was no positive significant SCA effects for Number of fruit per cluster and 2 crosses showed significant negative SCA effects (Table 9). The highest negative significant effect was G4×G3 (-1.167*) and the lowest negative significant effect was G4×G5 (-1.026*).

4.2.7 Number of fruits per Plant

The MS values for GCA and SCA were significant for this trait which suggests the presence of both additive and non-additive gene action for this trait. Among the eight parents studies the parent G3 (1.203 **) showed the significant positive GCA effects. On the other hand, G5 (-1.359 **) and G8 (-1.568 **) showed the significant negative GCA effects. So the parent G3 was the best general combiner for Number of fruits per Plant (Table 8).

Among the 56 cross combinations 8 crosses showed significant positive SCA effects (Table 9). The highest positive significant effect was G3×G1 (6.000**) and the lowest positive significant effect was G3×G5 (3.234*). Thus these 8 crosses were good specific combiner for Number of fruits per Plant. The cross G2×G3 was the best specific combiner and 5 crosses showed significant negative

SCA effects. The highest negative significant effect was G1×G5 (-9.536**) and the lowest negative significant effect was G2×G7 (-3.516*).

4.2.8 Days to maturity

The mean square (MS values) for GCA and SCA were significant for this trait which suggests the presence of both additive and non-additive gene action for this character. Among the eight parents studies the parent G1 and G5 showed the significant positive GCA effects. The GCA value of G5 (1.234**) was higher than G1 (0.797 **). On the other hand, no parents showed significant negative GCA effect. So the parent G1 and G5 were the best general combiner for Days to maturity (Table 8).

Among the 56 cross combinations 5 crosses; showed significant positive SCA effects (Table 9). The highest positive significant effect was G7×G1 (3.000**). Thus these 5 crosses were good specific combiner for Days to maturity. The cross G7×G1 was the best specific combiner and 4 crosses showed significant negative SCA effects. The highest negative significant effect was G2×G1 (-3.667**) and the lowest negative significant effect was G5×G8 (-2.193*).

4.2.9 Average fruit weight (g)

The mean square (MS values) for GCA was non-significant which suggests the absent of additive gene action and SCA was significant which suggests the present of non-additive gene action for this character. Among the eight parents studies no parents showed significant positive and negative GCA effects for Average fruit weight (g) (Table 8).

Among the 56 cross combinations 4 crosses; showed significant positive SCA effects (Table 9). The highest positive significant effect was G2×G1 (16.502**) and the lowest positive significant effect was G8×G5 (9.058*). Thus these 4 crosses were good specific combiner for Average fruit weight (g). The cross G2×G1 was the best specific combiner and 4 crosses showed significant negative

SCA effects. The highest negative significant effect was G8×G1 (-12.768**) and the lowest negative significant effect was G2×G4 (-8.562*).

4.2.10 Fruit skin diameter (mm)

The mean square (MS values) for GCA and SCA were non-significant for this trait which suggests the absent of both additive and non-additive gene action for this character (Table 7). Among the eight parents studies the parent G4 and G7 showed the significant positive GCA effects. The GCA value of G4 (0.019 **) was lower than G7 (0.023**). On the other hand, parent G2 (-0.017**) showed significant negative GCA effect. So the parent G1 and G5 were the best general combiner for Fruit skin diameter (Table 8).

Among the 56 cross combinations 3 crosses showed significant positive SCA effects (Table 9). The highest positive significant effect was G7×G1 (3.000**) and the lowest positive significant effect was G5×G3 (2.500*). Thus these 3 crosses were good specific combiner for Fruit skin diameter (mm). The cross G7×G1 was the best specific combiner and 3 crosses showed significant negative SCA effects. The highest negative significant effect was G1×G3 (-3.017**) and the lowest negative significant effect was G7×G5 (-2.500*).

4.2.11 Number of locule per fruit

The mean square (MS values) for GCA and SCA were significant for this trait which suggests the presence of both additive and non-additive gene action for this character. Among the eight parents studies the parent G2, G4 and G5 showed the significant positive GCA effects. The GCA value of G4 (0.313 **) was higher than G5 (0.250 **). On the other hand, G1 (-0.208 **) and G8 (-0.542 **) showed the significant negative GCA effect. So the parents G2, G4 and G5 were the best general combiner for Number of locule per fruit (Table 8).

Among the 56 cross combinations 12 crosses showed significant positive SCA effects (Table 9). The highest positive significant effect was G5×G4 (1.333**) and the lowest positive significant effect was G3×G5 (0.396 *). Thus these 12 crosses were good specific combiner for Number of locule per fruit. The cross G5×G4 was the best specific combiner and 13 crosses showed significant negative SCA effects. The highest negatives significant effect was G7×G5 (-1.667 **) and the lowest negative significant effect was G5×G8 (-0.396 *).

4.2.12 Fruit area index (cm^2)

The mean square (MS values) for GCA and SCA were significant for this trait which suggests the presence of both additive and non-additive gene action for this character (Table 7). Among the eight parents studies the parent G4 (105.839 **) showed the significant positive GCA effects. On the other hand, G7 (-85.349 **) and G8 (-79.724 **) showed the significant negative GCA effect. So the parent G4 was the best general combiner for Fruit area index (Table 8).

Among the 56 cross combinations 10 crosses; showed significant positive SCA effects (Table 9). The highest positive significant effect was G2×G1 (652.833**) and the lowest positive significant effect was G7×G6 (233.167*). Thus these ten crosses were good specific combiner for Fruit area index (cm2). The cross G2×G1 was the best specific combiner and 7 crosses showed significant negative SCA effects. The highest negative significant effect was G5×G2 (-474.000**) and the lowest negative significant effect was G6×G1 (-233.000*).

4.2.13 Fruit Yield per plant (g)

The mean square (MS values) for GCA was non-significant which suggests the absent of additive gene action and SCA was significant which suggests the present of non-additive gene action for this character. Among the eight parent studies the parent G4 (75.339 **) and G3 (45.210 *) showed the significant positive GCA effects. The GCA value of G4 (75.339 **) was higher than G3 (45.210 *). On the other hand, G5 (-91.519 **) showed the significant negative

GCA effect. So the parent G4 and G 3 were the best general combiner for Fruit Yield per plant (Table 8).

Among the 56 cross combinations 15 crosses; showed significant positive SCA effects (Table 9). The highest positive significant effect was G2×G1 (598.797**) and the lowest positive significant effect was G8×G4 (151.565*). Thus these 15 crosses were good specific combiner for Fruit Yield per plant (kg). The cross G2×G1 was the best specific combiner and 7 crosses showed significant negative SCA effects. The highest negative significant effect was G8×G3 (-369.513**) and the lowest negative significant effect was G7×G5 (-152.952*)

4.2.14 Leaf chlorophyll content

The mean square (MS values) for GCA and SCA were significant for this trait which suggests the presence of both additive and non-additive gene action for this character (Table 7). Among the eight parents studies the parent G4, G8 and G6 showed the significant positive GCA effects. The GCA value of G4 (7.503 **) was higher than G8 (0.897 **). On the other hand, G1 (-4.297 **), G2 (-2.047 **), G3 (-1.922 **), G5 (-0.216 **) and G7 (-1.247 **) showed the significant negative GCA effect. So the parents G4, G8 and G6 were the best general combiner for Leaf chlorophyll content (Table 8).

Among the 56 cross combinations 25 crosses; showed significant positive SCA effects (Table 9). The highest positive significant effect was G4×G8 (11.978**) and the lowest positive significant effect was G4×G6 (0.559**). Thus these 25 crosses were good specific combiner for Leaf chlorophyll content. The cross G4×G8 was the best specific combiner and 31 crosses showed significant negative SCA effects. The highest negative significant effect was G2×G4 (-13.347**) and the lowest negative significant effect was G3×G6 (-0.016**).

4.2.15 Relative Water Content (RWC)

The mean square (MS values) for GCA and SCA were significant for this trait which suggests the presence of both additive and non-additive gene action for this character. Among the eight parents studies the parent G1, G2, G5 and G6 showed the significant positive GCA effects. The GCA value of G2 (7.435 **) was higher than G6 (0.678 **). On the other hand, G3 (-5.002 **), G4 (-3.078 **), G7 (-3.142 **) and G8 (-1.565 **) showed the significant negative GCA effect. So the parents G1, G2, G5 and G6 were the best general combiner for relative water content (RWC) (Table 8).

Among the 56 cross combinations 34 crosses; showed significant positive SCA effects (Table 9). The highest positive significant effect was G2×G6 (21.986**) and the lowest positive significant effect was G4×G8 (0.710**). Thus these 34 crosses were good specific combiner for relative water content (RWC). The cross G2×G6 was the best specific combiner and 22 crosses showed significant negative SCA effects. The highest negative significant effect was G6×G7 (-14.068**) and the lowest negative significant effect was G5×G6 (-0.038**).

4.2.16 Brix percentage (%)

The mean square (MS values) for GCA and SCA were significant for this trait which suggests the presence of both additive and non-additive gene action for this character (Table 7).

Among the eight parents studies the parent G2, G3 and G8 showed the significant positive GCA effects. The GCA value of G3 (0.514 **) was higher than G8 (0.227 **). On the other hand, G1 (-0.023 **), G4 (-0.011 **), G5 (-0.442 **), G6 (-0.092 **) and G7 (-0.223 **) showed the significant negative GCA effect. So the parents G2, G3 and G8 were the best general combiner for Brix percentage (%), (Table 8).

Among the 56 cross combinations 31 crosses; showed significant positive SCA effects (Table 9). The highest positive significant effect was G8×G3 (1.250**) and the lowest positive significant effect was G6×G7 (0.080**). Thus these 31 crosses were good specific combiner for Brix percentage (%). The cross G8×G3 was the best specific combiner and 22 crosses showed significant negative SCA effects. The highest negative significant effect was G8×G5 (-1.000**) and the lowest negative significant effect was G5×G7 (-0.070**).

4.2.17 Vitamin C content (mg/100 g fruit)

The mean square (MS values) for GCA and SCA were significant for this trait which suggests the presence of both additive and non-additive gene action for this character. Among the eight parents studies the parent G7 and G8 showed the significant positive GCA effects. The GCA value of G8 (6.149 **) was higher than G7 (4.854 **). On the other hand, G1 (-0.932 **), G2 (-2.429 **), G3 (-2.528 **), G4 (-2.019 **), G5 (-1.235 **) and G (-1.860 **) showed the significant negative GCA effect. So the parents G7 and G8 were the best general combiner for Vitamin C content (Table 8).

Among the 56 cross combinations 23 crosses; showed significant positive SCA effects (Table 9). The highest positive significant effect was G2×G6 (10.946**) and the lowest positive significant effect was G5×G3 (0.100**). Thus these 23 crosses were good specific combiner Vitamin C content (mg/100 g fruit). The cross G2×G6 was the best specific combiner and 33 crosses showed significant negative SCA effects. The highest negative significant effect was G8×G5 (*15.050**) and the lowest negative significant effect was G4×G5 (-0.188**).

4.2.18 Titrable acidity (%)

The mean square (MS values) for GCA and SCA were significant for this trait which suggests the presence of both additive and non-additive gene action for this character (Table 7). Among the eight parents studies the parent G1, G3, G4 and

G6 showed the significant positive GCA effects. The GCA value of G4 (0.673 **) was higher than G1 (0.054 **). On the other hand, G2 (-0.529 **), G5 (-0.197 **), G7 (-0.408 **) and G8 (-0.228 **) showed the significant negative GCA effect. So the parents G1, G3, G4 and G6 were the best general combiner for Titrable acidity (%), (Table 8).

Among the 56 cross combinations 23 crosses; showed significant positive SCA effects (Table 9). The highest positive significant effect was G8×G4 (2.509**) and the lowest positive significant effect was G7×G2 (0.072**). Thus these 23 crosses were good specific combiner for Titrable acidity (%). The cross G8×G4 was the best specific combiner and 33 crosses showed significant negative SCA effects. The highest negative significant effect was G6×G3 (-2.781**) and the lowest negative significant effect was G2×G8 (-0.049**).

4.2.19 Fruit pH

The mean square (MS values) for GCA and SCA were significant for this trait which suggests the presence of both additive and non-additive gene action for this character. Among the eight parents studies the parent G1, G2, G3, G5 and G8 showed the significant positive GCA effects. The GCA value of G3 (0.193 **) was higher than G5 (0.021**). On the other hand, G4 (-0.173**), G6 (-0.106**) and G7 (-0.093**) showed the significant negative GCA effect. So the parents G1, G2, G3, G5 and G8 were the best general combiner for Fruit pH (Table 8).

Among the 56 cross combinations 20 crosses; showed significant positive SCA effects (Table 9). The highest positive significant effect was G6×G3 (0.905**) and the lowest positive significant effect was G6×G3 (0.905**). Thus these 20 crosses were good specific combiner for Fruit pH. The cross G6×G3 was the best specific combiner and 36 crosses showed significant negative SCA effects. The highest negative significant effect was G6×G3 (0.905**) and the lowest negative significant effect was G5×G1 (-0.465**).

From the above results and discussion it is observed that the parent G1 showed significant positive GCA effects for number of branches per plant, days to maturity, Relative Water Content (RWC), Titrable acidity (%) and Fruit pH. The parent G2 showed significant positive GCA effects for Number of locule per fruit, Relative Water Content (RWC), Brix percentage (%), Fruit pH. The parent G3 showed significant positive GCA effects for Number of fruits per Plant, Fruit Yield per plant (kg), Brix percentage (%), Titrable acidity (%), Fruit pH. The parent G4 showed significant positive GCA effects for Fruit skin diameter, Number of locule per fruit, Fruit area index, Fruit Yield per plant (kg), Leaf chlorophyll content, Titrable acidity (%). The parent G5 showed significant positive GCA effects for Number of branches per plant, Days to maturity, Number of locule per fruit, Relative Water Content (RWC), Fruit pH. The parent G6 showed significant positive GCA effects for Plant height, , Leaf chlorophyll content, Relative Water Content (RWC), Titrable acidity (%). The parent G7 showed significant positive GCA effects for Fruit skin diameter (mm), Vitamin C content (mg/100 g fruit). The parent G8 showed significant positive GCA effects for Leaf chlorophyll content, Brix percentage (%), Vitamin C content (mg/100 g fruit), Fruit pH.

