GENETIC DIVERSITY ANALYSIS OF CHILLI (*Capsicum* spp.)

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GENETIC DIVERSITY ANALYSIS OF CHILLI (*Capsicum* spp.)

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CERTIFICATE

This is to certify that the thesis entitled, "Genetic Diversity Analysis of Chilli (*Capsicum* spp.)" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in GENETICS AND PLANT BREEDING**, embodies the result of a piece of bonafide research work carried out by Deen Mohammad Deepo, Registration number: 08-02971 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2016
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(Prof. Dr. Naheed Zeba)

Supervisor

DEDICATED

TO

MY BELOVED PARENTS

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Some commonly used abbreviations

Full Word	Abbreviation
Agricultural	*Agril.*
Agro-Ecological Zone	AEZ
and others	*et al.*
and others (at elli)	*et al.*
Bangladesh Bureau of Statistics	BBS
Biology	*Biol.*
Biotechnology	*Biotechnol.*
Botany	*Bot.*
Centimeter	cm
Cultivar	cv.
Date After Seeding	DAS
Degree Celsius	^{0}C
Etcetera	Etc
Etcetera	etc.
exempli gratia (for example)	e.g.
Food and Agriculture Organization	FAO
Gram per liter	g/L
Hectare	ha
International	*Intl.*
Journal	*J.*
Muriate of Potash	MP
Newsletter	*Newsl.*
Pages	pp.
Physiology	*Physiol.*
Randomized Complete Block Design	RCBD
Research	*Res.*
Science	*Sci.*
Sher-e-Bangla Agricultural University	SAU
Species (Plural)	spp.
Square meter	m^2
Triple Super Phosphate	TSP
United Nations Development Program	UNDP

GENETIC DIVERSITY ANALYSIS OF CHILLI (*Capsicum* spp.)

BY

DEEN MOHAMMAD DEEPO

ABSTRACT

The present research work was conducted to study the genetic diversity analysis of chilli during the period from November 2015 to April 2016 in rabi season in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. In this experiment 15 chilli genotypes were used as experimental materials. Mean performance, variability, correlation matrix, path analysis and genetic diversity analysis on different yield attributes and yield of chilli genotypes was estimated. The highest yield/plant (427.44 g) was observed in G_3, while the lowest (242.89 g) from G_{14}. Phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the yield contributing traits and yield. In correlation study, highly significant positive association was recorded for days to 1^{st} flowering of chilli genotypes with plant height (0.369), number of fruits/plant (0.587), weight of individual fruit (0.634) and length of fruit (0.450). Path analysis revealed negative direct effect for days to 1^{st} flowering (-0.148), number of seeds/fruit (-0.133) and weight of 1000 seeds (-0.211), whereas positive direct effect for plant height (0.205), number of branches/plant (0.186), number of fruits/plant (0.132), weight of individual fruit (0.293), length of fruit (0.164) and diameter of fruit (0.078) on yield/plant. Diversity analysis revealed that Cluster I had the maximum 8 chilli genotypes and the lowest had in cluster IV which had a single genotype. Considering group distance and other agronomic performance special chilli of Bogra (G_3), Local 1 (G_6), SRCO 9 (G_{11}), SRCO 5 (G_{14}), Ca 001 (G_1) and SRC 13 (G_{12}) chilli genotypes may be suggested for further study for future hybridization program.

CHAPTER I

INTRODUCTION

Chili (*Capsicum annuum* L.) originated in South and Central America belongs to the family Solanaceae is a spice crop and also used as vegetable and widely cultivated throughout the world (Dias *et al*., 2013; Wahyuni *et al*., 2013). The constituents of chilli are important for it's nutritional value, aroma, texture, color and it is also a good source of oleoresin which has diversified uses in process food, beverage industries and in pharmaceuticals (Osuna-Garcia *et al.,* 1998; Marin *et al.*, 2004). Chili, of the genus *Capsicum,* has more than 25 commonly used species with four cultivars groups as *Chinense* group (West Indies chili), *Frutescens* group (bird chili), *Annuum* group (hot chili) and sweet pepper group (Nsabiyera *et al*., 2013). Throughout the world, chili is generally consumed either in fresh, dried or in powder (El-Ghoraba *et al*., 2013).

Generally chilli is grown as a cash crop but its commercial production and it is largely concentrated in Bogra, Rangpur, Comilla, Noakhali, Faridpur, Chittagong and Mymensingh district (Mustafiz, 1999). In Bangladesh 434,757 acres land is under its cultivation and total production of green chilli was approximately 1,549,474 metric tonnes (BBS, 2014). Chilli is rich in proteins, lipids, carbohydrates, fibres, mineral salts (Ca, P, Fe) and in vitamins A, D_3, E, C, K, B_2 and B_{12} (El-Ghoraba *et al*., 2013). The fruits are an excellent source of health-related phytochemical compounds, such as ascorbic acid, carotenoids, tocopherols (vitamin E), flavonoids, and capsaicinoids that are very important in preventing chronic diseases such as cancer, asthma, coughs, sore throats, diabetes (Wahyuni *et al*., 2013); The pharmaceutical application of capsaicinoid is attributed to its antioxidant, anticancer, antiarthritic, and analgesic properties (Akbar *et al.*, 2010). Moreover, the consumption of fresh fruits facilitates starchy food digestion in human body (Bhattacharya *et al*., 2010). It has antioxidant, antiutagenesis and hypocholesterolemic properties and also inhibits bacterial growth and platelet agglomeration (Wahyuni *et al*., 2013).

At global level, chili is one of the spices that generate huge revenues for producers and therefore contributes to poverty alleviation and improvement of women's social status (Karungi *et al*., 2013). Despite its economic, food and medicinal importance, chili remains in many countries a neglected crop that is rarely of national priority in terms of agricultural development (FAO, 2010). Therefore, its cultivation is still traditional and is facing many biotic (diseases, insects and viruses), and abiotic (drought, high soil moisture, heat, salinity, low soil fertility etc.) stresses that cause severe yield losses (Segnou *et al*., 2013; Zhani *et al*., 2013 and Khan *et al*., 2009). In Bangladesh the yield of chilli is very low (1.44 t/ha) and such low yield however is not an indication of low yielding potentially of this crop, but the fact of that the low yield may be attributed to such biotic and abiotic factors. Therefore, tailoring new variety of chili pepper have high potential yield, resistance to disease and good adaptability in the peat land through breeding works must be a high priority. It was revealed that great variation exists in ability to flowering, fruit set, yield and other qualitative attributes of chilli genotypes (Maurya *et al.*, 2016 and Rani, 1996).

The systematic breeding works involved the several steps, like collecting of germplasm, assessing of genetic variability, creating of genetic variability, implementing of selection, and developing of selected genotypes to be released as commercial variety (Poehlman and Sleper, 1995 and Syukur *et al*., 2012). For efficient and effective breeding work, investigation and better understanding of the variability existing in a population base of crop is required so that it can be exploited by plant breeder for crop improvement. Moreover, the success of any crops improvement program depends not only on the amount of genetic variation present in a crop but also on magnitude of variation which is heritable from the parent to the progeny (Bello *et al*., 2014). A wide range of variability is available in chilli genotypes which provide great scope for improving fruit yield through systematic breeding. Estimation of genetic variability present in the germplasm of a crop is a pre-requisite for designing effective breeding programme (Parkash, 2012).

Several researchers observed that PCV to be higher than GCV for all the studied traits (Kadwey *et al*., 2016; Gupta *et al.,* 2009 and Bendale *et al.,* 2006). Heritability was found to be very high for fruit yield per plant, seed yield per plant, fruit length, fruit weight of green chilli and fruit yield per hectare (Wilson and Philip, 2009 and Bharadwaj *et al.,* 2007). In order to benefit transgressive segregation, the knowledge of genetic distance between parents is necessary (Lahbib *et al*., 2012 and Khodadadi *et al*., 2011). The information the degree of genetic divergence is essential for the breeder to choose the right type of parents for purposeful hybridization in heterosis breeding (Khodadabi *et al*., 2011 and Farhad *et al*., 2010). More diverse the parents within a reasonable range, better are the chances of improving economic characters in the offspring. The critical assessment of nature and magnitude of variability in the germplasm stock is one of the important pre-requisites for formulating effective breeding methods (Krishna *et al*., 2007). 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 and heritability estimates.

Under the above mention situation and context, the present experiment was conducted for genetic diversity analysis of chilli with the following objectives:

- To know the yield contributing characters and yield potentiality of different chilli genotypes;
- To know the nature of association of traits, direct and indirect relation between yield contributing characters and yield of different chilli genotypes;
- To screen out the suitable parents group which are likely to provide superior segregants on hybridization and
- To assess the magnitude of genetic divergence in genotypes for identifying the genetically divergent parents to use them in future breeding program.

CHAPTER II

REVIEW OF LITERATURE

Chilli is one of the most important spices crops and this spices crop received much attention of the researchers throughout the world because of its various ways of consumption and nutritional value. Scientists are working continuously with this crop for development of new varieties and improvement of production techniques. Their findings suggest that growth and development of chilli plants largely depend on the germplasm. Large number of researchers has studied the effect of germplasm on the morpho-physiological, yield attributes of chilli in different countries of the world, but very few research works have been carried out for the improvement of this crop in the agro-climatic condition of Bangladesh. Therefore, the research work so far done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important informative works and research findings related to yield contributing characters, heritability, nature of association of traits and magnitude of genetic divergence in genotypes etc. so far been done at home and abroad have been reviewed below under the following headings:

2.1 Yield contributing characters and yield of chilli

2.1.1 Days to flower bud initiation

Kaouther *et al*. (2015) conducted an agronomic evaluation with five local accessions of chilli pepper namely, Tebourba, Somaa, Korba, Awled Haffouz and Souk Jedid, at Higher Institute of Agronomy, Chott Mariem, Sousse (Tunisia) and stated that Tebourba was the earliest to flowering with 44 days while Somaa took the longest days (58 days).

Hasan *et al.* (2014) carried out an experiment to study the morpho-physiological and yield performance of four chilli lines (coded from L_1 to L_4) at Sher-e-Bangla Agricultural University, Bangladesh and reported that early flower bud initiation from L_1 (30 days) whereas late from L_4 (42 days).

Barche *et al.* (2013) carried out an experiment at Horticulture complex, J.N.K.V.V. Jabalpur to study the performance of 22 diverse chilli (*Capsicum annuum* L.) genotypes collected from different parts of India including two control viz., LCA-334 and KA-2 at the Kymore plateau Region of Madhya Pradesh and recorded that genotype 2011/CHIVAR-8 was found to early which produced flowered in 40.66 DAT, whereas, late flowering 53.66 DAT was noted in the controlled genotype KA-2.

2.1.2 Plant height

Jaisankar *et al.* (2015) carried out a varietal evaluation with twelve varieties of Chilli (*Capsicum annuum* L.) at research farm of CIARI, South Andamanand and reported a wide range of differences in their variation for fruit yield and morphological traits and the tallest plant was found from V_3 (69.38 cm), while the shortest from V_{12} (32.02 cm) at 80 DAT from.

Kaouther *et al.* (2015) conducted an agronomic evaluation with five local accessions of chilli pepper (*Capsicum frutescens* L.) namely, Tebourba, Somaa, Korba, Awled Haffouz and Souk Jedid, in the experimental station of Higher Institute of Agronomy, Chott Mariem, Sousse (Tunisia) and reported that plant height (56.16 to 114.83 cm) of Korba cv demonstrated the best values while Souk Jedid cv had the lowest one among the accessions.

Barche *et al*. (2013) carried out an experiment at Horticulture complex, J.N.K.V.V. Jabalpur to study the performance of 22 diverse chilli (*Capsicum annuum* L.) genotypes collected from different parts of India including two control viz., LCA-334 and KA-2 at the Kymore plateau Region of Madhya Pradesh and recorded that plant height at 30 days after transplanting (30 DAT) ranged from 8.73 to 26.00 cm and 26.73 to 71.26 cm at 120 DAT in KA-2 and 2011/CHIVAR-2 genotypes.

Tembhurne *et al*. (2004) evaluated 11 advanced lines obtained from Chilli Research Station, Devihosur were evaluated along with KDC 1, Byadgi Dabbi and Byadgi Kaddi as checks at College of Agriculture, Bheemarayanagudi to know the varietal performance, variability and association of traits in chilli and observed that maximum plant height (80.93 cm) in Byadgi Kaddi and minimum plant height (50.17 cm) in HCS G_2.

2.1.3 Number of branches per plant

Jaisankar *et al.* (2015) conducted a varietal evaluation at research farm of CIARI, South Andamanand with twelve varieties of Chilli and recorded the maximum number of branches from V_3 (26.57/plant), while the minimum from V_5 (11.69/plant) at 80 DAT.

Hasan *et al.* (2014) carried out an experiment to study the morpho-physiological and yield performance of four chilli lines (coded from L_1 to L_4) at Sher-e-Bangla Agricultural University, Bangladesh and observed that the maximum number of branches (26.5/plant) from L_4 and the minimum number of branches (21.5/plant) from L_3.

Barche *et al.* (2013) found that number of primary branches per plant at 30 days after transplanting (30 DAT) ranged from 2.68 in 2011/CHIVAR-1 to 6.86 in 2012/CHIVAR-2 and 5.40 in KA-2 to 10.21 in 2012/CHIVAR-2 at 120 DAT genotypes from five randomly selected plants of each genotype in each replication.

Tembhurne *et al.* (2005) recorded the maximum number of primary branches (5.73) in HCS G_8, the minimum no of primary branches (4.33) in HCS G_2, the maximum number of secondary branches (7.13) in HCS G_1 and the minimum number of secondary branches (2.73) in 9626-6-1 among the 11 advanced lines.

2.1.4 Number of fruits per plant

Farooq *et al.* (2015) carried out an experiment at the Horticultural Research Institute, NARC, Islamabad to investigate the growth and yield of sweet pepper hybrids under plastic tunnel with five hybrids viz., Orobelle, Figaro, Green

Beauty, Mighty, Capistrano with control Yolowonder and observed that Orobella rank first regarding number of fruit/plant (43.47).

Chowdhury *et al*. (2015) conducted an experiment with four varieties of Chilli V_1 (Magura), V_2 (Kajoli), V_3 (Vaduria) and V_4 (Bogra Morich) and showed wide differences in their genotypic constituents reflected by morphological status. The maximum number of fruits (265.5/plant) was found from V_2, while minimum from V_4.

Jaisankar *et al.* (2015) noted that the maximum number of fruits from V_{11} (33.12/plant) which was followed by V_7 (31.28/plant), whereas the minimum number was recorded from V_1 (11.11/plant).

Hasan *et al.* (2014) carried out an experiment to study the morpho-physiological and yield performance of four chilli lines (coded from L_1 to L_4) at Sher-e-Bangla Agricultural University, Bangladesh and recorded the maximum number of fruit from L_2 (33.0/plant) which was statistically similar with L_3 (28.3/plant) and L_4 (26.0/plant), while the minimum from L_1 (14.3/pant) which was statistically similar with L_4 (26.0/plant).

Mohanty *et al.* (2005) evaluated eight varieties of chilli *(Capsicum annum* L.) over 3 years and found that the maximum number of fruits/plant (243.47) was recorded in X 235 among the chilli varieties.

Tembhurne *et al.* (2005) observed that HCS G_1 produced significantly the highest number of fruits per plant (144.2) among the 11 advanced lines that they evaluated.

2.1.5 Individual fruit weight

Jaisankar *et al.* (2015) conducted a varietal evaluation at research farm of CIARI, South Andamanand with twelve varieties of Chilli and noted the maximum single fruit weight in V_1 (4.64 g) followed by V_5 (2.78 g) which was on par with V_{10} (2.67 g), whereas the minimum from V_{11} (1.32 g).

Hasan *et al.* (2014) carried out an experiment to study the morpho-physiological and yield performance of four chilli lines (coded from L_1 to L_4) at Sher-e-Bangla Agricultural University, Bangladesh and found that maximum individual fruit weight from L_3 (1.3 g) while minimum from L_4 (0.9 g).

Barche *et al.* (2013) conducted an experiment at Horticulture complex, J.N.K.V.V. Jabalpur to study the performance of 22 diverse chilli (*Capsicum annuum* L.) genotypes collected from different parts of India including two control viz., LCA-334 and KA-2 at the Kymore plateau Region of Madhya Pradesh and recorded that genotype 2011/CHIVAR-8 produced the highest fruit weight (5.15 g) which was statistically similar (5.12 g) from the genotype 2012/CHIVAR-2 in green condition.

Tairu *et al.* (2013) observed that although the accessions did not differ significantly in their yield potential but the accessions PP9955-15 had the highest average fruit weight (13.39 g).

