STUDIES ON THE HETEROSIS AND COMBINING ABILITY IN CAPSICUM (*Capsicum annuum*)

SUJOY SARKER

DEPARTMENT OF HORTICULTURE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
SHER-E-BANGLA NAGAR, DHAKA 1207

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STUDIES ON THE HETEROSIS AND COMBINING ABILITY IN CAPSICUM (*Capsicum annuum*)

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SUJOY SARKER

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APPROVED BY:

Prof. Dr. Md. Ismail Hossain
Department of Horticulture
SAU, Dhaka
Supervisor

Dr. Md. Saifullah
Senior Scientific Officer
Olericulture Division
Horticulture Research Centre
BARI, Joydebpur, Gazipur
Co-Supervisor

Prof. Md. Hasannuzzaman Akand
Chairman
Examination Committee

DEDICATED

TO

MY BELOVED PARENTS

DEPARTMENT OF HORTICULTURE

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

Memo No: SAU/HORT/………………………………………………………………

CERTIFICATE

This is to certify that the thesis entitled **"Studies on the Heterosis and Combining Ability in Capsicum** (*Capsicum annuum*)**"** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Horticulture**, embodies the result of a piece of *bona fide* research work carried out by **Sujoy Sarker**, Registration No. **06-01921** 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 been duly acknowledged.

Date: June, 2013
Dhaka, Bangladesh

Prof. Dr. Md. Ismail Hossain
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka-1207
Supervisor

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ABSTRACT

The experiment was conducted during the period from November 2011 to March 2012 at the research field of the Olericulture Division, Bangladesh Agricultural Research Institute, Gazipur. A total of 5 parents (P_1 = ISPN 9-2, P_2 = ISPN 9-1, P_3 = Yellow wonder, P_4 = Yellow star and P_5 = California wonder) with 10 hybrid of capsicum were used in the experiment. The experiment was laid out in two factors Randomized Complete Block Design with three replications. Mean performance, variability, correlation matrix, combining ability and heterosis analysis were done on yield and yield contributing characters, viz. days to 50% flowering, plant height, individual fruit weight at green stage, individual fruit weight at mature stage, number of fruits per plant, length of fruit, diameter of fruit, fruit yield per plant at green stage, fruit yield per plant at mature stage, fruit yield per hectare at green stage and fruit yield per hectare at mature stage. Significant variation was recorded for yield contributing characters and yield of capsicum. Fruit yield per plant at mature stage in terms of phenotypic variation (11247.04) was higher than the genotypic variance (10315.43) with high heritability (91.72%) for fruit yield per plant at mature stage attached with high genetic advance (256.79%) and high genetic advance in percentage of mean (43.04). Both additive and non-additive gene actions were important in governing the yield and its attributing components. Hybrids $P_1 \times P_3$, $P_3 \times P_5$, $P_1 \times P_4$ and $P_3 \times P_4$ can be used in hybridization program in future based on highest heterosis.

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CHAPTER I

INTRODUCTION

Capsicum or sweet pepper (*Capsicum annuum*) is a flowering plant belongs to the family Solanaceae under the genus Capsicum, may be eaten as cooked or raw as well as in salad. It is relatively non-pungent with thick flesh and is the world's second most important vegetable after tomato (AVRDC, 1989). Sweet pepper and clilli, are native to Tropical South America. Especially Brazil is thought to be the original home of peppers (Shoemaker and Teskey, 1995). It is now widely cultivated in Central and South America, Peru, Bolivia, Costa Rica, Mexico, in almost all the European countries, Honkong and India. Most of the peppers cultivated in temperate and tropical areas belong to the botanical spices *Capsicum annuum*.

Capsicum is considered as a minor vegetable crop in Bangladesh and its production statistics is not available (Hasanuzzaman, 1999). Small scale cultivation is found in peri-urban areas primarily for the supply to some city markets in Bangladesh (Saha, 2001). Economically it is the second most important vegetables crop in Bulgaria and is thought to be the original home of pepper (Panajotov, 1998). It has great demand in Japan, Thailand, Philippines, Taiwan, Egypt and other countries even in Bangladesh. Capsicum has higher nutritive value and generally it contains 1.29 mg protein, 11 mg calcium, 870 I.U. vitamin A, 17.5 mg ascorbic acid, 0.6 mg thiamin, 0.03 mg riboflavin and 0.55 mg niacin per 100 g edible of fruit (Joshi and Singh, 1975). It is rich in capsaicin and have powerful antioxidant properties that may helps works against inflammation. Capsicum are used either green or red, come in variety of different colors-range from green to yellow, red, orange, purple, and black. Other capsicum include the red, heart-shaped; the pale green, slender and curved bull's horn which range in color from yellow to red and sweet banana pepper which is yellow and banana shaped (Teshm *et al*., 1999).

The genus *Capsicum* contains about 20 species. Now five domesticated species *Capsicum annuum, C. frutescens, C. chinense, C. baccatum, C. pubescens* are only recognized. All cultivated species of Capsicum have 2n = 24 chromosomes. Within *C. annuum*, a tremendous range in size, shape and mature color of fruits has been selected that now forms the basis for the types used in commerce throughout the world. All these species of capsicum have many cultivated varieties suited to different agro-climatic conditions.

In the *annuum* group, a considerable variation of genetic nature exists among different species and varieties within each species in respect of different morpho-physiological characters (Kakroo and Kumar, 1991). The choice of the most suitable breeding method for the rational improvement of yield and its components in any crop largely depends upon the genetic variability, correlations and association between qualitative and quantitative characters, heritability estimates and adaptability parameters in different environments. Hence, to formulate a successful breeding program for yield, related to yield components are very important.

The variability available in a population could be partitioned into heritable and non-heritable components with aid of genetic parameters, such as, genotypic coefficient of variation, heritability and genetic advance, which also serve as a basis for selection of any crop. Improvement in yield and quality of any crop is achieved by selecting genotypes with desirable character combinations present in the nature or genetic manipulation of diverse parents through hybridization (Golakia and Maken, 1992). The presence of self and cross incompatibility in flowering plant is a limitation in hybridization program. Cross-incompatibility exists among different cultivars, it is necessary to find out the compatible relationship of the selected genotypes before attempting any intervarietal hybridization program. Success of any controlled hybridization program depends on the high cross-compatibility of the parents chosen and is of profuse flowering types along with other desirable horticultural attributes.

The development of an intensive breeding and improvement program needs detailed biological information and an understanding of genetic variation for yield and its components. Furthermore, Gardner (1963) stressed that information on variation attributable to genetic differences and also on the relationship among various quantitative traits is fundamentally significant in a crop improvement program. There must be a thorough knowledge of the existence of genetic variability, the mode of inheritance of economic characters, heterosis, combining ability, the kind of gene action and the relative magnitude of additive, dominance and total genotypic and phenotypic variances of the population.

Therefore, the present investigation was carried out with the following objectives:

1. To study heterosis of different crosses and of parents of capsicum,
2. To study combining ability of different crosses and of parents of capsicum,
3. To develop the suitable hybrid of capsicum.

CHAPTER II

REVIEW OF LITERATURE

Sweet pepper (*Capsicum annuum*) is a flowering plant and a minor vegetable crop in Bangladesh. The genus *Capsicum* contains about 20 species and 5 species are only recognized and these cultivated species of Capsicum have 2n = 24 chromosomes. Very few research work have been carried out for the improvement of this crop in Bangladesh. Therefore, the research work so far done in different parts of the world is not adequate. Nevertheless, some of the important informative works and research findings related to heterosis and combining ability so far been done at home and abroad have been reviewed below:

Genetic variability, heritability and genetic advance for different yield contributing characters were studied by Munshi and Behera (2000) in 30 germplasm lines of chillies (*C. annuum*). The study indicated existence of considerable amount of genetic variability for all the characters studied except fruit girth. The number of fruits per plant exhibited highest values of genotypic and phenotypic coefficient of variation (GCV and PCV). High estimates of heritability (broad sense), genotypic coefficient of variation (GCV) and genetic advance was observed for fruit length, number of fruits per plant and yield per plant. These characters can be effectively improved through selection.

Six hot pepper cultivars, namely ‘Elephant Trunk’, ‘Pusa Jwala’, ‘Shalimar Long’, ‘SPE-1’, ‘Punjab Lal’ and ‘G-4’, were crossed by Ahmed *et al*. (1999) in all possible combinations without reciprocals. Data were collected on days to first fruit set, days to first fruit ripening, plant height, plant spread, fruit diameter, fruit length, average fruit weight, fruit number and total fruit yield/plant. Estimates of heterosis and combining ability were derived for each of the traits. The highest heterosis over better parent for yield and earliness was observed in Shalimar Long × Punjab Lal, Elephant Trunk × Shalimar Long and Shalimar Long × SPE-1. Variances due to general combining ability (GCA) and specific combining ability (SCA) were significant, indicating the involvement of both additive and non-additive gene effects in the expression of all the characters. Shalimar Long and Elephant Trunk recorded high GCA effects for most of the characters, while Punjab Lal, G-4 and Pusa Jwala exhibited high GCA effects for fruit number.

Ahmed and Muzafar (2000) conducted an experiment to collect information on heterosis is derived from data on 10 quantitative traits recorded in 11 parents (8 lines and 3 testers) and their 24 F_1 hybrids grown at Srinagar during 1997. It is suggested that the hybrids KSPS-461 × Oskash, KSPS-461 × KSPS-2, KSPS-461 × California Wonder, KSPS-13 × California Wonder and HC-201 × KSPS-2 which revealed the most significant desirable heterosis for yield and yield contributing characters can be successfully exploited under temperate growing conditions in India.

Parents and hybrids of a diallel cross of chilli (*Capsicum annuum*) involving 6 genotypes (Jwala (P_1), Guchender (P_2), MN-9 (P_3), HC-44 (P_4), IC 119769 (P_5) and IC 119440 (P_6)) were grown, together with the control variety Phule Jyoti, in a field experiment conducted by Gandhi *et al*. (2000) during the kharif season of 1997. Percentage heterosis was calculated for days to flowering and maturity, primary and secondary branches per plant, plant height and spread, length and girth of fruit, number of fruits and fresh and dry fruit weight per plant. They reported that the best cross combinations were HC-44 × IC 119769 and Jwala × IC 119769.

The heterosis and inheritance of four significant morphological fruit characters were studied by Todorova (2000). 'Gorogled 6' was tested as the maternal parent, and 'Buketen 50', 'Negral', 'Belrubi' and 'Kalocsai 801' as paternal parents. All F_1 hybrids showed negative heterosis, compared to the average of both parents, for fruit weight and usable fruit part. For the usable fruit part in all crosses, there was an overdominance of the parent with lower values. The depression in the F_2 varied most for fruit weight. Variability in fruit weight and usable fruit part was mostly due to genotype variability. The inheritance coefficient in the broad sense was the highest for usable fruit part (0.8-0.9).

Milerue and Nikornpun (2000) conducted an experiment with ten varieties of local chilli (*C. annuum*) collected from different locations in Thailand. Ten F_1 hybrid lines were obtained and compared with the male parents at a private company in Chiang Rai and at the Department of Horticulture, Chiang Mai University. The results showed that the three F1 hybrid lines, KY1-1 × Bang-Chang, KY 1-1 × Nhum Khiew and KY 1-1 × Nhum Khiew Maejo yielded 76.96%, 39.13% and 8.09% higher than the male parents which are landrace varieties, respectively. Moreover, the fruit quality was also higher than those of the male parents. KY 1-1 × Nhum Khiew Maejo, CF21789 × Nhum Khiew and KY 1-1 × Nhum Khiew showed high percentage of heterosis.

In a field experiment conducted by Nayaki and Natarajan (2000) in Tamil Nadu, India with hybrids of 30 *C. annuum*, heterosis over better parent was estimated for nine traits. The heterosis exhibited for plant height and number of branches per plant was mostly positive, while all the hybrids registered negative heterosis for days to 50% flowering. The heterobeltiosis for dry fruit yield per plant was the highest (219%) in CA 59 × CA 133, followed by CA 86 × CA 84 (184.8%). These hybrids also recorded the highest number of fruits per plant and fruit weight, respectively, and could be considered for commercial cultivation. The heterosis for fruit length was positive in most of the hybrids, while negative for fruit girth.

A study was undertaken by Mohammed *et al.* (2001) in Bellary, Karnataka, India, during 1997 to determine the variability pattern, heritability, genetic gain and degree of association between dry fruit yield and its component characters in 17 genotypes of chilli (*Capsicum annuum*). The phenotypic and genotypic coefficient of variations were highest for fruit length (26.64 and 26.21) followed by dry fruit yield (13.28 and 19.93) and number of branches per plant (19.46 and 15.10). The heritability was highest for plant height (98.12%) followed by fruit length (96.74%) and number of fruits per plant (96.18%). Number of fruits per plant showed highly significant positive correlation with number of branches and plant height, on the contrary, it had significant negative correlations with fruit length.

Lohithaswa *et al*. (2001) conducted an experiment with ten parents diallel analysis excluding reciprocals revealed the preponderance of non-additive gene action for all the characters except for fruit length and fruit diameter. The parents IHR-1822-1/3-1/5, Arka Iohit and G-4 were found to be good general combiners for fruit yield per plant. Best specific crosses involved parents with low GCA effects implying the need for heterosis breeding and recurrent selection for specific combining ability program in the segregating generations for substantial improvement in fruit yield per plant.

The estimates of heterosis were determined by Patel *et al*. (2001) based on the mean performance of chilli (*C. annuum*) hybrids, developed from crossing 3 lines (Jwala, S-49, and G-4) and 8 testers (Jagudan-103, Gujarat Chilli-1, Resham Patti, Kumathi, SG-5, Anand Chilli-1, DPS-120, and ACS 92-1), for yield and yield components (days to flowering, plant height, number of primary branches, number of fruits per plant, fruit length, fruit girth, fruit weight, days to fruit ripening, and fruit yield per plant) during 1997 and 1998 in Anand, Gujarat, India. The cross S-49 × DPS-120 exhibited significant standard heterosis (15.30%) for green fruit yield. However, the maximum relative heterosis (92.04%) for green fruit yield was observed in cross G-4 × Anand Chilli-1.