The maximum SCA effects was observed in the cross combinations G6×G3 for Plant height, G4×G3 for Days to first flowering, G4×G3 for Days to 50% flowering, G7×G1 for Number of branches per plant, G6×G1 and G7×G1 for Number of cluster per plant, G3×G1 for Number of fruits per Plant, G7×G1 for Days to maturity, G2×G1 for Average fruit weight (g), G7×G1 for Fruit skin diameter (mm), G5×G4 for Number of locule per fruit, G2×G1 for Fruit area index (cm^2), G2×G1 for Fruit Yield per plant (kg), G4×G8 for Leaf chlorophyll content, G2×G6 for Relative Water Content (RWC), G8×G3 for Brix percentage (%), G2×G6 for Vitamin C content, G8×G4 for Titrable acidity (%), G6×G3 for Fruit pH.

4.3 Heterosis

The analysis of variance for genotypes i.e., parents and crosses showed significant difference for all the characters studied. The estimates of percent heterosis observed in F_1 generation over better parents and mid parents are presented through Table 10, Table 11, Table 12 and Table 13.

4.3.1 Plant height

Among the 56 cross combinations 52 crosses showed positive heterobeltosis for plant height and 4 crosses showed negative heterobeltosis (Table 10). Heterosis for this character ranged from -23.39% to 181.60%. The highest negative heterosis was observed in G6×G3 (-23.39%). The highest positive heterosis effect was observed in the cross G2×G6 (181.60%).

Thirty-nine crosses showed positive heterosis over mid parent and 17 of them showed negative heterosis (Table 10). The estimate of heterosis ranges from -33.16% to 120.92%. The highest significant positive heterosis was observed in the cross G8×G2 (120.92%). The highest significant negative heterosis was observed in the cross G6×G3 (-33.16%).

4.3.2 Days to first flowering

Among the 56 cross combinations 40 crosses showed positive heterobeltosis for days to first flowering and 16 crosses showed negative heterosis (Table 10). Heterosis for this character ranged from -22.38% to 44.83%. The highest negative heterosis was observed in G3×G5 (-22.38 %). The highest positive heterosis effect was observed in the cross G7×G6 (44.83%).

Thirty-three crosses showed positive heterosis over mid parent and 23 of them showed negative heterosis (Table 10). The estimate of heterosis ranges from

Table 10. Estimation of heterosis over better parent and mid parent of four morphological traits in *Solanum lycopercum* L.

	Plant Height		Days to First Flowering		Days to 50% Flowering		Number of Branches per Plant	
	BP	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**
G1×G2	40.80 ns	-4.09 ns	8.39 ns	5.80 ns	5.85 ns	3.43 ns	-25.64 ns	-17.14 ns
G1×G3	65.29 **	36.99 *	8.39 ns	3.33 ns	9.36 ns	5.35 ns	2.56 ns	15.94 ns
G1×G4	21.07ns	5.40 ns	-4.13 ns	-12.12 ns	-5.30 ns	-11.18 ns	-10.26 ns	-5.41 ns
G1×G5	45.87 **	27.44 ns	-10.49 ns	-10.49 ns	-6.43 ns	-6.98 ns	-4.17 ns	5.75 ns
G1×G6	47.52 **	4.39 ns	12.07 ns	0.39 ns	8.97 ns	0.00 ns	-12.82 ns	-2.86 ns
G1×G7	0.00 ns	-1.02 ns	2.96 ns	0.00 ns	1.21 ns	-0.60 ns	7.69 ns	13.51 ns
G1×G8	33.70 ns	14.42 ns	0.00 ns	-0.70 ns	2.35 ns	2.05 ns	-30.77 *	-30.77 ns
G2×G1	112.00 **	44.41 ns	2.80 ns	0.34 ns	2.34 ns	0.00 ns	30.77 *	45.71 *
G2×G3	115.20 **	15.20 ns	-4.00 ns	-6.19 ns	-3.35 ns	-4.68 ns	-12.90 ns	-11.48 ns
G2×G4	90.40 **	8.43 ns	23.97 *	10.70 ns	21.19 **	10.91 ns	8.57 ns	15.15 ns
G2×G5	144.80 **	40.05 ns	-13.29 ns	-15.36 ns	-10.98 ns	-12.50 ns	-16.67 ns	1.27 ns
G2×G6	181.60 **	24.16 ns	23.28 *	7.52 ns	20.00 *	7.41 ns	25.81 ns	25.81 ns
G2×G7	68.80 *	13.44 ns	-12.59 ns	-17.19 ns	-9.70 ns	-13.37 ns	-2.86 ns	3.03 ns
G2×G8	68.00 *	37.25 ns	-3.55 ns	-6.53 ns	-2.35 ns	-4.87 ns	-25.64 ns	-17.14 ns
G3×G1	7.44 ns	-10.96 ns	-4.20 ns	-8.67 ns	-2.92 ns	-6.48 ns	-2.56 ns	10.14 ns
G3×G2	40.80 ns	-24.63 ns	1.33 ns	-0.98 ns	2.23 ns	0.83 ns	16.13 ns	18.03 ns
G3×G4	5.41 ns	0.91 ns	29.75 **	12.95 ns	24.50 **	12.24 ns	-20.00 ns	-13.85 ns
G3×G5	17.63 ns	12.23 ns	-22.38 **	-26.00 **	-19.08 **	-21.57 **	2.08 ns	25.64 ns
G3×G6	41.52 **	23.47 ns	26.72 **	7.69 ns	22.07 **	7.60 ns	41.94 *	44.26 *
G3×G7	51.82 **	27.33 ns	2.22 ns	-5.48 ns	1.82 ns	-3.72 ns	-5.71 ns	1.54 ns
G3×G8	25.97 ns	-12.81 ns	-7.80 ns	-12.75 ns	-5.29 ns	-9.04 ns	-7.69 ns	4.35 ns
G4×G1	12.81 ns	-1.80 ns	13.22 ns	3.79 ns	10.60 ns	3.73 ns	15.38 ns	21.62 ns
G4×G2	73.60 *	-1.14 ns	26.45 **	12.92 ns	21.19 **	10.91 ns	-17.14 ns	-12.12 ns
G4×G3	-2.87 ns	-7.01 ns	-4.13 ns	-16.55 ns	-3.97 ns	-13.43 ns	-37.14 *	-32.31 ns
G4×G5	9.62 ns	9.27 ns	30.58 **	19.70 *	25.17 **	16.67 *	-20.83 ns	-8.43 ns
G4×G6	47.13 **	22.22 ns	13.79 ns	11.39 ns	4.14 ns	2.03 ns	-22.86 ns	-18.18 ns
G4×G7	40.49 *	23.71 ns	9.92 ns	3.91 ns	11.92 ns	6.96 ns	-14.29 ns	-14.29 ns
G4×G8	41.99 ns	3.84 ns	28.10 **	18.32 ns	21.19 **	14.02 ns	-28.21 ns	-24.32 ns

ns=Non-significant, *=Significant at 5% probability level, **= Significant at 1% probability level

Table 10. (Cont'd)

	Plant Height		Days to First Flowering		Days to 50% Flowering		Number of Branches per Plant	
	BP	MP	BP	MP	BP	MP	BP	MP
G5×G1	11.98^{ns}	-2.17^{ns}	-2.80^{ns}	-2.80^{ns}	-7.02^{ns}	-7.56^{ns}	4.17^{ns}	14.94^{ns}
G5×G2	39.20^{ns}	-20.37^{ns}	0.00^{ns}	-2.39^{ns}	5.20^{ns}	3.41^{ns}	-20.83^{ns}	-3.80^{ns}
G5×G3	-13.14^{ns}	-17.13^{ns}	8.39^{ns}	3.33^{ns}	6.94^{ns}	3.64^{ns}	-29.17 *	-12.82^{ns}
G5×G4	-6.73^{ns}	-7.03^{ns}	3.31^{ns}	-5.30^{ns}	-1.99^{ns}	-8.64^{ns}	-43.75 **	-34.94 *
G5×G6	25.32^{ns}	3.71^{ns}	37.07 **	22.78 *	29.66 **	18.24 *	-22.92^{ns}	-6.33^{ns}
G5×G7	34.01 *	18.43^{ns}	6.67^{ns}	3.60^{ns}	10.30^{ns}	7.69^{ns}	-35.42 **	-25.30^{ns}
G5×G8	51.93 *	11.56^{ns}	4.26^{ns}	3.52^{ns}	-4.12^{ns}	-4.96^{ns}	-29.17 *	-21.84^{ns}
G6×G1	44.63 **	2.34^{ns}	37.07 **	22.78 *	34.48 **	23.42 **	-35.90 *	-28.57^{ns}
G6×G2	68.00 *	-25.93^{ns}	1.72^{ns}	-11.28^{ns}	1.38^{ns}	-9.26^{ns}	16.13^{ns}	16.13^{ns}
G6×G3	-23.39^{ns}	-33.16 **	18.10^{ns}	0.37^{ns}	22.07 **	7.60^{ns}	6.45^{ns}	8.20^{ns}
G6×G4	20.38^{ns}	0.00^{ns}	5.17^{ns}	2.95^{ns}	8.28^{ns}	6.08^{ns}	2.86^{ns}	9.09^{ns}
G6×G5	32.37 *	9.55^{ns}	32.76 **	18.92^{ns}	23.45 **	12.58^{ns}	-39.58 **	-26.58^{ns}
G6×G7	37.25 *	-1.60^{ns}	21.55 *	12.35^{ns}	17.93 *	10.32^{ns}	14.29^{ns}	21.21^{ns}
G6×G8	120.99 **	28.41^{ns}	13.79^{ns}	2.72^{ns}	10.34^{ns}	1.59^{ns}	0.00^{ns}	11.43^{ns}
G7×G1	19.42^{ns}	18.20^{ns}	0.00^{ns}	-2.88^{ns}	-0.61^{ns}	-2.38^{ns}	-38.46 *	-35.14^{ns}
G7×G2	96.00 **	31.72^{ns}	-17.78 *	-22.11 *	-13.94 *	-17.44 *	-25.71^{ns}	-21.21^{ns}
G7×G3	5.26^{ns}	-11.71^{ns}	-4.44^{ns}	-11.64^{ns}	-4.24^{ns}	-9.46^{ns}	0.00^{ns}	7.69^{ns}
G7×G4	18.22^{ns}	4.10^{ns}	19.01 *	12.50^{ns}	15.89 *	10.76^{ns}	22.86^{ns}	22.86^{ns}
G7×G5	0.00^{ns}	-11.63^{ns}	5.19^{ns}	2.16^{ns}	3.64^{ns}	1.18^{ns}	-4.17^{ns}	10.84^{ns}
G7×G6	68.02 **	20.46^{ns}	44.83 **	33.86 **	35.17 **	26.45 **	22.86^{ns}	30.30^{ns}
G7×G8	31.49^{ns}	11.21^{ns}	5.93^{ns}	3.62^{ns}	6.06^{ns}	4.48^{ns}	-2.56^{ns}	2.70^{ns}
G8×G1	64.09 **	40.43^{ns}	-10.64^{ns}	-11.27^{ns}	-11.18^{ns}	-11.44^{ns}	-5.13^{ns}	-5.13^{ns}
G8×G2	170.40 **	120.92 **	-9.93^{ns}	-12.71^{ns}	-9.41^{ns}	-11.75^{ns}	0.00^{ns}	11.43^{ns}
G8×G3	48.07 *	2.49^{ns}	-5.67^{ns}	-10.74^{ns}	-4.12^{ns}	-7.91^{ns}	-17.95^{ns}	-7.25^{ns}
G8×G4	73.48 **	26.87^{ns}	11.57^{ns}	3.05^{ns}	9.27^{ns}	2.80^{ns}	-17.95^{ns}	-13.51^{ns}
G8×G5	42.54^{ns}	4.67^{ns}	1.42^{ns}	0.70^{ns}	-0.59^{ns}	-1.46^{ns}	-43.75 **	-37.93 *
G8×G6	118.78 **	27.13^{ns}	20.69 *	8.95^{ns}	15.86 *	6.67^{ns}	-33.33 *	-25.71^{ns}
G8×G7	104.97 **	73.36 **	17.04 *	14.49^{ns}	14.55 *	12.84^{ns}	-17.95^{ns}	-13.51^{ns}

^{ns}=Non-significant, *=Significant at 5% probability level, **= Significant at 1% probability level

Table 11. Estimation of heterosis over better parent and mid parent of five morphological traits in *Solanum lycopercum* L.