Tembhurne *et al.* (2005) observed that the maximum individual fruit weight (1.12 g) in HCS (G_3) and the minimum individual fruit weight (0.4 g) in HCS (G_8) among the 11 advanced lines.

Das *et al.* (2004) evaluated the performance of chilli genotypes during summer season at Sabour, Bihar, India and they found that the genotype 94-3 showed the highest fruit weight of 20.31 g.

2.1.6 Fruit length

Jaisankar *et al.* (2015) carried out a varietal evaluation at research farm of CIARI, South Andamanand with twelve varieties of Chilli and recorded the maximum fruit length in V_6 (6.19 cm) which was statistically similar to V_3 (6.06 cm), while the minimum was recorded in V_{11} (3.93 cm).

Farooq *et al.* (2015) conducted an experiment at the Horticultural Research Institute, NARC, Islamabad to investigate the growth and yield of sweet pepper hybrids under plastic tunnel with five hybrids viz., Orobelle, Figaro, Green Beauty, Mighty, Capistrano with control Yolowonder and found that Orobella rank first regarding hybrid produced highest (5.98 cm) value for fruit length.

Barche *et al.* (2013) found the maximum fruit length (11.38 cm) in genotype 2012/CHIVAR-2 with regards to fruit length.

Tairu *et al.* (2013) recorded that fruit length (14.81 cm) was the maximum in accession PP9955-15 while all other cultivars were statistically at par with the check varieties.

Das *et al.* (2004) evaluated the performance of chilli genotypes during summer season at Sabour, Bihar, India and observed that the genotype 94-3 showed the highest fruit length of 5.90 cm.

Tembhurne *et al.* (2005) assessed different genotypes of chilli and reported that B. Kaddi produced the highest fruit length (11.78 cm), while the lowest length (7.73 cm) was observed in HCS G_4.

2.1.7 Fruit diameter

Jaisankar *et al.* (2015) conducted a varietal evaluation at research farm of CIARI, South Andamanand with twelve varieties of Chilli and found that the maximum fruit diameter from V_1 (6.41 mm) followed by V_5 (6.14 mm) and minimum was recorded in V_9 (5.85 mm).

Farooq *et al.* (2015) conducted an experiment at the Horticultural Research Institute, NARC, Islamabad to investigate the growth and yield of sweet pepper hybrids under plastic tunnel with five hybrids viz., Orobelle, Figaro, Green Beauty, Mighty, Capistrano with control Yolowonder and observed that Orobella rank the first regarding hybrid produced the highest (6.27 mm) value for fruit diameter.

Hasan *et al.* (2014) recorded that highest fruit length of individual fruit from L_2 (7.5 mm) at Sher-e-Bangla Agricultural University, Bangladesh. They also found that the maximum fruit diameter was found from L3 (0.7 cm), while the minimum from L4 (0.5 cm).

Barche *et al.* (2013) noted that the maximum fruit width (6.43 mm) in genotype 2012/CHIVAR-2 with regards to fruit width.

Tairu *et al*. (2013) recorded the maximum fruit width (6.8 mm) in accession PP9955-15, while all other cultivars were statistically at par with the check varieties.

Tembhurne *et al.* (2005) observed that HCS G_1 produced significantly the highest fruit width (6.36 mm) among eleven elite advanced lines obtained from Chilli Research Station, Devihosur and the better performance of 9626-6-1 was due to fruit width.

2.1.8 Number of seeds per fruit

Jaisankar *et al.* (2015) conducted a varietal evaluation at research farm of CIARI, South Andamanand with twelve varieties of Chilli and recorded that the maximum number of seeds in V_5 (99.24/fruit), while the minimum was recorded in V11 (48.04/fruit).

Kaouther *et al.* (2015) conducted an agronomic evaluation with five local accessions of chilli pepper namely, Tebourba, Somaa, Korba, Awled Haffouz and Souk Jedid, in the experimental station of Higher Institute of Agronomy, Chott Mariem, Sousse (Tunisia) and notated that Tebourba produced the higher number of seeds (126.8), while Souk Jedid produced the lowest number (63.26).

Hasan *et al.* (2014) observed that number of seed/fruit varied significantly among the chilli lines and the maximum number of seeds/fruit was found from L_2 (69.0) which was statistically similar to L_3 (67.3), while the minimum number of seeds/fruit from L_4 (46.8).

Tairu *et al*. (2013) recorded the highest number of seeds per pod (48*)* in PP9955-15 as regards seed production by five exotic pepper accessions.

Nkansah *et al.* (2010) found the highest seed number per fruit (155) in ICPN16#7, while ICPN16#2 had the least seed number per fruit (65).

2.1.9 Weight of 1000 seeds

Tairu *et al*. (2013) recorded highest 1000-seeds weight (88.34 g) in PP9955-15 as regards seed production by five exotic pepper accessions (PP9955-15, PP0337-7562, PP0201-7532, PP9950-5197, PP9952-173) obtained from AVRDC, The World Vegetable Center.

Zewdie (1997) made a trial to studied variation in Yugoslavian hot pepper (*Capsicum annuum L.*). He evaluated 67 accessions of hot pepper based on 35 morphological and physiological characters and recorded highly significant differences among the genotypes. He grouped the accessions into six clusters and mainly based on 1000-seeds weight, fruit weight, fruit number per plant and yield per plant showed wide genetic diversity among the genotypes.

2.1.10 Yield per plant

The present experiment was carried out by Maurya *et al*. (2017) during spring summer season at Vegetable Research Center of GBPUAT, Pantnagar (Uttarakhand) to estimate the performance of chilli genotypes for yield and qualitative traits. There was found significant variation among all the genotypes for different characters under study and in case of fruit yield per plant genotype PC 20132 (89.79 g) produced the maximum fruit yield.

Chowdhury *et al*. (2015) conducted an experiment with four varieties of Chilli V_1 (Magura), V_2 (Kajoli), V_3 (Vaduria) and V_4 (Bogra Morich) and showed wide differences in their genotypic constituents reflected by morphological status. The maximum yield (291.3 g/plant) was found from V_2, while minimum from V_4.

Jaisankar *et al.* (2015) carried out a varietal evaluation at research farm of CIARI, South Andamanand with twelve varieties of Chilli and recorded that the maximum yield was found in V_3 (69.74 g/plant) followed by V_2 (55.26 g/plant), whereas the minimum was recorded in V_5 (37.68 g/plant).

Kaouther *et al.* (2015) conducted an agronomic evaluation with five local accessions of chilli pepper (*Capsicum frutescens* L.) namely, Tebourba, Somaa, Korba, Awled Haffouz and Souk Jedid, and stated that yield in g per plant showed that Korba was the most performing accession (870.61 g) while Souk Jedid produce the lowest yield per plant (406.8 g).

Farooq *et al.* (2015) conducted an experiment at the Horticultural Research Institute, NARC, Islamabad to investigate the growth and yield of sweet pepper hybrids under plastic tunnel with five hybrids viz., Orobelle, Figaro, Green Beauty, Mighty, Capistrano with control Yolowonder and observed that Orobella rank first regarding fruit weight/plant (1.96 kg).

Hasan *et al.* (2014) carried out an experiment to study the morpho-physiological and yield performance of four chilli lines (coded from L_1 to L_4) at Sher-e-Bangla Agricultural University, Bangladesh and observed maximum yield from L_3 (149.2 g/plant) whereas minimum from L_1 (45.0 g/plant).

Barche *et al.* (2013) conducted an experiment at Horticulture complex, J.N.K.V.V. Jabalpur to study the performance of 22 diverse chilli (*Capsicum annuum* L.) genotypes including two control viz., LCA-334 and KA-2 at the Kymore plateau Region of Madhya Pradesh and recorded that the genotype 2012/ CHIVAR-2 recorded the highest fresh fruit yield (993.33 g). Among the twenty two genotypes studied 2011/CHIVAR-8 was found to be superior followed by 2012/CHIVAR-2 and 2011/CHIVAR-6 for this region.

Tembhurne *et al.* (2005) evaluated 11 advanced lines obtained from Chilli Research Station, Devihosur were evaluated along with KDC 1, Byadgi Dabbi and Byadgi Kaddi as checks to know the varietal performance, variability and association of traits in chilli and observed that HCS G_1 recorded significantly highest yield per plant (100.2 g).

2.2 Genetic variability in chilli

Thirty three chilli germplasm were evaluated by Pandiyaraj *et al.* (2017) to estimate genetic variability, heritability and genetic advance of twelve quantitative and four qualitative traits. The overall values of GCV lower than the PCV for all the traits. High magnitude of PCV and GCV were recorded for carotene content and followed by red pod yield/plant, dry pod yield/plant and capsaicin. High values of GCV are an indication of high genetic variability among the germplasm. The heritability estimates in broad sense were found to be high for all the characters except number of secondary branches per plant, days to first flowering, pod girth and thousand seed weight. High heritability estimates indicated the presence of large number of fixable additive factors and hence these traits can be improved by selection. The traits like red pod yield per plant, dry pod yield per plant and mean pod weight with high phenotypic coefficient of variation, genotypic coefficient of variation, heritability and genetic advance as percent of mean, indicating that these characters are under additive gene effects and more reliable for effective selection.

Fifty germplasm were used by Kumar *et al.* (2017) to study the genetic variability, heritability, genetic advance and correlation for growth and yield contributing characters in fennel. Experiment laid out at National Research Centre on Seed Spices, Ajmer for yield and its yield attributing characters. The analysis of variance revealed significant differences among the germplasms for number of primary branches, number of umbels per plant, number of umbellate per umbel, number of seed per umbellate, test weight (g) and seed yield (5 plant g). The phenotypic coefficient of variance (PCV) was higher than genotypic coefficient of variance (GCV) for most of the characters. Number of umbels per plant, number of umbels per umbellate per umbel, number of seed per umbellate, test weight, seed yield and number of secondary branches exhibited high genetic advance as percentage of mean along with high heritability.

Eight diverse genotypes of chilli were evaluated by Kannan *et al*. (2016) an open field study to evaluate the genetic variability, heritability and genetic advance. The higher estimates of genotypic coefficient of variation (GCV) were observed for flowers per branch (21.59%), clusters per plant (19.26%), flower per branch (16.93%) and stem diameter (15.49%). While the higher estimates of phenotypic coefficient of variation (PCV) were found for flowers per branch (26.70%), fruits per branch (24.44%), clusters per plant (24.04%) and stem diameter (19.26%). The higher estimates of broad sense heritability along with genetic advance recorded for flowers per branch (65%), fruits per plant (64%), cluster per plant (64%), stem diameter (65%), plant weight (59%) and days to 50% flowering (50%) indicated the scope for improvement of these characters through selection.

Rosmaina *et al*. (2016) carried out an experiment to estimate the magnitude of genetic variability, heritability and genetic advance for yield and contributing characters of the sixteen of local chili genotypes cultivated in peat land. Analysis of variance revealed that there are highly significant difference among the genotypes tested for all characters studied indicating the presence of variability. In this study, PCV value was relatively greater than GCV for all traits; however, GCV values were near to PCV values for the characters like plant height, stem length, leaf width, fruit length, fruit diameter, day to flowering, day to first harvest, and single fruit weight indicating high contribution of genotypic effect for phenotypic expression of such characters. High heritability coupled with high genetic advance per percent of mean was obtained for, plant height, stem length; leaf width; plant canopy width, days to flowering, fruit length; fruit diameter, single fruit weight, number of fruit per plant, fruit weight per plant reflecting the presence of additive gene action for the expression of these traits, and improving of these characters could be done through selection.

Quresh *et al*. (2015) conducted an experiment with 10 accessions of *Capsicum annuum* acquired from the Centre for Genetic Resources, the Netherlands (CGN) through Plant Genetic Resources Institute (PGRI), National Agricultural Research Centre (NARC) Islamabada for genetic diversity and phenotypic variability in the available germplasm is a prelude to crop improvement. The present study was undertaken. The accessions were evaluated for 35 qualitative and 11 quantitative parameters. Wide variation was noted among the genotypes for important characters pertaining to fruit and seed yield.

Maurya *et al*. (2015) evaluated thirty genotypes of chilli in a field study to assess genetic variability, heritability and genetic advance and found that the knowledge of the magnitude of genetic variability for marketable fruit yield and quality traits is needed to improve quality breeding in chilli. Higher phenotypic and genotypic coefficients of variation were observed for days to 50% flowering, number of fruits per plant, fruit body length, number of seeds per fruit, weight of seeds per fruit, seed husk ratio, average dry fruit weight and dry fruit yield per plant. High heritability coupled with high genetic advance were observed for seed husk ratio, average dry fruit weight and dry fruit yield per plant, so these characters imply the potential for crop improvement through selection.

Genetic variability, heritability, and genetic advance as a per cent over mean for eleven characters were assessed by Jogi *et al*. (2015) by field evaluation of fifty chilli genotypes. High degree of variation was observed for all characters. The difference between phenotypic coefficient of variation and genotypic coefficient of variation were found to be narrow for most of the traits. The high estimates of heritability was found for number of fruits per plant at first picking (98.20%), total number of fruits per plant (94.67%), early yield (94.67%), late yield (95.62%) and total yield (91.37%), fruit length (96.22%), fruit width (96.22%), stalk length (81.04%) and ten fruit weight (96.44%).

A investigation was carried out by Janaki *et al*. (2015) during kharif at Horticultural Research Station, Lam, Guntur with 63 genotypes of chilli (*Capsicum annuum* L.) to estimate the genetic variability, heritability and genetic advance for ten quantitative traits. Analysis of variance revealed significant differences among the genotypes for all the traits studied indicating the presence of sufficient variability in the studied material. The PCV was higher than GCV and the difference between PCV and GCV was narrow for most of the characters revealing little influence of the environment in the expression of these traits. High magnitude of PCV and GCV were observed for per cent fruit set, number of fruits per plant, fruit diameter, average dry fruit weight, number of seeds per fruit and yield per plant suggesting the existence of wide range of genetic variability in the germplasm for these traits and thus the scope for improvement of these characters through simple selection would be better. High heritability coupled with high genetic advance as per cent of mean was observed for all the characters except days to 50% flowering indicating the predominance of additive gene action making the simple selection more effective.

Two experiments were carried out by Usman *et al*. (2014) to study the genetic variability among chili pepper for heat tolerance and morphophysiological traits and to estimate heritability and genetic advance expected from selection. There was a highly significant variation among the genotypes in response to high temperature (CMT), photosynthesis rate, plant height, disease incidence, fruit length, fruit weight, number of fruits, and yield per plant. At 5% selection intensity, high genetic advance as percent of the mean (>20%) was observed for CMT, photosynthesis rate, fruit length, fruit weight, number of fruits, and yield per plant. Similarly, high heritability (>60%) was also observed indicating the substantial effect of additive gene more than the environmental effect.

Twenty three genotypes were used by Amit *et al*. (2014) to study the genetic variability, heritability, genetic advance and correlation for growth and yield contributing characters in chilli under Kashmir conditions. Significant variations were observed for all the characters studied except for days to flowering and crop duration [mature (green) as well as dry (red)]. High Phenotypic Coefficient Variation (PCV) and Genotypic Coefficient Variation (GCV) were recorded for number of fruits plant^{-1}, fruit weight and dry yield. All the characters showed high heritability however, number of the fruits plant^{-1}, green fruit yield plant^{-1}, dry (red) yield plant^{-1}, number of seeds plant^{-1} and plant height exhibited high genetic advance as percentage of mean indicating additive gene effect.

Genetic variability, heritability, genetic advance and genetic advance as a percent of mean for fifteen characters were assessed by Bijalwan and Madhvi (2013) field evaluation of sixteen chilli genotypes at Vegetable Research Block of Veer Chandra Singh Garhwali Uttarakhand University of Horticulture and Forestry, Ranichauri Campus, Tehri-Garhwal. The phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the characters indicating the influence of environment on these characters. High GCV and PCV, heritability and genetic advance as percentage of mean were noted for fruit weight at edible maturity (61.04% & 61.37%, 99.02% and 125.09%), fruit yield per plant (47.67% & 48.24%, 97.63% and 97.03%) and number of fruits per plant (39.77% & 40.11%, 98.31% and 81.24%). Therefore, selection should be imposed considering these traits for improvement of population in chilli in temperate hills of Uttarakhand.

An experiment was conducted by Chattopadhyay *et al*. (2011) to identify the most promising chilli variety suited for green and dry purposes, to study the genetic variability for different traits and to assess the association of different yield attributing traits of thirty four genotypes. Most of the genotypes possessed the character constellation of *C. annuum*. Two genotypes, ‘Chaitali Pointed’ and ‘BC CH Sel-4’ were found most promising with respect to green fruit yield (272.79 g, 221.10 g per plant) and dry fruit yield (54.56 g, 44.44 g per plant). Phenotypic and Genotypic Coefficient of Variation values for green fruit weight (119.95%, 111.26%), green fruit girth (89.76%, 48.93%), weight of red ripe fruit (112.02%, 111.93%), weight of dry fruit (111.63%, 110.97%) and number of fruits per plant (86.05%, 85.02%) were recorded to be high. Green fruit yield per plant, ascorbic acid content, and number of fruits per plant also showed very high broad-sense heritability and genetic advance.