In a study conducted by Burli *et al*. (2001) to determine the suitable combinations for exploiting hybrid vigour through identifying high heterotic hybrids, 6 hot chilli lines (G-3 (P_1), GAD Sel-35 (P_2), Phule sai (P_3), GCH-1 (P_4), Delhired (P_5) and M Sel-11 (P_6) were crossed with two paprika-type chillies (GA Sel-31 (P_7) and Vietnam (P_8). The resulting 12 crosses and their parents were transplanted during the kharif season of 1999 in Maharashtra, India. $P_3 \times P_8$ exhibited the highest negative heterobeltiosis to the extent of -10.26% for days to 50% flowering. For plant height, all the crosses showed negative heterosis over better parent. Significant positive heterobeltiosis was expressed by $P_6 \times P_7$ for fruit length (3.82%) and for fruit weight (2.25%). However, none of the crosses showed positive heterobeltiosis for fruit breadth. Significant heterobeltiosis was recorded by $P_1 \times P_8$ (8.57%) and $P_1 \times P_7$ (6.46%) for the number of fruits. All the crosses under study showed significant heterobeltiosis for dry fruit yield per plant except $P_5 \times P_8$. Hybrids expressing high magnitude of heterobeltiosis also showed high per se performance for the number of fruits, fruit weight and dry fruit yield per plant. $P_1 \times P_8$ was identified as the best hybrid for exploiting hybrid vigour.

Six parental sweet pepper (*Capsicum annuum*) cultivars (L-Zdorovje, L-Rub, L-Sir, L-Bond, L-Top and L-Sar) and their 15 F_1 hybrids were evaluated by Mamedov and Pyshnaja (2001) for heterosis in yield and yield components. The number of crosses that exhibited significant desirable heterosis over better parent was 15 for early yield, 15 for total yield, 5 for germination-flowering, 5 for germination-technical ripening, 7 for fruit weight, 12 for fruit number per plant, 9 for fruit length, 4 for fruit girth and 8 for pericarp thickness. Among the yield components, plant height, early flowering, fruit weight, pericarp thickness and the number of fruits per plant were highly correlated with yield.

Ten parental *C. annuum* cultivars (S-49, Jwala, Arkalohit, BC-14-2, RHRC-50-1, RHRC-16-5, SG-5, Guchhedar, ACS-92-3 and Balochpur) and their 41 F_1 hybrids were evaluated by Doshi *et al*. (2001) in Anand, Gujarat, India in 1998 for heterosis and combining ability. Significant variation was observed among the genotypes for seedling height 40 days after sowing (DAS), number of leaves per plant 40 DAS, growth rate and basal roots per plant, but not for leaf production per week. Maximum heterosis over mid parent and better parent was observed for seedling height 40 DAS (52.3%, 27.8%), number of leaves per plant 40 DAS (38.6%, 21.4%), growth rate (67.1%, 33.1%), leaf production per week (18.4%, 14.0%) and basal roots per plant (64.2%, 28.8%).

Nayaki and Natarajan (2002) conducted a field experiment in Coimbatore, Tamil Nadu, India with 30 chilli hybrids, heterosis over better parent was estimated for nine traits. The heterosis exhibited for plant height and number of branches per plant was mostly positive, while all the hybrids registered negative heterosis for days to 50% flowering.

The heterobeltiosis for dry fruit yield per plant was the highest (219%) in hybrid CA 59 × CA 133, followed by CA 86 × CA 84 (184.8%). The heterosis for fruit length was positive in most of the hybrids, while negative for fruit girth.

The genetic variability among 52 chilli (*Capsicum* spp.) cultivars and lines with regard to yield and yield components was studied by Dipendra and Gautam (2002) in Jorhat, Assam, India, from February to October 1999. Significant variation was observed in all characters. Fruit drop percentage, fresh fruit yield per plant, and dry fruit yield per plant showed high genotypic and phenotypic coefficients of variation. Heritability estimates were moderate to high for all characters except the number of primary branches. The highest genetic advance along with high heritability was recorded for fruit drop percentage, followed by fresh fruit yield per plant, dry fruit yield per plant, number of fruits per plant, leaf area index, and fruit length, indicating the importance of these traits in selection for high yield.

Thirty-two accessions of hot chilli (*C. chinense*) were evaluated by Manju and Sreelathakumary (2002) in Kerala, for variability, heritability and genetic advance for 20 characters. Higher phenotypic and genotypic coefficients of variation were observed for number of fruits per plant, yield per plant, number of seeds per fruit, and fruit weight. High estimates of heritability coupled with high genetic advance were also observed for these characters, indicating that these traits can be effectively improved through selection.

Vandana *et al*. (2002) conducted an experiment with 45 *C. annuum* hybrids and their parents (Arka Basant, EC-114360, EC-143570, EC- 119058, Bull Nose, Bell Orange, Yolo Wonder, CW-51, Sel-2, and Pangla) to evaluate heterosis and combining ability for fruit yield per plant, fruit number per plant, and ascorbic acid content. The greatest average heterosis was recorded for fruit yield. Yolo Wonder x CW-51 exhibited the greatest heterosis over the best parent (51.78%), significant positive heterosis for fruit number (98.45%) and ascorbic acid content (14.21%), and the highest specific combining ability for all characters. General and specific combining ability significantly varied among characters.

Variability parameters were studied by Rathod *et al*. (2002) in 8 yield components during the kharif season of 1999/2000 in 13 chilli cultivars (PBC-161, PBC-308, PP-977116, PP-977126, PP-977127, PP-977195, PP-977261, PP-977268, PP-977275, PP-977421, PP-977623, PP-977635, and PP-977664) planted at the farm of the Chilli and Vegetable Research Unit, Akola, Maharashtra, India. The analysis of variance revealed considerable variability among various components. The number of fruits per plant, fresh red chilli yield per plant, and plant height recorded high genotypic coefficients of variation. Heritability estimates were high for all characters (days to 50% flowering, plant height, number of primary branches and fruits per plant, length and diameter of fruit, 100-seed weight, seed percentage, harvest index, and fresh red chilli yield per plant). High heritability coupled with high expected genetic advance were recorded for the number of fruits per plant, fresh red chilli yield per plant, and plant height.

A set of 36 F_1 hybrids produced from a 9×9 half diallel mating design involving one bell pepper cultivar (Arka Gaurav) and eight hot pepper advanced breeding lines (VR-1, VR-2, VR-42, VR-14, VR-17, VR-27, VR-47 and VR-55) were evaluated by Prasad *et al*. (2003) in Karnataka, India during 1999 for earliness, fruit length, fruit width, number of fruits per plant, and dry fruit yield per plant. The superior hybrids consisted of Arka Gaurav × VR-1 for earliness, VR-2 × VR-47 for fruit length, Arka Gaurav × VR-2 for fruit width, VR-47 × VR-55 for number of fruits per plant, and VR-2 × VR-55 for dry fruit yield per plant. Data on the magnitude of heterosis revealed that VR-2 × VR-55 was superior over best parent and standard control with respect to dry fruit yield per plant. VR-1 × VR-2 was superior over best parent and standard control with respect to number of fruits per plant.

An experiment was conducted by Sreelathakumary and Rajamony (2003) to estimate the genetic variability, heritability and genetic advance in 20 available accessions of bird pepper (*C. frutescens*) collected from different parts of Kerala, India. Analysis of variance significantly differed for plant height, stem girth, leaf area, leaf petiole length, fruits per plant, fruit length, fruit girth, fruit weight and yield per plant among the accessions. A considerable amount of variation was observed for all the characters. The highest values of genotypic (3250.51) and phenotypic variances (3333.35) were recorded for yield per plant. Higher phenotypic and genotypic coefficients of variation (PCV and GCV, respectively) were observed for yield per plant, fruit weight, fruits per plant, fruit length and fruit girth than for other characters. Days to first flower and node at first flower had the lowest PCV and GCV. The highest magnitude of heritability (>90%) was registered for fruits per plant, fruit length, fruit girth, fruit weight and yield per plant.

Genetic diversity for growth, yield and quality traits was studied by Khurana *et al*. (2003) in 48 *C. annuum* genotypes grown in Punjab, India during 1994 and 1995. Highly significant variation was observed among the genotypes in terms of fruit yield, fruit length, fruit thickness, number of fruits per plant, and peel:seed ratio. High genetic coefficient of variation was recorded for number of fruits per plant, fruit yield per plant, fruit thickness, and peel:seed ratio. Fruit yield, number of fruits per plant, fruit length, fruit diameter, and number of seeds per fruit had high values of heritability. Capsaicin content and colouring matter showed high heritability values coupled with moderate level of genetic advance. Fruit yield was positively correlated with number of fruits, fruit length and diameter, peel : seed ratio, plant height, leaf area, capsaicin content, and colouring matter, but was negatively correlated with number of days to flowering, number of days to fruit set, and wilt and viral incidence.

Gomide *et al*. (2003) conducted an experiment for estimating the combining ability of *C. annuum* breeding lines grown in Minas Gerais, Brazil, to identify superior hybrids for fruit yield and quality, and to determine the mode of gene action involved in the expression of economically important traits of *C. annuum*. North Carolina-II scheme partial diallel crosses were obtained and used to estimate general combining abilities of parental lines and specific combining abilities of parental combinations. Heterosis was observed among experimental hybrids for total yield and mean fruit mass. Early yield was conditioned, predominantly, by recessive alleles. Heterosis values relative to the standard cultivar Magali-R-F1 ranged from 7.50 to 49.89% for early yield; 0.45 to 28.55% for total yield; and 3.07 to 47.37% for mean fruit mass.

Heterosis and combining ability effects for growth parameters (stem girth, plant height, height at first branching, plant spread, number of primary branches, and number of secondary branches) were studied by Linganagouda *et al*. (2003) in 27 F_1 hybrids and 12 parental lines (3 Capsicum lines as female parents and 9 chilli [*Capsicum annuum*] lines as male parents) grown in Karnataka, India. High magnitude of heterosis over mid- and better parents was recorded among the hybrids for stem girth. High ratio of general combining ability to specific general combining ability was recorded for stem girth and height at first branching, indicating that the non-additive component of genetic variance was predominant for these traits.

Sixteen chilli (*C. annuum*) genotypes were evaluated by Nehru *et al*. (2003) during 1995-96, 1996-97 and 1997-98 in Bangalore, Karnataka, India, for mean genotypic coefficient of variation (GCV), heritability in broadsense (h) and genetic advance over mean (GA) for 6 characters, i.e. canopy (CAN), height (HT), primary branches per plant (PB), fruits per plant (FP), fruit length (FL) and fruit yield per plant (FY); for correlations among the characters; and for stability of genotypes for CAN, HT, FP and FY. The ANOVA for stability revealed the significance of genotype × environment (linear) as well as pooled deviation components, indicating that it is rather difficult to predict the performance of genotypes over years. Ceylon was found to be the most stable genotype for yield.

Studies were undertaken by Kanthaswamy *et al*. (2003) to elicit information on the physiological basis for heterosis in chilli. Twelve F_1 hybrids consisting of direct and reciprocal crosses involving four parents (P_1: CA 100; P_2: Jayant; P_3: RHRC and P_4: CA-133) were raised. P_4 recorded the highest yield (73 g) followed by P_1 (68.00 g). Hybrid $P_4 \times P_1$ was also superior, registering 99.25 g. The direct cross $P_1 \times P_4$ recorded 49.48 g. $P_4 \times P_1$ had the highest heterosis in heterobeltiosis, and the per se performance also proved to be high for capsaicin content and dry fruit yield per plant. $P_4 \times P_1$ recorded a leaf area index of 1.69, dry fruit yield of 99.25 g, and net assimilation rate of 0.060 g dm-1 day^{-1}. Leaf area index was positively associated with yield and net assimilation rate in all hybrids. Hybrids had larger leaf area than the parents. Dry matter production exhibited negative heterosis in all hybrids. Crop growth rate and net assimilation rate were positively correlated with yield. $P_2 \times P_4$ exhibited the highest photosynthetic rate by the heterosis percent and per se performance.

A field experiment was conducted by Prabhakaran *et al*. (2004) in Coimbatore, Tamil Nadu, India with 97 genotypes of chilli to study genetic variability, heritability and genetic advance for 18 characters. The genotypic coefficient of variation was high for plant spread, number of fruits per plant, yield per plant, fruit length, mean fruit weight, placenta length and capsaicin. The heritability estimates were high for most of the characters. The genetic advance as percentage of mean was high for yield per plant, mean fruit weight, placenta length and capsaicin. High heritability estimates coupled with high genetic advance as percentage of mean were observed for yield per plant, mean fruit weight, placenta length and capsaicin.

An experiment was conducted by Verma *et al*. (2004) on 12 chilli (*Capsicum annuum*) genotypes to determine the extent of genetic variability, genetic coefficient of variation, heritability, genetic advance as percent of mean and correlation of different characters. Data were recorded for days to 50% germination, days to 50% flowering, days to 50% fruiting, plant height, plant canopy, number of branches per plant, leaf length, leaf width, pod length, pod width and number of fruits per plant. The phenotypic coefficient of variation was higher than the genotypic coefficient of variation in all the characters. Plant canopy, number of fruits per plant, days to 50% fruiting, plant height, days to 50% flowering and pod length showed high heritability.

Eight single, six three-way and six double cross hybrids were evaluated by Geleta and Labuschagne (2004) with a standard control to assess their yield potential and agronomic performance. The study was conducted in the field and greenhouse using a randomized complete block design with three replications at the University of the Free State during 2002/03. The three categories of hybrids performed differently and showed high variation for the majority of characters studied. Three-way cross hybrids showed better performance for days to flowering (70.9 days after sowing), fruit diameter (3.2 cm) and fruit weight (30.3 g/fruit). As expected, single cross hybrids were the most uniform followed by three-way cross hybrids. Higher mean heterosis for fruit yield (35.6%), fruit number (24.0%) and fruit weight (16.9%) was also observed in double cross hybrid.