	Number of Cluster per Plant		Number of Fruit per Cluster		Number of Fruit per Plant		Days to Maturity		Fruit Weight	
	BP	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**
G1×G2	-13.21^{ns}	-8.00^{ns}	0.003^{ns}	3.70^{ns}	-5.43^{ns}	-2.79^{ns}	-0.83^{ns}	-2.45^{ns}	49.16^{ns}	62.15^{ns}
G1×G3	13.21^{ns}	14.29^{ns}	0.003^{ns}	3.70^{ns}	3.88^{ns}	20.18 *	4.17^{ns}	2.25^{ns}	-21.10^{ns}	-8.57^{ns}
G1×G4	-7.14^{ns}	-4.59^{ns}	0.003^{ns}	7.69^{ns}	10.85^{ns}	22.75 *	0.00^{ns}	-0.81^{ns}	35.72^{ns}	55.32^{ns}
G1×G5	10.91^{ns}	12.96^{ns}	-22.22^{ns}	-12.50^{ns}	-45.74 **	-38.86 **	2.81^{ns}	0.99^{ns}	-22.32^{ns}	6.75^{ns}
G1×G6	11.32^{ns}	18.00^{ns}	0.00^{ns}	3.45^{ns}	-24.03 **	-18.67 *	1.24^{ns}	-0.41^{ns}	128.71 **	144.44 **
G1×G7	3.57^{ns}	6.42^{ns}	-7.14^{ns}	8.33^{ns}	4.65^{ns}	11.11^{ns}	2.86^{ns}	2.02^{ns}	4.54^{ns}	14.73^{ns}
G1×G8	3.77^{ns}	8.91^{ns}	0.00^{ns}	0.00^{ns}	-11.63^{ns}	-8.06^{ns}	-4.82 *	-4.82^{ns}	15.35^{ns}	38.69^{ns}
G2×G1	13.21^{ns}	20.00^{ns}	-14.29^{ns}	-11.11^{ns}	5.43^{ns}	8.37^{ns}	8.30 **	6.53 *	70.14 *	84.97 *
G2×G3	-3.85^{ns}	1.01^{ns}	15.38^{ns}	15.38^{ns}	0.82^{ns}	13.89^{ns}	-1.25^{ns}	-1.46^{ns}	42.80^{ns}	77.43 *
G2×G4	-8.93^{ns}	-0.97^{ns}	0.00^{ns}	4.00^{ns}	0.82^{ns}	8.85^{ns}	2.90^{ns}	2.06^{ns}	32.38^{ns}	62.65^{ns}
G2×G5	-9.09^{ns}	-1.96^{ns}	-33.33 *	-22.58^{ns}	-15.57 *	-7.21^{ns}	3.73^{ns}	0.20^{ns}	-26.95^{ns}	5.69^{ns}
G2×G6	21.28^{ns}	21.28^{ns}	-13.33^{ns}	-7.14^{ns}	-22.95 **	-19.66 *	3.32^{ns}	3.32^{ns}	-6.28^{ns}	8.25^{ns}
G2×G7	-1.79^{ns}	6.80^{ns}	15.38^{ns}	30.43^{ns}	-21.31 **	-18.64 *	1.24^{ns}	0.41^{ns}	9.61^{ns}	29.68^{ns}
G2×G8	27.08^{ns}	28.42^{ns}	0.00^{ns}	3.70^{ns}	-2.46^{ns}	-1.24^{ns}	-0.83^{ns}	-2.45^{ns}	66.51 **	73.56 *
G3×G1	-7.55^{ns}	-6.67^{ns}	28.57^{ns}	33.33^{ns}	-24.03 **	-12.11^{ns}	3.33^{ns}	1.43^{ns}	-21.50^{ns}	-9.04^{ns}
G3×G2	13.46^{ns}	19.19^{ns}	-15.38^{ns}	-15.38^{ns}	13.93^{ns}	28.70 **	2.50^{ns}	2.29^{ns}	-3.70^{ns}	19.65^{ns}
G3×G4	-17.86^{ns}	-14.81^{ns}	-23.08^{ns}	-20.00^{ns}	28.85 **	35.35 **	-0.83^{ns}	-1.86^{ns}	-9.90^{ns}	-8.58^{ns}
G3×G5	20.00^{ns}	23.36^{ns}	-33.33 *	-22.58^{ns}	22.00 *	25.77 *	7.92 **	4.02^{ns}	-14.53^{ns}	5.05^{ns}
G3×G6	19.23^{ns}	25.25^{ns}	0.00^{ns}	7.14^{ns}	14.29^{ns}	24.27 *	5.83 *	5.61 *	22.21^{ns}	33.32^{ns}
G3×G7	-12.50^{ns}	-9.26^{ns}	7.69^{ns}	21.74^{ns}	11.40^{ns}	22.12 *	1.25^{ns}	0.21^{ns}	43.62^{ns}	52.56^{ns}
G3×G8	5.77^{ns}	10.00^{ns}	0.00^{ns}	3.70^{ns}	-8.40^{ns}	2.35^{ns}	2.50^{ns}	0.61^{ns}	49.16^{ns}	62.15^{ns}
G4×G1	16.07^{ns}	19.27^{ns}	14.29^{ns}	23.08^{ns}	-16.28 *	-7.30^{ns}	4.08^{ns}	3.24^{ns}	-21.10^{ns}	-8.57^{ns}
G4×G2	-16.07^{ns}	-8.74^{ns}	-7.69^{ns}	-4.00^{ns}	3.28^{ns}	11.50^{ns}	-0.83^{ns}	-1.65^{ns}	35.72^{ns}	55.32^{ns}
G4×G3	-28.57 *	-25.93^{ns}	30.77^{ns}	36.00^{ns}	7.69^{ns}	13.13^{ns}	-3.33^{ns}	-4.33^{ns}	-22.32^{ns}	6.75^{ns}
G4×G5	-3.57^{ns}	-2.70^{ns}	-50.00 **	-40.00 *	15.38^{ns}	17.65^{ns}	1.22^{ns}	-1.39^{ns}	128.71 **	144.44 **
G4×G6	-1.79^{ns}	6.80^{ns}	0.00^{ns}	11.11^{ns}	-6.25^{ns}	-2.78^{ns}	-1.66^{ns}	-2.47^{ns}	4.54^{ns}	14.73^{ns}
G4×G7	-19.64^{ns}	-19.64^{ns}	25.00^{ns}	36.36^{ns}	15.79^{ns}	21.10 *	-2.04^{ns}	-2.04^{ns}	15.35^{ns}	38.69^{ns}
G4×G8	-16.07^{ns}	-9.62^{ns}	21.43^{ns}	30.77^{ns}	-0.84^{ns}	5.83^{ns}	-2.86^{ns}	-3.64^{ns}	70.14 *	84.97 *

^{ns}=Non-significant, *=Significant at 5% probability level, **= Significant at 1% probability level

Table 11 (Cont'd)

	Number of Cluster per Plant		Number of Fruit per Cluster		Number of Fruit per Plant		Days to Maturity		Fruit Weight	
	BP	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**
G5×G1	21.82 ^{ns}	24.07 ^{ns}	-44.44 **	-37.50 *	-25.58 **	-16.16^{ns}	4.42^{ns}	2.56^{ns}	45.89^{ns}	49.93^{ns}
G5×G2	1.82 ^{ns}	9.80 ^{ns}	-11.11 ^{ns}	3.23 ^{ns}	-6.56^{ns}	2.70^{ns}	2.90^{ns}	-0.60^{ns}	-7.78^{ns}	5.53^{ns}
G5×G3	5.45 ^{ns}	8.41 ^{ns}	-16.67 ^{ns}	-3.23 ^{ns}	29.00 **	32.99 **	1.67^{ns}	-2.01^{ns}	9.67^{ns}	34.75^{ns}
G5×G4	-19.64 ^{ns}	-18.92 ^{ns}	-33.33 *	-20.00 ^{ns}	11.54^{ns}	13.73^{ns}	-3.27^{ns}	-5.77 *	-36.57^{ns}	-35.64^{ns}
G5×G6	-3.64 ^{ns}	3.92 ^{ns}	-16.67 ^{ns}	-9.09 ^{ns}	10.71^{ns}	16.98^{ns}	2.49^{ns}	-1.00^{ns}	-52.96 **	-41.53^{ns}
G5×G7	-12.50 ^{ns}	-11.71 ^{ns}	-27.78 ^{ns}	-7.14 ^{ns}	0.88^{ns}	7.48^{ns}	-1.63^{ns}	-4.17^{ns}	-20.13^{ns}	-14.03^{ns}
G5×G8	-3.64 ^{ns}	2.91 ^{ns}	-16.67 ^{ns}	-6.25 ^{ns}	-4.20^{ns}	4.11^{ns}	-2.01^{ns}	-3.75^{ns}	45.58^{ns}	52.51^{ns}
G6×G1	-18.87 ^{ns}	-14.00 ^{ns}	-20.00 ^{ns}	-17.24 ^{ns}	-10.08^{ns}	-3.73^{ns}	-2.49^{ns}	-4.08^{ns}	-30.76 *	-12.14^{ns}
G6×G2	17.02 ^{ns}	17.02 ^{ns}	-13.33 ^{ns}	-7.14 ^{ns}	11.48^{ns}	16.24^{ns}	2.07^{ns}	2.07^{ns}	-43.29 **	-22.07^{ns}
G6×G3	5.77 ^{ns}	11.11 ^{ns}	0.00 ^{ns}	7.14 ^{ns}	5.36^{ns}	14.56^{ns}	1.25^{ns}	1.04^{ns}	-35.41 *	-6.55^{ns}
G6×G4	-5.36 ^{ns}	2.91 ^{ns}	-6.67 ^{ns}	3.70 ^{ns}	5.36^{ns}	9.26^{ns}	2.07^{ns}	1.23^{ns}	-41.93 **	-28.63^{ns}
G6×G5	-1.82 ^{ns}	5.88 ^{ns}	-16.67 ^{ns}	-9.09 ^{ns}	11.61^{ns}	17.92^{ns}	-0.83^{ns}	-4.21^{ns}	-50.57 **	-38.56^{ns}
G6×G7	-10.71 ^{ns}	-2.91 ^{ns}	-6.67 ^{ns}	12.00 ^{ns}	0.88^{ns}	1.77^{ns}	3.73^{ns}	2.88^{ns}	-28.18^{ns}	-5.66^{ns}
G6×G8	12.50 ^{ns}	13.68 ^{ns}	-33.33 ^{ns}	-31.03 ^{ns}	-5.04^{ns}	-2.16^{ns}	3.32^{ns}	1.63^{ns}	-40.33 **	-23.18^{ns}
G7×G1	-25.00 *	-22.94 ^{ns}	0.00 ^{ns}	16.67 ^{ns}	0.00^{ns}	6.17^{ns}	-4.49^{ns}	-5.26^{ns}	6.56^{ns}	11.77^{ns}
G7×G2	-21.43 ^{ns}	-14.56 ^{ns}	0.00 ^{ns}	13.04 ^{ns}	4.10^{ns}	7.63^{ns}	-2.07^{ns}	-2.88^{ns}	3.50^{ns}	10.62^{ns}
G7×G3	-7.14 ^{ns}	-3.70 ^{ns}	15.38 ^{ns}	30.43 ^{ns}	19.30 *	30.77 **	2.08^{ns}	1.03^{ns}	13.85^{ns}	31.50^{ns}
G7×G4	8.93 ^{ns}	8.93 ^{ns}	0.00 ^{ns}	9.09 ^{ns}	12.28^{ns}	17.43^{ns}	3.27^{ns}	3.27^{ns}	37.04^{ns}	49.51^{ns}
G7×G5	10.71 ^{ns}	11.71 ^{ns}	-22.22 ^{ns}	0.00 ^{ns}	9.65^{ns}	16.82^{ns}	4.49^{ns}	1.79^{ns}	0.42^{ns}	8.10^{ns}
G7×G6	12.50 ^{ns}	22.33 ^{ns}	-6.67 ^{ns}	12.00 ^{ns}	-7.89^{ns}	-7.08^{ns}	4.98 *	4.12^{ns}	-55.76 **	-41.88^{ns}
G7×G8	-1.79 ^{ns}	5.77 ^{ns}	-14.29 ^{ns}	0.00 ^{ns}	-2.52^{ns}	-0.43^{ns}	1.22^{ns}	0.40^{ns}	31.04^{ns}	34.83^{ns}
G8×G1	1.89 ^{ns}	6.93 ^{ns}	-14.29 ^{ns}	-14.29 ^{ns}	-27.13 **	-24.19 **	-0.80^{ns}	-0.80^{ns}	76.11 **	79.63 *
G8×G2	16.67 ^{ns}	17.89 ^{ns}	7.14 ^{ns}	11.11 ^{ns}	-18.03 *	-17.01^{ns}	3.32^{ns}	1.63^{ns}	-6.18^{ns}	2.97^{ns}
G8×G3	-5.77 ^{ns}	-2.00 ^{ns}	-21.43 ^{ns}	-18.52 ^{ns}	1.68^{ns}	13.62^{ns}	0.83^{ns}	-1.02^{ns}	70.64 *	101.87 **
G8×G4	-7.14 ^{ns}	0.00 ^{ns}	0.00 ^{ns}	7.69 ^{ns}	-2.52^{ns}	4.04^{ns}	-1.22^{ns}	-2.02^{ns}	20.49^{ns}	27.99^{ns}
G8×G5	-16.36 ^{ns}	-10.68 ^{ns}	-33.33 *	-25.00 ^{ns}	2.52^{ns}	11.42^{ns}	-4.82 *	-6.51 *	-20.22^{ns}	-16.42^{ns}
G8×G6	-6.25 ^{ns}	-5.26 ^{ns}	-13.33 ^{ns}	-10.34 ^{ns}	-21.01 **	-18.61 *	-2.07^{ns}	-3.67^{ns}	-42.59 **	-26.10^{ns}
G8×G7	-10.71 ^{ns}	-3.85 ^{ns}	-21.43 ^{ns}	-8.33 ^{ns}	-18.49 *	-16.74^{ns}	-1.22^{ns}	-2.02^{ns}	11.53^{ns}	14.76^{ns}

^{ns}=Non-significant, *=Significant at 5% probability level, **= Significant at 1% probability level

26% to 33.86%. The highest significant positive heterosis was observed in the cross G7×G6 (33.86%). The highest significant negative heterosis was observed in the cross G3×G5 (-26%).

4.3.3 Days to 50% flowering

Among the 56 cross combinations 36 crosses showed positive heterobeltosis for days to 50% flowering and 20 crosses showed negative heterosis (Table 10). Heterosis for this character ranged from -19.08% to 35.17%. The highest negative heterosis was observed in G3×G5 (-19.08 %). The highest positive heterosis effect was observed in the cross G7×G6 (35.17%).

Thirty-three crosses showed positive heterosis over mid parent and 23 of them showed negative heterosis (Table 10). The estimate of heterosis ranges from -21.57% to 26.45%. The highest significant positive heterosis was observed in the cross G7×G6 (26.45%). The highest significant negative heterosis was observed in the cross G3×G5 (-21.57%).

4.3.4 Number of branches per plant

Among the 56 cross combinations 19 crosses showed positive heterobeltosis for number of branches per plant and 37 crosses showed negative heterosis (Table 10). Heterosis for this character ranged from -43.75% to 41.94%. The highest negative heterosis was observed in G5×G4 (-43.75%). The highest positive heterosis effect was observed in the cross G3×G6 (41.94%).

Thenty-seven crosses showed positive heterosis over mid parent and 29 of them showed negative heterosis (Table 10). The estimate of heterosis ranges from -37.93% to 45.71% The highest significant positive heterosis was observed in the cross G2×G1 (45.71%). The highest significant negative heterosis was observed in the cross G8×G5 (-37.93%).