Field experiments were conducted Joyothi *et al*. (2011) at Regional Agricultural Research Station, Lam, Guntur, Andhra Pradesh, with ten chilli genotypes to study genetic variability, heritability and genetic advance as per cent mean for several economic characters. Phenotypic Coefficient of Variation (PCV) was slightly higher than Genotypic Coefficient of Variation (GCV) for all the traits, indicating a low environmental influence on expression of these traits. High GCV and PCV were observed for ripe-chilli yield, dry-chilli yield, number of fruits per plant, number of seeds per fruit and fruit length indicating a higher magnitude of variability in these traits and, consequently, a greater scope for improvement through simple selection. Low GCV and PCV were recorded for plant height, plant spread and fruit girth suggesting a limited variability, for these traits. High heritability, coupled with high Genetic Advance as per cent mean, was observed for ripe-chilli yield, dry chilli yield, number of fruits per plant, number of seeds per fruit and fruit length, indicating the influence of additive genes. These characters-with high GCV, PCV, Heritability and Genetic Advance as per cent mean-should be considered as reliable selection criteria for crop improvement for yield and yield attributing characters in chilli.

Forty nine genotypes of chilli were evaluated by Sarkar *et al*. (2009) to study the genetic variability as well as association for 12 growth and fruit characters. There was significant variation among the genotypes. Fruit yield (g)/plant, number of fruits/plant, fruit length (cm), placenta length (cm), fruit weight (g), number of seeds/fruit and plant height (cm) showed high values of GCV and PCV. High heritability in broad sense coupled with high GA in % grand mean was recorded for fruit yield/plant, number of fruits/plant, fruit length, days to 50% flowering and plant height indicating such characters were controlled by additive gene action The phenotypic path-coefficient analysis revealed that number of fruits/plant, fruit weight and 1000 seed weight had positive and high direct effect on fruit yield indicating their reliability as selection criteria to improve yield of chilli.

Estimates of genetic variability were analyzed by Shirshat *et al*. (2007) in seventy-two germplasm lines and three commercial cultivars. The phenotypic coefficient of variation was higher than genotypic coefficient of variation for all characters indicating the influence of environment on these characters. Fruit attributes viz., fruit length, fruit surface area, weight of dry fruit, pericarp weight of fruit, number of seeds per fruit, weight of seeds per fruit and stalk length showed very narrow differences between phenotypic and genotypic coefficient of variation, indicating lesser sensitivity to environmental influence. Heritability estimates in respect of fruit length, fruit surface area, number of seeds per fruit, weight of seeds per fruit, weight of dry fruit, pericarp weight of fruit, ascorbic acid content and sugar content were high ranging from 74.00 per cent to 99.40 per cent. Moderate genetic advance was observed for the characters like number of fruits per plant, number of seeds per fruit and sugar content of the fruit. Heritability was high in these characters except for number of fruits per plant. In case of attributes like fruit length, fruit surface area, weight of dry fruit, pericarp weight of fruit, number of seeds per fruit and weight of seeds per fruit, the genetic advance was low to moderate coupled with high heritability. Yield per plant, the complex trait, which is dependent on several component characters showed moderate heritability with low genetic advance.

Genetic variability, heritability, genetic advance and genetic advance as a percent over mean for twelve characters were assessed by Krishna *et al*. (2007) field evaluation of eighty chilli accessions at Kittur Rani Channamma of Horticulture, Arabhavi. The difference between phenotypic coefficient of variation and genotypic coefficient of variation were found to be narrow for most of the traits except primary and secondary branches, tertiary branches, fifty per cent flowering, early and late fruit yield per plant. The high estimates of heritabilty was found for plant height (93.40%), days to first flowering (83.50%), number of fruits per plant (81.10%), fruit length (92.40%), ten fruit weight (92.40%) and total green fruits per plant (88.40%).

Bendale *et al*. (2006) reported that the magnitude of phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV). High heritability (broad sense) was the characteristic observation for all the characters except crop duration. High heritability coupled with high genetic advance was observed for 10 fresh fruit weight, yield plant^{-1}, Number of seeds fruit^{-1} and fruits plant^{-1} indicated the presence of additive gene action for these characters and therefore, these characters can be improved through selection. Low genetic advance was recorded for primary branches plant-1, fruit width, fruit length and dry weight of fruits plant^{-1}.

Thirty-five chilli (*Capsicum annuum* L.) genotypes were evaluated by Sreelathakumary and Rajamony (2004), in a field study 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.

Hosmani and Nandadevi (2003) found that the high degree of phenotypic and genotypic coefficients of variation for number of primary branches, fruit length, pericarp thickness, number of fruits per plant; fruit yield per plant and also estimate the high heritability coupled with high genetic advance as a percentage of mean with respect to fruit length and green fruit yield per plant in chilli.

Mishra *et al*. (2001) evaluated the nine genotypes of chilli for fruit characters. The phenotypic coefficient of variation (PCV) had slightly higher values compared to the genotypic coefficient of variation (GCV) indicating the negligible effect of the environment on the fruit characters. The highest PCV and GCV were observed for fruits per plant, followed by fruit length, dry weight of single fruit and red chilli yield per plant.

2.3 Relationship between yield and yield attributes of chilli

Fifty germplasm were used by Kumar *et al.* (2017) to study the genetic variability, heritability, genetic advance and correlation for growth and yield contributing characters in fennel. Experiment laid out at National Research Centre on Seed Spices, Ajmer for yield and its yield attributing characters. Number of primary branches (0.75***), number of secondary branches (0.63***), umbel per plant (0.87***), umbellate per umbel (0.63***), seeds per umbellate (0.70***) and test weight (0.52***) exhibited positive and significant correlated with the seed yield.

Twenty three genotypes were used by Amit *et al*. (2014) to study the genetic variability, heritability, genetic advance and correlation for growth and yield contributing characters in chilli under Kashmir conditions. It was revealed that fruit yield (green and red) plant^{-1} was positively and significantly correlated with number of fruits plant^{-1} and fruit length. It revealed that the characters viz., plant height, fruit length, number of fruits plant^{-1}, fruit weight and fruit yield (green & red) are the most important traits for genetic improvement of chilli.

Two experiments were carried out by Usman *et al*. (2014) to study the genetic variability among chili pepper for heat tolerance and morphophysiological traits and to estimate heritability and genetic advance expected from selection. Yield per plant showed strong to moderately positive correlations (r = 0.23-0.56) at phenotypic level while at genotypic level correlation coefficient ranged from 0.16 to 0.72 for CMT, plant height, fruit length, and number of fruits.

The present experiment was conducted by Chattopadhyay *et al*. (2011) to identify the most promising chilli variety suited for green and dry purposes, to study the genetic variability for different traits and to assess the association of different yield attributing traits with the green and dry yield of chilli of thirty four genotypes. From the study of correlation analyses, the number of fruits per plant, green fruit length for green chilli, weight of dry fruit and the number of fruits per plant for dry chilli were found to the most important selection indices.

Wilson and Philip (2009) observed the higher genotypic correlation coefficient the phenotypic correlation coefficient. Yield plant^{-1} exhibited significant positive association with fruits plant^{-1}, fruit length, fruit weight, 100-seed weight, plant height and negative correlated with 50% flowering.

Pandit *et al*. (2009) recorded significant positive correlation of fruit yield plant^{-1} with fruit length, fruit pedicel length, number of fruits plant^{-1}, fruit weight and 1000-seed weight. Fruit weight was significantly positively correlated with number of seeds fruit^{-1} and 100-seed weight. Fruit yield plant^{-1} was positively correlated with number of fruits plant^{-1} and fruit length.

Acharya *et al*. (2007) observed that total fresh yield was positively and significantly correlated with fresh fruit weight and number of fruits plant^{-1} at both genotypic and phenotypic levels. Fruit yield was positively associated with number of branches plant^{-1} and number of fruits plant^{-1}. Number of branches plant^{-1} is also positively correlated with fruit width, number of fruits plant^{-1}, capsaicin content and fruit yield.

Abu and Uguru (2006) found a significant positive correlation for fresh fruit weight with number of branches plant^{-1}, number of nodes plant^{-1} and umber of fruits plant^{-1}. However, fruit yield plant^{-1} observed significant positive correlation with average fruit weight and fruit width.

Ajjapplavara *et al*. (2005) observed that positive correlation between dry fruit yield plant^{-1} with all other characters except number of primary and secondary branches, fruit diameter, fruits volume, powdery mildew disease incidence and leaf curl complex incidence.

Dipendra and Gautam (2003) found that, the fresh fruit yield plant^{-1} exhibited positive correlation with dry yield, fruits plant^{-1}, flowers plant^{-1}, fresh fruit weight, leaves plant^{-1}, fruiting percentage, dry fruit weight, 1000-seed weight, plant height, plant spread, specific leaf weight, fruit length, seeds fruit^{-1} and number of primary branches.

Rathod *et al*. (2002) recorded that genotypic correlation coefficient was higher than the phenotypic correlation coefficient for all the characters studied. The yield of chilli was positively and significantly associated with the number of fruits plant^{-1}, 100 seed weight, seed percentage and harvest index.

Ibrahim *et al*. (2001) revealed the results on simple correlation coefficient revealed that dry fruit yield exhibited positive correlation with all the characters. Number of fruits plant^{-1} showed high positive correlation with number of branches and plant height; on the contrary, it had significant negative correlations with fruit length.

Munshi *et al*. (2000) observed that the yield plant^{-1} was significantly and positively correlated with number of fruits plant^{-1} and fruit weight. Negative association of days to first fruit harvest with number of fruits and yield plant^{-1} revealed selection aimed to improve yield and yield associated characters. Fruit weight showed significant negative correlation with fruit length.

Benchaim and Paran (2000) found that, the highest genotypic correlation coefficient among pairs of traits were found between fruit weight and each of the 3 width characters: fruit diameter, pericarp thickness and pedicel diameter in contrast fruit weight had a low correlation coefficient with fruit length, indicating that the size of the pepper fruit in this cross was determined primarily by its width.

Warade *et al*. (1997) recorded that, the yield plant^{-1} was positively correlated with plant height, plant spread, fruit weight, seeds plant^{-1}, days to 50% fruit set, fruit length and fruit girth, and negatively correlation with days to 50% flowering and maturity. However, fruit yield exhibited positive significant correlation with weight of fruits, fruits plant^{-1} and primary branches plant^{-1}. Fruit diameter showed negative association with fruit length.

2.4 Path coefficients on yield and yield attributes of chilli

The present experiment was conducted by Chattopadhyay *et al*. (2011) to identify the most promising chilli variety suited for green and dry purposes, to study the genetic variability for different traits and to assess the association of different yield attributing traits with the green and dry yield of chilli of thirty four genotypes. From the study of path coefficient analyses, the number of fruits per plant, green fruit length for green chilli, weight of dry fruit and the number of fruits per plant for dry chilli were found to the most important selection indices.

Datta and Jana (2010) path analysis indicated that among the different characters higher direct effect was noticed in individual fruit weight, number of fruits per plant, primary and secondary branches per plant and fruit diameter. So, number of fruits, individual fruit weight, fruit diameter, primary and secondary branches per plant should be given more importance during selection for higher yield in green chilli.

Sarkar *et al*. (2009) reported that number of fruits/plant, fruit weight and 1000 seed weight had positive and high direct effect on fruit yield indicating their reliability as selection criteria to improve yield of chilli.

Vani *et al*. (2007) high positive direct effect of yield attributing characters such as fruit length, stalk weight and fruit weight resulted in significant correlation with yield. Number of fruits per plant and average fruit weight also contributed indirectly through all characters, which made the correlation significant.

Abdullah *et al.* (2006) revealed that the number of fruits per plant, fruit weight and fruit length, fruit girth is the important components of fruit yield on the basis of the estimates of path analysis.

Raika (2005) path analysis revealed that fresh weight and fruits plant^{-1} are the most important and reliable yield indicators in chilli. Similarly, Dipendra and Gautum (2003) reported that number of fruits plant^{-1} exerted highest positive direct effect on yield, followed by fruit length and fruit width. Number of fruits per plant and average fruit weight also contributed indirectly through all characters, which made the correlation significant.

Sreelathakumar and Rajamony (2004) revealed that fruits plant^{-1}, fruit weight and fruit girth had positive direct effects on yield, fruit length had a negative direct effect on yield, but its indirect effect through fruits plant^{-1}, fruit girth and fruit weight was high and positive. One hundred seed weight recorded the highest positive direct effects on the wet red chilli yield plant^{-1} followed by seed percentage, days to 50% flowering and number of primary branches plant^{-1}, Fruits plant^{-1}, fruit weight and fruit girth had positive direct effects on yield. Fruit length had a negative direct effect on yield, but its indirect effect through fruits plant^{-1}, fruits girth and fruit weight was high and positive.

Singh and Singh (2004) observed from their earlier study that the yield and yield components as the number of fruits plant^{-1}, fruit weight and fruit length, fruit girth had direct positive effect on yield plant^{-1}.

Bhalekar *et al*. (2002) reported that pollen viability showed significant maximum positive direct effect on yield followed by fruit set and number of primary branches. Positive direct effect of number of primary branches together with pollen viability and fruit set was mainly responsible for the number of primary branches and yield. These results indicate that the number of primary branches is an important trait to be taken into consideration while breeding chilli varieties for high yield.

Devi and Arumugam (1999) observed the number of fruits plant^{-1} had the most positive effect on dry fruit yield plant^{-1}. Plant height exhibited a negative direct effect, but influenced yield indirectly through number of fruits plant^{-1}, fruit shape index, number of secondary branches, capsaicin content and number of seeds fruit^{-1}.

2.5 Genetic divergence among chilli genotypes

Thirteen genotypes of chili were investigated by Rakib Hasan *et al*. (2015) to understand the extent of genetic diversity through 6 yield attributing characters. Genetic diversity in chilli genotypes based on six characters was estimated using Mahalanobis's D^2 statistics. The genotypes were grouped into five different clusters by non-hierachical clustering. The cluster I had the maximum number (5) of genotypes, while cluster IV and V each contained only one genotype. The higher inter-cluster distance was observed between cluster I and IV (24.48) and the lowest inter-cluster distance was observed between the clusters II and V (11.63). The results indicated that fruits/plant (35.8%) contributed the maximum to the total divergence followed by fruit length (21.6%) and yield/plant (21.1%). Cluster IV produced the highest mean for fruit weight (4.48) and fruits/plan (149.90) and yield/plant (676.03). Cluster V produced the highest mean for fruit length (10.23), pedicel length (4.94) and fruit diameter (10.36). Cluster I and III produced maximum the lowest mean for almost all characters. Therefore, genotypes belonging to the cluster IV and V may be used as potential parents for future hybridization program to develop superior chill variety with desired traits.

A study on genetic diversity was conducted by Hasan *et al*. (2014) with 54 Chili (*Capsicum annuum* L.) genotypes through Mohalanobis's D^2 and principal component analysis for twelve quantitative characters. Cluster analysis was used for grouping of 54 chili genotypes and the genotypes were fallen into seven clusters. Cluster II had the maximum (13) and cluster III had the minimum number (1) of genotypes. The highest inter-cluster distance was observed between cluster I and III and the lowest between cluster II and VII. The characters yield/plant, canopy breadth, secondary branches/plant, plant height and seeds/fruit contributed most for divergence in the studied genotypes. Considering group distance, mean performance and variability the inter genotypic crosses between cluster I and cluster III, cluster III and cluster VI, cluster II and cluster III and cluster III and cluster VII may be suggested to use for future hybridization program.

Study on genetic diversity was conducted by Yatung *et al*. (2014) with 30 chilli (*Capsicum annuum* L.) genotypes of Indian origin at the research farm of Vegetable Science, College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh, India. Twelve quantitative characters *viz.* plant height (cm), number of primary branch per plant, days to first flowering, fruit length (cm), fruit diameter (cm), number of fruit per plant, average fruit weight (g), green fruit yield per plant (g), number of seed per fruit, ascorbic acid (mg/100 g), capsaicin content (%) and chlorophyll content (mg/g) were taken into consideration. Cluster analysis was used for grouping of 30 chilli genotypes under the study grouped into six clusters. Cluster III had the maximum (14) and cluster IV and V had the minimum number (1) of genotypes. The highest (459.81) inter cluster distance was observed between cluster II and IV and the lowest (36.04) between cluster I and IV. Cluster III (D^2= 67.66) have exhibited highest intra cluster distance and the lowest was observed in cluster II (D^2=11.19). The characters capsaicin content and ascorbic acid contributed the maximum towards divergence. Considering diversity pattern and other horticultural performance the genotypes CHFC-7 from cluster VI, genotype CHFC-27 from cluster II and CHFC-15 from cluster III may be taken into consideration as better parents for an efficient hybridization program of chilli.