Genetic variability, heritability and genetic advance for plant height, number of primary branches, number of secondary branches, plant spread, days to first flowering, fruit length, fruit width, number of fruits per plant, green fruit yield per plant, average fruit weight, number of seeds per fruit, 100-seed weight, fruiting span and crop duration were assessed by Mini and Khader (2004) in 25 genotypes of wax-type chilli during 2002-03 in Kerala, India. Analysis of variance revealed significant differences among genotypes for all traits. High values of genotypic (GCV) and phenotypic coefficient of variation (PCV) were recorded for green fruit yield per plant, number of fruits per plant and average fruit weight, indicating more scope for their improvement through selection. High heritability coupled with high genetic advance was observed for 100-seed weight, fruit length, average fruit weight, number of fruits per plant, green fruit yield per plant, fruiting span and number of secondary branches, indicating that selection based on these traits would be ideal.

Heterosis, hetrobeltiosis and standard heterosis were studied by Gondane and Deshmukh (2004) in thirty-three chilli hybrids obtained by crossing three male sterile lines viz., CA-960, Jwala, AKC-86-25 with eleven pollen parent (testers) viz., GP-89, GP-90, GP-93, GP-219, GP-234, GP-312, GP-313, GP-314, GP-315 and GP-361. The experiments were conducted in Maharashtra, India. Most of the hybrids expressed positive and significant heterosis over the mid-parent values, better parental values and over the check values. The cross combinations Jwala × GP-90, AKC-86-25 × GP-313, CA-960 × GP-22 and AKC-86-25 × GP-314 were the best crosses on the basis of high heterosis, heterobeltiosis and standard heterosis. Therefore, these crosses could be used for commercial exploitation of heterosis.

Mishra *et al*. (2004) conducted this investigation on genetic variability including mean, genotypic and phenotypic variances, coefficients of variation, heritability, genetic advance and genetic gain with 22 genotypes of capsicum (*Capsicum annuum*) in the mid-hills of Uttaranchal, India. Significant differences among the genotypes were observed for all 18 characters studied. The cultivars Pepper Peprika, Sel. 1-2 and Sel. 1-3 were promising with more than one desirable traits. High phenotypic and genotypic coefficients of variation, heritability and genetic gain were observed for ascorbic acid content, number of fruits per plant, fruit yield per plant, seed yield per fruit and fruit length.

The present study was undertaken by Geleta *et al*. (2004) to evaluate genetic divergence among seven pepper cultivars and to assess the relationship between heterosis and parental genetic distance. Twenty-one F_1 hybrids and seven parents were evaluated for 15 morphological characters in a greenhouse and in the field. The parents were examined for DNA polymorphisms using six amplified fragment length polymorphism (AFLP) primer combinations. Cluster analysis using two genetic distance measures grouped the seven parents differently. Mid-parent and high-parent heterosis was observed for most characters. Most hybrids outperformed the parental lines for fruit yield, earliness and plant height. Morphological and AFLP-based distance measurements were efficient enough to allocate pepper genotypes into heterotic groups. The correlations of morphological distances with mid-parent heterosis were significant for days to flowering and maturity, suggesting earliness can be predicted from morphological distances of parental lines.

However, the correlations of AFLP-measured genetic distances with mid- and high-parent heterosis were non-significant for all characters, except for fruit diameter, and proved to be of no predictive value.

Thirty-five chilli (*Capsicum annuum*) genotypes were evaluated by Sreelathakumary and Rajamony (2004) in a field study conducted during 1997-98 at Vellayani, Kerala, India to assess genetic variability, heritability and genetic advance. Higher phenotypic and genotypic coefficients of variation were observed for leaf area, fruits per plant, fruit weight, fruit length, fruit girth and yield per plant. High heritability coupled with high genetic advance observed for these characters imply the potential for crop improvement through selection.

Two F_1 hybrids of chilli (*C. annuum*), namely CA 86-1 x CA 84 (Hybrid-1) and CA 86-2 × CA 84 (Hybrid 2), were evaluated by Malathi and Veeraragavathatham (2004) in Coimbatore, Tamil Nadu, India, in 3 different seasons (June-November 2000, October 2000-March 2001, and December 2000-May 2001). Hybrid-1 showed highly significant and positive heterosis over mid, better and best parents in all seasons for all traits. On the other hand, Hybrid 2 showed highly significant and positive heterosis over mid and better parents in all seasons for all traits, but showed negative heterosis over the best parent in the third season.

A field experiment was conducted by Singh and Chaudhury (2005) in Uttar Pradesh, India, to study the heterosis and inbreeding depression for 14 yield and yield attributing characters in 15 F_1 chilli hybrids derived from 7 parents (IC-119367, IC-119797, EC-321437, EC-305591, Pusa Sadabahar, RHRC-CE and Punjab Lal). Heterosis for total fresh yield per plant was considerable and it ranged from 7.40 to 33.24% in the IC-119367 × Pusa Sadabahar and EC-305591 × Punjab Lal crosses, respectively. The highest positive and significant heterosis over the mid-parent was recorded for the EC-305591 × RHRC-CE cross followed by EC-305591 × Punjab Lal. Out of the 15 crosses, only 4 showed positive and significant heterosis over the better parent for number of fruits per plant. The maximum positive and significant value over the mid-parent was shown by IC-

119797 × RHRC-CE. Crosses exhibiting high heterosis for total fresh yield per plant were also good heterosis crosses for some of the yield component characters such as number of fruits per plant, fruit length and number of seeds per fruit.

Mishra *et al*. (2005) conducted an investigation on genetic variability including mean, genotypic and phenotypic variances, coefficients of variation, heritability, genetic advance and genetic gain was conducted with 22 genotypes of capsicum under mid-hills of Uttaranchal, India during the summer-rainy season of 1998. Significant differences among the genotypes for all the characters were noted. The cultivars Pepper Peprika, Sel. 1-2 and Sel. 1-3 were promising with more than one desirable traits. High phenotypic and genotypic coefficients of variation, heritability and genetic gain were observed for ascorbic acid content, number of fruits per plant, fruit yield per plant, seed yield per fruit and fruit length.

Singh *et al*. (2005) studied genetic variability for various agromorphological traits (number of days to first flowering, number of days to 50% flowering, number of days to first ripening, number of days to 50% ripening, fruit length, fruit breadth, pedicel : fruit ratio, number of seeds per fruit, plant height, number of primary branches per plant, fresh yield per plant, dry yield per plant, number of fruits per plant, fresh yield per plot, and dry yield per plot) in 31 local *C. annuum* cultivars or lines grown in Imphal, Manipur, India, during the kharif of 1998 and 1999. Significant variation between the genotypic and phenotypic variances was registered for fresh yield per plant, dry yield per plant, number of fruits per plant, plant height, and number of seeds per fruit. Traits that had close values of phenotypic and genetic variances were dry yield per plot, fresh yield per plot, and number of primary branches per plant. The highest heritability values were recorded for fruit length. The genetic advance was greatest for fresh yield per plant, dry yield per plant, and number of seeds per fruit. Heritability estimates were very high for all traits except number of primary branches per plant.

Genetic variability, heritability and genetic advance for fourteen characters in twenty-two genotypes of capsicum (*Capsicum annuum* L.) were studied by Sonia *et al*. (2006) in Palampur (India). A wide range of phenotypic variability was observed for all the fourteen characters like: fruits yield per plant, fruits per plant, marketable fruits per plant, fruit length, plant height etc. High estimates of heritability were also shown by these characters. This indicates that selection can be better option for improvement in these traits. Genetic advance for many characters were high like that of fruits per plant, marketable fruits per plant and fruits per plant. Also, PCV and GCV values were high for marketable fruits per plant, fruits per plant, fruit yield per plant and fruit weight.

An experiment was conducted by Pawandeep *et al*. (2007) during 2004-05, in Ludhiana, Punjab, India, to evaluate 40 cultivars and local landraces of chilli (*Capsicum annuum*). Results showed that the phenotypic coefficient of variation (PCV) was higher than the genetic coefficient of variation (GCV) for most traits. High GCV accompanied by high heritability and genetic gain were recorded for coloring matter, ascorbic acid and dry matter, indicating that these traits could be improved by simple selection. Moderate to high heritability with low GCV and genetic gain were observed for capsaicin content, fruit weight, oleoresin content, fruit breadth and number of fruits per plant, which warrants heterosis breeding for their improvement. Total yield showed positive and significant phenotypic and genotypic correlation with fruit length, fruit breadth and fruits per plant.

The present investigation was carried out by Nayeema *et al*. (2009) in 2007-08 using 25 chilli genotypes to elucidate the association of various yield attributing traits to develop a reliable set of traits for indirect selection. The data were observed from five randomly selected competitive plants from each replication for eight quantitative traits. The genotypic coefficients were higher in the magnitudes relative to corresponding estimates of phenotypic coefficients, which indicated high heritability of the traits under study. The fruits yield/plant exhibited highly significant correlation with number of fruits/plant, number of branches/plant and height of the plant, indicating the usefulness of these traits for improving upon fruit yield in chilli.

Heterosis for green fruits and related characters in chilli was studied by Patel *et al*. (2010) in line x tester fashion involving five GMS lines and 10 testers. The hybrids differed significantly for all the characters, as evident from their highly significant mean square values. Mean squares due to hybrids × environments were significant for all the characters except average fruit weight, which indicated more sensitivity of hybrids to environments. The hybrids ACMS 8 × IPS-2005-15, ACMS 5 × IPS-2005-15, ACMS 6 × ACS-2004-03, ACMS 4 × IPS-2005-15, ACMS 6 × IPS-2005-15 and ACMS 8 × ACS-2004-03 exhibited higher magnitude of heterobeltiosis and standard heterosis for green fruit yield per plant and number of fruits per plant. In general the hybrids, which depicted higher magnitude of heterotic effects also exerted greater amount of heterotic effects for various growth attributes and yield related traits; therefore, heterotic effects for green fruit yield could be because of direct and indirect effects of various yield contributing characters. A cross ACMS 8 × IPS-2005-15 was consistent across the environments and so, it can be used for commercial exploitation after its critical evaluation.

In this study, morphological characterization was carried out by Binbir and Bas (2010) on 26 different populations of pepper, conserved in Aegean Agricultural Research Institute National Gene Bank, collected from Marmara, Black Sea, Eastern Anatolia and Central Anatolia regions in 2005, 2006 and 2007, and on 3 different standards pepper varieties belonging to the same institute. Characterization studies were made by using the IPGRI descriptor list published for pepper and UPOV property document of the same species. All populations were characterized in terms of 54 morphological features. In the study; the minimum, maximum, average values and frequency percentage of examined characters were determined. A wide variation was observed because examined populations included many types of pepper. This study indicates that genetic diversity of pepper is high in Turkey. Principal component (PC) analysis extracted 9 autonomous PC axes containing 85.35% of the total multivariate variation.

Nogueira (2010) conducted an experiment to obtain information on the combining ability of sweet pepper lines by multivariate diallel analysis. Thirteen sweet pepper lines previously selected based on the reaction of sweet pepper yellow mosaic, being eight lines with resistance reaction and five susceptible lines, were used in a 8×5 partial diallel evaluated with the parental lines. The 53 genotypes were evaluated in greenhouse trials in a randomized blocks design with four replications. The traits total fruit yield, early fruit yield, mean fruit mass and plant height were evaluated. From these four traits, a univariate and multivariate diallel analysis was performed. Multivariate diallel analysis results were similar to those from univariate diallel analyses, with a predominance of non-additive effects. Favorable estimates of the GCA occurred for total fruit yield and early fruit yield in PIX-031D-188- 14-10 and PIM- 013 in groups 1 and 2, respectively. The PIX-031D-171-10-10, PIX-031D- 188-14-05 and PIM-004 lines were higher for mean fruit mass and plant height.

An investigation was undertaken by Padhar and Zaveri (2010) to study the variability parameters, correlation and path coefficient analysis for 12 metric traits in 50 genotypes of chilli. Significant genotypic differences were observed for all the traits studied indicating considerable amount of variation among genotypes for each character. The estimates of genotypic (GCV) and phenotypic (PCV) coefficient of variation were high for number of fruits per plant, fresh fruit yield per plant, dry fruit yield per plant, pulp:seed ratio, girth of fruit and length of fruit. Similarly, high amount of heritability and genetic advance was also observed for all the above mentioned characters indicating the scope for their improvement through selection.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from November 2011 to March 2012 to study the heterosis and combining ability in capsicum. The materials and methods that were used for conducting the experiment have been presented in this chapter. It includes a brief description of the location of experimental site, soil and climate condition of the experimental plot, materials used for the experiment, design of the experiment, intercultural operation, data collection procedure and procedure of data analysis.

3.1 Location of the experimental site

The experiment was conducted at the research field of the Olericulture Division, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The experimental area was located in $24^0 00^/$N latitude and $90^0 25^/$E longitudes. The altitude the location will be 8.4 m from the sea level (Anon., 1995).

3.2 Characteristics of soil

The soil of the experimental field was sandy clay loam in texture having a pH around 6.0 and belongs to the Chitra soil series of red brown terrace soil with in the AEZ number 28 (UNDP, 1988). The soil was later developed by riverbed silt. The nutrient status of the farm soil under the experimental plot with in a depth 0-20 cm were collected and analyzed in the Soil Research and Development Institute, Dhaka and result have been presented in Appendix I.

3.3 Climatic condition of the experimental site

The area has sub-tropical climate, which is characterized by high temperature accompanied by moderately high rainfall during Kharif season and low temperature in the Rabi (October-March) season. Details of the meteorological data including temperature, rainfall, humidity and sunshine hour during the period of the experiment was presented in Appendix II.

3.4 Planting materials

Five parents with 10 hybrid of capsicum were used in the experiment. The source of all the capsicum used in this experiment was collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The names of parents and hybrids are presented in Table 1.