4.3.5 Number of cluster per plant

Among the 56 cross combinations 24 crosses showed positive heterobeltosis for number of cluster per plant and 32 crosses showed negative heterosis (Table 11). Heterosis for this character ranged from -28.57% to 27.08 %. The highest negative heterosis was observed in G4×G3 (-28.57 %). The highest positive heterosis effect was observed in the cross G2×G8 (27.08 %).

Thirty-three crosses showed positive heterosis over mid parent and 23 of them showed negative heterosis (Table 11). The estimate of heterosis ranges from -25.93 % to 120.92%. The highest significant positive heterosis was observed in the cross G2×G8 (28.42 %). The highest significant negative heterosis was observed in the cross G4×G3 (-25.93 %).

4.3.6 Number of fruit per cluster

Among the 56 cross combinations 25 crosses showed positive heterobeltosis for number of fruit per cluster and 31 crosses showed negative heterosis (Table 11). Heterosis for this character ranged from -50% to 30.77 %. The highest negative heterosis was observed in G4×G5 (-50 %). The highest positive heterosis effect was observed in the cross G4×G3 (30.77 %).

Thirty-three crosses showed positive heterosis over mid parent and 24 of them showed negative heterosis (Table 11). The estimate of heterosis ranges from -40 % to 36.36%. The highest significant positive heterosis was observed in the cross G4×G7 (36.36 %). The highest significant negative heterosis was observed in the cross G4×G5 (-40 %).

4.3.7 Number of fruits per Plant

Among the 56 cross combinations 24 crosses showed positive heterobeltosis for number of fruit per Plant and 32 crosses showed negative heterosis (Table 11). Heterosis for this character ranged from -28.57% to 27.08 %. The highest negative heterosis was observed in G4×G3 (-28.57%). The highest positive heterosis effect was observed in the cross G2×G8 (27.08%).

Thirty-three crosses showed positive heterosis over mid parent and 23 of them showed negative heterosis (Table 11). The estimate of heterosis ranges from -25.93% to 28.42%. The highest significant positive heterosis was observed in the cross G2×G8 (28.42%). The highest significant negative heterosis was observed in the cross G4×G3 (-25.93%).

4.3.8 Days to maturity

Among the 56 cross combinations 34 crosses showed positive heterobeltosis for days to maturity and 22 crosses showed negative heterosis (Table11). Heterosis for this character ranged from -4.82 % to 8.3 %. The highest negative heterosis was observed in G1×G8 (-4.82 %). The highest positive heterosis effect was observed in the cross G2×G1 (8.3 %).

Twenty-seven crosses showed positive heterosis over mid parent and 29 of them showed negative heterosis (Table 11). The estimate of heterosis ranges from -6.51% to 6.53%. The highest significant positive heterosis was observed in the cross G2×G1 (6.53%). The highest significant negative heterosis was observed in the cross G8×G5 (-6.51%).

4.3.9 Average fruit weight (g)

Among the 56 cross combinations 31 crosses showed positive heterobeltosis for average fruit weight and 25 crosses showed negative heterosis (Table 11). Heterosis for this character ranged from -55.76 % to 128.71 %. The highest negative heterosis was observed in G7×G6 (-55.76 %). The highest positive heterosis effect was observed in the cross G1×G6 (128.71 %).

Thirty-nine crosses showed positive heterosis over mid parent and 17 of them showed negative heterosis (Table 11). The estimate of heterosis ranges from -

41.88% to 144.44 %. The highest significant positive heterosis was observed in the cross G1×G6 (144.44 %). The highest significant negative heterosis was observed in the cross G7×G6 (-41.88 %).

4.3.10 Fruit skin diameter (mm)

Among the 56 cross combinations 27 crosses showed positive heterobeltosis for fruit skin diameter and 29 crosses showed negative heterosis (Table 12). Heterosis for this character ranged from -84% to 61.54%. The highest negative heterosis was observed in G3×G1 (-84%). The highest positive heterosis effect was observed in the cross G8×G7 (61.54%).

Thirty-three crosses showed positive heterosis over mid parent and 23 of them showed negative heterosis (Table 12). The estimate of heterosis ranges from -75% to 68%. The highest significant positive heterosis was observed in the cross G8×G7 (68%). The highest significant negative heterosis was observed in the cross G3×G1 (-75%).

4.3.11 Number of locule per fruit

Among the 56 cross combinations 42 crosses showed positive heterobeltosis for number of locule per fruit and 14 crosses showed negative heterosis (Table 12). Heterosis for this character ranged from -25% to 114.286 %. The highest negative heterosis was observed in G1×G7 (-25%). The highest positive heterosis effect was observed in the cross G2×G3 (114.286 %).

Forty-seven crosses showed positive heterosis over mid parent and 9 of them showed negative heterosis (Table 12). The estimate of heterosis ranges from-20.004% to 130.769%. The highest significant positive heterosis was observed in the cross G2×G3 (130.769%). The highest significant negative heterosis was observed in the cross G1×G7 (-20.004%).

Table 12. Estimation of heterosis over better parent and mid parent of next five morphological traits in *Solanum lycopercum* L.

	Fruit Skin Diameter (mm)		Number of locule per fruit		Fruit area index (cm^2)		Yield per Plant (kg)		Leaf Chlorophyll content	
	BP	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**
G1×G2	-20.00^{ns}	0.00^{ns}	100.004**	100.004**	86.040 **	110.847 **	84.64 **	111.25 **	-22.222 **	-5.085 **
G1×G3	-25.00^{ns}	-6.25^{ns}	14.286 ^{ns}	23.077 ^{ns}	-15.327 **	-12.624 **	-0.48^{ns}	33.21^{ns}	-27.349 **	-10.540 **
G1×G4	-30.00 *	-22.22^{ns}	0.004^{ns}	0.004^{ns}	-30.111 **	-26.180 **	-13.71^{ns}	-7.99^{ns}	-50.930 **	-31.263 **
G1×G5	-30.00 *	-22.22^{ns}	-11.111 ^{ns}	0.004^{ns}	8.515 *	27.311 **	-41.81^{ns}	-36.72^{ns}	-5.450 **	10.680 **
G1×G6	-35.00 *	-18.75^{ns}	0.004^{ns}	0.004^{ns}	-48.765 **	-40.262 **	-68.87 **	-62.50 **	36.120 **	40.830 **
G1×G7	-40.00 **	-27.27^{ns}	-25.000 ^{ns}	-20.004^{ns}	-39.698 **	-37.826 **	-1.48^{ns}	11.16^{ns}	-40.771 **	-35.045 **
G1×G8	-35.00 *	-18.75^{ns}	0.004^{ns}	7.692 ^{ns}	-17.438 **	-3.572 ns	-31.77^{ns}	-27.43^{ns}	-7.932 **	-0.307 **
G2×G1	-40.00 **	-25.00^{ns}	28.571 ^{ns}	28.571 ^{ns}	-7.916 ^{ns}	4.363 ns	-22.02^{ns}	-10.78^{ns}	-43.803 **	-31.421 **
G2×G3	0.25^{ns}	0.72^{ns}	114.286 **	130.769 **	17.540 **	29.511 **	46.00^{ns}	75.84^{ns}	-45.720 **	-45.090 **
G2×G4	0.06^{ns}	14.29^{ns}	57.143 **	57.143 **	25.568 **	49.198 **	-6.94^{ns}	0.38^{ns}	-47.067 **	-36.590 **
G2×G5	-25.00^{ns}	-14.29^{ns}	44.444 **	62.500 **	13.425 *	18.054 **	36.73^{ns}	44.58^{ns}	-24.786 **	-20.899 **
G2×G6	8.33^{ns}	8.33^{ns}	57.143 **	57.143 **	-20.951 **	2.196 ns	-34.90 *	-12.85^{ns}	-38.889 **	-23.427 **
G2×G7	30.77^{ns}	36.00^{ns}	62.500 **	73.333 **	-3.012 ns	6.952 ns	129.88 **	103.12 **	-26.068 **	-16.727 **
G2×G8	58.33 *	58.33 *	0.004^{ns}	7.692 ^{ns}	82.309 **	88.763 **	3.62^{ns}	12.04^{ns}	-20.940 **	-9.866 **
G3×G1	-84.00 **	-75.00 **	0.004^{ns}	7.692 ^{ns}	31.231 **	35.421 **	-13.35^{ns}	15.98^{ns}	-43.633 **	-30.591 **
G3×G2	25.00^{ns}	25.00^{ns}	0.004^{ns}	7.692 ^{ns}	-11.941 **	-2.972 ns	92.42 **	131.75 **	-43.633 **	-42.978 **
G3×G4	-12.50^{ns}	0.44^{ns}	14.286 ^{ns}	23.077 ^{ns}	-9.451 **	-1.481 ns	84.36 **	135.70 **	-15.880 **	-0.170 **
G3×G5	0.03^{ns}	14.29^{ns}	22.222 ^{ns}	46.667 *	45.436 **	66.097 **	58.00 *	98.89 *	-18.580 **	-13.430 **
G3×G6	25.00^{ns}	25.00^{ns}	57.143 **	69.231 **	-15.460 **	1.181 ns	-17.96^{ns}	23.70^{ns}	-19.624 **	1.583 **
G3×G7	0.00^{ns}	4.00^{ns}	-12.500 ^{ns}	0.004^{ns}	22.001 **	22.110 **	6.52^{ns}	29.94^{ns}	-30.480 **	-20.903 **
G3×G8	25.00^{ns}	25.00^{ns}	0.004^{ns}	0.004^{ns}	5.958 ns	20.448 **	0.17^{ns}	28.31^{ns}	-46.347 **	-38.221 **
G4×G1	-30.00 *	-22.22^{ns}	100.004**	100.004**	-2.465 ns	3.022 ns	51.14 *	61.15 *	-45.207 **	-23.246 **
G4×G2	-18.75^{ns}	-7.14^{ns}	71.429 **	71.429 **	-40.334 **	-29.106 **	-5.08^{ns}	2.38^{ns}	-64.235 **	-57.155 **
G4×G3	-6.25^{ns}	7.14^{ns}	100.004**	115.385 **	-30.090 **	-23.936 **	-0.62^{ns}	27.05^{ns}	-47.067 **	-37.182 **
G4×G5	12.50^{ns}	12.50^{ns}	66.667 **	87.500 **	38.234 **	69.648 **	5.71^{ns}	7.96^{ns}	-44.778 **	-31.133 **
G4×G6	18.75^{ns}	35.71^{ns}	0.004^{ns}	0.004^{ns}	-24.811 **	-16.486 **	-20.81^{ns}	0.36^{ns}	-26.037 **	5.726 **
G4×G7	-12.50^{ns}	-3.45^{ns}	87.500 **	100.004**	51.414 **	64.609 **	54.33^{ns}	63.97^{ns}	-55.794 **	-41.808 **
G4×G8	-6.25^{ns}	7.14^{ns}	14.286 ^{ns}	23.077 ^{ns}	10.330 **	34.835 **	63.03 *	63.45 *	-28.898 **	-5.513 **

^{ns}=Non-significant, *=Significant at 5% probability level, **= Significant at 1% probability level

Table 12. (Cont'd)