A Study on genetic diversity was conducted by Srinivas *et al*. (2013) with 78 chilli genotypes which were collected from different parts of Kerala. Fifteen quantitative characters and one qualitative character were taken into consideration. Mahalanobis D^2 statistics was employed to study genetic divergence among 78 genotypes and they were grouped into nine clusters on the basis of relative magnitude of D^2 values using Euclidean2 method. Cluster II accommodated the maximum number (24) of genotypes and the minimum with cluster III (1 genotype).The inter cluster distances (D values) ranged between 3.90 to12.68. The minimum inter cluster distance was between cluster II and IV (3.90) and the maximum inter cluster distance was observed between cluster VII and VIII (12.68). The intra cluster divergence varied from 3.32 to 5.45. The maximum intra cluster distance was achieved in cluster VIII (5.45) and the minimum divergence was observed in cluster V (3.32). Cluster III was showed zero intra cluster distance as it contains only one genotype.The maximum relative contribution to the total divergence was made by fruit yield per plant (61.07 %) and cluster VIII and cluster IX may be taken into consideration as better parents for an efficient hybridization program of chilli.

Two experiments were carried out by Usman *et al*. (2014) to study the genetic variability among chili pepper for heat tolerance and morphophysiological traits and to estimate heritability and genetic advance expected from selection. Cluster analysis revealed eight groups and Group VIII recorded the highest CMT and yield. Group IV recorded 13 genotypes while Groups II, VII, and VIII recorded one each. The results showed that the availability of genetic variance could be useful for exploitation through selection for further breeding purposes.

Singh and Singh (2004) reported that fruits/plant (36.4%) contributed the maximum to the total divergence followed by fruit length (23.22%) and yield/plant (20.5%) and cluster IV produced the highest mean for fruit weight (4.96) and fruits/plan (232.15) and yield/plant (453.33).

It may be understood from the above reviews that different yield attributes significantly influences the growth, development and yield of chilli and genetic variability, correlations and association between qualitative and quantitative characters and heritability was existed due to different genotypes. On the other hand, genotypes itself as an important factor for economical chilli production and different traits played a major role in the improvement of yield of chilli.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to study the genetic diversity analysis of chilli. The details of the materials and methods i.e. location of experimental site, soil and climate condition of the experimental plot, materials used, design of the experiment, data collection procedure and procedure of data analysis that used or followed in this experiment has been presented below under the following headings:

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from November 2015 to April 2016 in *rabi* season.

3.1.2 Site description

The present research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude with an elevation of 8.2 meter from sea level. Experimental location presented in Appendix I.

3.1.3 Characteristics of soil

The soil belonged to “The Modhupur Tract”, AEZ-28 (FAO, 1988). Top soil was silty-clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 6.1 and had organic matter 1.13%. The experimental area was flat having available irrigation and drainage system and above flood level. The details have been presented in Appendix II.

3.1.4 Climatic condition

The climate of the study area is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix I. During the study period the maximum temperature (33.4^{0}C) was recorded from April, 2016 and the minimum temperature (12.4^{0}C) in the month of January, 2016. Highest relative humidity (78%) in the month of November, 2015 and the highest rainfall (78 mm) was recorded in the month of April 2016 and the highest sunshine hour (6.9) was recorded in the month of April, 2016.

3.2 Experimental details

3.2.1 Planting materials

In this experiment 15 chilli genotypes presented below were used as experimental materials which were produced in the 2014-15 cropping season, and the purity and germination percentage were leveled as 98% and 95%, respectively. These genotypes were collected from Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka and Plant Genetic Resources Centre (PGRC) of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

Name of chilli genotypes used in the present study

Genotypes	Name of genotypes	Genotypes	Name of genotypes
G_1	Ca 001	G_9	SRCO 1
G_2	Ca 002	G_{10}	SRCO 2
G_3	Special chilli of Bogra	G_{11}	SRCO 9
G_4	Surjamukhi IMP	G_{12}	SRC 13
G_5	Black Lady	G_{13}	CO 613
G_6	Local 1	G_{14}	SRCO 5
G_7	HP 1029	G_{15}	Hot Morich of Bogra
G_8	CO 610		

3.2.2 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 371.3 m^2 with length 39.5 m and width 9.4 m. The total area was divided into three equal blocks. Each block was divided into 15 plots where 15 chilli genotypes were allotted at random. There were 45 unit plots altogether in the experiment. The size of the each plot was 2.0 m × 1.8 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively.

3.3 Growing of crops

3.3.1 Raising of seedlings

Chilli seedlings were raised in small tray as seed bed of 250 cm × 80 cm size. The soil was well prepared and converted into loose friable and dried for seedbed. All weeds and stubbles were removed and well rotten cowdung was mixed with the soil. Seeds were soaked in separate plastic bags for two days then sown on 7th November 2015 in individual seed bed. After sowing, seeds were covered with light soil. Heptachlor 40 WP was applied @ 4 kg ha^{-1}, around each seedbed as precautionary measure against ants and worm. The emergence of the seedlings took place with 5 to 6 days after sowing. For healthy and uniform seedlings seed beds were watering when necessary and cleaned by removing weeds when emerged.

3.3.2 Land preparation

The plot selected of the study was opened in the 1st week of December 2015 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain until good tilth. Weeds and stubbles were removed, and finally obtained a desirable tilth of soil was obtained for transplanting chilli seedlings. The study plot was partitioned into unit blocks and blocks into unit plots in accordance with the mentioned design. Cowdung and chemical fertilizers as indicated below in 3.3.3 were mixed with the soil of each unit plot.

3.3.3 Application of manure and fertilizers

Well decomposed cowdung (10 t/ha) was applied at the time of final land preparation. The sources of fertilizers used for N, P, K, S and Zn were urea (210 kg/ha), TSP (300 kg/ha), MoP (200 kg/ha), Gypsum (110 kg/ha) and Znic sulphate (15 kg/ha), respectively (Rashid, 1993). The entire amounts of TSP, MoP were applied during final land preparation. Only urea was applied in two equal installments at 30 and 60 Days after transplanting (DAT).

3.3.4 Transplanting of seedlings

Healthy and uniform size of chilli seedlings were uprooted separately from the seed bed and were transplanted in the study plots in the afternoon of 10th December, 2016 with maintaining 60 cm distance from row to row and 40 cm from plant to plant. This allowed an accommodation of 15 plants in each plot. The seed bed was watered before uprooting the seedlings from the seed bed so as to minimize damage to the roots. Seedlings were also planted around the border area of the study plots for gap filling.

3.3.5 Intercultural operations

After transplanting of seedlings, various intercultural operations such as irrigation (as per treatment), weeding and top dressing etc. were accomplished for better growth and development of the chilli seedlings.

3.3.5.1 Irrigation and drainage

Over-head irrigation was provided with a watering can to the plots as per necessary. Excess water from the plot was effectively drained out at the time of heavy rain.

3.3.5.2 Weeding

Weeding was done to keep the plots clean and easy aeration of soil which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully as per necessary.

3.3.5.3 Top dressing

Urea was used as top-dressed as mentioned in 3.3.3. The urea fertilizer were applied on both sides of plant rows and mixed well with the soil. Earthing up operation was done immediately after top-dressing with fertilizer.

3.4 Crop sampling

Five plants from each treatment were randomly selected and marked with sample card and data were recorded as per the objectives of the experiment.

3.5 Data collection

The following data were recorded at different stages:

3.5.1 Days to 1st flowering

Days required for sowing to 1st initiation of flower was counted from the date of sowing to the initiation of flowering and was recorded. Data were recorded as the average of 5 plants selected from the inner rows of each plot.

3.5.2 Plant height

Plant height was measured from the ground level to the tip of the longest stem and mean value was calculated. Plant height was recorded during 1st flowering as the average of 3 plants to observe the growth rate of plants.

3.5.3 Number of branches per plant

The total number of branches per plant was counted from plant of each unit plot. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.5.4 Number of fruits per plant

The number of fruits per plant was counted from plant of each unit plot and the number of fruits per plant was recorded. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.5.5 Individual fruit weight

The weight of individual fruit was recorded in gram (gm) by an electronic balance from 10 fruits of selected 5 plants and converted individually.

3.5.6 Fruit length

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).

3.5.7 Fruit diameter

The diameter of individual fruit was measured in several directions with a slide calipers and the average of all directions was finally recorded and expressed in millimeter (mm).

3.5.8 Number of seeds per fruit

Numbers of total seeds of 10 selected chilli from the 5 selected plants of each plot were counted and the mean numbers were expressed as per fruit basis.

3.5.9 Weight of 1000 seeds

One hundred cleaned, dried seeds were counted randomly from each harvest sample and weighed by using a digital electric balance and weight was expressed in weight of 1000 seeds in gram (g).

3.5.10 Yield per plant

The fruits collected from 5 selected plant of each unit plot were sun dried properly. The weight of seeds was taken and recorded in per plant basis.

3.6 Statistical analysis

The data obtained for different characters were statistically analyzed by using MSTAT-C computer package program. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations of means was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

3.7 Estimation of variability

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

3.7.1 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 –

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

Where,

σ^2_{ph} = phenotypic variance

σ^2_g = genotypic variance

σ^2_e = error variance

3.7.2 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

3.7.3 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

3.7.4 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

3.7.5 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):

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

3.8 Estimation of correlation

Simple correlation was estimated of the 14 traits with the following formula (Singh and Chaudhary, 1985):

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

Where,

$\sum$ = Summation

x and y are the two variables

N = Number of observations

3.9 Path co-efficient analysis

Path co-efficient analysis was done according to the procedure employed by Dewey and Lu (1959) also quoted in Singh and Chaudhary (1985) using simple correlation values. In path analysis, correlation co-efficient is partitioned into direct and indirect of independent variables on the dependent variable.

In order to estimate direct and indirect effect of the correlated characters, say x_1, x_2, x_3 yield y, a set of simultaneous equations (three equations in this example) is required to be formulated as given below:

$$ryx_1 = Pyx_1 + Pyx_2rx_1x_2 + Pyx_3rx_1x_3$$

$$ryx_2 = Pyx_1rx_1x_2 + Pyx_2 + Pyx_3rx_2x_3$$

$$ryx_3 = Pyx_1rx_1x_3 + Pyx_2\, rx_2x_3 + Pyx_3$$

Where, r's denotes simple correlation co-efficient and P's denote path co-efficient (unknown). P's in the above equations may be conveniently solved by arranging them in matrix form. Total correlation, say between x_1 and y is thus partitioned as follows:

Pyx_1 = The direct effect of x_1 on y

$Pyx_1rx_1x_2$ = The indirect effect of x_1 via x_2 on y

$Pyx_1rx_1x_3$ = The indirect effect of x_1 via x_3 on y

After calculating the direct and indirect effect of the characters, residual effect (R) was calculated by using the formula given below (Singh and Chaudhary, 1985):

$$P^2RY = 1 - \sum Piy.riy$$

Where,

$P^2RY = (R^2)$; and hence residual effect, $R = (P^2RY)^{1/2}$

Piy = Direct effect of the character on yield

riy = Correlation of the character with yield

3.10 Multivariate analysis

The genetic diversity among the genotypes was assessed using Mahalanobis's (1936) general distance (D^2) statistic and its auxiliary analyses. The parents selection in hybridization program based on Mahalanobis's D^2 statistic is more reliable as requisite knowledge of parents in respect of a mass of characteristics is available prior to crossing. Rao (1952) suggested that the quantification of genetic diversity through biometrical procedures had made it possible to choose genetically diverse parents for a hybridization program. Multivariate analysis viz. principal component analysis (PCA), principal coordinate analysis (PCA), cluster analysis and canonical variate analysis (CVA), which quantify the differences among several quantitative traits, are efficient method of evaluating genetic diversity. These are as follows:

3.10.1 Principal component analysis (PCA)

Principal component analysis, one of the multivariate techniques, is used to examine the inter-relationships among several characters and can be done from the sum of squares and products matrix for the characters. Thus, PCA finds linear combinations of a set variate that maximize the variation contained within them, thereby displaying most of the original variability in a smaller number of dimensions. Therefore, principles components were computed from the correlation matrix and genotypes scores obtained for first components (which has the property of accounting for maximum variance) and succeeding components with latent roots greater than unity. Contribution of the different morphological characters towards divergence is discussed from the latent vectors of the first two principal components.

3.10.2 Principal coordinate analysis (PCO)

Principal coordinate analysis is equivalent to PCA but it is used to calculate inter unit distances. Through the use of all dimension of p it gives the minimum distance between each pair of the n points using similarity matrix (Digby *et al.*, 1989).

3.10.3 Cluster analysis (CA)

Cluster analysis divides the genotypes of a data set into some number of mutually exclusive groups. Clustering was done using non-hierarchical classification. In Genstat, the algorithm is used to search for optimal values of chosen criterion proceeds as follows. Starting from some initial classification of the genotypes into required number of groups, the algorithm repeatedly transferred genotypes from one group to another so long as such transfer improved the value of the criterion. When no further transfer can be found to improve the criterion, the algorithm switches to a second stage which examines the effect of swooping two genotypes of different classes and so on.

3.10.4 Canonical variate analysis (CVA)

Canonical variate analysis (CVA) finds linear combination of original variabilities that maximize the ratio of between group to within group variation, thereby giving functions of the original variables that can be used to discriminate between the groups. Thus, in this analysis a series of orthogonal transformations sequentially maximizing of the ratio of among groups to the within group variations. The canonical vector are based upon the roots and vectors of WB, where W is the pooled within groups covariance matrix and B is the among groups covariance matrix.

3.10.5 Calculation of D^2 values

The Mahalanobis's distance (D^2) values were calculated from transformed uncorrelated means of characters according to Rao (1952), and Singh and Chaudhury (1985). The D^2 values were estimated for all possible combinations between genotypes. In simpler form D^2 statistic is defined by the formula

$$D^2 = \sum_{i}^{x} d_i^2 = \sum_{i}^{x} (Y_i^j - Y_j^k) \qquad (j \neq k)$$

Where,

Y = Uncorrelated variable (character) which varies from i = 1 --to x

x = Number of characters.

Superscript j and k to Y = A pair of any two genotypes.

3.10.6 Computation of average intra-cluster distances

Average intra-cluster distances were calculated by the following formula as suggested by Singh and Chuadhury (1985).

Average intra-cluster distance= $\dfrac{\sum D_i^2}{n}$

Where,

D_i^2 = the sum of distances between all possible combinations (n) of genotypes included in a cluster.

n = Number of all possible combinations between the populations in cluster.

3.10.7 Computation of average inter-cluster distances

Average inter-cluster distances were calculated by the following formula as suggested by Singh and Chuadhury (1985).

Average inter-cluster distance= $\dfrac{\sum D_{ij}^2}{n_i \times n_j}$

Where,

$\sum D_{ij}^2$ = The sum of distances between all possible combinations of the populations in cluster i and j.

n_i = Number of populations in cluster i. and n_j = Number of populations in cluster j.

3.10.8 Cluster diagram

Using the values of intra and inter-cluster distances (D $=\sqrt{D^2}$), a cluster diagram was drawn as suggested by Singh and Chuadhury (1985). It gives a brief idea of the pattern of diversity among the genotypes included in a cluster.

3.10.9 Selection of varieties for future hybridization program

Divergence analysis is usually performed to identify the diverse genotypes for hybridization purposes. The genotypes grouped together are less divergent among themselves than those, which fall into different clusters. Clusters separated by the largest statistical distance (D^2) express the maximum divergence among the genotypes. Variety (s) or line(s) were selected for efficient hybridization program according to Singh and Chuadhury (1985).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the genetic diversity analysis of chilli. Mean performance, variability, correlation matrix, path analysis and genetic diversity analysis on different yield attributes and yields of different chilli genotypes was estimated. The findings of the experiment have been presented under the following headings and sub-headings:

4.1 Evaluation of mean performance of different yield contributing characters and yields of chilli genotypes

Analysis of variance and mean performance was estimated and presented in Table 1 and Table 2. 'F' test revealed highly significant variation among 15 chilli genotypes in terms of all the yield contributing characters and yields of chilli. Significantly high level of variation for different yield contributing characters and yield of chilli for the genotypes revealed the possibilities of improving the genetic yield potential of chilli genotypes.