Table 1. Name of capsicum parents and hybrids used in the present study

Sl. No.	Hybrid	Sl. No.	Parents
01	$P_1 \times P_2$	11	P_1
02	$P_1 \times P_3$	12	P_2
03	$P_1 \times P_4$	13	P_3
04	$P_1 \times P_5$	14	P_4
05	$P_2 \times P_3$	15	P_5
06	$P_2 \times P_4$		
07	$P_2 \times P_5$		
08	$P_3 \times P_4$		
09	$P_3 \times P_5$		
10	$P_4 \times P_5$		

Here, P_1 = ISPN 9-2, P_2 = ISPN 9-1, P_3 = Yellow wonder, P_4 = Yellow star and P_5 = California wonder

3.5 Design and layout of the experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 368.0 m^2 with length 23.0 m and width 16.0 m. The total area was divided into three equal blocks. Each block was divided into 15 plots where 15 hybrids and parents were allotted at random. There were 45 unit plots altogether in the experiment. The size of the each plot was 4.0 m × 1.0 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment was shown in Figure 1.

3.6 Seedling raising

Seeds of different hybrids and parents of capsicum were sown on seed bed on 04 November, 2011 for seedling raising of the experiment.

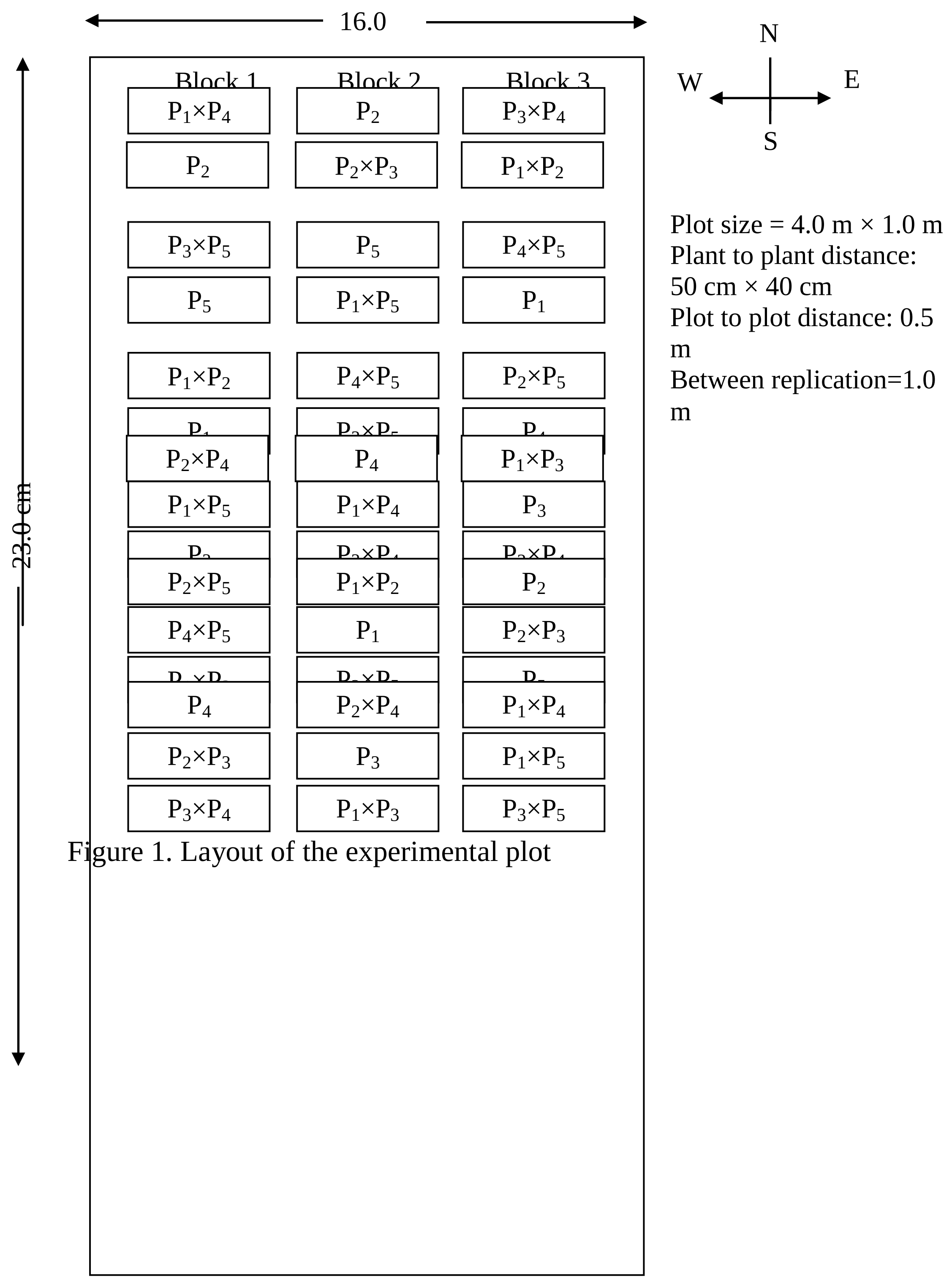

Figure 1. Layout of the experimental plot

3.7 Preparation of the main field

The selected plot of the experiment was opened in the 2nd week of November 2011 with a power tiller, and left exposed to the sun for a week. Subsequently cross ploughing was done five times with a country plough followed by laddering to make the land suitable for transplanting the seedlings. All weeds, stubbles and residues were eliminated from the field. Finally, a good tilth was achieved. The soil was treated with insecticides (cinocarb 3G @ 4 kg/ha) at the time of final land preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

3.8 Application of manure and fertilizers

The fertilizers N, P, K, S and Zn in the form of urea, TSP, MP, Gypsum and Zinc oxide, respectively were applied. Half of the quantity of cowdung was applied during final land preparation. The remaining half of cowdung, the entire amount of TSP, Gypsum, Zinc oxide and one third of MP were applied during pit preparation. Urea and MP were applied in two equal installments at before flowering and fruit setting. The dose and method of application of fertilizer are shown in Table 2.

Table 2. Dose and method of application of fertilizers in capsicum field

Manure and Fertilizers	Dose (ha)	Application (%)			
		Final land preparation	Installments		
			Pit preparation	Before flowering	Fruiting stage
Cowdung	10 ton	50.00	50.00	--	--
Urea	220 kg	--	--	50.00	50.00
TSP	330 kg	--	100.00	--	--
MP	200 kg	--	33.33	33.33	33.33
Gypsum	111 kg	--	100.00	--	--
Zinc	5 kg	--	100.00	--	--

3.9 Transplanting

Healthy and uniform capsicum seedlings of 20 days old seedlings with 4-5 leaves were transplanting in the experimental plots on 24 November, 2011. The seedlings were uploaded carefully from the seed bed to avoid damage to the root system. To minimize the damage to the roots of seedlings, the seed beds were watered one hour before uprooting the seedlings. Transplanting was done in the afternoon. The seedlings were watered immediately after transplanting. Seedlings were sown in the plot with maintaining distance between row to row and plant to plant was 50 cm and 40 cm, respectively.

3.10 Netting and polythene shade

All the plots covered by 20 mesh nylolon net from the protection of mites and other insects. When night temperature below of 16^0C than polythene shade were maintained during night. In day time polythene shade were removed.

3.11 Intercultural operation

After raising seedlings, various intercultural operations such as gap filling, weeding, earthing up, irrigation pest and disease control etc. were accomplished for better growth and development of the capsicum seedlings.

3.11.1 Gap filling

The transplanted seedlings in the experimental plot were kept under careful observation. Very few seedlings were damaged after transplanting and such seedling were replaced by new seedlings from the same stock. Those seedlings were transplanted with a big mass of soil with roots to minimize transplanting stock. Replacement was done with healthy seedling having a boll of earth. The transplants were given shading and watering for 7 days for their proper establishment.

3.11.2 Weeding

The hand weeding was done 15, 30 and 45, 60 after transplanting to keep the plots free from weeds.

3.11.3 Earthing up

Earthing up was done at 20 and 40 days after transplanting on both sides of rows by taking the soil from the space between the rows by a small spade.

Plate 1. Photograph showing netting in capsicum field

Plate 2. Photograph showing plants in capsicum field

3.11.4 Irrigation

Light watering was given by a watering cane at every morning and afternoon. Following transplanting and it was continued for a week for rapid and well establishment of the transplanted seedlings.

3.11.5 Pest and disease control

Insect infestation was a serious problem during the period of establishment of seeding in the field. In spite of Cirocarb 3G applications during final land preparation few young plants were damaged due to attack of mole cricket and cut worm. Cut worms were controlled both mechanically and spraying Darsban 29 EC @ 3%. Some of plants were infected by *Alternaria* leaf spot diseases caused by *Alternaria brassicae*. To prevent the spread of the disease Rovral @ 2 gm per liter of water was sprayed in the field. The diseased leaves were also collected from the infested plant and removed from the field.

3.12 Harvesting

Harvesting of fruits was started at 70 DAT and continued upto 100 DAT with an interval of 07 days. Harvesting was done usually by hand picking.

3.13 Data collection

Three plants were randomly selected for data collection from the middle rows of each unit plot for avoiding border effect, except yields of fruits, which was recorded plot wise. Data were collected in respect of the following parameters to assess plant growth; yield attributes and yields.

3.13.1. Days from transplanting to 50% flowering

Difference between the dates of sowing to the date of flowering of a plot was counted as days to 50% flowering. Days to 50% flowering was recorded when 50% flowers of a plot were at the flowering stage.

3.13.2. Plant height

The height of plant was recorded in centimeter (cm) at harvest in the experimental plots. Data were recorded as the average of 3 plants selected at random from the inner rows of each plot after harvest. The height was measured from the ground level to the tip of the growing point of the main branch.

3.13.3. Individual fruit weight

The weight of individual fruit was recorded in gram (gm) by a beam balance from all fruits of selected three plants and converted individually. Individual fruit weight was recorded at green and mature stage of fruit.

3.13.4. Number of fruits/plant

The number of fruits per plant was counted after setting of fruits and recorded per plant basis.

3.13.5. Length of fruit

The length of individual fruit was measured in one side to another side of fruit from five selected fruits with a meter scale and average of individual fruit length recorded and expressed in centimeter (cm).

3.13.6. Diameter of fruit

The diameter of individual fruit was measured in several directions with meter scale and the average of all directions was finally recorded and expressed in centimeter (cm).

3.13.7. Fruit yield/plant

Fruit yield per plant was recorded in gram through multiplying individual fruit weight and number of fruits/plant by a beam balance. Fruit yield per plant was recorded at green and mature stage of fruit.

3.13.8. Fruit yield/hectare

Fruit yield per hectare was recorded in ton through multiplying plant yield in hectare yield. Fruit yield per hectare was recorded at green and mature stage of fruit.

3.14 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance of the difference among the capsicum genotypes. The mean values of all the characters were evaluated and analysis of variance was performing by the 'F' test. The significance of the difference among the treatments means was estimated by the least significant difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984). Correlation coefficient was estimated according to Singh and Chaudhury (1985).

3.15 Estimation of variability

Genotypic and phenotypic coefficient of variation and heritability were estimated by using the following formulae:

3.15.1. Estimation of components of variance from individual environment

Genotypic and phenotypic variances were estimated with the help of the following formula suggested by Johnson *et al*. (1955). The genotypic variance (σ^2_g) was estimated by subtracting error mean square (σ^2_e) from the genotypic mean square and dividing it by the number of replication (r). This is given by the following formula -

$$\text{Genotypic variance } (\sigma^2_g) = \frac{MS_V - MS_E}{r}$$

Where,

MS_V = genotype mean square

MS_E = error mean square

r = number of replication

The phenotypic variance (σ^2_p), was derived by adding genotypic variances with the error variance, as given by the following formula –

Phenotypic variance (σ^2_{ph}) = $\sigma^2_g + \sigma^2_e$

Where,

σ^2_{ph} = phenotypic variance

σ^2_g = genotypic variance

σ^2_e = error variance

3.15.2. Estimation of genotypic co-efficient of variation (GCV) and phenotypic co-efficient of variation (PCV)

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated following formula as suggested by Burton (1952):

$$\% \text{ Genotypic coefficient of variance} = \frac{\sigma_g}{\bar{x}} \times 100$$

Where,

σ_g = genotypic standard deviation

$\bar{x}$ = population mean

$$\% \text{ Phenotypic coefficient of variance} = \frac{\sigma_{ph}}{\bar{x}} \times 100$$

Where,

σ_{ph} = phenotypic standard deviation

$\bar{x}$ = population mean

3.15.3. Estimation of heritability

Heritability in broad sense was estimated following the formula as suggested by Johnson *et al*. (1955):

$$\text{Heritability (\%)} = \frac{\sigma^2_g}{\sigma^2_{ph}} \times 100$$

Where,

σ^2_g = genotypic variance

σ^2_{ph} = phenotypic variance

3.15.4. Estimation of genetic Advance

The following formula was used to estimate the expected genetic advance for different characters under selection as suggested by Allard (1960):

$$GA = \frac{\sigma^2_g}{\sigma^2_p} \times K.\ \sigma_p$$

Where,

GA = Genetic advance

σ^2_g = genotypic variance

σ^2_{ph} = phenotypic variance

σ_{ph} = phenotypic standard deviation

K = Selection differential which is equal to 2.64 at 5% selection intensity

3.15.5. Estimation of Genetic Advance in percentage of mean

Genetic advance in percentage of mean was calculated by the following formula given by Comstock and Robinson (1952):

$$\text{Genetic Advance in percentage of mean} = \frac{\text{Genetic advance}}{\bar{x}} \times 100$$

3.16 Estimation of correlation

Simple correlation was estimated with the following formula (Singh and Chaudhary, 1985):

$$r = \frac{\sum xy - \frac{\sum x.\ \sum y}{N}}{\left[\left\{\sum x^2 - \frac{(\sum x)^2}{N}\right\}\left\{\sum y^2 - \frac{(\sum y)^2}{N}\right\}\right]^{1/2}}$$

Where,

$\sum$ = Summation

x and y are the two variables

N = Number of observations

3.17 Analysis of heterosis

For estimation of heterosis in each character the mean values of the 15 hybrids and parents have been compared with better parent (BP) for heterobeltosis.