	Fruit Skin Diameter (mm)		Number of locule per fruit		Fruit area index (cm^2)		Yield per Plant (kg)		Leaf Chlorophyll content	
	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP
G5×G1	-35.00 *	-27.78^{ns}	-11.111 ^{ns}	0.004^{ns}	68.769 **	98.002 **	13.39^{ns}	23.29^{ns}	-22.512 **	-9.293 **
G5×G2	-18.75^{ns}	-7.14^{ns}	-22.222 ^{ns}	-12.500 ^{ns}	102.635 **	110.904 **	2.99^{ns}	8.91^{ns}	-8.761 **	-4.045 **
G5×G3	0.23^{ns}	14.29^{ns}	22.222 ^{ns}	46.667 *	34.518 **	53.628 **	37.35^{ns}	72.88^{ns}	-24.008 **	-19.201 **
G5×G4	0.60^{ns}	0.890^{ns}	-22.222 ^{ns}	-12.500 ^{ns}	-17.445 **	1.315 ^{ns}	-29.13^{ns}	-27.62^{ns}	-34.907 **	-18.822 **
G5×G6	-31.25^{ns}	-21.43^{ns}	-22.222 ^{ns}	-12.500 ^{ns}	-43.548 **	-24.937 **	-48.49 **	-33.71^{ns}	-11.137 **	6.990 **
G5×G7	-6.25^{ns}	3.45^{ns}	-11.111 ^{ns}	-5.882 ^{ns}	-6.585 ^{ns}	6.768 ^{ns}	-10.24^{ns}	-6.54^{ns}	-16.351 **	-10.064 **
G5×G8	0.04^{ns}	14.29^{ns}	-22.222 ^{ns}	-6.667 ^{ns}	23.906 **	24.577 **	54.38 *	58.07^{ns}	-6.872 **	1.419 **
G6×G1	-40.00 **	-25.00^{ns}	57.143 **	57.143 **	-24.777 **	-12.294 **	-28.38^{ns}	-13.73^{ns}	31.773 **	36.332 **
G6×G2	16.67^{ns}	16.67^{ns}	71.429 **	71.429 **	-39.396 **	-21.650 **	-31.68 *	-8.54^{ns}	2.991 **	29.050 **
G6×G3	0.10^{ns}	0.88^{ns}	28.571 ^{ns}	38.462 ^{ns}	-27.831 **	-13.626 **	-33.41 *	0.41^{ns}	-22.338 **	-1.847 **
G6×G4	-37.50 *	-28.57^{ns}	57.143 **	57.143 **	3.089 ^{ns}	14.504 **	-39.29 *	-23.06^{ns}	-37.053 **	-10.020 **
G6×G5	-18.75^{ns}	-7.14^{ns}	33.333 *	50.004**	-44.080 **	-25.645 **	-45.17 **	-29.44^{ns}	-3.791 **	15.835 **
G6×G7	7.69^{ns}	12.00^{ns}	-12.500 ^{ns}	-6.667 ^{ns}	-21.688 **	-6.341 ^{ns}	-26.66^{ns}	-2.87^{ns}	-3.581 **	9.034 **
G6×G8	16.67^{ns}	16.67^{ns}	14.286 ^{ns}	23.077 ^{ns}	-5.148 ^{ns}	25.665 **	-40.11 *	-24.25^{ns}	23.796 **	38.291 **
G7×G1	-25.00^{ns}	-9.09^{ns}	0.004^{ns}	6.667 ^{ns}	19.189 **	22.889 **	6.18^{ns}	19.79^{ns}	19.284 **	30.816 **
G7×G2	0.34^{ns}	4.00^{ns}	-25.000 ^{ns}	-20.004^{ns}	-9.852 *	-0.591 ^{ns}	18.98^{ns}	20.90^{ns}	5.983 **	19.374 **
G7×G3	23.08^{ns}	28.00^{ns}	-12.500 ^{ns}	0.004^{ns}	-10.516 *	-10.436 *	39.69^{ns}	70.40^{ns}	-7.098 **	5.701 **
G7×G4	-6.25^{ns}	3.45^{ns}	12.500 ^{ns}	20.004^{ns}	-31.826 **	-25.885 **	68.53 *	79.07 *	-39.914 **	-20.904 **
G7×G5	-18.75^{ns}	-10.34^{ns}	100.004**	111.765 **	41.246 **	61.435 **	22.22^{ns}	27.27^{ns}	-13.981 **	-7.516 **
G7×G6	23.08^{ns}	28.00^{ns}	0.004^{ns}	6.667 ^{ns}	-45.693 **	-35.050 **	-58.39 **	-44.89^{ns}	35.813 **	53.583 **
G7×G8	53.85 *	60.00 *	12.500 ^{ns}	28.571 ^{ns}	-5.079 ^{ns}	7.985 ^{ns}	33.60^{ns}	42.30^{ns}	4.132 **	5.587 **
G8×G1	-35.00 *	-18.75^{ns}	0.004^{ns}	7.692 ^{ns}	-10.602 **	4.412 ^{ns}	24.55^{ns}	32.48^{ns}	32.011 **	42.945 **
G8×G2	0.34^{ns}	1.90^{ns}	0.004^{ns}	7.692 ^{ns}	-5.740 ^{ns}	-2.403 ^{ns}	-20.26^{ns}	-13.78^{ns}	-9.615 **	3.045 **
G8×G3	25.00^{ns}	25.00^{ns}	100.004**	100.004**	32.754 **	50.908 **	74.94 **	124.08 **	-36.326 **	-26.683 **
G8×G4	-18.75^{ns}	-7.14^{ns}	14.286 ^{ns}	23.077 ^{ns}	16.438 **	42.300 **	32.36^{ns}	32.71^{ns}	-0.286 **	32.510 **
G8×G5	-31.25^{ns}	-21.43^{ns}	-22.222 ^{ns}	-6.667 ^{ns}	8.047 ^{ns}	8.632 ^{ns}	-9.98^{ns}	-7.83^{ns}	-16.114 **	-8.645 **
G8×G6	25.00^{ns}	25.00^{ns}	0.004^{ns}	7.692 ^{ns}	-29.375 **	-6.433 ^{ns}	-49.67 **	-36.34^{ns}	31.445 **	46.835 **
G8×G7	61.54 **	68.00 **	-12.500 ^{ns}	0.004^{ns}	-3.241 ^{ns}	10.075 ^{ns}	-6.41^{ns}	-0.32^{ns}	0.004 ^{ns}	1.397 **

^{ns}=Non-significant, *=Significant at 5% probability level, **= Significant at 1% probability level

Table 13. Estimation of heterosis over better parent and mid parent of last five morphological traits in *Solanum lycopercum* L.

	Relative Water Content		Brix (%)		Vitamin C content		Titrable Acidity (%)		Fruit pH	
	BP	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**
G1×G2	59.434 **	65.539 **	-30.004**	-30.004**	91.319 **	105.943 **	-39.988 **	-35.728 **	-29.663 **	-22.042 **
G1×G3	128.226 **	136.874 **	-42.857 **	-33.333 **	78.777 **	86.410 **	-28.854 **	-11.907 **	-29.268 **	-25.720 **
G1×G4	-21.125 **	6.382 **	0.004^{ns}	11.111 **	-39.858 **	-29.708 **	-14.294 **	0.661 **	-24.045 **	-15.288 **
G1×G5	11.532 **	59.306 **	-18.000 **	-8.889 **	22.227 **	51.102 **	0.218 **	2.534 **	-27.191 **	-21.739 **
G1×G6	43.732 **	71.146 **	0.004^{ns}	0.004^{ns}	-29.069 **	-22.205 **	0.323 **	7.161 **	-31.910 **	-21.705 **
G1×G7	-23.172 **	12.382 **	-20.004**	-11.111 **	-48.146 **	-30.824 **	-13.235 **	-8.308 **	-31.461 **	-20.261 **
G1×G8	64.054 **	118.126 **	0.004^{ns}	0.004^{ns}	-30.728 **	0.298 **	48.017 **	75.325 **	-26.517 **	-16.900 **
G2×G1	87.707 **	94.894 **	0.004^{ns}	0.004^{ns}	32.066 **	42.160 **	-46.704 **	-42.921 **	-8.764 **	1.121 **
G2×G3	162.842 **	182.837 **	-28.571 **	-16.667 **	90.262 **	112.854 **	-68.879 **	-59.417 **	-28.049 **	-16.706 **
G2×G4	27.089 **	67.079 **	-20.004**	-11.111 **	5.806 **	31.419 **	-40.719 **	-26.346 **	-5.307 **	-4.641 **
G2×G5	-9.621 **	26.219 **	-10.004**	0.004^{ns}	-3.895 **	25.621 **	10.028 **	20.364 **	-0.522 **	2.834 **
G2×G6	186.322 **	230.288 **	-20.004**	-20.004**	88.718 **	121.166 **	6.564 **	6.865 **	-11.453 **	-7.715 **
G2×G7	12.446 **	61.038 **	-22.000 **	-13.333 **	-24.695 **	5.448 **	-61.241 **	-60.689 **	26.257 **	33.333 **
G2×G8	20.459 **	55.998 **	0.004^{ns}	0.004^{ns}	-44.662 **	-16.608 **	-25.185 **	-16.579 **	3.631 **	6.000 **
G3×G1	118.783 **	127.073 **	-38.571 **	-28.333 **	-5.108 **	-1.057 **	-82.679 **	-78.554 **	-14.837 **	-10.566 **
G3×G2	94.138 **	108.906 **	-28.571 **	-16.667 **	3.039 **	15.274 **	-64.729 **	-54.006 **	-26.016 **	-14.353 **
G3×G4	16.350 **	60.748 **	-35.714 **	-18.182 **	25.111 **	40.998 **	-47.180 **	-43.669 **	-30.081 **	-18.580 **
G3×G5	-23.745 **	11.240 **	-42.857 **	-27.273 **	-17.763 **	-1.684 **	-51.270 **	-40.732 **	-27.033 **	-17.943 **
G3×G6	-7.483 **	13.517 **	-44.286 **	-35.000 **	2.312 **	7.868 **	-56.659 **	-43.593 **	4.065 **	24.726 **
G3×G7	-72.354 **	-58.751 **	-35.714 **	-18.182 **	-45.541 **	-29.443 **	-41.401 **	-24.347 **	-37.805 **	-24.631 **
G3×G8	-11.591 **	20.498 **	7.143 **	25.000 **	-76.511 **	-66.808 **	-34.622 **	-8.152 **	-34.553 **	-22.782 **
G4×G1	-27.524 **	-2.248 **	-20.004**	-11.111 **	-10.900 **	4.137 **	12.321 **	31.921 **	-14.607 **	-4.762 **
G4×G2	-1.841 **	29.045 **	0.004^{ns}	11.111 **	-50.624 **	-38.671 **	19.177 **	48.073 **	-4.469 **	-3.797 **
G4×G3	-57.994 **	-41.965 **	-42.857 **	-27.273 **	23.255 **	38.906 **	-11.295 **	-5.399 **	-33.130 **	-22.130 **
G4×G5	-28.922 **	-22.271 **	0.004^{ns}	0.004^{ns}	-55.818 **	-52.713 **	-34.605 **	-24.666 **	-14.883 **	-11.413 **
G4×G6	3.382 **	20.883 **	-20.004**	-11.111 **	-37.630 **	-33.065 **	-54.508 **	-43.599 **	-12.748 **	-9.677 **
G4×G7	-48.846 **	-41.891 **	25.000 **	25.000 **	-18.181 **	-3.848 **	-5.079 **	16.658 **	1.983 **	6.984 **
G4×G8	3.165 **	5.397 **	-4.000 **	6.667 **	-55.610 **	-42.207 **	37.688 **	85.574 **	9.632 **	11.367 **

^{ns}=Non-significant, *=Significant at 5% probability level, **= Significant at 1% probability level

Table 13 (Cont'd)

	Relative Water Content		Brix (%)		Vitamin C content		Titrable Acidity (%)		Fruit pH	
	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP
G5×G1	-33.793 **	-5.434 **	-40.004**	-33.333 **	11.262 **	37.547 **	-14.924 **	-12.957 **	-6.292 **	0.725 **
G5×G2	-3.125 **	35.291 **	-42.000 **	-35.556 **	-20.343 **	4.122 **	20.778 **	32.124 **	-18.799 **	-16.059 **
G5×G3	-47.323 **	-23.156 **	-57.143 **	-45.455 **	-18.408 **	-2.455 **	-36.963 **	-23.330 **	-24.187 **	-14.743 **
G5×G4	-34.695 **	-28.584 **	0.004ns	0.004ns	24.485 **	33.233 **	-29.044 **	-18.259 **	-13.838 **	-10.326 **
G5×G6	-21.526 **	-1.220 **	-16.000 **	-6.667 **	-18.730 **	-7.131 **	-39.288 **	-33.755 **	-16.971 **	-10.674 **
G5×G7	-17.889 **	-14.364 **	-25.000 **	-25.000 **	-33.294 **	-26.209 **	-67.158 **	-64.538 **	2.611 **	11.807 **
G5×G8	-1.141 **	10.226 **	-36.000 **	-28.889 **	-66.956 **	-59.136 **	-62.224 **	-54.415 **	-8.616 **	-3.448 **
G6×G1	29.586 **	54.301 **	0.004ns	0.004ns	-20.042 **	-12.304 **	57.955 **	68.722 **	-26.742 **	-15.762 **
G6×G2	54.706 **	78.462 **	-40.004**	-40.004**	22.946 **	44.085 **	-12.381 **	-12.133 **	-0.559 **	3.639 **
G6×G3	26.522 **	55.240 **	-44.286 **	-35.000 **	-7.145 **	-2.103 **	49.964 **	95.172 **	-32.724 **	-19.367 **
G6×G4	-19.253 **	-5.584 **	-10.004**	0.004ns	12.117 **	20.323 **	-3.218 **	19.991 **	-2.833 **	0.587 **
G6×G5	-12.867 **	9.679 **	0.004ns	11.111 **	-46.143 **	-38.456 **	15.132 **	25.624 **	-2.611 **	4.775 **
G6×G7	-43.383 **	-26.490 **	-14.000 **	-4.444 **	1.362 **	26.218 **	127.908 **	130.514 **	16.109 **	17.720 **
G6×G8	-9.091 **	4.381 **	-20.004**	-20.004**	-33.713 **	-9.386 **	-12.816 **	-2.545 **	3.216 **	5.216 **
G7×G1	-11.433 **	29.553 **	-30.004**	-22.222 **	17.518 **	56.776 **	-42.607 **	-39.349 **	-23.596 **	-11.111 **
G7×G2	-15.406 **	21.150 **	0.004ns	11.111 **	-49.710 **	-29.580 **	-66.297 **	-65.816 **	17.039 **	23.599 **
G7×G3	-51.495 **	-27.629 **	-28.571 **	-9.091 **	2.665 **	33.011 **	-69.047 **	-60.039 **	-27.439 **	-12.069 **
G7×G4	-73.182 **	-69.535 **	-2.500 **	-2.500 **	23.771 **	45.453 **	-66.687 **	-59.058 **	-5.949 **	-1.337 **
G7×G5	-37.258 **	-34.564 **	5.000 **	5.000 **	-19.483 **	-10.932 **	-24.481 **	-18.456 **	-7.050 **	1.280 **
G7×G6	-72.685 **	-64.535 **	-22.000 **	-13.333 **	23.511 **	53.798 **	-18.689 **	-17.760 **	1.520 **	2.928 **
G7×G8	-67.056 **	-61.880 **	-20.004**	-11.111 **	-26.945 **	-17.168 **	30.951 **	47.853 **	-1.170 **	2.115 **
G8×G1	-20.909 **	5.159 **	-28.000 **	-28.000 **	6.895 **	54.770 **	-27.302 **	-13.890 **	-7.640 **	4.447 **
G8×G2	-42.500 **	-25.536 **	-12.000 **	-12.000 **	-32.718 **	1.390 **	-12.440 **	-2.369 **	25.698 **	28.571 **
G8×G3	-9.773 **	22.976 **	-28.571 **	-16.667 **	-24.756 **	6.326 **	-72.835 **	-61.837 **	-22.764 **	-8.873 **
G8×G4	-37.971 **	-36.629 **	-10.004**	0.004ns	-24.557 **	-1.778 **	-72.212 **	-62.547 **	-5.666 **	-4.173 **
G8×G5	-46.241 **	-40.060 **	4.000 **	15.556 **	-7.040 **	14.962 **	-30.443 **	-16.064 **	12.272 **	18.621 **
G8×G6	-0.227 **	14.558 **	-36.000 **	-36.000 **	-28.936 **	-2.855 **	38.291 **	54.583 **	14.035 **	16.244 **
G8×G7	-52.157 **	-44.639 **	-28.000 **	-20.004**	-15.400 **	-4.078 **	16.668 **	31.727 **	-8.772 **	-5.740 **

ns=Non-significant, *=Significant at 5% probability level, **= Significant at 1% probability level

4.3.12 Fruit area index (cm^2)

Among the 56 cross combinations 23 crosses showed positive heterobeltosis for fruit area index and 33 crosses showed negative heterosis (Table 12). Heterosis for this character ranged from -48.765 % to 102.635 %. The highest negative heterosis was observed in G1×G6 (-48.765 %). The highest positive heterosis effect was observed in the cross G5×G2 (102.635 %).