4.1.1 Days to 1st flowering

Days to 1st flowering showed statistically significant differences for different chilli genotypes (Table 1). The average days to 1st flowering was recorded 46.73 days with a range from 42.67 to 53.67 days (Table 2). The highest days to 1st flowering (53.67) was found in the genotype G_6 (Local 1) which was closely followed by the other chilli genotypes except G_{15} (Hot Morich of Bogra) and the lowest days (42.67) was found from the genotype of G_{15}. Data revealed that different genotypes required different days to the initiation of 1st flowering. Although days to 1st flowering is a genetical characters but the management practices also influences the number of branches per plant but varieties itself also manipulated it. Barche *et al.* (2013) reported that genotype 2011/CHIVAR-8 was found to early which produced flowered in 40.66 DAT, whereas, late flowering 53.66 DAT was noted in the controlled genotype KA-2.

Table 1. Analysis of variance (ANOVA) of the data on yield attributes and yields of different chilli genotypes

Characters	Degrees of freedom (df)			Mean Sum of Squares (MSS)		
	Replication	Genotypes	Error	Replication	Genotypes	Error
Days to 1st flowering	2	14	28	0.800	16.676*	6.990
Plant height (cm)	2	14	28	10.718	154.988**	32.786
Number of branches/plant	2	14	28	0.019	2.179**	0.671
Number of fruits/plant	2	14	28	14.532	314.398**	37.262
Weight of individual fruit (g)	2	14	28	0.017	2.365**	0.098
Length of fruit (cm)	2	14	28	0.006	9.376**	0.124
Diameter of fruit (mm)	2	14	28	0.013	3.921**	0.309
Number of seeds/fruit	2	14	28	35.558	136.799**	35.939
Weight of 1000 seeds (g)	2	14	28	3.021	59.028*	25.445
Yield/plant (g)	2	14	28	305.738	12037.511**	1428.603

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

Table 2. Mean performance of yield attributes and yields of different chilli genotypes

Germplasms		Days to 1st flowering	Number of branches/ plant	Number of fruits/plant	Length of fruit (cm)	Diameter of fruit (mm)	Number of seeds/fruit	Weight of 1000 seeds (g)	Yield/ plant (g)
G_1		46.33 bc	8.33 ab	75.60 b	6.57 e	7.75 b-d	68.53 ab	64.65 b	329.63 b-d
G_2		44.67 bc	8.67 ab	72.80 bc	8.10 ab	5.84 fg	71.20 ab	68.47 b	375.66 a-c
G_3		46.67 bc	7.87 a-c	88.73 a	7.79 bc	6.64 ef	67.60 ab	64.72 b	427.44 a
G_4		45.67 bc	9.07 a	80.67 ab	6.82 de	7.56 c-e	67.00 ab	67.28 b	392.49 ab
G_5		48.33 b	6.60 c	63.87 c-f	6.53 e	7.52 c-e	44.40 c	64.95 b	310.58 c-f
G_6		53.67 a	8.33 ab	59.73 d-f	8.51 a	8.59 b	60.67 b	68.93 b	424.83 a
G_7		45.67 bc	8.47 ab	69.13 b-e	5.27 fg	8.50 bc	69.27 ab	67.05 b	305.12 c-f
G_8		46.33 bc	8.40 ab	70.00 b-d	4.80 g	5.70 fg	66.40 ab	71.78 b	273.70 d-f
G_9		46.33 bc	6.47 c	57.93 ef	5.75 f	7.54 c-e	63.00 ab	81.07 a	388.34 ab
G_{10}		46.00 bc	7.07 bc	77.00 b	7.58 bc	6.36 fg	69.00 ab	62.44 b	329.00 b-d
G_{11}		47.33 bc	7.33 bc	79.47 ab	7.47 bc	6.37 fg	68.73 ab	71.58 b	412.53 a
G_{12}		48.33 b	7.67 a-c	54.40 f	1.53 h	9.53 a	67.53 ab	67.43 b	252.23 ef
G_{13}		46.33 bc	8.33 ab	62.20 c-f	5.07 g	5.56 g	66.13 ab	65.78 b	315.62 c-e
G_{14}		46.67 bc	7.67 a-c	55.27 f	7.38 cd	7.47 c-e	62.33 ab	66.00 b	242.89 f
G_{15}		42.67 c	6.33 c	63.73 c-f	7.44 c	7.39 de	73.47 a	66.07 b	266.06 d-f
Mean		46.73	7.77	68.70	6.44	7.22	65.68	67.88	336.41
Range	Lowest	42.67	6.33	54.40	1.53	5.56	44.40	62.44	242.89
	Highest	53.67	9.07	88.73	8.51	9.53	73.47	81.07	427.44
Significance level		0.05	0.01	0.01	0.01	0.01	0.01	0.05	0.01
CV(%)		5.66	10.54	8.89	5.47	7.70	9.13	7.43	11.24

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

4.1.2 Plant height

Statistically significant variation was recorded in terms of plant height due to different chilli genotypes (Table 1). Data revealed that the average plant height was observed 73.10 cm with a range from 64.36 to 84.57 cm (Figure 1). The longest plant (84.57 cm) was found in the genotype G_4 (Surjamukhi IMP) which was statistically similar (84.22 cm, 83.22 cm and 82.45 cm) to G_6 (Local 1), G_8 (CO 610) and G_3 (Special chilli of Bogra) and closely followed (73.95 cm and 73.77 cm) by G_7 (HP 1029) and G_2 (Ca 002) and they were statistically similar, while the shortest plant (64.36 cm) was observed from the genotype G_{13} (CO 613). Generally plant height is a gentical character and it is controlled by the genetic make up of the genotypes and different genotypes produced different size of plant. Although plant height of chilli depended upon their differences in input requirements and response, growth process and off course the prevailing environmental conditions during the growing season but genotypes is the key component for producing different size of plant. Kaouther *et al.* (2015) reported that plant height (56.16 to 114.83 cm) and Korba cv demonstrated the best values while Souk Jedid cv had the lowest one among the accessions.

4.1.3 Number of branches/plant

Different chilli genotypes varied significantly for number of branches/plant under the trial (Table 1). The average number of branches/plant was observed in 7.77 with a range from 6.33 to 9.07 (Table 2). The maximum number of branches/plant (9.07) was found in the genotype G_4 (Surjamukhi IMP) which was statistically similar (8.67, 8.47, 8.40 and 8.33) to G_2 (Ca 002), G_7 (HP 1029), G_8 (CO 610), G_1 (Ca 001), G_6 (Local 1) and G_{13} (CO 613), whereas the minimum number of branches/plant (6.33) was recorded from the genotype of G_{15} (Hot Morich of Bogra) which was statistically similar (6.47 and 6.60) to G_9 (SRCO 1) and G_5 (Black Lady). Tembhurne *et al.* (2005) recorded that the maximum number of primary branches (5.73) in HCS G_8, the minimum number (4.33) in HCS G_2 genotypes.

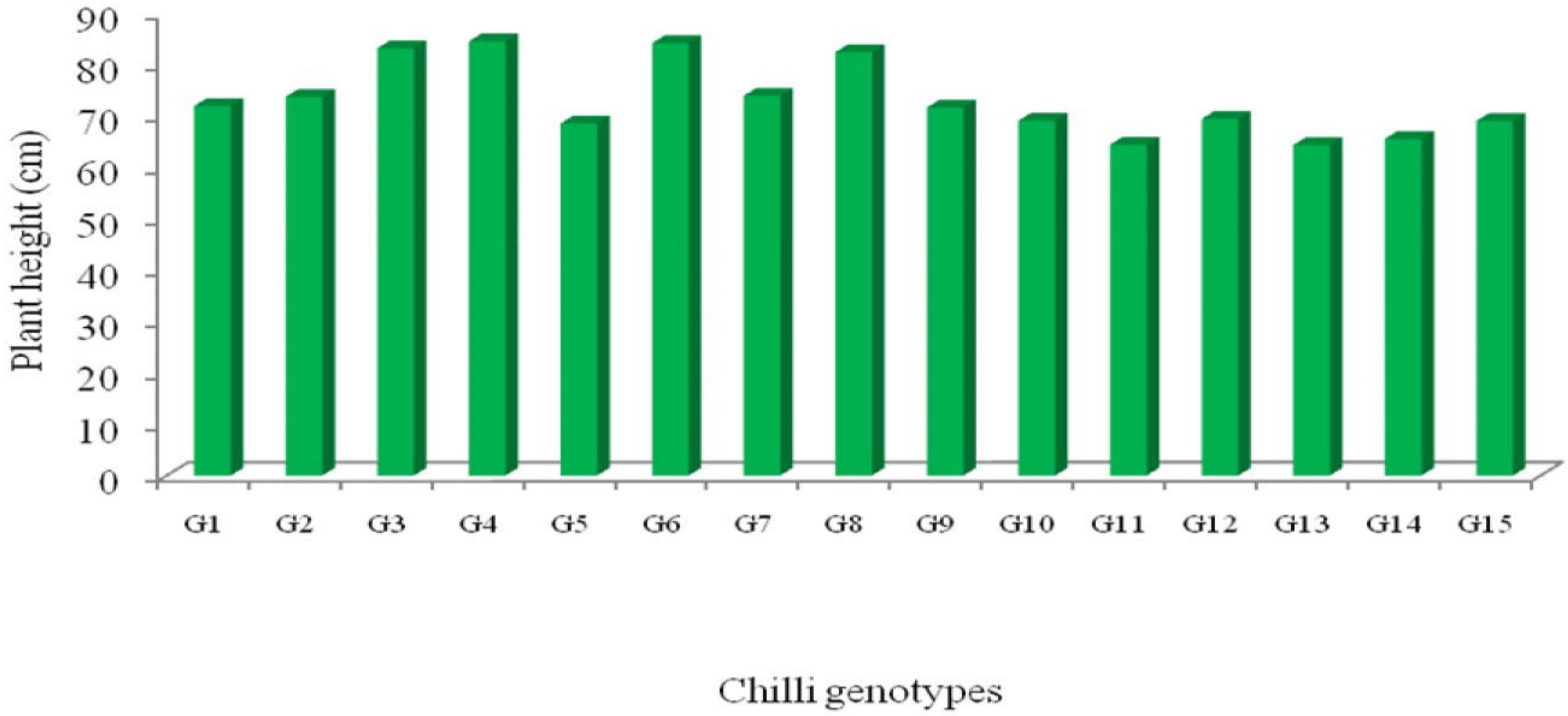

Figure 1. Plant height of chilli for different genotypes

4.1.4 Number of fruits/plant

Number of fruits/plant showed statistically significant variation due to different chilli genotypes under the present trial (Table 1). It was observed from the recorded data that the average number of fruits/plant was observed in 68.70 with a range from 54.40 to 88.73 (Table 2). The maximum number of fruits/plant (88.73) was found in the genotype G_3 (Special chilli of Bogra) which was statistically similar (80.67 and 79.47) to G_4 (Surjamukhi IMP) and G_{11} (SRCO 9) and also closely followed (77.00 and 75.60) by G_{10} (SRCO 2) and G_1 (Ca 001) and they were statistically similar, while the minimum number of fruits/plant (54.40) was recorded from the genotype of G_{12} (SRC 13) which was statistically similar (55.27) to G_{14} (SRCO 5). Farooq *et al.* (2015) observed that Orobella rank first regarding number of fruit/plant (43.47). Jaisankar *et al.* (2015); noted that the maximum number of fruits from V_{11} (33.12/plant) whereas the minimum number from V_1 (11.11/plant).

4.1.5 Weight of individual fruit

Statistically significant variation was recorded in terms of weight of individual fruit due to different chilli genotypes (Table 1). Data revealed that the average weight of individual fruit was found in 4.93 g with a range from 3.91 g to 7.11 g (Figure 2). The highest weight of individual fruit (7.11 g) was observed in the genotype G_6 (Local 1) which was statistically similar (6.70 g) to G_9 (SRCO 1) and closely followed (5.16 g, 5.19 g and 5.07 g) by G_2 (Ca 002), G_{11} (SRCO 9) and G_{13} (CO 613) and they were statistically similar, while the lowest weight of individual fruit (3.91 g) was found from the genotype G_8 (CO 610). Jaisankar *et al.* (2015) noted the maximum single fruit weight in V_1 (4.64 g), whereas minimum from V_{11} (1.32 g). Barche *et al.* (2013) recorded that genotype 2011/CHIVAR-8 produced the highest fruit weight (5.15 g) in green condition but Tairu *et al.* (2013) observed from their earlier experiment that the highest average fruit weight (13.39 g) which was also differ from the findings of the present experiment.

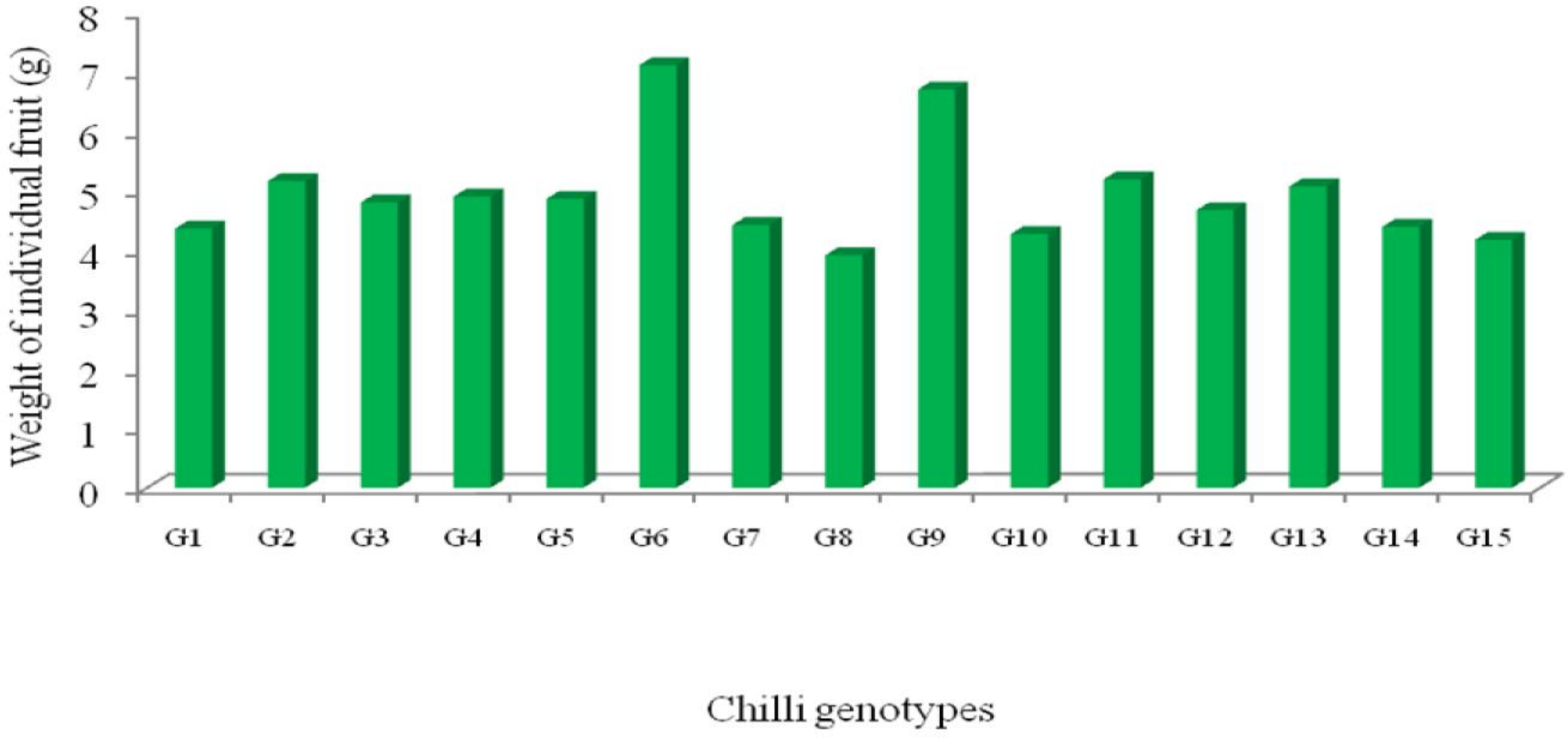

Figure 2. Weight of individual fruit of chilli for different genotypes

4.1.6 Length of fruit

Length of fruit showed statistically significant differences due to different chilli genotypes (Table 1). The average length of fruit was observed in 6.44 cm with a range from 1.53 cm to 8.51 cm (Table 2). The longest fruit (8.51 cm) was recorded in the genotype G_6 (Local 1) which was statistically similar (8.10 cm) to G_2 (CA 002) and also closely followed (7.79 cm, 7.58 cm and 7.47 cm) by G_3 (Special chilli of Bogra), G_{10} (SRCO 2) and G_{11} (SRCO 9) and they were statistically similar, while the shortest fruit (1.53 cm) was recorded from the genotype of G_{12} (SRC 13) which was followed (4.80 cm) by G_8 (CO 610) (Plate 1). Jaisankar *et al.* (2015) recorded the maximum fruit length in V_6 (6.19 cm), while the minimum was recorded in V_{11} (3.93 cm).