The significant test for heterosis was done by using standard error of the value of better parent as;

$$SE (BP) = \sqrt{3/2 \times MSE/r}$$

3.18 Statistical procedure adopted for combining ability analysis

3.18.1. General combining ability (GCA) and specific combining ability (SCA) analysis

Combining ability analysis of the traits with significant genotypic differences were done according to the Model 1 (fixed genotypic effects) and Method 2 (half diallel) of Griffing (1956). The fixed genotypic effect model was more appropriate in the present case since the parents selected were self-pollinated lines and the parents and F_1s were the populations considered. This analysis partitioned the variation due to genotypic differences into general combining ability (GCA) and specific combining ability (SCA) effects.

GCA measures the average performance of parent in hybrid combination, whereas SCA refers to those instances in which the performances of a hybrid is relatively better or worse than would be expected on the basis of the average performances of the parents involved. In an experiment, which includes parents as well as hybrids, analyzed by Griffing's techniques, GCA represents additive gene effect (perhaps modified by epitasis) while SCA represents non-additive gene effects.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was carried out to studies the heterosis and combining ability in capsicum. A total of 5 parents and 10 hybrids of capsicum were included in the experiment. Mean performance, variability, correlation matrix, heterosis, general combining ability and specific combining ability were done on yield and yield contributing characters of capsicum, viz. days to 50% flowering, plant height, individual fruit weight at green stage, individual fruit weight at mature stage, number of fruits per plant, length of fruit, diameter of fruit, fruit yield per plant at green stage, fruit yield per plant at mature stage, fruit yield per hectare at green stage and fruit yield per hectare at mature stage. The results have been presented and discussed under the following headings.

4.1 Mean performance of yield contributing characters and yield

Statistically significant variation was recorded on yield contributing characters and yield of 5 parents and 10 hybrids of capsicum that where tested the differences as well as similarity among different genotypes. Analysis of variance (ANOVA) of the data due to genotypes is presented in Appendix III. The mean performance of the genotypes are presented in Table 3 and 4 and discussed character wise under the following headings -

4.1.1. Days to 50% flowering

The maximum days required for 50% flowering (68.67) was recorded for the genotypes P_5 parents, which was statistically similar to all other parents and crosses are except $P_1 \times P_2$, $P_1 \times P_3$, $P_1 \times P_4$, $P_1 \times P_5$ and $P_3 \times P_5$ crosses, whereas the minimum days to 50% flowering (61.67) was found from $P_1 \times P_5$ and $P_3 \times P_5$ crosses (Table 3). Kakroo and Kumar (1991) reported that the *annum* group, a considerable variation exists among different species and varieties in respect of different morpho-physiological characters including days to 50% flowering.

Table 3. Yield contributing characters of capsicum hybrids and parents

Genotypes	Days to 50% flowering	Plant height (cm)	Individual fruit weight at green stage (g)	Individual fruit weight at mature stage (g)	Number of fruits/plant
$P_1 \times P_2$	62.67 bc	87.00 b	111.00 cd	99.33 b-d	6.07 c-e
$P_1 \times P_3$	62.33 c	97.00 a	123.33 b	110.33 b	7.10 bc
$P_1 \times P_4$	63.00 bc	84.33 bc	134.33 a	122.67 a	6.33 b-e
$P_1 \times P_5$	61.67 c	82.67 b-d	117.00 b-d	105.67 bc	5.67 de
$P_2 \times P_3$	65.00 a-c	102.67 a	106.67 de	92.33 de	6.33 b-e
$P_2 \times P_4$	62.67 bc	75.67 c-e	117.33 b-d	107.00 bc	5.67 de
$P_2 \times P_5$	64.00 a-c	82.33 b-d	98.00 e	87.00 e	6.33 b-e
$P_3 \times P_4$	64.67 a-c	86.67 b	122.00 bc	110.00 b	6.67 b-d
$P_3 \times P_5$	61.67 c	85.00 b	111.67 cd	100.00 b-d	6.67 b-d
$P_4 \times P_5$	66.33 a-c	75.33 de	109.33 d	99.33 b-d	5.33 de
P_1	66.00 a-c	81.00 b-e	116.00 b-d	105.00 bc	5.33 de
P_2	66.33 a-c	96.00 a	66.67 f	53.33 f	8.67 a
P_3	67.33 ab	85.67 b	109.33 d	97.33 c-e	5.00 e
P_4	65.67 a-c	81.00 b-e	111.33 cd	100.67 b-d	5.33 de
P_5	68.67 a	73.00 e	72.00 f	62.00 f	7.67 ab
Mean	64.53	85.02	108.40	96.80	6.28
$LSD_{(0.05)}$	4.212	7.735	9.961	10.84	1.218
Significance level	0.05	0.01	0.01	0.01	0.01

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Here, P_1 = ISPN 9-2, P_2 = ISPN 9-1, P_3 = Yellow wonder, P_4 = Yellow star and P_5 = California wonder

4.1.2. Plant height

Among the different hybrids and parents the tallest plant (102.67 cm) was recorded for the crosses $P_2 \times P_3$ which was statistically similar (97.00 cm and 96.00 cm) to $P_1 \times P_3$ crosses and P_2 parent, whereas the shortest plant (73.00 cm) was found from P_5 parent. Different varieties produced different plant height on the basis of their varietal characters but environmental and management factor also influences different growth parameters as well as plant height (Table 3).

4.1.3. Individual fruit weight at green stage

In case of individual fruit weight at green stage of capsicum varied significantly which was ranged from 66.67 – 134.33 g and among the different genotypes the highest fruit weight at green stage (134.33 g) was recorded from $P_1 \times P_4$ crosses plants, while the minimum fruit weight at green stage (66.67 g) was observed from P_2 parent (Table 3).

4.1.4. Individual fruit weight at mature stage

Data revealed that individual fruit weight at mature stage of capsicum varied from 53.33 – 122.67 g. Among the different genotypes the highest fruit weight at mature stage (122.67 g) was found from the genotype $P_1 \times P_4$ crosses plants and the minimum fruit weight at mature stage (53.33 g) was collected from P_2 parent plant (Table 3).

4.1.5. Number of fruits per plant

Among the different genotypes under the present trial the maximum number of fruits per plant (8.67) was recorded from the genotype P_2 parent plant which was statistically similar (7.67) to P_5 parent, whereas the minimum number of fruits per plant (5.00) was found from P_3 parent (Table 3). Data revealed that among the genotypes parents produced maximum as well as minimum number of fruits per plant under the present trial.

4.1.6. Length of fruit

From the data on length of fruits it was found that comparatively the crosses of capsicum gave the longest length of fruit that that of parent plants under the present experiment and the length of fruit of capsicum varied from 8.80 – 12.50 cm. Within the different genotypes the longest length of fruit (12.50 cm) was recorded for the genotype $P_1 \times P_4$ cross plant which was statistically similar (12.00 cm, 12.00 cm and 11.70 cm) to $P_1 \times P_2$, $P_1 \times P_5$ and $P_2 \times P_5$, while the shortest length of fruit (8.80 cm) was found from $P_2 \times P_3$ cross plant (Table 4).

4.1.7. Diameter of fruit

Diameter of fruit varied from 3.70 – 7.80 cm for the different capsicum genotypes under the present trial. Comparatively the crosses produce the fruit with highest diameter than that of parents. In case of diameter of fruit the highest diameter of fruit (7.80 cm) was recorded for the genotype $P_4 \times P_5$ cross plant which was statistically similar (7.70 cm) to P_4 parent and followed by the other genotypes, while the lowest diameter of fruit (3.70 cm) from P_2 parent (Table 4).

4.1.8. Fruit yield per plant at green stage

From the data it was exposed that fruit yield per plant at green stage comparatively the crosses of capsicum gave the highest fruit yield per plant that of parent plants under the present trial. The highest fruit yield per plant at green stage varied from 516.78 – 894.55 g. Among the genotypes the highest fruit yield per plant and green stage (894.55 g) was obtained from the genotype $P_1 \times P_4$ cross plant which was statistically similar (892.56 g and 842.00 g) to $P_1 \times P_3$ and $P_3 \times P_4$, while the lowest (516.78 g) was found from P_2 parent plant (Table 4). Fruit yield per plant at green stage varied for different varieties might be due to genetical and environmental influences as well as management practices

4.1.9. Fruit yield per plant at mature stage

From the data it was exposed that fruit yield per plant at mature stage comparatively the crosses of capsicum gave the highest fruit yield per plant that that of parent plants under the present trial. The highest fruit yield per plant at

Table 4. Yield contributing characters and yield of capsicum hybrids and parents

Genotypes	Length of fruit (cm)	Diameter of fruit (cm)	Fruit yield/ plant at green stage (g)	Fruit yield/ plant at mature stage (g)
$P_1 \times P_2$	12.00 a	6.50 cd	698.78 c	602.47 c
$P_1 \times P_3$	11.50 ab	6.30 cd	892.56 a	783.13 a
$P_1 \times P_4$	12.50 a	6.90 bc	894.55 a	775.33 a
$P_1 \times P_5$	12.00 a	7.20 ab	703.56 c	599.00 c
$P_2 \times P_3$	8.80 c	6.50 cd	677.78 cd	586.67 cd
$P_2 \times P_4$	9.30 c	6.20 d	710.33 c	607.00 c
$P_2 \times P_5$	11.70 a	7.20 ab	637.00 d	551.00 c-e
$P_3 \times P_4$	10.00 bc	7.20 ab	842.00 a	734.00 a
$P_3 \times P_5$	11.30 ab	6.60 b-d	763.00 b	667.33 b
$P_4 \times P_5$	9.80 bc	7.80 a	626.67 de	529.33 ef
P_1	10.00 bc	7.20 ab	668.33 cd	560.00 c-e
P_2	11.00 ab	3.70 f	516.78 g	461.67 g
P_3	9.30 c	6.30 cd	578.66 ef	481.33 fg
P_4	9.30 c	7.70 a	638.67 d	536.00 de
P_5	11.00 ab	4.30 e	539.33 fg	475.00 g
Mean	10.63	6.51	692.53	596.62
$LSD_{(0.05)}$	1.500	0.575	51.19	51.05
Significance level	0.01	0.01	0.01	0.01

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability
Here, P_1 = ISPN 9-2, P_2 = ISPN 9-1, P_3 = Yellow wonder, P_4 = Yellow star and P_5 = California wonder

mature stage varied from 461.67 – 783.13 g. Among the genotypes the highest fruit yield per plant and mature stage (783.13 g) was obtained from the genotype $P_1 \times P_3$ cross plant which was statistically similar (775.33 g and 734.00 g) to $P_1 \times P_4$ and $P_3 \times P_4$, while the lowest fruit yield per plant (461.67 g) was found from P_2 parent plant (Table 4).

4.1.10. Fruit yield per hectare at green stage

Fruit yield per hectare at green stage comparatively the crosses of capsicum gave the highest fruit yield per hectare that that of parent plants under the present investigation. The highest fruit yield per hectare at green stage varied from 17.65 – 29.37 ton. Among the genotypes the highest fruit yield per hectare at green stage (29.37 ton) was obtained from the genotype $P_1 \times P_3$ cross plant which was statistically similar (29.33 ton and 28.01 ton) to $P_1 \times P_4$ and $P_3 \times P_4$, while the lowest fruit yield per hectare (17.65 ton) was found from P_2 parent plant (Figure 2).

4.1.11. Fruit yield per hectare at mature stage

From the data it was found that fruit yield per hectare at mature stage comparatively the crosses of capsicum gave the highest fruit yield per hectare that that of parent plants under the present trial. The highest fruit yield per hectare at mature stage varied from 15.70 – 26.63 ton. Among the genotypes the highest fruit yield per hectare and mature stage (26.63 ton) was obtained from the genotype $P_1 \times P_3$ cross plant which was statistically similar (26.36 ton and 24.96 ton) to $P_1 \times P_4$ and $P_3 \times P_4$, while the lowest (15.70 ton) from P_2 parent plant (Figure 3). Different genotypes influences growth parameter as well as yield but environmental and management factor also influences it. Kakroo and Kumar (1991) reported that the *annuum* group, a considerable variation exists among different species and varieties in respect of different morpho-physiological characters as well as yield. Geleta and Labuschagne (2004) reported that hybrids performed differently and showed high variation for the majority of characters as well as yield.

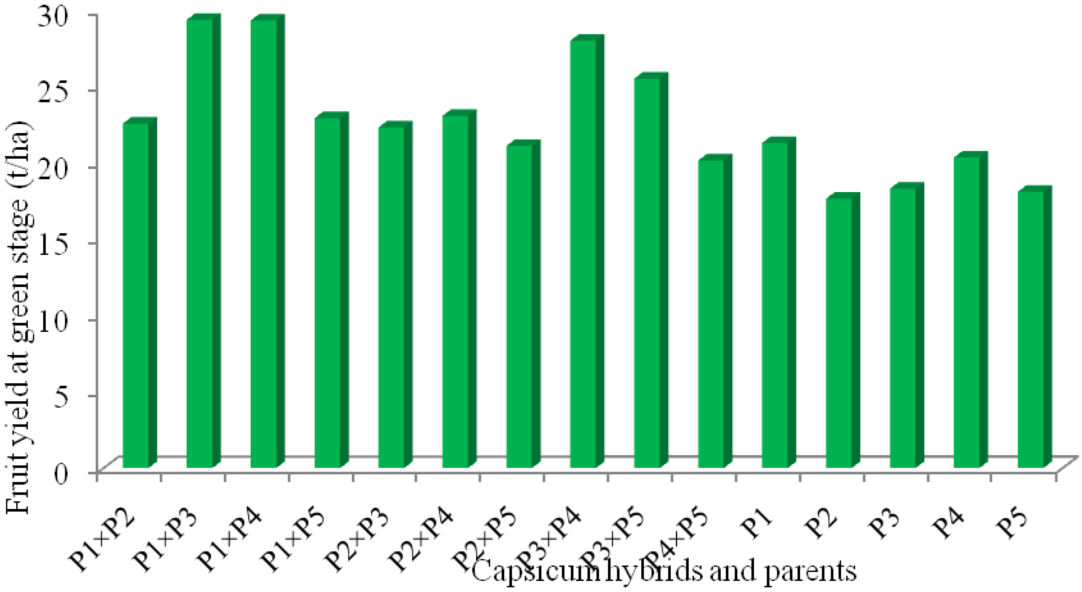

Figure 2. Fruit yield per hectare at green stage of different capsicum hybrids and parents