Thirty-four crosses showed positive heterosis over mid parent and 22 of them showed negative heterosis (Table 12). The estimate of heterosis ranges from-

40.262% to 110.904%. The highest significant positive heterosis was observed in the cross G5×G2 (110.904%). The highest significant negative heterosis was observed in the cross G1×G6 (-40.262%).

4.3.13 Fruit Yield per plant (kg)

Among the 56 cross combinations 27 crosses showed positive heterobeltosis for fruit Yield per plant and 29 crosses showed negative heterosis (Table 12). Heterosis for this character ranged from -68.87 % to 129.88 %. The highest negative heterosis was observed in G1×G6 (-68.87 %). The highest positive heterosis effect was observed in the cross G2×G7 (129.88 %).

Thirty-six crosses showed positive heterosis over mid parent and 20 of them showed negative heterosis (Table 12). The estimate of heterosis ranges from -62.5% to 135.7%. The highest significant positive heterosis was observed in the cross G3×G4 (135.7%) and the highest significant negative heterosis was found in the cross G1×G6 (-62.5%).

4.3.14 Leaf chlorophyll content

Among the 56 cross combinations 11 crosses showed positive heterobeltosis for leaf chlorophyll content and 45 crosses showed negative heterosis (Table 12). Heterosis for this character ranged from -64.235% to 36.12%. The highest negative heterosis was observed in G4×G2 (-64.235%). The highest positive heterosis effect was observed in the cross G1×G6 (36.12%).

Twenty-one crosses showed positive heterosis over mid parent and 35 of them showed negative heterosis (Table 12). The estimate of heterosis ranges from -57.155% to 53.583%. The highest significant positive heterosis was observed in the cross G7×G6 (53.583%). The highest significant negative heterosis was observed in the cross G4×G2 (-57.155%).

4.3.15 Relative Water Content (RWC)

Among the 56 cross combinations 19 crosses showed positive heterobeltosis for relative Water Content and 37 crosses showed negative heterosis (Table 13). Heterosis for this character ranged from -73.182 % to 186.322 %. The highest negative heterosis was observed in G7×G4 (-73.182 %). The highest positive heterosis effect was observed in the cross G2×G6 (186.322 %).

Thirty-five crosses showed positive heterosis over mid parent and 21 of them showed negative heterosis (Table 13). The estimate of heterosis ranges from -69.535% to 230.288%. The highest significant positive heterosis was observed in the cross G2×G6 (230.288%). The highest significant negative heterosis was observed in the cross G7×G4 (-69.535%).

4.3.16 Brix percentage (%)

Among the 56 cross combinations 15 crosses showed positive heterobeltosis for brix percentage and 41 crosses showed negative heterosis (Table 13). Heterosis for this character ranged from -57.143 % to 25 %. The highest negative heterosis was observed in G5×G3 (-57.143 %). The highest positive heterosis effect was observed in the cross G4×G7 (25 %).

Ninteen crosses showed positive heterosis over mid parent and 37 showed negative heterosis. The estimate of heterosis ranges from -45.455 % to 25%. The highest significant positive heterosis was found in the cross G3×G8 (25%). The highest significant negative heterosis was observed in the cross G5×G3 (-45.455 %).

4.3.17 Vitamin C content (mg/100 g fruit)

Among the 56 cross combinations 21 crosses showed positive heterobeltosis for Vitamin C content and 35 crosses showed negative heterosis (Table 13). Heterosis for this character ranged from -76.511 % to 91.319 %. The highest negative heterosis was observed in G3×G8 (-76.511 %). The highest positive heterosis effect was observed in the cross G1×G2 (91.319 %).

Twenty-nine crosses showed positive heterosis over mid parent and 27 of them showed negative heterosis (Table 13). The estimate of heterosis ranges from -66.808 % to 121.166%. The highest significant positive heterosis was observed in the cross G2×G6 (121.166%). The highest significant negative heterosis was observed in the cross G3×G8 (-66.808 %).

4.3.18 Titrable acidity (%)

Among the 56 cross combinations 16 crosses showed positive heterobeltosis for titrable acidity and 40 crosses showed negative heterosis (Table 13). Heterosis for this character ranged from -82.679 % to 127.908 %. The highest negative heterosis was observed in G3×G1 (-82.679 %). The highest positive heterosis effect was observed in the cross G6×G7 (127.908 %).

Nineteen crosses showed positive heterosis over mid parent and 37 of them showed negative heterosis (Table 13). The estimate of heterosis ranges from -78.554 % to 130.514 %. The highest significant positive heterosis was observed in the cross G3×G1 (130.514 %). The highest significant negative heterosis was observed in the cross G3×G1 (-78.554 %).

4.3.19 Fruit pH

Among the 56 cross combinations 13 crosses showed positive heterobeltosis for fruit pH and 43 crosses showed negative heterosis (Table 13). Heterosis for this character ranged from -37.805 % to 26.257 %. The highest negative heterosis was observed in G3×G7 (-37.805 %) and highest positive heterosis effect was observed in the cross G2×G7 (26.257 %).

Thenty-two crosses showed positive heterosis over mid parent and thirty four crosses showed negative heterosis (Table 13). The estimate of heterosis ranges from -25.72 % to 33.333 %. The highest significant positive heterosis was observed in the cross G2×G7 (33.333 %) while the highest significant negative heterosis was found in the cross G1×G3 (-25.72 %).

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted to study the heterosis and combining ability of tomato during the winter season of 2017-2018 and 2018-2019 at the experimental farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. The nature of combining ability and heterosis of eight parents and 56 cross combinations were evaluated for ninteen parameters.

Among the eight parents G1 showed significant positive GCA effects for number of branches per plant, days to maturity, Relative Water Content (RWC), Titrable acidity (%) and Fruit pH. The parent G2 showed significant positive GCA effects for Number of locule per fruit, Relative Water Content (RWC), Brix percentage (%), Fruit pH. The parent G3 showed significant positive GCA effects for Number of fruits per Plant, Fruit Yield per plant (kg), Brix percentage (%), Titrable acidity (%), Fruit pH. The parent G4 showed significant positive GCA effects for Fruit skin diameter, Number of locule per fruit, Fruit area index, Fruit Yield per plant (kg), Leaf chlorophyll content, Titrable acidity (%). The parent G5 showed significant positive GCA effects for Number of branches per plant, Days to maturity, Number of locule per fruit, Relative Water Content (RWC), Fruit pH. The parent G6 showed significant positive GCA effects for Plant height, Leaf chlorophyll content, Relative Water Content (RWC), Titrable acidity (%). The parent G7 showed significant positive GCA effects for Fruit skin diameter (mm), Vitamin C content (mg/100 g fruit). The parent G8 showed significant positive GCA effects for Leaf chlorophyll content, Brix percentage (%), Vitamin C content (mg/100 g fruit), Fruit pH.

The maximum SCA effects was observed in the cross combinations G6×G3 for Plant height, G4×G3 for Days to first flowering, G4×G3 for Days to 50% flowering, G7×G1 for Number of branches per plant, G6×G1 and G7×G1 for

Number of cluster per plant, G3×G1 for Number of fruits per Plant, G7×G1 for Days to maturity, G2×G1 for Average fruit weight (g), G7×G1 for Fruit skin diameter (mm), G5×G4 for Number of locule per fruit, G2×G1 for Fruit area index (cm^2), G2×G1 for Fruit Yield per plant (kg), G4×G8 for Leaf chlorophyll content, G2×G6 for Relative Water Content (RWC), G8×G3 for Brix percentage (%), G2×G6 for Vitamin C content, G8×G4 for Titrable acidity (%), G6×G3 for Fruit pH.

Heterotic responses over the better parent were calculated and significant heterosis was found. Highest significant positive heterobeltosis was observed in the cross G2×G6 (plant height), G3×G6 (number of branches), G2×G8 (number of cluster per plant), G4×G3 (fruit per cluster), G2×G8 (number of fruit per plant), G1×G6 (average fruit weight), G8×G7 (fruit skin diameter), G2×G3 (number of locule per plant), G5×G2 (fruit area), G2×G7 (yield per plant), G1×G6 (leaf chlorophyll content), G2×G6 (relative water content), G4×G7 (Brix%), G1×G2 (Vit-C content), G6×G7 (titrable acidity%) and G2×G7 (fruit pH). Significant negative heterosis over the better parent were found in crosses G3×G5 (Days to first flowering), G7×G6 (days to 50% flowering) and G1×G8 (days to maturity).

G2×G1could be recommended for selection of higher yield for variety development. G2×G7 could be recommended for selection to obtain short duration crop and G2×G1 for early maturity.

REFERENCE

Ahmed, S., Quamruzzaman, A.K.M. and Uddin, M.N. (2011). Estimate of heterosis in tomato (*Solanum lycopersicum* L.). *Bangladesh J. Agric. Res.* **36**(3): 521-527.

Ahmad, S. (2002). Genetics of fruit set and related traits in tomato under hot-humid conditions. Ph.D. Thesis. BSMRAU. Gazipur, Bangladesh.

Ahmed, S.U., Shaha, H.K. and Sharfuddin, A.F.M. (1988). Study of heterosis and correlation in tomato. *Thai J. Agric. Sci*. **21**(2): 117-123.

Allard, R. W. (1960). Principles of plant breeding. John Wiley and Song. Inc. New York, USA. pp. 1-485.

Al-Daej, M.I. (2014). Line×tester analysis of heterosis and combining ability in tomato (*Lycopersicon esculentum* Mill.) fruit quality traits. *Pakistan J. Biol. Sci.* **21** (5): 224-231.

Alvarez, M. (1985). Evaluation of tomato hybrids in summer. Heterosis for Morphological characteristics and fruit weight. *Cultivars-Tropicals*. **7**(1): 37-45.

Anita, S., Gautam, J.P.S., Upadhyay, M. and Joshi, A. (2005). Heterosis for yield and quality characters in tomato. *Crop Res. Hissar*. **29**(2): 285-287.

Angadi, A. and Dharmatti, P.R. (2012). Combining ability studies for processing quality traits in tomato (*Solanum lycopersicum* L.). *Res. J. Agric. Sci*. **3** (5): 1083-1085.

Angadi, A., Dharmatti, P.R. and Angadi, P.K. (2012). Combining ability studies for productivity related traits in tomato (*Lycopersicon esculentum* Mill.). *Asian J. Hort.* **7** (1): 17-20.

Anonymous. (2014). Year book of agriculture statistics. Bangladesh Bureau of Statistics. Ministry of Planning's. Govt. Peoples Republic of Bangladesh, Dhaka.

Bangladesh Bureau of Statistics (BBS). (2018). Statistical Year Book Bangladesh (37th Edition). Stat. Inf. Div. Min. Planning, Dhaka, Bangladesh.

Barrs, H.D. and Weatherley, P.E. (1962). A re-examination of the relative turgidity technique for estimating water deficits in leaves. *Australian J. Biol. Sci*. **15**: 413-428.

Bhatt, R.P., Biswas, V.R. and Kumar, N. (2001). Heterosis, combining ability and genetics for vitamin C, total soluble solids and yield in tomato (*Lycopersicon esculentum*) at 1700m altitude. *J. Agri. Sci*. **137**(2): 71-75.

Bhatt, R.P., Biswas, V.R., Pandey, H.K., Verma, G.S. and Kumar, N. (1998). Heterosis for vitamin C in tomato (*Lycopersicon esculentum* Mill.). *Indian J. Agril. Sci.* **68**(3): 176-178.

Bhavna, M. and Patel, A.I., (2014). Combining ability study in tomato (*Lycopersicon esculentum* Mill.). *Trends Biosci.* **7**: 245-256.

Bhutan, R.D. and Kallo. (1991). Inheritance studies of locule number in tomato (*Lycopersicon esculentum* Mill.). *Haryana J. Hort. Sci.* **20**(1-2): 119-124.

Bhuiyan, M.S.R. (1982). Heterosis and Combining ability in tomato (*Lycopersicon esculentum* Mill.). MS Thesis, BAU, Mymensingh, Bangladesh.

Burdick, A. (1954). Genetics of Heterosis for earliness in the tomato. *Genetics*. **39**: 488- 505.

Chandrasekhar, P. and Rao, M.R. (1989). Studies on combining ability of certain characters in tomato. *South Indian Hort.* **37**(1): 10-12.

Chadha, S., Vidyasagar and Kumar, J. (1997). Combining ability and gene action studies in tomato involving important bacterial wilt resistant lines. *Himachal J. Agric. Res*. **23**(1 -2): 26-32.

Chattopadhyay, A. and Paul, A. (2012). Studies on heterosis in tomato (*Solanum lycopersicum* L.). *Intl. J. Bio-Res.* **3**(3): 278.

Chaudhury, R.C. and Khanna, K.R. (1972). Exploitation of heterosis in tomato yield and components. *South Indian Hort*. **20**: 59-65.

Charles, W.B. and Harris, R.E. (1972). Tomato fruit set at high and low temperatures. *Canadian J. Plant. Sci.* **52**: 497-506.

Cruz, C.D., Regazzi, A.J. and Carneiro, P.C.S. (2012). Modelos biométricos aplicados ao melhoramento genético. Editora UFV, *Viçosa*. p.514.

Daskalof, Yordanov, C.M. and Ognyanova, A. (1967). Heterosis in tomatoes. *Academy Press, Sofia*. p. 180.

Dev, H., Rattan, R.S. and Thakur, M.C. (1994). Heterosis in tomato *(Lycopersicon esculentum* Mill.). *Hort. J.* **7**(2): 125-132.

Dhaliwal, M.S., Singh, S., Cheema, D.S. and Singh, P. (2004). Genetic analysis for important fruit characters of tomato by involving lines possessing male sterility genes. *Acta Hort*. **637**: 123-131.

Dod, V.N. and Kale, P.B. (1992). Heterosis for certain quality traits in tomato (*Lycopersicon esculentum* Mill.). *Crop Res*. **5**(2): 302-308.