4.1.7 Diameter of fruit

Different chilli genotypes varied significantly for diameter of fruits under the present trial (Table 1). The average diameter of fruits was observed in 7.22 mm with a range from 5.56 mm to 9.53 mm (Table 2). The highest diameter of fruit (9.53 mm) was found in the genotype G_{12} (SRC 13) which was closely followed (8.59 mm, 8.50 mm and 7.75 mm) by G_6 (Local 1), G_7 (HP 1029) and G_1 (Ca 001), G_6 (Local 1) and G_{13} (CO 613), whereas the lowest diameter of fruit (5.56 mm) was recorded from the genotype of G_{13} (CO 613) which was statistically similar (5.70 mm, 5.84 mm, 6.36 mm and 6.37 mm) to G_8 (CO 610), G_2 (Ca 002), G_{10} (SRCO 2) and G_{11} (SRCO 9) (Plate 1). Farooq *et al.* (2015) observed that Orobella rank first regarding produced the highest (6.27 mm) value for fruit diameter.

4.1.8 Number of seeds/fruit

Number of seeds/fruits showed statistically significant differences due to different chilli genotypes under the present trial (Table 1). It was revealed from the recorded data that the average number of seeds/fruits was observed in 65.68 with a range from 44.40 to 73.47 (Table 2). The maximum number of seeds/fruit (73.47) was found in the genotype G_{15} (Hot Morich of Bogra) which was

Plate 1. Photograph showing fruits of different chilli genotypes

statistically similar with other genotypes except to G_5 (Black Lady) and G_6 (Local 1), while the minimum number of seeds/fruit (44.40) was recorded from the genotype of G_5 (Black Lady) which was followed (60.67) by G_6 (Local 1). Kaouther *et al.* (2015) notated that Tebourba produced the higher number of seeds (126.8) while Souk Jedid produced the lowest number of fruits (63.26) (Plate 2).

4.1.9 Weight of 1000 seeds

Statistically significant variation was recorded in terms of weight of 1000 seeds due to different chilli genotypes (Table 1). The average weight of 1000 seeds was recorded in 67.88 g with a range from 62.44 g to 81.07 g (Table 2). The highest weight of 1000 seeds (81.07 g) was observed in the genotype G_9 (SRCO 1) which was closely followed by all other genotypes but the lowest weight of 1000 seeds (62.44 g) was found from the genotype G_{10} (SRCO 2). Tairu *et al.* (2013) recorded highest 1000-seeds weight (88.34 g) in PP9955-15.

4.1.10 Yield/plant

Yield/plant of different chilli genotypes showed statistically significant variation under the present trial (Table 1). Data revealed that the average yield/plant was found in 336.41 g with a range from 242.89 g to 427.44 g (Table 2). The highest yield/plant (427.44 g) was observed in the genotype G_3 (Special chilli of Bogra) which was statistically similar (424.83 g, 412.53 g, 392.49 g, 388.34 g and 375.66 g) to G_6 (Local 1), G_{11} (SRCO 9), G_4 (Surjamukhi IMP), G_9 (SRCO 1) and G_2 (Ca 002) and closely followed (329.63 g and 329.00 g) by G_1 (Ca 001) and G_{10} (SRCO 2) and they were statistically similar, while the lowest yield/plant (242.89 g) was found from the genotype G_{14} (SRCO 5) which was statistically similar (252.23 g) to G_{12} (SRC 13). Maurya *et al.* (2017) reported that genotype PC 20132 (89.79 g) produced the maximum fruit yield/plant. Tembhurne *et al.* (2005) observed that HCS G_1 recorded significantly the highest yield per plant (100.2 g).

Plate 2. Photograph showing seeds of different chilli genotypes

4.2 Variability study for 10 traits of chilli

Genotypic and phenotypic variance, heritability, genetic advance and genetic advance in percentage of mean were estimated for 10 traits in 15 chilli genotypes and presented in Table 3.

4.2.1 Days to 1st flowering

Days to 1st flowering refers to phenotypic variance (10.22) was higher than the genotypic variance (3.23) that indicating high environmental influence on this characters which was supported by high difference between phenotypic (6.84%) and genotypic (3.85%) co-efficient of variation (Table 3). The high difference for this parameter was also suggested a highly significant influence of environment. Low heritability (31.60%) was recorded in days to 1st flowering attached with low genetic advance (2.67) and moderate genetic advance in percentage of mean (5.71). The low heritability along with moderate genetic advance in percentage of mean for days to 1st flowering indicated that environment control was not predominant for this character.

4.2.2 Plant height

Plant height refers to phenotypic variance (73.52) was higher than the genotypic variance (40.73) that indicating high environmental influence on this characters which was supported by moderate difference between phenotypic (8.73%) and genotypic (11.73%) co-efficient of variation (Table 3). The high difference for this parameter was also suggested a highly significant influence of environment. Moderate heritability (55.41%) was observed in plant height attached with low genetic advance (12.54) and high genetic advance in percentage of mean (17.16). Moderate estimate of heritability and low genetic advance for plant height of chilli genotypes suggested that this character was predominantly controlled by environment with complex gene interaction and this also indicated the importance of both additive and non additive genetic effects for the control of this character.

Table 3. Genetic parameters for yield attributes and yields of different chilli genotypes

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 1st flowering	3.23	10.22	3.85	6.84	31.60	2.67	5.71
Plant height (cm)	40.73	73.52	8.73	11.73	55.41	12.54	17.16
Number of branches/plant	0.50	1.17	9.12	13.94	42.83	1.22	15.76
Number of fruits/plant	92.38	129.64	13.99	16.57	71.26	21.42	31.18
Weight of individual fruit (g)	0.76	0.85	17.63	18.74	88.52	2.16	43.80
Length of fruit (cm)	3.08	3.21	27.27	27.81	96.13	4.55	70.59
Diameter of fruit (mm)	1.20	1.51	15.20	17.04	79.58	2.58	35.79
Number of seeds/fruit	33.62	69.56	8.83	12.70	48.33	10.64	16.20
Weight of 1000 seeds (g)	11.19	36.63	4.93	8.92	30.54	4.88	7.19
Yield/plant (g)	3536.30	4964.91	17.68	20.95	71.23	132.49	39.38

4.2.3 Number of branches/plant

Number of branches/plant refers to phenotypic variance (1.17) was higher than the genotypic variance (0.50) that indicating high environmental influence on this characters which was supported by high difference between phenotypic (13.94%) and genotypic (9.12%) co-efficient of variation (Table 3). The high difference for this parameter was also suggested a highly significant influence of environment. Moderate heritability (42.83%) was observed in number of branches/plant attached with low genetic advance (1.22) and high genetic advance in percentage of mean (15.76). Moderate estimate of heritability and low genetic advance for number of branches/plant of chilli genotypes suggested that this character was predominantly controlled by environment with complex gene interaction and this also indicated the importance of both additive and non additive genetic effects for the control of this character.

4.2.4 Number of fruits/plant

Number of fruits/plant refers to phenotypic variance (129.64) was higher than the genotypic variance (92.38) that indicating high environmental influence on this characters which was supported by high difference between phenotypic (16.57%) and genotypic (13.99%) co-efficient of variation (Table 3). The high difference for this parameter was also suggested a highly significant influence of environment. High heritability (71.26%) was observed in number of fruits/plant attached with low genetic advance (21.42) and high genetic advance in percentage of mean (31.18). The high heritability along with low genetic advance in number of fruits/plant 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.

4.2.5 Weight of individual fruit

Weight of individual fruit refers to phenotypic variance (0.85) was higher than the genotypic variance (0.76) that indicating high environmental influence on this characters which was supported by low difference between phenotypic

(18.74%) and genotypic (17.63%) co-efficient of variation (Table 3). The low difference for this parameter was also suggested a minimum significant influence of environment. High heritability (88.52%) was attained in weight of individual fruits attached with low genetic advance (2.16) and high genetic advance in percentage of mean (43.80). The high heritability along with low genetic advance in weight of individual 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.

4.2.6 Length of fruit

Length of fruit refers to phenotypic variance (3.31) was higher than the genotypic variance (3.08) that indicating high environmental influence on this characters which was supported by low difference between phenotypic (27.81%) and genotypic (27.27%) co-efficient of variation (Table 3). The low difference for this parameter was also suggested a minimum significant influence of environment. High heritability (96.13%) was found in length of fruit attached with low genetic advance (4.55) and high genetic advance in percentage of mean (70.59). The high heritability along with low genetic advance in weight of individual fruit indicated the possible scope for improvement through selection of the character length of chilli fruit and breeder may expect reasonable benefit in next generation in respect of this trait.

4.2.7 Diameter of fruit

Diameter of fruit refers to phenotypic variance (1.51) was higher than the genotypic variance (1.20) that indicating high environmental influence on this characters which was supported by low difference between phenotypic (17.04%) and genotypic (15.20%) co-efficient of variation (Table 3). The low difference for this parameter was also suggested a minimum significant influence of environment. High heritability (79.58%) was observed in diameter of fruit attached with low genetic advance (2.58) and high genetic advance in percentage of mean (35.79). The high heritability along with low genetic advance in weight of individual fruit indicated the possible scope for improvement through selection of the character diameter of fruit and breeder may expect reasonable benefit in next generation in respect of this trait.

4.2.8 Number of seeds/fruit

Number of seeds/fruit refers to phenotypic variance (69.56) was higher than the genotypic variance (33.62) that indicating high environmental influence on this characters which was supported by high difference between phenotypic (12.70%) and genotypic (8.83%) co-efficient of variation (Table 3). The high difference for this parameter was also suggested a highly significant influence of environment. Moderate heritability (48.33%) was observed in number of seeds/fruit attached with low genetic advance (10.64) and high genetic advance in percentage of mean (16.20). Moderate estimate of heritability and low genetic advance for number of branches/plant of chilli genotypes suggested that this character was predominantly controlled by environment with complex gene interaction and this also indicated the importance of both additive and non additive genetic effects for the control of this character.

4.2.9 Weight of 1000 seeds

Weight of 1000 seeds refers to phenotypic variance (36.63) was higher than the genotypic variance (11.19) that indicating high environmental influence on this characters which was supported by high difference between phenotypic (8.92%) and genotypic (4.93%) co-efficient of variation (Table 3). The high difference for this parameter was also suggested a highly significant influence of environment. Low heritability (30.54%) was recorded in weight of 1000 seeds attached with low genetic advance (4.88) and moderate genetic advance in percentage of mean (7.19). The low heritability along with moderate genetic advance in percentage of mean for weight of 1000 seeds indicated that environment control was not predominant for this character.

4.2.10 Yield/plant

Yield/plant refers to phenotypic variance (4964.91) was higher than the genotypic variance (3536.30) that indicating high environmental influence on this characters which was supported by high difference between phenotypic (20.95%) and genotypic (17.68%) co-efficient of variation (Table 3). The high difference for this parameter was also suggested a highest significant influence of environment this traits. High heritability (71.23%) was found in yield/plant of fruit attached with high genetic advance (132.49) and low genetic advance in percentage of mean (39.38). The high heritability along with high genetic advance in yield/plant indicated the presence of additive gene action for the expression of these traits, and improving of these characters could be done through selection and breeder may expect reasonable benefit in next generation in respect of this trait.

Different researcher observed phenotypic coefficient of variance (PCV) was higher than genotypic coefficient of variance (GCV) and different range of heritability for most of the studied traits of chilli. Kannan *et al*. (2016) estimated that genotypic coefficient of variation (GCV) were observed for flowers per branch (21.59%), clusters per plant (19.26%), flower per branch (16.93%) and stem diameter (15.49%). While the higher estimates of phenotypic coefficient of variation (PCV) were found for flowers per branch (26.70%), fruits per branch (24.44%), clusters per plant (24.04%) and stem diameter (19.26%). Rosmaina *et al*. (2016) reported high heritability coupled with high genetic advance per percent of mean for plant height, days to flowering, fruit length; fruit diameter, single fruit weight, number of fruit per plant and fruit weight per plant. Jogi *et al*. (2015) reported the high estimates of heritability for total number of fruits per plant (94.67%), total yield (91.37%), fruit length (96.22%), fruit width (96.22%), stalk length (81.04%) and ten fruit weight (96.44%). Similar results also reported earlier by Amit *et al*. (2014); Chattopadhyay *et al*. (2011) and Sarkar *et al*. (2009).

4.3 Correlation matrix

To measure the mutual relationship among yield and yield attributes of chilli genotypes correlation matrix analysis was done and also to determine the component characters for improvement in yield of 15 chilli genotypes (Table 4).

4.3.1 Days to 1st flowering

Highly significant positive association was recorded for days to 1st flowering of chilli genotypes with weight of individual fruit (0.446), whereas the non significant positive association was recorded for plant height (0.142), number of branches/plant (0.158), length of fruit (0.032), diameter of fruit (0.273) and yield/plant (0.154) (Table 4). On the other hand, highly significant negative association was recorded for number of seeds/fruit (-0.319), while non significant negative association was found with number of fruits/plant (-0.240) and weight of 1000 seeds (-0.186).

4.3.2 Plant height

Highly significant positive association was recorded for plant height of chilli genotypes with number of branches/plant (0.365), number of fruits/plant (0.360) and yield/plant (0.369), while the non significant positive association was recorded for days to 1st flowering (0.142), weight of individual fruit (0.145), length of fruit (0.161), diameter of fruit (0.065) and weight of 1000 seeds (0.070) (Table 4). On the other hand, non significant negative association was observed with number of seeds/fruit (-0.001).

4.3.3 Number of branches/plant

Highly significant positive association was recorded for number of branches/plant of chilli genotypes with plant height (0.365), while the non significant positive association was recorded for days to 1st flowering (0.158), number of fruits/plant (0.229), number of seeds/fruit (0.188) and yield/plant (0.149) (Table 4). On the other hand, non significant negative association was observed with weight of individual fruit (-0.030), length of fruit (-0.032), diameter of fruit (-0.107) and weight of 1000 seeds (-0.027).

Table 4. Correlation matrix for yield attributes and yields of different chilli genotypes

Characters	Days to 1st flowering	Plant height (cm)	Number of branches/ plant	Number of fruits/plant	Weight of individual fruit (g)	Length of fruit (cm)	Diameter of fruit (mm)	Number of seeds/fruit	Weight of 1000 seeds (g)	Yield/ plant (g)
Days to 1st flowering	1.00									
Plant height (cm)	0.142	1.00								
Number of branches/plant	0.158	0.365**	1.00							
Number of fruits/plant	-0.240	0.360*	0.229	1.00						
Weight of individual fruit (g)	0.446**	0.145	-0.030	-0.245	1.00					
Length of fruit (cm)	0.032	0.161	-0.032	0.376**	0.191	1.00				
Diameter of fruit (mm)	0.273	0.065	-0.107	-0.353*	0.200	-0.329*	1.00			
Number of seeds/fruit	-0.319*	-0.001	0.188	0.275	-0.205	-0.021	-0.175	1.00		
Weight of 1000 seeds (g)	-0.186	0.070	-0.027	-0.222	0.365**	-0.118	-0.062	-0.017	1.00	
Yield/plant (g)	0.154	0.369**	0.149	0.587**	0.634**	0.450**	-0.119	0.048	0.119	1.00

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

4.3.4 Number of fruits/plant

Highly significant positive association was recorded for number of fruits/plant of chilli genotypes with plant height (0.360), length of fruit (0.376) and yield/plant (0.587), while the non significant positive association was recorded for number of branches/plant (0.229) and number of seeds/fruit (0.275) (Table 4). On the other hand, highly significant negative association was found for diameter of fruit (-0.353), whereas non significant negative association was observed with days to 1st flowering (-0.240), weight of individual fruit (-0.245) and weight of 1000 seeds (-0.222).

4.3.5 Weight of individual fruit

Highly significant positive association was recorded for weight of individual fruit of chilli genotypes with days to 1st flowering (0.446), weight of 1000 seeds (0.365) and yield/plant (0.634), whereas the non significant positive association was recorded for days plant height (0.145), length of fruit (0.191) and diameter of fruit (0.200) (Table 4). On the other hand, non significant negative association was obtained with number of branches/plant (-0.030), number of fruits/plant (-0.245) and number of seeds/fruit (-0.205).