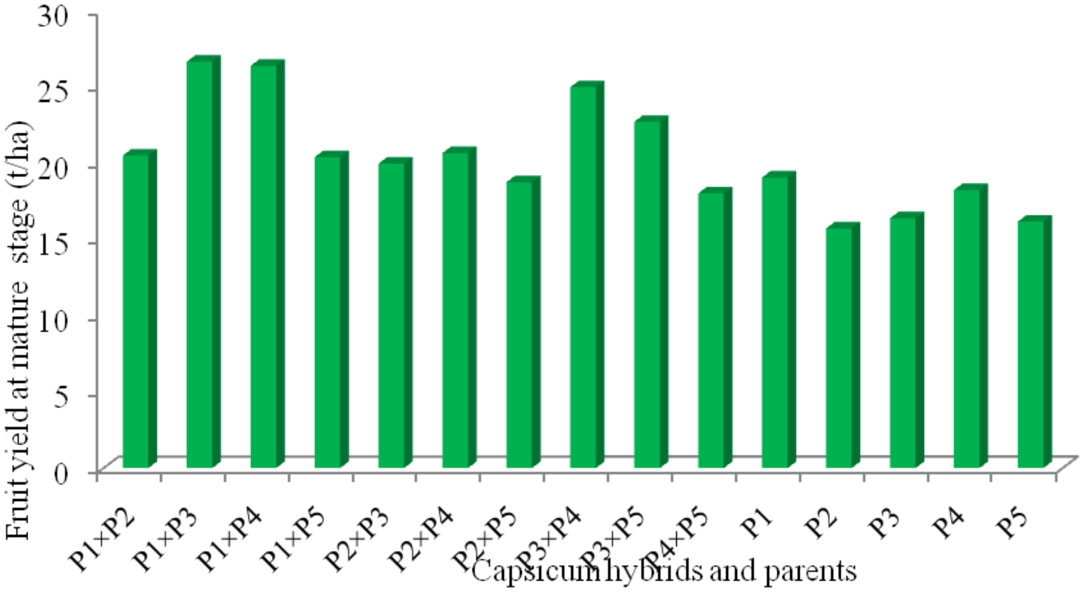

Figure 3. Fruit yield per hectare at mature stage of different capsicum hybrids and parents

4.2 Genetic variability for yield and yield contributing characters

Genotypic and phenotypic variance, heritability, genetic advance and genetic advance in percentage of mean was estimated for 11 yield contributing characters, yield of 5 parents and 10 hybrids of capsicum those are presented in Table 5.

4.2.1. Days to 50% flowering

Phenotypic variation (8.94) was higher than the genotypic variance (2.60) for indicating high environmental influence on this characters which was supported by narrow difference between phenotypic (4.63%) and genotypic (2.50%) co-efficient of variation for days to 50% flowering. The difference between these parameters was also moderate suggested a considerable influence of environment on days to 50% flowering for its expression. Moderate heritability (29.05%) for days to 50% flowering attached with low genetic advance (2.29%) and low genetic advance in percentage of mean (3.55). Moderate estimate of heritability and low genetic advance were found for days to 50% flowering suggested that this character was not predominantly controlled by environment with complex gene interaction.

4.2.2. Plant height

Plant height in terms of phenotypic variation (82.40) was higher than the genotypic variance (61.00) for indicating high environmental influence on this characters which was supported by narrow difference between phenotypic (10.68%) and genotypic (9.19%) co-efficient of variation. The difference between phenotypic and genotypic variation was high indicated great influence of the environment for the expression of this character. Therefore, the breeder must have to simultaneous consideration of genetic work predicted environment for improving the trait. High heritability (74.04%) for plant height attached with high genetic advance (17.74%) and high genetic advance in percentage of mean (20.87). As this trait possessed high variation, it was potential for effective selection for further genetic improvement. Rathod *et al*. (2002) reported that high heritability coupled with high expected genetic advance for plant height.

Table 5. Genetic parameters of different yield contributing characters and yield of capsicum hybrids and parents

Characters	Genotypic Variance ($\sigma^2 g$)	Phenotypic Variance ($\sigma^2 p$)	% Genotypic Coefficient of Variation	% Phenotypic Coefficient of Variation	Heritability (%)	Genetic Advance (GA)	GA in percentage of mean
Days to 50% flowering	2.60	8.94	2.50	4.63	29.05	2.29	3.55
Plant height (cm)	61.00	82.40	9.19	10.68	74.04	17.74	20.87
Individual fruit weight at green stage (g)	309.43	344.90	16.23	17.13	89.72	43.99	40.58
Individual fruit weight at mature stage (g)	309.66	351.63	18.18	19.37	88.06	43.60	45.04
Number of fruits/plant	0.81	1.34	14.30	18.41	60.32	1.84	29.31
Length of fruit (cm)	1.16	1.97	10.14	13.19	59.10	2.19	20.57
Diameter of fruit (cm)	1.25	1.37	17.21	18.00	91.40	2.83	43.44
Fruit yield/plant at green stage (g)	13049.04	13985.63	16.49	17.08	93.30	291.30	42.06
Fruit yield/plant at mature stage (g)	10315.43	11247.04	17.02	17.78	91.72	256.79	43.04
Fruit yield/hectare at green stage (t/ha)	13.77	16.89	16.37	18.12	81.58	8.85	39.03
Fruit yield/hectare at mature stage (t/ha)	11.55	13.76	16.75	18.29	83.90	8.22	40.51

4.2.3. Individual fruit weight at green stage

Phenotypic variation (344.90) was higher than the genotypic variance (309.43) for indicating high environmental influence on this characters which was supported by narrow difference between phenotypic (17.13%) and genotypic (16.23%) co-efficient of variation for individual fruit weight at green stage. The difference between these parameters was also moderate suggested a considerable influence of environment. High heritability (89.72%) for individual fruit weight at green stage attached with high genetic advance (43.99%) and high genetic advance in percentage of mean (40.58). The high heritability estimate coupled with high expected genetic advance for this trait indicated the importance of both additive and non additive genetic effects for the controlling the character. The heritability estimates provides the basis for selection on the phenotypic performance. Rathod *et al*. (2002) reported that high heritability coupled with high expected genetic advance for fresh yield per plant of chilli.

4.2.4. Individual fruit weight at mature stage

Data revealed that individual fruit weight at mature stage of capsicum in respect of phenotypic variation (351.63) was higher than the genotypic variance (309.43) that indicate high environmental influence on this characters which was supported by narrow difference between phenotypic (19.37%) and genotypic (18.18%) co-efficient of variation. The difference between phenotypic and genotypic variance then was high indicated great influence of the environment for the expression of this character. High heritability (88.06%) for individual fruit weight at mature stage attached with high genetic advance (43.60%) and high genetic advance in percentage of mean (45.04). The high heritability estimate coupled with high expected genetic advance for this trait indicated the importance of both additive and non additive genetic effects for the controlling the character is very high. Genetic improvement of this character would therefore be moderately effective. Mishra *et al*. (2004) recorded high phenotypic and genotypic coefficients of variation, heritability and genetic gain for fruit yield per plant.

4.2.5. Number of fruits per plant

Number of fruits per plant in terms of phenotypic variation (1.34) was higher than the genotypic variance (0.81) for indicating high environmental influence on this character. On the other way high difference between phenotypic (18.41%) and genotypic (14.30%) co-efficient of variation also recorded for number of fruits per plant. The difference between them was high indicated great influence of the environment for the expression of this character. Moderate high heritability (60.32%) for number of fruits per plant attached with low genetic advance (1.84%) and high genetic advance in percentage of mean (29.31). Moderate high estimate of heritability and low genetic advance were registered for days to flowering of male suggested that this character was predominantly controlled by environment with complex gene interaction. Munshi and Behera (2000) exhibited highest values of genotypic and phenotypic coefficient of variation (GCV and PCV). Rathod *et al*. (2002) reported that high heritability coupled with high expected genetic advance for the number of fruits per plant.

4.2.6. Length of fruit

Length of fruit for phenotypic variation (1.97) was very higher than the genotypic variance (1.16) for indicating high environmental influence on this characters which was supported by narrow difference between phenotypic (13.19%) and genotypic (10.14%) co-efficient of variation. The difference between phenotypic and genotypic variation then was high indicated great influence of the environment for the expression of this character. Moderately high heritability (59.10%) for length of fruit attached with low genetic advance (2.19%) and high genetic advance in percentage of mean (20.57). The moderately high heritability estimate coupled with low expected genetic advance for length of fruit indicated the importance of both additive and non additive genetic effects for the control of this character. Moderate estimates of heritability (broad sense), genotypic coefficient of variation (GCV) and genetic advance were observed for fruit length by Munshi and Behera (2000). Mohammed *et al*. (2001) reported that phenotypic and genotypic coefficient of variations was highest for fruit length (26.64 and 26.21).

4.2.7. Diameter of fruit

Diameter of fruit in respect of phenotypic variation (1.37) was higher than the genotypic variance (1.25) for indicating high environmental influence on this characters which was supported by narrow difference between phenotypic (18.00%) and genotypic (17.21%) co-efficient of variation. That mean the very close to phenotypic and genotypic variance which indicated that environment had played a little role with little genetic variation among the genotypes of this trait i.e. environmental influence was minimum. Therefore, diameter of fruit was the inherent potential among the five parents ten crosses of capsicum. High heritability (91.40%) for diameter of fruit attached with lowest genetic advance (2.83%) and highest genetic advance in percentage of mean (43.44). The high heritability along with high genetic advance in percentage of mean of diameter of fruit indicated the possible scope for improvement through selection of the character and breeder may expect reasonable benefit in next generation in respect of this trait.

4.2.8. Fruit yield per plant at green stage

Fruit yield per plant at green stage in terms of phenotypic variation (13985.63) was higher than the genotypic variance (13049.04) for indicating high environmental influence on this characters which was supported by narrow difference between phenotypic (17.08%) and genotypic (16.49%) co-efficient of variation. The difference between these parameters was also moderate suggested a considerable influence of environment of fruit yield per plant at green stage for its expression. High heritability (93.30%) for fruit yield per plant at green stage attached with high genetic advance (291.30%) and high genetic advance in percentage of mean (42.06). The high heritability estimate coupled with high expected genetic advance for fruit yield per plant at green stage indicated the importance of both additive and non additive genetic effects for the control of this character. Genetic improvement of this character would therefore be highly effective. High estimates of heritability (broad sense), genotypic coefficient of variation (GCV) and genetic advance were observed for yield per plant by Munshi and Behera (2000). Mini and Khader (2004) recorded the high values of genotypic (GCV) and phenotypic coefficient of variation (PCV) for green fruit yield per plant of capsicum. Sreelathakumary and Rajamony (2004) reported that higher phenotypic and genotypic coefficients of variation for yield per plant and high heritability coupled with high genetic advance observed for these characters imply the potential for crop improvement through selection.

4.2.9. Fruit yield per plant at mature stage

Fruit yield per plant at mature stage in terms of phenotypic variation (11247.04) was higher than the genotypic variance (10315.43) for indicating high environmental influence on this characters which was supported by narrow difference between phenotypic (17.78%) and genotypic (17.02%) co-efficient of variation. The difference between these parameters was also moderate suggested a considerable influence of environment of fruit yield per plant at mature stage for its expression. High heritability (91.72%) for fruit yield per plant at mature stage attached with high genetic advance (256.79%) and high genetic advance in percentage of mean (43.04). The high heritability estimate coupled with high expected genetic advance for fruit yield per plant at mature stage indicated the importance of both additive and non additive genetic effects for the control of this character. Genetic improvement of this character would therefore be highly effective. Nayeema *et al*. (2009) reported that genotypic coefficients were higher in the magnitudes relative to corresponding estimates of phenotypic coefficients, which indicated high heritability of the trait fruit yield per plant of capsicum at mature stage.

4.2.10. Fruit yield per hectare at green stage

Fruit yield per hectare at green stage in terms of phenotypic variation (16.89) was higher than the genotypic variance (13.77) for indicating high environmental influence on this characters which was supported by narrow difference between phenotypic (18.12%) and genotypic (16.37%) co-efficient of variation. The difference between then was high indicated great influence of the environment for the expression of this character. High heritability (81.58%) for fruit yield per hectare at green stage attached with high genetic advance (8.85%) and high genetic advance in percentage of mean (39.03). The high heritability estimate coupled with high expected genetic advance for fruit yield per hectare at green stage indicated the simultaneous importance of additive genetic and environmental effects for the control of this character. Pawandeep *et al*. (2007) reported that high PCV accompanied by high heritability and genetic gain were recorded for yield per hectare indicating that these traits could be improved by simple selection.

4.2.11. Fruit yield per hectare at mature stage

Phenotypic variation (13.76) was higher than the genotypic variance (11.55) in terms of fruit yield per hectare at mature stage for indicating high environmental influence on this characters which was supported by narrow difference between phenotypic (18.29%) and genotypic (16.75%) co-efficient of variation. The difference between then was high indicated great influence of the environment for the expression of this character. High heritability (83.90%) for fruit yield per hectare at mature stage attached with high genetic advance (8.22%) and high genetic advance in percentage of mean (40.51). The high heritability estimate coupled with high expected genetic advance for fruit yield per hectare at mature stage indicated the simultaneous importance of additive genetic and environmental effects for the control of this character. Sonia *et al*. (2006) observed a wide range of phenotypic variability, also, PCV and GCV values. Munshi and Behera (2000) recorded high of heritability (broad sense), genotypic coefficient of variation (GCV) and genetic advance in yield and reported that these characters can be effectively improved through selection.

The highest genetic advance along with high heritability was recorded for plant height, individual fruit weight at green and mature stage, number of fruits per plant, length & diameter of fruit and fruit yield at green & mature stage, indicating the importance of these traits in selection for high yield.

4.3 Correlation matrix

Correlation matrix analysis was done to measure the mutual relationship between eleven different yield contributing characters and yield of 10 hybrids and 5 parents of capsicum (Table 6).