Dod, V.N., Kale, P.B. and Wankhade, R.V. (1995). Combining ability for certain quality traits in tomato. *Crop Res. Hisar*. **9**(3): 407-412.

Duhan, D., Partap, P.S., Rana, M.K. and Dahiya, M.S. (2005). Heterosis study for quality characters in a line x tester set of tomato. *Haryana J. Hort. Sci*. **34:** 371-375.

East, E.M., Hayes, H.K. (1912). Heterozygosis in evolution and in plant breeding. USD A Bur Plant Ind Bull. **243**: 58.

EI-Mahdy, I., E-Metwally, G., EI-Fadly and Mazrouh, A.Y. (1990). Inheritance of yield and fruit setting quality of some tomato crosses grown under heat stress conditions in Egypt. *J. Agril. Res. Tanta Univ*. **16**(3): 517-526.

Eswara Reddy, G., Nandan, R., Vaishampayan, A. and Srivastava, K. (2016). Heterosis and genetic analysis for fruit quality traits in tomato. *Progress. Res*. **11**: 1210-1213.

Falconer, D.S. (1981). Introduction to Quantitative Genetics. Longman Inc. Ltd., New York. USA. p. 340.

Farzane, A., Nemati, H., Arouiee, H. and Kakhki, A.M. (2013). The estimate of heterosis and combining ability of some morphological characters in tomato transplants (*Lycopersicon esculentum* M.). *Intl. J. Farm Allied Sci*. **2**: 290-295.

Gardner, C.O. (1968). Principles of Genetics. John Willey and Sons. New York. USA.

Ghosh, P.K., Syamal, M.M. and Joshi, A.K. (1996). Graphical analysis of gene effects in tomato (*Lycopersicon esculentum* Mill.). *Adv. Plant. Sci*. **9**(1): 55-59.

Ghosh, P.K. Syamal, M.M. and Rath, S. (1997). Heterosis studies in tomato. *J. Maharasthra Agril. Univ*. **19**(1): 83-85.

Gomez, K.A. and Gomez, A.A. (1984). Statistical procedures for Agricultural Research. John Wiley and Sons, Inc. New York. USA. pp. 67-215.

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

Gunasekera, D.M. and Parera, A.L.T. (1999). Production and genetic evalution of tomato hybrids using the diallel genetic design. *Tropical Agril. Res*. **11**: 123-133.

Gul, R., Hidayat, U.R., Khalil, I.H., Shah, M.A. and Ghafoor, A. (2010). Heterosis for flower and fruit traits in tomato (*Lycopersicon escuantum* Mill). *African J. Biotecnol*. **9**(27): 4144-4151.

Hannan, M.M., Ahmed, M.B., Razvy, R., Karim, R., Khatun, M., Haydar, A., Hossain, M. and Roy, U.K. (2007). Heterosis and correlation of yield and yield components in tomato (*Lycopersicon esculentum* Mill.). *American-Eurasian J. Sci. Res*. **2**(2): 146-150.

Hayes, H.K. (1952). Development of the heterosis concept. **In**: Heterosis. *J.W. Gowen, (ed.)*. Iowa State College Press. Iowa, America.

Hedrick, U.P. and Booth, N.O. (1907). Mendelian characters in tomatoes. *Proc. American Soc. Hort. Sci*. **5**: 19-24.

Heisar, C.J. (1969). Love apples. **In**: Nightshades: The paradoxical plants. Freemann, SanFrancisco, USA. pp. 53-105.

Islam, M.R., Ahmad, S. and Rahman, M.M. (2012). Heterosis and qualitative attributes in winter tomato (*Solanum lycopersicum* L.) hybrids. *Bangladesh J. Agril. Res*. **37**(1): 39-48.

Izge, A. U. and Garba, Y. M. (2012). Combining ability for fruit worm resistance in some commercially grown tomatoes in parts of north eastern Nigeria. *Int. J. Agric. Sci*., **2**(8): 240- 244.

Jamwal, R.S., Pattan, R.S. and Saini, S.S. (1984). Hybrid vigour and combining ability in tomato. *South Indian Hort*. **32**(2): 69-74.

Jenkins, J.A. (1948). The origin of the cultivated tomato. *Economic Botany*. **2**: 379-392.

Kakjzaki, Y. (1930). Breeding crossed eggplants in Japan. *J. Hered*. **21**: 253-258.

Kurian, A., Peter, K.V. and Rajan, S. (2001). Heterosis for yield components and fruit characters in tomato. *J. Tropical Agric*. **39**(1): 5-8.

Kumar, S. and Lal, G., (1988), Variability and correlation studies in tomato (*Lycopersicon esculentum* Mill.) under low temperature conditions. *Haryana J. Hort. Sci.* **17**: 261-264.

Kumar, S., Banerjee, M.K. and Pratap, P.S. (1995a). Studies on Heterosis for various characters in tomato. *Haryana J. Hort. Sci.* **24**(1): 54-60.

Kumar, S., Banerjee, M.K. and Partap, P.S. (1995b). Heterosis study for fruit yield and its components in tomato. *Ann. Agric. Res.* **16**(2): 212-217.

Kumar, Y.K.H. Patil, S.S., Dharmatti, P.R., Byadagi, A.S., Kajjidoni, S.T. and Patil, R.H. (2009). Estimation of heterosis for tospovirus resistance in tomato. *Karnataka J. Agril. Sci.* **22**(5): 1073-1075.

Kumar, R., Srivastava, K., Somappa, J., Kumar, S. and Singh, R.K. (2012). Heterosis for yield and yield components in tomato (*Lycopersicon esculentum* Mill.). *Electro. J. Plant Breed*. **3**(2): 800-805.

Kumar, R., Srivastava, K., Singh, N.P., Vasistha, N.K.,Singh, R.K. and Singh, M.K.(2013). Combining ability analysis for yield and quality traits in tomato (*Solanum lycopersicum* L.). *J. Agril. Sci.* **5**(2): 213-218.

Kumar, P., Paliwal, A., Pant, S.C., Bahuguna, P. and Abrol, G. (2016). Heterosis studies in tomato (*Lycopersicon esculentum* Mill.) for yield and yield attributing traits for further implications in crop improvement. *J. Bio. Innov*. **5**(6): 959-972.

Kumari, N., Srivastava, J.P., Singh, B. and Deokaran. (2010). Heterotic expression for yield and its component in tomato (*Lycopersicon esculentum* Mill). *Ann. Hortic.* **3**(1): 98-101.

Kumari, S. and Sharma, M.K. (2011). Exploitation of heterosis for yield and its contributing traits in tomato (*Solanum lycopersicum* L.). *Intl. J. Farm Sci.* **1**(2): 45-55.

Kumari, S. and Sharma, M.K. (2012). Line × tester analysis to study combining ability effects in tomato (*Solanum lycopersicum* L.). *Veg. Sci.* **39**(1): 65-69.

Kurian, A. and K.V. Peter. (2001). Heterosis for quality traits in tomato. *J. Tropical Agric.* **39**(1): 13-16.

Maluf, W.R. (2001). Heterose e emprego de híbridos F_1 em hortaliças. **In**: Recursos genéticos e melhoramento – plantas. L.L. Nass., A.C.C. Valois, I.S. Melo, and M.C. Valadares, (eds.). Editora Fundação *MT, Rondonólis*, p. 327-356.

Me Daniel, R.G. (1986). Biochemical and Physiological basis of heterosis. *Critical Rev. Plant Sci.* **4**(3): 227-246.

Mirshamssi, A., Farsi, M., Shahriari, F. and Nemati, H. (2006). Estimation of heterosis and combining ability for yield components and crossing method. *Agril. Sci. Technol.* **20**(3): 3-12.

Panchal, B.B., Patel, N.B., Patel, A.I., Tank, R.V. and Patel, H.B. (2016). Combining ability analysis for yield and its related traits in tomato (*Solanum lycopersicum* L.). *Adv. Life Sci.* **5**(1): 188-193.

Peter, K.V. and Rai, B. (2012). Genetic divergence in tomato. *Indian J. Genet. Plant Breed.* **36**(3): 379-383.

Perera, A.L.T. and Liyanaarachchi, D.S. (1993). Production and evaluation of tomato hybrids using diallel genetic design. *Sri-Lankan J. Agric. Sci.* **30**: 41-48.

Premalakshme, V., Thangaraj, T., Veeraragavathatham and Arumugam, T. (2002). Hybrid vigour for yield and shelf life in tomato (*Lycopersicon esculentum* Mill.). *South Indian Hort*. **50**(4-6): 360-369.

Premalakshme, V., Thangaraj, T., Veeraragavathatham, D. and Arumugam, T. (2005). Heterosis and combining ability in tomato (*Solanum lycopersicum* L.). *Veg. sci*. **32**(1): 47-50.

Premalakshme, V., Thangaraj, T., Veeraranathatham, D. and Arumagam, T. (2006). Heterosis and combining Ability analysis in tomato (*Solanum lycopersicom* Mill.). for yield and yield contributing traits. *Veg. Sci*. **33**(1): 5-9.

Rashid, M.A. (1999). Sabji biggan (Vegetable Science) in Bengali. Second Edn. Rashid publishing house, 94 old DOHS, Dhaka-1206. pp. 1-526.

Resende, L.V., Maluf, W.R., Resende, J.T.V., Gomes, L.A.A. (2000). Combining ability of oblong-fruit tomato breeding lines with different genetic controls and levels of tospovirus resistance. *Ciencia- e-Agrotecnologia*. **24**(3): 549-559.

Rick, C.M. (1969), Origin of cultivated tomato, current status and the problem. *Intl. Botanical Cong*. p.180.

Roy, S.K. and Choudhury, B. (1972). Studies on Physiochemical characteristics of few varieties in relation to processing. *J. Food Sci. Technol*. **9**(3):151-153.

Rood, S.B., Buzzel, R.I. and McDonald, M.D. (1988). Influence of temperature on heterosis in maize seedling growth. *Crop Sci*. **28**: 283-286.

Saeed, A., Hasan, N., Shakeel, A., Saleem, M.F., Khan, N.H., Ziaf, K., Khan, R.A.M. and Saeed, N. (2014). Genetic analysis to find suitable parents for development of tomato hybrids. *Researcher*. **6**(6):77-82.

Schiable, L.W. (1962). Fruit setting response of tomatoes to high temperatures. Plant Science Symposium. pp. 89-98.

Saleem, M.Y., Asghar, M., Ahsanul, M.H., Rafique, T., Kamran, A. and Khan, A. A. (2009). Genetic analysis to identify suitable parents for hybrid seed production in tomato (*Lycopersicon esculentum* Mill). *Pakistan J. Bot*. **41**(3): 1107-1116.

Scott, J.W., Volin, R.B., Bryan, H.H. and Olson, S.M. (1986). Use of hybrids to develop heat tolerant tomato cultivars proceedings of the Florida State *Hort. Soc*. **99**: 311- 314.

Sekar, K. (2001). Heterosis for yield and yield components in tomato (*Lycopersicon esculentum* Mill.). *Adv. Hort. Forestry*. **8**: 95-102.

Sethi, V. and Ananad, J.C. (1986). Quality characteristics of hybrid tomatoes for puree preparation. *Indian food packer*. **40**(3): 13-19.

Sharma, D. and Sharma, H.R. **(**2013). Production and evaluation of tomato hybrids using diallel genetic design. *Indian J. Hort*. **70**(4): 531-537.

Sharma, A. (2014). Heterosis and combining ability studies in tomato (*Solanum lycopersicum* L.). Ph.D. Thesis. G.B.Pant university of agriculture & technology pantnagar-263 145 (Uttarakhand), India. p-146.

Shankar, A., Reddy, R.V.S.K., Sujatha, M. and Pratap, M. (2013a). Combining ability analysis to identify superior F1 hybrids for yield and quality improvement in tomato (*Solanum lycopersicum* L.). *Agrotechnol*, **2**: 114.

Shankar, A., Reddy, R.V.S.K., Protap, M., Sujatha, M. (2013b). Combining ability and gene action studies for yield and yield contributing traits in tomato (*Solanum lycopersicum* L.). *Helix*. **6**: 431-435.

Shende, V.D., Seth, T., Mukherjee, S. and Chattopadhyay, A. (2012). Breeding tomato (*Solanum lycopersicum*) for higher productivity and better processing qualities. *SABRAO J. Breed. Genet*. **44** (2): 302-321.

Sherif, T.H.I. and Hussein H.A. (1992). A genetic analysis of growth and yield characters in the tomato (*Lycopersicon esculentum* Mill.) under the heat stress of late summer in Upper Egypt. *Australian J. Agric. Sci*. **23**(2): 3-28.

Shull, G.H. (1908). The Composition of field maize. *American Breed. Assoc.* pp. 296-301.

Shull, G.H. (1914). The genotype of maize. *America Nature*. **45**: 234.

Singh, R.K. and Singh, V.K. (1993). Heterosis breeding in tomato (*Lycopersicon esculentum* Mill.). *Ann. Agric. Res.* **14**(4): 416-420.

Singh, A., Singh, P.K., Dixit, J. and Gautam, J.P.S. (1995). Heterosis and inbreeding depression in tomato. *Hort. J.* **8**(2): 125-129.

Singh, S., Dhaliwa, M.S.L., Cheema, D.S. and Brar, G.S. (1998). Diallel analysis of some processing attributes in tomato. *J. Genet. Breed*. **52**(3): 265-269.

Singh, A., Gautam, J.P.S., Upadhyay, M. and Joshi, A. (2005). Heterosis for yield and quality characters in tomato. *Crop Res. Hisar*. **29**(2): 285-287.

Singh, B., Kaul, S., Kumar, D. and Kumar, V. (2010). Combining ability for yield and its contributing characters in tomato. *Indian J. Hort*. **67**(1): 50-55.

Singh, A.K. and Asati, B.S. (2011). Combining ability and heterosis studies in tomato under bacterial wilt condition. *Bangladesh J. Agric. Res*. **36**(2): 313-318.

Singh, J. and Sastry, E.V.D. (2011). Heterosis and stress susceptibility index for fruit yield and contributing traits in tomato (*Lycopersicon esculentum*). *Indian J. Agril. Sci*. **81**(10): 957-966.