4.3.6 Length of fruit

Highly significant positive association was recorded for length of fruit of chilli genotypes with number of fruits/plant (0.376) and yield/plant (0.450), while the non significant positive association was recorded for days to 1st flowering (0.032), plant height (0.161) and weight of individual fruit (0.191) (Table 4). On the other hand, highly significant negative association was recorded for diameter of fruit (-0.329), whereas non significant negative association was observed with number of branches/plant (-0.032), number of seeds/fruit (-0.021) and weight of 1000 seeds (-0.118).

4.3.7 Diameter of fruit

Non significant positive association was recorded for diameter of fruit with days to 1st flowering (0.273), plant height (0.065) and weight of individual fruit (0.200) (Table 4). On the other hand, highly significant negative association was recorded for number of fruits/plant (-0.353) and length of fruit (-0.329), whereas non significant negative association was observed with number of branches/plant (-0.107), number of seeds/fruit (-0.175) and weight of 1000 seeds (-0.062) and yield/plant (-0.119).

4.3.8 Number of seeds/fruit

Non significant positive association was recorded for number of seeds/fruit for number of branches/plant (0.188), number of fruits/plant (0.275) and yield/plant (0.048) (Table 4). On the other hand, highly significant negative association was recorded for days to 1st flowering (-0.319), whereas non significant negative association was observed with plant height (-0.001), weight of individual fruit (-0.205), length of fruit (-0.021), diameter of fruit (-0.175) and weight of 1000 seeds (-0.017).

4.3.9 Weight of 1000 seeds

Highly significant positive association was recorded for weight of 1000 seeds of chilli genotypes with weight of individual fruit (0.365), while the non significant positive association was recorded for plant height (0.070) and yield/plant (0.119) (Table 4). On the other hand, non significant negative association was observed with days to 1st flowering (-0.186), number of branches/plant (-0.027), number of fruits/plant (-0.222), length of fruit (-0.118), diameter of fruit (-0.062) and number of seeds/fruit (-0.017).

4.3.10 Yield/plant

Highly significant positive association was recorded for days to 1st flowering of chilli genotypes with plant height (0.369), number of fruits/plant (0.587), weight of individual fruit (0.634) and length of fruit (0.450), while the non significant positive association was recorded for days to 1st flowering (0.154), number of branches/plant (0.149), number of seeds/fruit (0.048) and weight of 1000 seeds (0.119) (Table 4). On the other hand, non significant negative association was observed with diameter of fruit (-0.119).

It was revealed that there are different traits existing correlation with each other. Similar results also reported by different study by the different researcher earlier. The findings of the present study similar with the findings of Wilson and Philip (2009) and they found that yield plant^{-1} exhibited significant positive association with fruits plant^{-1}, fruit length, fruit weight, 100-seed weight, plant height and negative correlated with 50% flowering. On the other hand, Pandit *et al*. (2009) found significant positive correlation with fruit yield plant^{-1} with fruit length, fruit pedicel length, number of fruits plant^{-1}, fruit weight and 1000-seed weight which also similar with the findings of the present study.

On the other hand, fruit yield was positively associated with number of branches plant^{-1} and number of fruits plant^{-1} and whereas number of branches plant^{-1} is also positively correlated with fruit width, number of fruits plant^{-1} and fruit yield reported earlier by Acharya *et al*. (2007). The findings of the present study also similar with the findings of Dipendra and Gautam (2003) and earlier they reported that the fresh fruit yield plant^{-1} exhibited positive correlation with dry yield, fruits plant^{-1}, flowers plant^{-1}, fresh fruit weight, leaves plant^{-1}, fruiting percentage, dry fruit weight, 1000-seed weight, plant height, plant spread, specific leaf weight, fruit length, seeds fruit^{-1} and number of primary branches per plant.

4.4 Path co-efficient analysis

Path co-efficient analysis denotes the components of correlation co-efficient within different traits into the direct and indirect effects and indicates the relationship in more meaningful way. The results of the path co-efficient analysis are presented in Table 5.

4.4.1 Yield/plant *vs* days to 1st flowering

Path analysis revealed that days to 1st flowering had negative direct effect (-0.148) on yield/plant (Table 5). It showed negligible positive indirect effect through plant height, number of branches/plant, length of fruit and number of seeds/fruit, whereas days to 1st flowering showed negative indirect effect through number of fruits/plant, weight of individual fruit, diameter of fruit and weight of 1000 seeds.

4.4.2 Yield/plant *vs* plant height

Path analysis revealed that plant height had positive direct effect (0.205) on yield/plant (Table 5). It showed negligible positive indirect effect through days to 1st flowering, weight of individual fruit, length of fruit and diameter of fruit, whereas plant height showed negative indirect effect through number of branches/plant, number of fruits/plant number of seeds/fruit and weight of 1000 seeds.

4.4.3 Yield/plant *vs* number of branches/plant

Path analysis revealed that number of branches/plant had positive direct effect (0.186) on yield/plant (Table 5). It showed negligible positive indirect effect through plant height, number of fruits/plant, diameter of fruit, number of seeds/fruit and weight of 1000 seeds, whereas number of branches/plant showed negative indirect effect through days to 1st flowering, weight of individual fruit and length of fruit.

Table 5. Path coefficients for yield attributes and yields of different chilli genotypes

Characters	**Days to 1st flowering**	**Plant height (cm)**	**Number of branches/ plant**	**Number of fruits/plant**	**Weight of individual fruit (g)**	**Length of fruit (cm)**	**Diameter of fruit (mm)**	**Number of seeds/fruit**	**Weight of 1000 seeds (g)**	**Yield/ plant (g)**
Days to 1st flowering	**-0.148**	0.379	0.234	-0.063	-0.211	0.136	-0.142	0.167	-0.198	0.154
Plant height (cm)	0.156	**0.205**	-0.102	-0.132	0.198	0.219	0.169	-0.267	-0.077	0.369
Number of branches/plant	-0.231	0.123	**0.186**	0.208	-0.229	-0.289	0.125	0.165	0.091	0.149
Number of fruits/plant	0.176	-0.067	0.218	**0.132**	0.169	0.109	-0.157	0.045	-0.038	0.587
Weight of individual fruit (g)	0.187	0.213	-0.029	-0.138	**0.293**	-0.084	0.125	-0.189	0.256	0.634
Length of fruit (cm)	-0.113	-0.158	0.228	0.073	-0.104	**0.164**	-0.072	0.190	0.242	0.450
Diameter of fruit (mm)	0.133	0.094	-0.188	-0.152	0.055	-0.212	**0.078**	0.055	0.018	-0.119
Number of seeds/fruit	-0.152	0.073	0.097	0.128	0.038	0.131	0.133	**-0.133**	-0.267	0.048
Weight of 1000 seeds (g)	0.184	-0.109	-0.138	-0.055	0.289	-0.044	-0.105	0.308	**-0.211**	0.119

Residual effect = 0.3803

4.4.4 Yield/plant *vs* number of fruits/plant

Path analysis revealed that number of fruits/plant had positive direct effect (0.132) on yield/plant (Table 5). It showed negligible positive indirect effect through days to 1^{st} flowering, number of branches/plant, weight of individual fruit, length of fruit and number of seeds/fruit, whereas number of fruits/plant showed negative indirect effect through plant height, diameter of fruit and weight of 1000 seeds.

4.4.5 Yield/plant *vs* weight of individual fruit

Path analysis revealed that weight of individual fruit had positive direct effect (0.293) on yield/plant (Table 5). It showed negligible positive indirect effect through days to 1^{st} flowering, plant height, diameter of fruit and weight of 1000 seeds, whereas weight of individual fruit showed negative indirect effect through number of branches/plant, number of fruits/plant, length of fruit and number of seeds/fruit.

4.4.6 Yield/plant *vs* length of fruit

Path analysis revealed that length of fruit had positive direct effect (0.164) on yield/plant (Table 5). It showed negligible positive indirect effect through number of branches/plant, number of fruits/plant, number of seeds/fruit and weight of 1000 seeds, whereas length of fruit showed negative indirect effect through days to 1^{st} flowering, plant height, weight of individual fruit and diameter of fruit.

4.4.7 Yield/plant *vs* diameter of fruit

Path analysis revealed that diameter of fruit had positive direct effect (0.078) on yield/plant (Table 5). It showed negligible positive indirect effect through days to 1^{st} flowering, plant height, weight of individual fruit, number of seeds/fruit and weight of 1000 seeds, whereas diameter of fruit showed negative indirect effect through number of branches/plant, number of fruits/plant and length of fruit.

4.4.8 Yield/plant *vs* number of seeds/fruit

Path analysis revealed that number of seeds/fruit had negative direct effect (-0.133) on yield/plant (Table 5). It showed negligible positive indirect effect through plant height, number of branches/plant, number of fruits/plant, weight of individual fruit, length of fruit and diameter of fruit, while number of seeds/fruit showed negative indirect effect through days to 1st flowering and weight of individual fruit.

4.4.9 Yield/plant *vs* weight of 1000 seeds

Path analysis revealed that weight of 1000 seeds had negative direct effect (-0.211) on yield/plant (Table 5). It showed negligible positive indirect effect through days to 1st flowering, weight of individual fruit and number of seeds/fruit, whereas weight of 1000 seeds showed negative indirect effect through plant height, number of branches/plant, number of fruits/plant, length of fruit and diameter of fruit.

Positive and high direct effect on fruit yield indicating their reliability as selection criteria to improve yield of chilli (Sarkar *et al.*, 2009). Datta and Jana (2010) path analysis indicated that among the different characters higher direct effect was noticed in individual fruit weight, number of fruits per plant, primary and secondary branches per plant and fruit diameter. Abdullah *et al.* (2006) revealed that the number of fruits per plant, fruit weight and fruit length, fruit girth is the important components of fruit yield on the basis of the estimates of path analysis. Singh and Singh (2004) observed from their earlier study that the yield and yield components as the number of fruits plant^{-1}, fruit weight and fruit length, fruit girth had direct positive effect on yield plant^{-1}. Sreelathakumar and Rajamony (2004) revealed that fruits plant^{-1}, fruit weight and fruit girth had positive direct effects on yield, fruit length had a negative direct effect on yield, but its indirect effect through fruits plant^{-1}, fruit girth and fruit weight was high and positive.

4.5 Genetic diversity analysis

Diversity is the function of parent selection and also heterosis. The availability of transgressive sergeants in a breeding program depends upon the divergence of parents. Thus, the accurate information on the nature and degree of diversity of the parents is the pre-requisite of an effective breeding program. The knowledge of genotypic variation within genotypes in relation to morphology, phenology and yield would help to screen better genotypes for hybridization program.

4.5.1 Multivariate analysis

Genetic diversity of 15 chilli genotypes were determined by using multivariate analysis and presented in Table 6 to Table 8 under the following headings:

4.5.1.1 Principal component analysis

Eigen values and latent vectors of corresponding 10 principal component axes and percentage of total variation accounting for them obtained from the principal component analysis (Table 6). Eigen values represents that the cumulative Eigen values of first five principal components accounted for 94.55% of the total variation; the first principle component accounted for 33.14% of the total variation; the second, third, fourth and fifth components accounted for 25.81%, 18.03%, 10.92% and 6.64% of the total variation, respectively. The rest of the components accounted for only 5.45% of the total variation.

4.5.1.2 Construction of scatter diagram

Based on the values of principal component score a two-dimensional scatter diagram, using component score 1 as X-axis and component score as Y-axis was constructed (Figure 3). The position of the chilli genotypes in the scatter diagram was apparently distributed. The distribution of 15 chilli genotypes based on their principle component score and superimposed with clusters indicated that the genotypes were apparently distributed into four groups (Figure 3). The scattered diagram for the chilli genotypes of four cluster revealed that the genotypes G_2, G_6, G_8, G_{11} and G_{12} distantly located which suggesting more diverged from the rest of the genotypes.

Table 6. Eigen values and yield percent contribution of 10 characters of 15 different chilli genotypes

Characters	Eigen values	Percent variation	Cumulative % of percent variation
Days to 1st flowering	2.984	33.14	33.14
Plant height (cm)	2.324	25.81	58.96
Number of branches/plant	1.623	18.03	76.99
Number of fruits/plant	0.983	10.92	87.90
Weight of individual fruit (g)	0.598	6.64	94.55
Length of fruit (cm)	0.233	2.59	97.13
Diameter of fruit (mm)	0.155	1.72	98.86
Number of seeds/fruit	0.062	0.69	99.54
Weight of 1000 seeds (g)	0.037	0.41	99.96
Yield/plant (g)	0.004	0.04	100.00

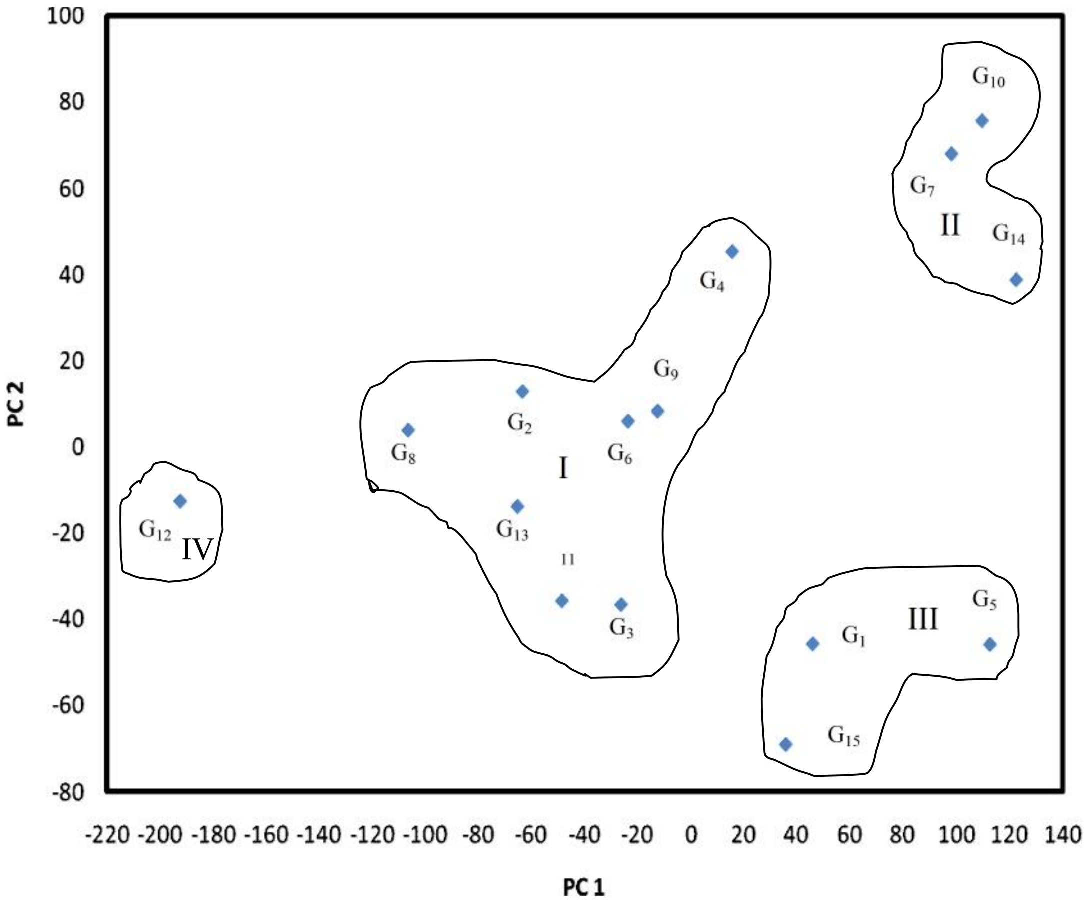

Figure 3. **Scatter distribution of 15 chilli genotypes based on their principal component score superimposed with cluster**

4.5.1.4 Non-hierarchical clustering

With the application of co-variance matrix for non-hierarchical clustering, 15 chilli genotypes were grouped into 4 different clusters (Table 7). Cluster I had maximum 8 chilli genotypes [G_2, G_3, G_4, G_6, G_8, G_9, G_{11} and G_{13}] followed by cluster II and III which had 3 genotypes in each in cluster II the genotypes are G_7, G_{10} and G_{14} and cluster III the 3 genotypes G_1, G_5 and G_{15} and the lowest genotypes had in cluster IV which had only 1 genotype [G_{12}]. It is clear from the above that the results obtained through PCA were supported by non-hierarchical clustering.

4.5.1.5 Intra cluster distances

The intra-cluster distances were computed by the values of inter-genotypic distance matrix of PCO according to Singh and Chowdhury (1985).

Cluster distances denoted by the average inter and intra-cluster distances are the approximate measure of the cluster divergence (Table 8). Inter cluster distance was maximum (12.541) between clusters II and IV, followed by clusters II and III (9.672). The intra and inter cluster distance presented in Figure 4. The results revealed that genotypes chosen for hybridization from clusters with highest distances would give high heterotic F_1 and broad spectrum of variability in segregating generations. The varieties belonging to the distant clusters could be used for further base population improvement.