4.3.1. Days to 50% flowering

Among the studied characters of this trial negative significant association was found for days to 50% flowering in capsicum parents and hybrids with individual fruit weight at green stage (-0.435), individual fruit weight at mature stage (-0.423), length of fruit (-0.349), fruit yield per plant at green stage (-0.522), fruit yield per plant at mature stage (-0.525), fruit yield per hectare at green stage (-0.594), fruit yield per hectare at mature stage (-0.591) but non significant negative association was recorded with plant height (-0.234) and diameter of fruit (-0.279). On the contrary, positive non significant association was recorded for number of fruits per plant (-0.133). The results revealed that increase of days to 50% flowering decreases most of yield contributing characters and yield in capsicum.

4.3.2. Plant height

Positive significant association was recorded on plant height in capsicum genotypes in respect of fruit yield per hectare at green stage (0.305), fruit yield per hectare at mature stage (0.311) but non significant positive association was recorded with individual fruit weight at green stage (0.015), individual fruit weight at mature stage (0.051), number of fruits per plant (0.280), length of fruit (0.003), fruit yield per plant at green stage (0.193) and fruit yield per plant at mature stage (0.228). On the other hand, negative non significant association was recorded with diameter of fruit (-0.167). The results revealed that plant height increase considerably with highest yield and yield contributing characters. This suggested that plant height for different genotypes were more potential to allocate their photosynthesis towards highest yield.

Table 6. Correlation matrix of different yield contributing characters and yield of capsicum hybrids and parents

Characters	Days to 50% flowering	Plant height (cm)	Individual fruit weight at green stage (g)	Individual fruit weight at mature stage (g)	Number of fruits/ plant	Length of fruit (cm)	Diameter of fruit (cm)	Fruit yield/ plant at green stage (g)	Fruit yield/ plant at mature stage (g)	Fruit yield/ hectare at green stage (t/ha)	Fruit yield /hectare at mature stage (t/ha)
Days to 50% flowering	1.00										
Plant height (cm)	-0.234	1.00									
Individual fruit weight at green stage (g)	-0.435**	0.015	1.00								
Individual fruit weight at mature stage (g)	-0.423**	0.051	0.996**	1.00							
Number of fruits/plant	0.133	0.280	-0.560**	-0.580**	1.00						
Length of fruit (cm)	-0.349*	0.003	0.011	0.009	0.245	1.00					
Diameter of fruit (cm)	-0.279	-0.167	0.708**	0.716**	-0.683**	-0.066	1.00				
Fruit yield/plant at green stage (g)	-0.522**	0.193	0.781**	0.763**	-0.015	0.243	0.394*	1.00			
Fruit yield/plant at mature stage (g)	-0.525**	0.228	0.706**	0.685**	0.085	0.278	0.319*	0.993**	1.00		
Fruit yield/hectare at green stage (t/ha)	-0.594**	0.305*	0.679**	0.660**	0.024	0.272	0.343*	0.892**	0.891**	1.00	
Fruit yield per hectare at mature stage (t/ha)	-0.591**	0.311*	0.684**	0.662**	0.032	0.269	0.339*	0.906**	0.907**	0.996**	1.00

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

4.3.3. Individual fruit weight at green stage

Individual fruit weight at green stage in capsicum genotypes showed positive significant association for in respect of individual fruit weight at mature stage (0.996), diameter of fruit (0.708), fruit yield per plant at green stage (0.781), fruit yield per plant at mature stage (0.706), fruit yield per hectare at green stage (0.679), fruit yield per hectare at mature stage (0.684) but non significant positive association was recorded with length of fruit (0.011) and plant height (0.015). On the other hand, negative significant association was recorded with number of fruit per plant (-0.560) and days to 50% flowering (-0.435).

4.3.4. Individual fruit weight at mature stage

Positive significant association was recorded for individual fruit weight at mature stage in capsicum genotypes in respect of individual fruit weight at green stage (0.996), diameter of fruit (0.716), fruit yield per plant at green stage (0.763), fruit yield per plant at mature stage (0.685), fruit yield per hectare at green stage (0.660), fruit yield per hectare at mature stage (0.662) but non significant positive association was recorded with length of fruit (0.009) and plant height (0.051). On the other hand, negative significant association was recorded with number of fruit per plant (-0.580) and days to 50% flowering (-0.423).

4.3.5. Number of fruit per plant

Days to 50% flowering (0.133), plant height (0.280), length of fruit (0.245), fruit yield per plant at mature stage (0.085), fruit yield per hectare at green stage (0.024), fruit yield per hectare at mature stage (0.032) showed positive non significant association with number of fruits per plant in capsicum genotypes. On the other hand, negative significant association was recorded with diameter of fruit (-0.683), individual fruit weight at green stage (-0.560) and individual fruit weight at mature stage (-0.580), whereas non significant negative association was recorded for fruit yield per plant and green stage (-0.015). Mohammed *et al*. (2001) reported that number of fruits per plant showed highly significant positive correlation with plant height; on the contrary, it had significant negative correlations with fruit length.

4.3.6. Length of fruit

Among different capsicum genotypes positive non significant association was recorded for length of fruit with fruit yield per plant at green stage (0.243), fruit yield per plant at mature stage (0.278), fruit yield per hectare at green stage (0.272), fruit yield per hectare at mature stage (0.269), plant height (0.003), individual fruit weight at green stage (0.011) and individual fruit weight at mature stage (0.009) and number of fruits per plant (0.245), while negative significant association was recorded with days to 50% flowering (-0.349) and non significant negative association was recorded for diameter of fruit (-0.066).

4.3.7. Diameter of fruit

Diameter of fruit of capsicum genotypes showed positive non significant association for number of fruits per plant in capsicum genotypes with in respect of individual fruit weight at green stage (0.708), individual fruit weight at mature stage (0.716), fruit yield per plant at green stage (0.394), fruit yield per plant at mature stage (0.319), fruit yield per hectare at green stage (0.343), fruit yield per hectare at mature stage (0.339) but significant negative association was recorded with number of fruits per plant (-0.683) and negative non significant association was recorded with days to 50% flowering (-0.279), plant height (-0.167) and length of fruit (-0.066).

4.3.8. Fruit yield per plant at green stage

Positive significant association was recorded for fruit yield per plant at green stage of capsicum genotypes in respect of fruit yield per plant at mature stage (0.993), fruit yield per hectare at green stage (0.892), fruit yield per hectare at mature stage (0.906), individual fruit weight at green stage (0.781), individual fruit weight at green stage (0.763) and diameter of fruit (0.394), whereas non significant positive association was recorded for plant height (0.193) and length of fruit (0.243). On the other hand significant negative association was recorded with days to 50% flowering (-0.522) and non significant negative association was recorded for number of fruit per plant (-0.015).

4.3.9. Fruit yield per plant at mature stage

Fruit yield per plant at mature stage (0.993)fruit yield per hectare at mature stage (0.891), fruit yield per hectare at green stage (0.907), individual fruit weight at green stage (0.706), individual fruit weight at mature stage (0.685) and diameter of fruit (0.319) showed positive significant association for fruit yield per plant at mature stage of capsicum genotypes, whereas non significant positive association was recorded for plant height (0.228) and number of fruit per plant (0.085) and length of fruit (0.278). On the other hand, significant negative association was recorded with days to 50% flowering (-0.525).

4.3.10. Fruit yield per hectare at green stage

Positive significant association was recorded for fruit yield per hectare at green stage of capsicum genotypes in respect of fruit yield per hectare at mature stage (0.996), plant height (0.305), individual fruit weight at green stage (0.679), individual fruit weight at green stage (0.660) and diameter of fruit (0.343), fruit yield per plant at green stage (0.892) and fruit yield per plant at mature stage (0.891), while non significant positive association was recorded for number of fruit per plant (0.024) and length of fruit (0.272). On the other hand, significant negative association was recorded with days to 50% flowering (-0.594).

4.3.11. Fruit yield per hectare at mature stage

Fruit yield per hectare at mature stage of capsicum genotypes showed positive significant association with fruit yield per hectare at green stage (0.996), plant height (0.311), individual fruit weight at green stage (0.684), individual fruit weight at green stage (0.662) and diameter of fruit (0.339), fruit yield per plant at green stage (0.906) and fruit yield per plant at mature stage (0.907), while non significant positive association was recorded for number of fruit per plant (0.032) and length of fruit (0.269). On the other hand, significant negative association was recorded with days to 50% flowering (-0.591).

4.4 Combining ability

A half diallel cross was made for the study of combining ability and heterosis in capsicum. The analysis of variance for general and specific combining ability were found highly significant for all the eleven characters studied (Table 7 and 8), indicating both additive and non-additive gene actions for the expression for theses characters.

4.4.1. General combining ability (GCA)

The estimates of GCA effects for this trait are given in Table 7. Only parents P_5 showed significant positive value for days to 50% flowering therefore P_5 parents was the best general combiner for earliness. In plant height P_3 showed the highest significant positive value can be used as the best general combiner in a crossing program for producing tallest type of plant. In individual fruit weight for green and mature stage P_2 parent showed the positive significant value so P_2 was the best general combiner for individual fruit weight. Parent P_5 showed the positive significant value for number of fruits per plant so P_5 was the best general combiner for number of fruits. In length of fruit P_4 gave the highest significant positive value so P_4 was the best general combiner for fruit length. P_5 showed negative significant value for diameter of fruit so was the best general combiner for producing comparatively thickens fruits. P_1 parent showed highest positive value for fruit yield per plant and P_5 showed the highest negative value for fruit yield per hectare so for the best general combiner P_1 should be included in crossing program and try to avoid P_5.

4.4.2. Specific combining ability (SCA)

The estimates of GCA effects for this trait are given in Table 8. Among 10 crosses 3 for days to flowering, 1 for plant height, 3 for individual fruit weight at green stage, 2 for individual fruit weight at mature stage, 1 for number of fruits per plant, 1 for length of fruit showed positive significant value but in diameter of fruit 1 showed negative significant value. In case of fruit yield per plant at green stage 4 showed positive significant value and 3 for fruit yield per plant at mature stage and 2 for fruit yield per hectare and green and mature stage.

Table 7. Estimates of general combining ability (GCA) effects for different characters of capsicum

Parents	GCA										
	Days to 50% flowering	Plant height (cm)	Individual fruit weight at green stage (g)	Individual fruit weight at mature stage (g)	Number of fruits per plant	Length of fruit (cm)	Diameter of fruit (cm)	Fruit yield per plant at green stage (g)	Fruit yield per plant at mature stage (g)	Fruit yield per hectare at green stage (t/ha)	Fruit yield per hectare at mature stage (t/ha)
P_1	-0.012	-0.030	0.229*	0.234*	-0.013	-0.005	0.018	0.776**	0.738*	0.015	0.014
P_2	0.030	0.015	0.589**	0.590**	-0.058	-0.026	0.034*	0.026	-0.546*	0.012	0.011
P_3	-0.118*	0.980**	0.108	-0.032	0.027	0.015	-0.012	-0.050	0.095	-0.022	-0.019
P_4	-0.046	-0.124	0.303*	0.315**	-0.020	0.050*	-0.022*	-0.622**	0.628**	-0.052*	-0.065*
P_5	0.976**	0.096	0.065	-0.044	0.138**	0.013	-0.085**	-0.022	0.057	-0.030	-0.001
SE(Gi)	0.05	0.18	0.21	0.17	0.07	0.04	0.02	0.56	0.52	0.04	0.06
$LSD_{(0.05)}$	0.11	0.36	0.43	0.35	0.14	0.08	0.05	1.03	1.04	0.08	0.13

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Here, P_1 = ISPN 9-2, P_2 = ISPN 9-1, P_3 = Yellow wonder, P_4 = Yellow star and P_5 = California wonder

Table 8. Estimates of specific combining ability (SCA) effects for different characters of capsicum

Hybrids	SCA										
	Days to 50% flowering	Plant height (cm)	Individual fruit weight at green stage (g)	Individual fruit weight at mature stage (g)	Number of fruits per plant	Length of fruit (cm)	Diameter of fruit (cm)	Fruit yield per plant at green stage (g)	Fruit yield per plant at mature stage (g)	Fruit yield per hectare at green stage (t/ha)	Fruit yield per hectare at mature stage (t/ha)
$P_1 \times P_2$	-0.004	0.018	0.060	0.057	0.003	0.002	-0.001	0.731**	0.676**	0.023	0.021
$P_1 \times P_3$	0.000	-0.336**	0.551**	0.618**	-0.031	0.000	0.005	0.255*	-0.367**	-0.000	-0.005
$P_1 \times P_4$	-0.053	0.926**	0.262**	0.165	-0.009	-0.035	-0.011	0.061	-0.135	0.109	0.095
$P_1 \times P_5$	-0.683**	-0.115	0.048	0.114	-0.031	0.199	0.009	-0.231*	0.206	0.463**	0.392*
$P_2 \times P_3$	0.394**	-0.066	-0.240**	-0.153	0.042	-0.020	0.100	0.322**	-0.343**	0.572**	0.447**
$P_2 \times P_4$	0.479**	-0.043	0.262**	0.209*	0.020	-0.394*	0.061	-0.466**	0.456**	0.199	0.181
$P_2 \times P_5$	0.345**	0.034	0.186*	-0.010	0.049	0.879**	0.182	-0.139	0.133	-0.006	0.000
$P_3 \times P_4$	0.064	0.092	-0.661**	0.699**	0.092	0.096	0.004	-0.055	0.059	0.077	-0.179
$P_3 \times P_5$	-0.004	0.018	0.060	0.057	0.004	0.002	-0.002	0.731**	0.676**	0.023	0.021
$P_4 \times P_5$	0.030	-0.020	0.072	-0.026	0.758**	0.062	-0.641**	-0.011	0.000	0.022	0.056
SE(Gi)	0.12	0.17	0.08	0.09	0.22	0.17	0.22	0.11	0.16	0.23	0.15
$LSD_{(0.05)}$	0.24	0.34	0.16	0.18	0.44	0.34	0.44	0.22	0.32	0.46	0.30

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Here, P_1 = ISPN 9-2, P_2 = ISPN 9-1, P_3 = Yellow wonder, P_4 = Yellow star and P_5 = California wonder

4.5 Heterosis

Analysis of variance for genotypes (parent and crosses) showed highly significant differences for all the eleven characters studied. The estimates of percent heterosis observed in F_1 generation over better parent are presented in Table 9.