Singh, B., Singh, S.K., Naresh, R.K., Singh, K.V., Bhatnagar, S.K. and Kumar, A. (2011). General combining ability analysis of yield and its contributing traits in tomato (*Solanum lycopersicum* L.). *Plant Archives*. **11**(1): 201-204.

Souza, L.M., Paterniani, M.E.A.G.Z., Melo, P.C.T. and Melo, A.M.T. (2012). Diallel cross among fresh market tomato inbreeding lines. *Hort. Brasileira*. **30**: 246-251.

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

Sprague, G.F. (1983). Heterosis in maize. Theory and practices. **In**: Heterosis, Reappraisal of Theory and practice. Monographs on Theoretical and Applied Genetics. R. Frannkel, (ed.). Springer-Verlag Berlin, Heidelberg, Germany.

Srivastava, J.P., Singh, H., Srivastava, B.P. and Verma, H.P.S. (1998). Heterosis in relation to combining ability in tomato. *Vegetable. Sci.* **25**(1): 43-47.

Tee, E.S., Young, S.I., Ho, S.K. and Mizura, S.S. (1998). Determination of vitamin C in fresh fruits and vegetables using the dye-titration and microfluorometric methods. *Pertanika*. **11**(1): 39-44.

Tiwari, A. and Lal, G. (2004). Studies on heterosis for quantitative and qualitative characters in tomato (*Lycopersicon esculentum* Mill.). *Progres. Hort.* **36**(1): 122-127.

Vedyasagar, S., Chadha, S. and Kumar, J. (1997). Heterosis in bacterial wilt resistant tomato lines. *Himachal J. Agric. Res.* **23**(1-2): 40-44.

Villareal, R.L. (1980). Tomatoes in the tropics. West View Press, Boulder, Colorado. USA. pp. 174.

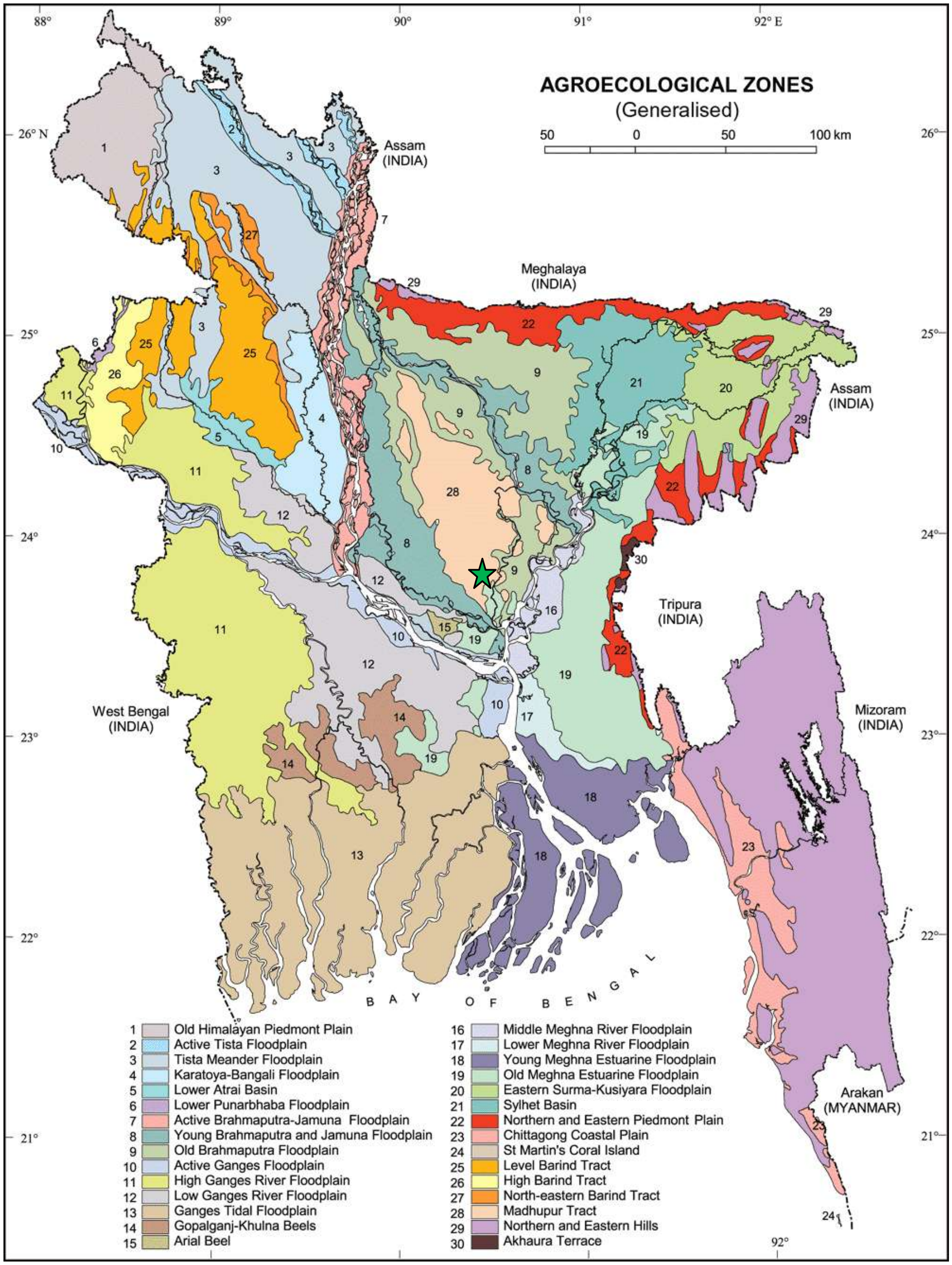
Virupannavar, H., Dharmatti, P.R., Yashvant, K.H. and Ajjappa, Sogalad. (2010). Combining ability studies on bacterial wilt resistance in tomato for processing qualities and yield. *Asian J. Hort.* **5**(1): 111-113.

Wang, L., Wang, M., Shi, Y., Tian, S.P. and Yu, Q.H. (1998). Genetic and correlation studies on characters in processing tomato. *Adv. Hort.* **2**: 378-383.

Zhou, Y.J. and Xu, H.J. (1990). A genetic analysis of several of the main processing characteristics in tomato. *Hereditas Beijing*. **12**(2): 1-3.

APPENDICES

Appendix I. Map showing the experimental site under the study



★ The experimental site under the study

Appendix II. Morphological, physical and chemical characteristics of initial soil (0- 15 cm depth) of the experimental site

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical composition of the soil

Soil separates	**%**	**Methods employed**
Sand	26	Hydrometer method (Day, 1915)
Silt	45	Do
Clay	29	Do
Texture class	Silty loam	Do

Appendix II. (Cont'd)

C. Chemical composition of the soil

Sl. No.	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.45	Walkley and Black, 1947
2	Total N (%)	0.03	Bremner and Mulvaney, 1965
3	Total S (ppm)	225.00	Bardsley and Lanester, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	54.00	Bremner, 1965
6	Available P (ppm)	20.54	Olsen and Dean, 1965
7	Exchangeable K (me/100 g soil)	0.10	Pratt, 1965
8	Available S (ppm)	16.00	Hunter, 1984
9	pH (1:2.5 soil to water)	5.6	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Source: Soil Resource and Development Institute (SRDI), Farmgate, Dhaka

Appendix III. Monthly average temperature, average relative humidity and total rainfall and average sunshine of the experimental site during the period from October, 2017 to March, 2018.

Month	Average temperature (ºc)		Average RH (%)	Rainfall (mm) (total)	Average sunshine (hr)
	Minimum	Maximum			
October, 2017	25	32	79	175	6
Novenber, 2017	21	30	65	35	8
December, 2017	15	29	74	15	9
January, 2018	13	24	68	7	9
February, 2018	18	30	57	25	8
March, 2018	20	33	57	65	7

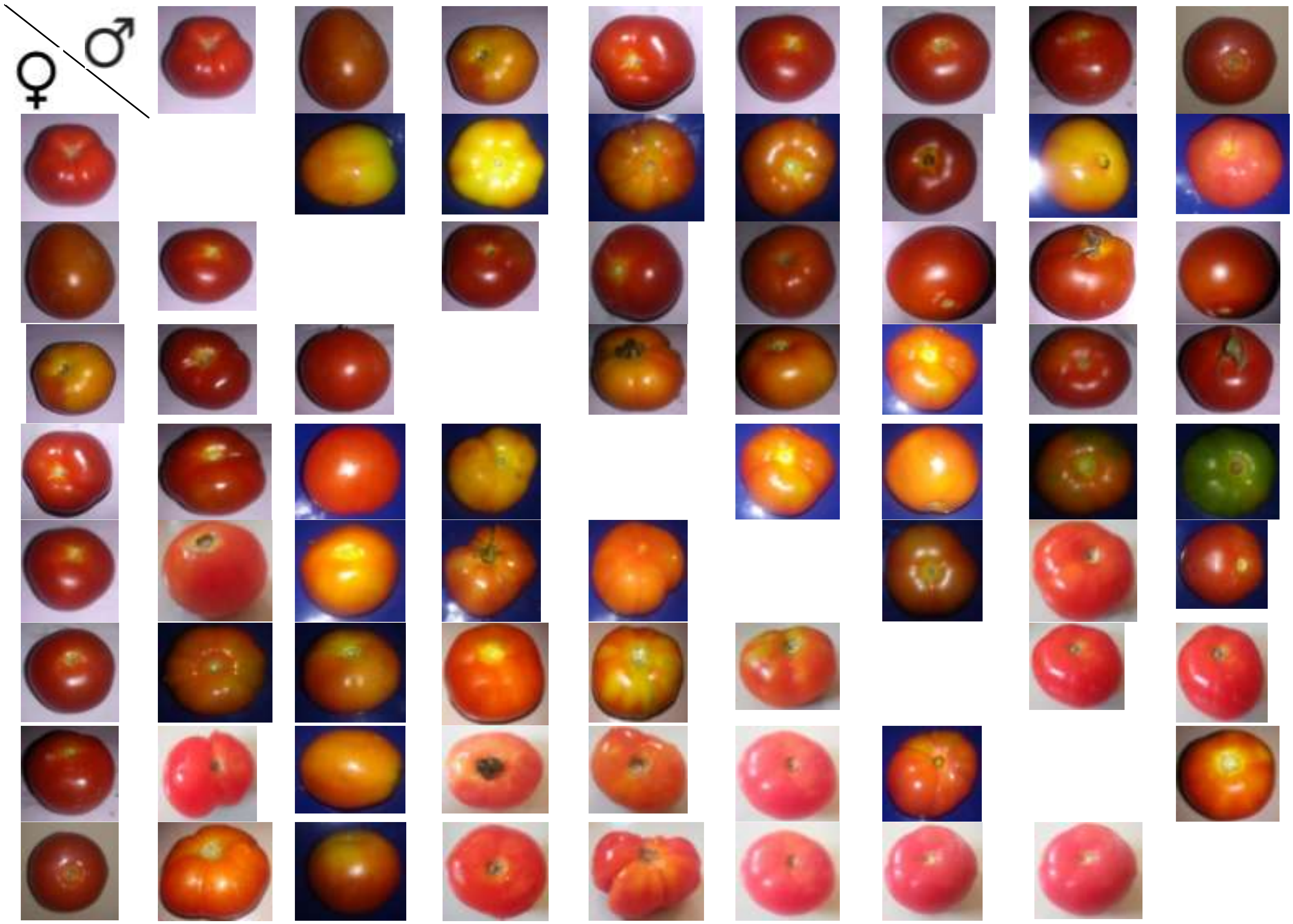
Source: Bangladesh Meteorological Department (Climate & Weather Division), Agargoan, Dhaka – 1212

Appendix IV. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from November 2018 to March 2019

Month	Year	Monthly average air temperature (^{o}C)			Average relative humidity (%)	Total rainfall (mm)	Total sunshine (hours)
		Maximum	Minimum	Mean			
Nov	2018	31	18	24	63	Trace	216.4
Dec	2018	27.12	11.56	19.34	61	Trace	212.50
Jan.	2019	28	10	14	65	Trace	212.50
Feb	2019	32	12	22	73.23	4.0	195.00
Mar.	2019	34	16	25	67.23	4.5	225.50

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix V. Fruits of F_1 generation including 8 parents in diallel pattern



Appendix VI. Analysis of variance (MS Value) for 19 different characters of *Solanum lycopersicum* L.

Source	d.f	Plant Height	Days to First Flowering	Days to 50% Flowering	Number of Branches per Plant	Number of Cluster per Plant	Number of Fruit per Cluster	Number of Fruit per Plant	Days to Maturity	Fruit Weight
Replication	2	166.40	86.79	58.33	23.94	15.66	0.11	28.44	23.94	229.81
Genotype	63	1884.93**	59.57**	66.29**	15.38**	12.46*	1.21^{ns}	66.11**	15.38**	219.47**
Error	126	366.14	28.57	29.42	7.46	9.87	1.51	18.87	7.46	96.28

^{ns}=Non-significant, *=Significant at 5% probability level, **= Significant at 1% probability level

Appendix V. (Cont'd)

Source	d.f	Fruit Skin Diameter (mm)	Number of locule per fruit	Fruit area index (cm^2)	Yield per Plant (kg)	Leaf Chlorophyll Content	Relative Water content	Brix (%)	Vitamin C content	Titrable Acidity (%)	Fruit pH
Replication	2	0.01	0.40	11.08	508873.42	144.00	576.00	40.96	368.64	23.04	23.04
Genotype	63	0.02^{ns}	2.69**	458257.04 **	321804.94 **	255.11^{ns}	623.70^{ns}	2.05**	307.75**	6.01^{ns}	0.61**
Error	126	0.02	3.01E-01	6261.888	146908.36	-3.70E-12	-1.85E-12	1.80E-14	9.24E-13	-1.62E-14	7.22E-15

^{ns}=Non-significant, *=Significant at 5% probability level, **= Significant at 1% probability level

Appendix VII. Pictorial views of the experimental field.

Visit of research supervisor in the field