4.5.1.6 Selection of genotypes as parent for hybridization program

Considering the magnitude of cluster mean and field performance the genotype Special chilli of Bogra, Local 1 and SRCO 9 for the maximum yield per plant from cluster I; SRCO 5 for branches/plant from cluster II; Ca 001 for the maximum number of fruits/plant from cluster III and SRC 13 for fruit diameter in cluster IV in were found promising. Therefore considering group distance and other agronomic performance Special chilli of Bogra, Local 1, SRCO 9, SRCO 5, Ca 001 and SRC 13 chilli genotypes may be suggested for future hybridization program.

Table 7. Clustering pattern of 15 chilli genotypes by Tocher's method

Cluster	Members	Chilli Genotypes	Name of genotypes
I	8	G_2, G_3, G_4, G_6, G_8, G_9, G_{11} and G_{13}	Ca 002, Special chilli of Bogra, Surjamukhi IMP, Local 1, CO 610, SRCO 1, SRCO 9 and CO 613
II	3	$G_{7,}$ G_{10} and G_{14}	HP 1029, SRCO 2 and SRCO 5
III	3	G_1, G_5 and G_{15}	Ca 001, Black Lady and Hot Morich of Bogra
IV	1	G_{12}	SRC 13

Table 8. Average intra (bold) and inter-cluster D^2 and D values of 4 clusters for 15 chilli genotypes formed by Torcher's method

Cluster	I	II	III	IV
I	**0.000**			
II	5.452	**0.1574**		
III	4.023	9.672	**0.4765**	
IV	5.134	12.541	8.679	**0.6732**

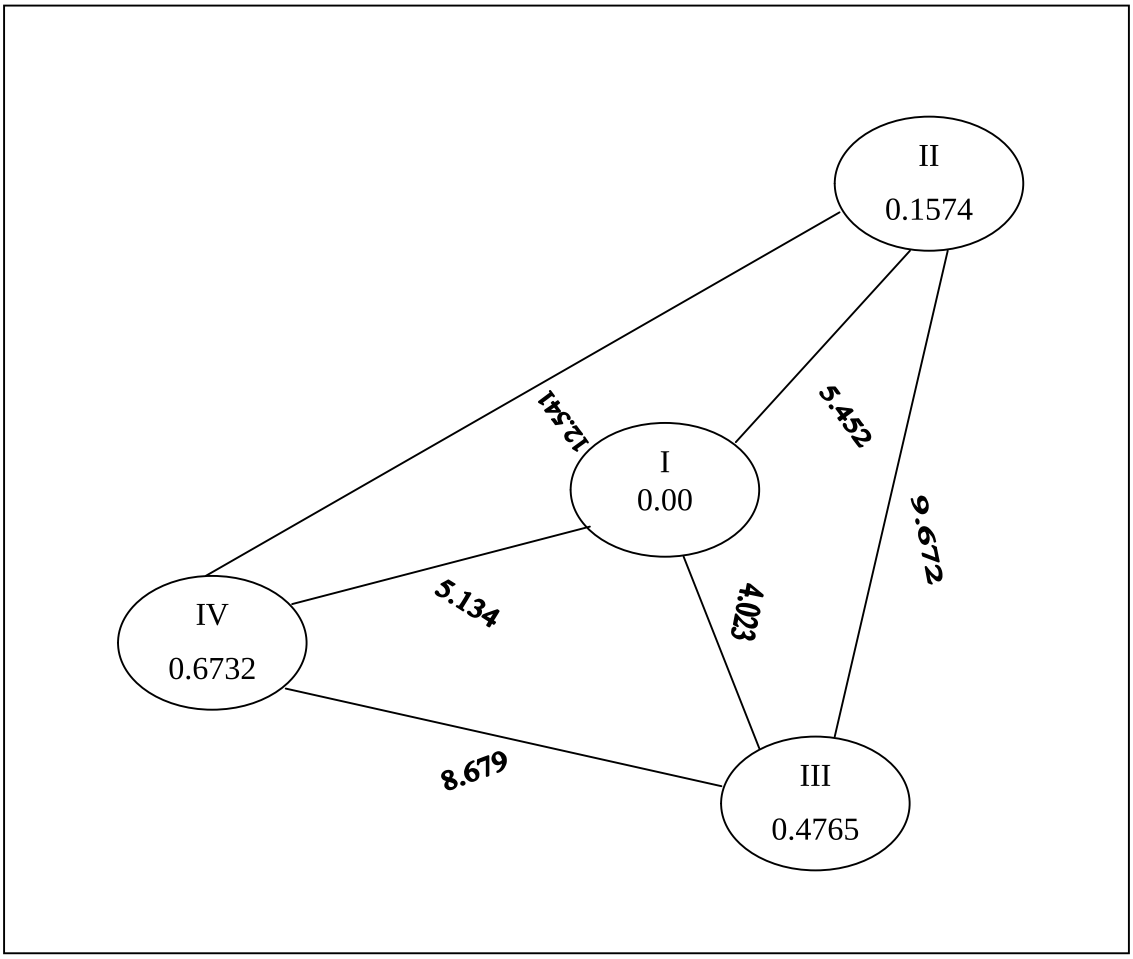

Figure 4. Intra and inter cluster distance between different clusters

CHAPTER V

SUMMARY AND CONCLUSION

The present research work was conducted to study the genetic diversity analysis of chilli during the period from November 2015 to April 2016 in *rabi* season in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. In this experiment 15 chilli genotypes were used as experimental materials. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Mean performance, variability, correlation matrix, path analysis and genetic diversity analysis on different yield attributes and yield of chilli genotypes was estimated and significant variation was observed for different mustard genotypes.

The highest days to 1st flowering (53.67) was found in the genotype G_6 (Local 1) and the lowest days (42.67) was found from the genotype of G_{15}. The longest plant (84.57 cm) was found in the genotype G_4 (Surjamukhi IMP), while the shortest plant (64.36 cm) was observed from the genotype G_{13} (CO 613). The maximum number of branches/plant (9.07) was found in the genotype G_4, whereas the minimum number of branches/plant (6.33) was recorded from the genotype of G_{15} (Hot Morich of Bogra). The maximum number of fruits/plant (88.73) was found in the genotype G_3, while the minimum number of fruits/plant (54.40) was recorded from the genotype of G_{12} (SRC 13). The highest weight of individual fruit (7.11 g) was observed in the genotype G_6 (Local 1), while the lowest weight of individual fruit (3.91 g) was found from the genotype G_8 (CO 610). The longest fruit (8.51 cm) was recorded in the genotype G_6 (Local 1), while the shortest fruit (1.53 cm) was recorded from the genotype of G_{12} (SRC 13). The highest diameter of fruit (9.53 mm) was found in the genotype G_{12} (SRC 13), whereas the lowest diameter of fruit (5.56 mm) was recorded from the genotype of G_{13} (CO 613). The maximum number of seeds/fruit (73.47) was found in the genotype G_{15} (Hot Morich of Bogra), while the minimum number of seeds/fruit (44.40) was recorded from the genotype of G_5 (Black Lady). The highest weight of 1000 seeds (81.07 g) was observed in the genotype G_9 (SRCO 1) but the lowest weight of 1000 seeds (62.44 g) was found from the genotype G_{10} (SRCO 2). The highest yield/plant (427.44 g) was observed in the genotype G_3 (Special chilli of Bogra), while the lowest yield/plant (242.89 g) was found from the genotype G_{14} (SRCO 5).

Days to 1st flowering refers to phenotypic variance (10.22) was higher than the genotypic variance (3.23) supported by high difference between phenotypic (6.84%) and genotypic (3.85%) co-efficient of variation with low heritability (31.60%) was recorded in days to 1st flowering attached with low genetic advance (2.67) and moderate genetic advance in percentage of mean (5.71). Plant height refers to phenotypic variance (73.52) was higher than the genotypic variance (40.73) supported by moderate difference between phenotypic (8.73%) and genotypic (11.73%) co-efficient of variation with moderate heritability (55.41%) was observed in plant height attached with low genetic advance (12.54) and high genetic advance in percentage of mean (17.16). Number of branches/plant refers to phenotypic variance (1.17) was higher than the genotypic variance (0.50) supported by high difference between phenotypic (13.94%) and genotypic (9.12%) co-efficient of variation with moderate heritability (42.83%) was observed in number of branches/plant attached with low genetic advance (1.22) and high genetic advance in percentage of mean (15.76). Number of fruits/plant refers to phenotypic variance (129.64) was higher than the genotypic variance (92.38) supported by high difference between phenotypic (16.57%) and genotypic (13.99%) co-efficient of variation with high heritability (71.26%) was observed in number of fruits/plant attached with low genetic advance (21.42) and high genetic advance in percentage of mean (31.18). Weight of individual fruit refers to phenotypic variance (0.85) was higher than the genotypic variance (0.76) supported by low difference between phenotypic (18.74%) and genotypic (17.63%) co-efficient of variation with high heritability (88.52%) was attained in weight of individual fruits attached with low genetic advance (2.16) and high genetic advance in percentage of mean (43.80). Length of fruit refers to phenotypic variance (3.31) was higher than the genotypic variance (3.08) supported by low difference between phenotypic (27.81%) and genotypic (27.27%) co-efficient of variation with high heritability (96.13%) was found in length of fruit attached with low genetic advance (4.55) and high genetic advance in percentage of mean (70.59). Diameter of fruit refers to phenotypic variance (1.51) was higher than the genotypic variance (1.20) supported by low difference between phenotypic (17.04%) and genotypic (15.20%) co-efficient of variation with high heritability (79.58%) was observed in diameter of fruit attached with low genetic advance (2.58) and high genetic advance in percentage of mean (35.79). Number of seeds/fruit refers to phenotypic variance (69.56) was higher than the genotypic variance (33.62) supported by high difference between phenotypic (12.70%) and genotypic (8.83%) co-efficient of variation with moderate heritability (48.33%) was observed in number of seeds/fruit attached with low genetic advance (10.64) and high genetic advance in percentage of mean (16.20). Weight of 1000 seeds refers to phenotypic variance (36.63) was higher than the genotypic variance (11.19) supported by high difference between phenotypic (8.92%) and genotypic (4.93%) co-efficient of variation with low heritability (30.54%) was recorded in weight of 1000 seeds attached with low genetic advance (4.88) and moderate genetic advance in percentage of mean (7.19). Yield/plant refers to phenotypic variance (4964.91) was higher than the genotypic variance (3536.30) supported by high difference between phenotypic (20.95%) and genotypic (17.68%) co-efficient of variation with high heritability (71.23%) was found in yield/plant of fruit attached with high genetic advance (132.49) and low genetic advance in percentage of mean (39.38).

In correlation study, highly significant positive association was recorded for days to 1st flowering of chilli genotypes with plant height (0.369), number of fruits/plant (0.587), weight of individual fruit (0.634) and length of fruit (0.450), while the non significant positive association was recorded for days to 1st

flowering (0.154), number of branches/plant (0.149), number of seeds/fruit (0.048) and weight of 1000 seeds (0.119), while non significant negative association was observed with diameter of fruit (-0.119).

Path analysis revealed that days to 1st flowering had negative direct effect (-0.148), plant height had positive direct effect (0.205), number of branches/plant had positive direct effect (0.186), number of fruits/plant had positive direct effect (0.132), weight of individual fruit had positive direct effect (0.293), length of fruit had positive direct effect (0.164), diameter of fruit had positive direct effect (0.078), number of seeds/fruit had negative direct effect (-0.133) and weight of 1000 seeds had negative direct effect (-0.211) on yield/plant.

In diversity analysis, revealed that Cluster I had the maximum 8 chilli genotypes [G_2, G_3, G_4, G_6, G_8, G_9, G_{11} and G_{13}] followed by cluster II and III which had 3 genotypes in each in cluster II ($G_{7,}$ G_{10} and G_{14}) and cluster III the 3 genotypes (G_1, G_5 and G_{15}) and the lowest genotypes had in cluster IV which had only 1 genotype [G_{12}]. Inter cluster distance was the maximum (12.541) between clusters II and IV. Considering group distance and other agronomic performance Special chilli of Bogra (G_3), Local 1 (G_6), SRCO 9 (G_{11}), SRCO 5 (G_{14}), Ca 001 (G_1) and SRC 13 (G_{12}) chilli genotypes may be suggested for future hybridization program.

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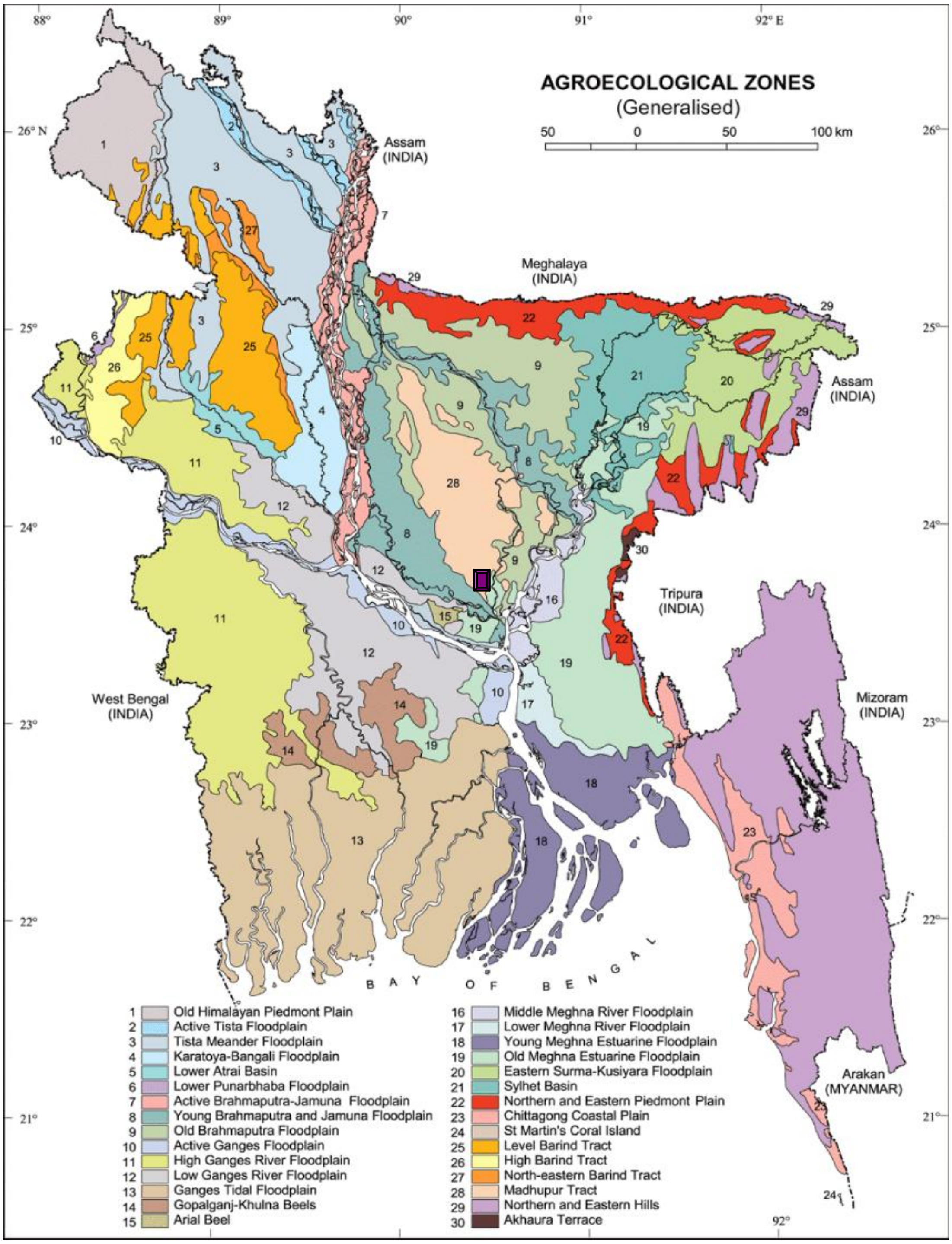
APPENDICES

Appendix I. The Map of the experimental site



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agricultural Botany field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	6.1
Organic matter (%)	1.13
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	23

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

Appendix III. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2015 to April 2016

Month	*Air temperature (°c)		*Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2015	25.8	16.0	78	00	6.8
December, 2015	22.4	13.5	74	00	6.3
January, 2016	24.5	12.4	68	00	5.7
February, 2016	27.1	16.7	67	30	6.7
March, 2016	28.1	19.5	68	00	6.8
April, 2016	33.4	23.2	67	78	6.9

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka-1207

Appendix IV. Photograph showing experimental plot

Appendix V. Photograph showing data collection procedure