The results revealed that among 10 crosses all of then showed negative better parent heterosis for days to 50% flowering. In case of plant height, 5 crosses showed negative better parent heterosis and 5 showed positive better parent heterosis. For individual fruit weight at mature stage 3 showed negative better parent heterosis and 7 crosses showed positive better parent heterosis. In case of number of fruits per plant 6 crosses showed negative and 4 crosses showed positive better parent heterosis and for diameter of fruit 5 crosses showed negative better parent heterosis and 5 crosses showed positive better parent heterosis. In case of fruit yield per plant and hectare at green and mature stage only 1 crosses showed negative better parent heterosis but other 9 crosses showed positive better parent heterosis. Data revealed that highest percentage of heterosis was observed from the hybrids $P_1 \times P_3$ (39.86%), $P_3 \times P_5$ (38.60%), $P_1 \times P_4$ (38.44%) and $P_3 \times P_4$ (36.99%) in consideration of fruit yield per hectare at mature stage. So, these hybrids can be used in hybridization program in future.

Table 9. Percent heterosis over better parents on different yield contributing characters and yield of capsicum

Genotypes	Days to 50% flowering	Plant height (cm)	Individual fruit weight at green stage (g)	Individual fruit weight at mature stage (g)	Number of fruits/ plant	Length of fruit (cm)	Diameter of fruit (cm)	Fruit yield/ plant at green stage (g)	Fruit yield/ plant at mature stage (g)	Fruit yield/ hectare at green stage (t/ha)	Fruit yield/ hectare at mature stage (t/ha)
$P_1 \times P_2$	-5.05	-9.37	-4.98	-5.40	-29.98	9.09	-9.72	6.89	7.58	6.92	7.56
$P_1 \times P_3$	-5.56	13.22	5.45	5.07	33.20	15.00	-12.50	40.22	39.84	40.17	39.86
$P_1 \times P_4$	-4.06	4.11	15.42	16.82	18.76	25.00	-4.16	36.46	38.45	37.86	38.44
$P_1 \times P_5$	-6.56	2.06	0.78	0.63	-26.07	9.09	0.00	7.02	6.96	7.04	6.98
$P_2 \times P_3$	-2.00	6.94	-6.01	-5.13	-26.98	-20.00	3.17	20.89	21.88	21.33	21.86
$P_2 \times P_4$	-4.56	-21.17	5.78	6.29	-34.60	-15.00	-19.48	12.66	13.24	12.02	13.28
$P_2 \times P_5$	-3.51	-14.23	42.32	40.32	-26.98	6.36	67.44	15.89	16.00	16.04	15.97
$P_3 \times P_4$	-1.52	1.16	9.56	9.26	25.14	7.52	-6.49	37.55	36.94	37.06	36.99
$P_3 \times P_5$	-8.40	-0.78	2.67	2.74	13.03	2.72	4.76	38.94	38.64	39.02	38.60
$P_4 \times P_5$	1.00	-7.0	-1.27	-1.33	-30.50	-10.90	1.29	-1.33	-1.24	-1.29	-1.20

Here, P_1 = ISPN 9-2, P_2 = ISPN 9-1, P_3 = Yellow wonder, P_4 = Yellow star and P_5 = California wonder

Plate 3. Photograph showing fruits of better heterosis hybrids

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted during the period from November 2011 to March 2012 at the research field of the Olericulture Division, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, to study the heterosis and combining ability in capsicum. Five parents (P_1 = ISPN 9-2, P_2 = ISPN 9-1, P_3 = Yellow wonder, P_4 = Yellow star and P_5 = California wonder) with 10 hybrid of capsicum were used in the experiment. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Mean performance, variability, correlation matrix, combining ability and heterosis analysis were done on yield contributing and yield characters viz., days to 50% flowering, plant height, individual fruit weight at green stage, individual fruit weight at mature stage, number of fruits per plant, length of fruit, diameter of fruit, fruit yield per plant at green stage, fruit yield per plant at mature stage, fruit yield per hectare at green stage and fruit yield per hectare at mature stage. Statistically significant variation was recorded for yield and yield contributing characters of capsicum.

In consideration of days to 50% flowering of capsicum the maximum days required for 50% flowering (68.67) was recorded for the genotypes P_5 parents, whereas the minimum days to 50% flowering (61.67) was found from $P_1 \times P_5$ and $P_3 \times P_5$ crosses. Among the different genotypes the tallest plant (102.67 cm) was recorded for the genotype $P_2 \times P_3$ crosses plants, whereas the shortest plant (73.00 cm) was found from P_5 parent. In case of individual fruit weight at green stage the highest fruit weight at green stage (134.33 g) was recorded for the genotype $P_1 \times P_4$ crosses, while the minimum fruit weight at green stage (66.67 g) was observed from P_2 parent. Among the different genotypes the highest fruit weight at mature stage (122.67 g) was recorded for the genotype $P_1 \times P_4$ crosses plants and the minimum fruit weight at mature stage (53.33 g) was found from P_2 parent plant. Among the different genotypes the maximum number of fruits per plant (8.67) was recorded for the genotype P_2 parent plant, whereas the minimum number of fruits per (5.00) was found from P_4 parent. Within the different genotypes the longest length of fruit (12.50 cm) was recorded for the genotype $P_1 \times P_4$ cross plant, while the shortest length of fruit (8.80 cm) was found from $P_2 \times P_3$ cross plant. In case of diameter of fruit the highest diameter of fruit (7.80 cm) was recorded for the genotype $P_4 \times P_5$ cross plant, while the lowest diameter of fruit (3.70 cm) was observed from P_2 parent. Among the genotypes the highest fruit yield per plant and green stage (894.55 g) was obtained from the genotype $P_1 \times P_4$ cross plant, while the lowest (516.78 g) was found from P_2 parent plant. Among the genotypes the highest fruit yield per plant and mature stage (783.13 g) was obtained from the genotype $P_1 \times P_3$ cross plant, while the lowest fruit yield per plant (461.67 g) was found from P_2 parent plant. The highest fruit yield per hectare at green stage (29.37 ton) was obtained from the genotype $P_1 \times P_3$ cross plant, while the lowest fruit yield per hectare (17.65 ton) was found from P_2 parent plant. Among the genotypes the highest fruit yield per hectare and mature stage (26.63 ton) was obtained from the genotype $P_1 \times P_3$ cross plant, while the lowest (15.70 ton) from P_2 parent plant.

Phenotypic variation (8.94) was higher than the genotypic variance (2.60) for days to 50% flowering with moderate heritability (29.05%) attached with moderate genetic advance (2.29%) and moderate genetic advance in percentage of mean (3.55). Plant height in terms of phenotypic variation (82.40) was higher than the genotypic variance (61.00) with high heritability (74.04%) and high genetic advance (17.74%) and high genetic advance in percentage of mean (20.87). Phenotypic variation (344.90) was much higher than the genotypic variance (309.43) for individual fruit weight at green stage with high heritability (89.72%) for individual fruit weight at green stage attached with high genetic advance (43.99%) and high genetic advance in percentage of mean (40.58). Individual fruit weight at mature stage of capsicum in respect of phenotypic variation (351.63) was higher than the genotypic variance (309.43) with high heritability (88.06%) attached with high genetic advance (43.60%) and high genetic advance in percentage of mean (45.04). Number of fruits per plant in terms of phenotypic variation (1.34) was higher than the genotypic variance (0.81) with moderate high heritability (60.32%) attached with low genetic advance (1.84%) and high genetic advance in percentage of mean (29.31). Length of fruit for phenotypic variation (1.97) was very higher than the genotypic variance (1.16) with moderately high heritability (59.10%) attached with low genetic advance (2.19%) and high genetic advance in percentage of mean (20.57). Diameter of fruit in respect of phenotypic variation (1.37) was higher than the genotypic variance (1.25) with high heritability (91.40%) for diameter of fruit attached with lowest genetic advance (2.83%) and highest genetic advance in percentage of mean (43.44). Fruit yield per plant at green stage in terms of phenotypic variation (13985.63) was higher than the genotypic variance (13049.04) and high heritability (93.30%) attached with high genetic advance (291.30%) and high genetic advance in percentage of mean (42.06). Fruit yield per plant at mature stage in terms of phenotypic variation (11247.04) was higher than the genotypic variance (10315.43) with high heritability (91.72%) for fruit yield per plant at mature stage attached with high genetic advance (256.79%) and high genetic advance in percentage of mean (43.04). Fruit yield per hectare at green stage in terms of phenotypic variation (16.89) was higher than the genotypic variance (13.77) and high heritability (81.58%) for fruit yield per hectare at green stage attached with high genetic advance (8.85%) and high genetic advance in percentage of mean (39.03). Phenotypic variation (13.76) was higher than the genotypic variance (11.55) in terms of fruit yield per hectare with high heritability (83.90%) for fruit yield per hectare at mature stage attached with high genetic advance (8.22%) and high genetic advance in percentage of mean (40.51). The highest genetic advance along with high heritability was recorded for plant height, individual fruit weight at green and mature stage, number of fruits per plant, length & diameter of fruit and fruit yield at green & mature stage, indicating the importance of these traits in selection for high yield.

Positive significant association was recorded for fruit yield per plant at green stage of capsicum genotypes in respect of fruit yield per plant at mature stage (0.993), fruit yield per hectare at green stage (0.892), fruit yield per hectare at mature stage (0.906), individual fruit weight at green stage (0.781), individual fruit weight at green stage (0.763) and diameter of fruit (0.394), whereas non significant positive association was recorded for plant height (0.193) and length of fruit (0.243).

On the other hand significant negative association was recorded with days to 50% flowering (-0.522) and non significant negative association was recorded for number of fruit per plant (-0.015). Fruit yield per plant at green stage (0.993) fruit yield per hectare at mature stage (0.891), fruit yield per hectare at mature stage (0.907), individual fruit weight at mature stage (0.706), individual fruit weight at mature stage (0.685) and diameter of fruit (0.319) showed positive significant association for fruit yield per plant at mature stage of capsicum genotypes, whereas non significant positive association was recorded for plant height (0.228) and number of fruit per plant (0.085) and length of fruit (0.278). On the other hand, significant negative association was recorded with days to 50% flowering (-0.525).

Only parents P_5 showed significant positive value for days to 50% flowering therefore P_5 parents was the best general combiner for earliness. In plant height P_3 showed the highest significant positive value can be used as the best general combiner in a crossing program for producing tallest type of plant. In individual fruit weight for green and mature stage P_2 parent showed the positive significant value so P_2 was the best general combiner for individual fruit weight. Parent P_5 showed the positive significant value for number of fruits per plant so P_5 was the best general combiner for number of fruits. In length of fruit P_4 gave the highest significant positive value so P_4 was the best general combiner for fruit length. P_5 showed negative significant value for diameter of fruit so was the best general combiner for producing comparatively thickens fruits. P_1 parent showed highest positive value for fruit yield per plant and P_5 showed the highest negative value for fruit yield per hectare so for the best general combiner P_1 should be included in crossing program and try to avoid P_5. The estimates of GCA effects for this trait are given in. Among 10 crosses 3 for days to flowering, 1 for plant height, 3 for individual fruit weight at green stage, 2 for individual fruit weight at mature stage, 1 for number of fruits per plant, 1 for length of fruit showed positive significant value but in diameter of fruit 1 showed negative significant value. In case of fruit yield per plant at green stage 4 showed positive significant value and 3 for fruit yield per plant at mature stage and 2 for fruit yield per hectare and green and mature stage.

Based on the above findings the following conclusion can be drawn

1. Both additive and non-additive gene actions were important in governing the yield and its attributing components.

2. Hybrids $P_1 \times P_3$, $P_3 \times P_5$, $P_1 \times P_4$ and $P_3 \times P_4$ can be used in hybridization program in future based on highest heterosis

Recommendations

Considering the above findings of the present experiment, the following recommendations and suggestions may be made:

1. Selected hybrids are needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.

2. More parents with different crosses with different environment may be included for further study.

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APPENDICES

Appendix I. Results of mechanical and chemical analysis of soil of the experimental plot

Mechanical analysis

Constituents	Percent
Sand	32.45
Silt	61.35
Clay	6.10
Textural class	Silty loam

Chemical analysis

Soil properties	Amount
Soil pH	6.15
Organic carbon (%)	1.32
Total nitrogen (%)	0.075
Available P (ppm)	19.5
Exchangeable K (%)	0.2

Appendix II. Monthly record of air temperature, rainfall, relative humidity, rainfall and sunshine of the experimental site during the period from November, 2011 to March, 2012

Month	*Air temperature (°c)		*Relative humidity (%)	*Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2011	25.8	16.0	78	00	6.8
December, 2011	22.4	13.5	74	00	6.3
January, 2012	24.5	12.4	68	00	5.7
February, 2012	27.1	16.7	67	30	6.7
March, 2012	31.4	19.6	54	11	8.2

* Monthly average,

Source: Weather Station, BARI, Joydebpur, Gazipur 1701

Appendix III. Analysis of variance of different yield contributing characters of capsicum as influenced by genotypes

Genotypes	Days to 50% flowering	Plant height (cm)	Individual fruit weight at green stage (g)	Individual fruit weight at mature stage (g)	Number of fruits/plant
Replication	1.867	10.013	0.467	1.400	0.286
Genotypes	14.133*	204.403**	963.771**	970.943**	2.947**
Error	6.343	21.391	35.467	41.971	0.530
CV(%)	4.90	5.44	5.49	6.69	11.59

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix IV. Continued

Genotypes	Length of fruit (cm)	Diameter of fruit (cm)	Fruit yield/plant at green stage (g)	Fruit yield/plant at mature stage (g)	Fruit yield/ hectare at green stage (t/ha)	Fruit yield/hectare at mature stage (t/ha)
Replication	0.131	0.014	641.010	575.800	2.791	1.727
Genotypes	4.289**	3.881**	40083.7**	31877.9**	44.434**	36.855**
Error	0.804	0.118	936.594	931.612	3.111	2.215
CV(%)	8.43	5.27	4.42	5.13	7.78	7.34

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability