ULTIVARIATE ANALYSIS OF CHILLI (*Capsicum spp.*) GENOTYPES BASED ON YIELD AND YIELD CONTRIBUTING TRAITS

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MULTIVARIATE ANALYSIS OF CHILLI (*Capsicum spp.*) GENOTYPES BASED ON YIELD AND YIELD CONTRIBUTING TRAITS

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CERTIFICATE

This is to certify that thesis entitled, "Multivariate analysis of chilli (Capsicum spp.) genotypes based on yield and yield contributing traits" submitted to the faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of ***MASTER OF SCIENCE IN GENETICS AND PLANT BREEDING****, embodies the result of a piece of bona fide research work carried out by Anup Halder, Registration No.: 15-06911 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has been duly been acknowledged by him.

Dated: December 2016
Place: Dhaka, Bangladesh

(Prof. Dr. Naheed Zeba)
Supervisor

Dedicated to my beloved parents

NIRMAL CHANDRA HALDER

and

ANJU RANI HALDER

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The Author

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SOME COMMONLY USED ABBREVIATIONS

Full Word	Abbreviation
Agro-Ecological Zone	AEZ
and others	*et al.*
Bangladesh Bureau of Statistics	BBS
Centimeter	Cm
Degree Celsius	^{0}C
Date After Seeding	DAS
Etcetera	Etc
Food and Agriculture Organization	FAO
Muriate of Potash	MP
Randomized Complete Block Design	RCBD
Square meter	m^2
Triple Super Phosphate	TSP
United Nations Development Program	UNDP
Sher-e-Bangla Agricultural University	SAU

MULTIVARIATE ANALYSIS OF CHILLI (*Capsicum spp.*) GENOTYPES BASED ON YIELD AND YIELD CONTRIBUTING TRAITS

ANUP HALDER

ABSTRACT

The present research work was conducted to study the multivariate 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 fifteen chilli genotypes were used as experimental materials. The experiment was laid out in randomized complete block design with three replications. Mean performance, variability, correlation matrix, path analysis and genetic diversity analysis on different yield and yield attributes of chilli genotypes was estimated and significant variation was observed for different chilli genotypes. The highest days to 1st flowering (75.33) was found in the genotype G_{10} (SRC10) and the lowest days (58.33) was found from the genotype of G_2 (Bogra Zhal Morich). The maximum number of fruits/plant (55.22) was found in the genotype G_7 (SRC07), while the minimum number of fruits/plant (20.67) was recorded from the genotype of G_{15} (Dark Green Papper). The highest yield/plant (178.73 g) was observed in the genotype G_2 (Bogra Zhal Morich), while the lowest yield/plant (32.70 g) was found from the genotype G_6 (SRC04). 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 fruit weight per plot of chilli genotypes with number of branches per plant, fruit length, single fruit weight and fruit weight per plant. Path analysis revealed that number of branches per plant, days to 50% fruiting, single fruit weight and fruit weight per plant had positive direct effect on fruit weight per plot. Diversity analysis revealed that cluster I had the maximum (8) chilli genotypes followed by cluster III and II which had 4 genotypes and 3 genotypes respectively. Inter cluster distance was maximum (11.862) between clusters I and II. Considering group distance and other agronomic performance Bogra Zhal Morich, Bora Special Morich, SRC06, SRC07, SR09 and SRC10 genotypes may be suggested for future hybridization program.

CHAPTER I

INTRODUCTION

Chilli (*Capsicum spp.*) is an important crop both as a vegetable and spice valued for its aroma, taste, flavour and pungency (Vikram *et al*., 2014). Chilli, 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).

The constituents of chilli are important for its 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). Chilli is rich in proteins, lipids, carbohydrates, fibres, mineral salts (Ca, P, Fe) and 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).

Worldwide it is cultivated over 1.4 million ha with a production of 18.8 million tonnes (Narolia *et al.,* 2012). Generally, chilli is grown as a cash crop in Bangladesh. Its commercial production is largely concentrated in Bogra, Rangpur, Comilla, Noakhali, Faridpur, Chittagong and Mymensingh district (Munshi *et al.,* 2000). In Bangladesh about 94 thousand hectares of land under chilli cultivation and the total production is approximately 123 thousand metric tons (BBS, 2015). Thus, the average yield of chilli is about 2121.80 kg per hectare which is very low compare to others country of the world.

As a result, a huge amount of money is spent to import it from abroad. During early 80's, the country did not import chilli from abroad. Now the area under chilli cultivation decreased due to increase of rice cultivation. The low yield of chilli in Bangladesh, however, is not an indication of the low yielding potentiality of this crop but the fact is the absence of high yielding cultivars of chilli. High yielding cultivars of chilli and traditional methods of cultivation are expected. Since the soil and climate condition of Bangladesh are suitable to cultivate chilli, it is expected the selection of high yielding varieties will augment the yield considerably. Indeed, there is a vast scope to increase chilli production with the introduction of selected high yielding varieties.

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 and abiotic stresses that cause severe yield losses (Segnou *et al.*, 2013; Zhani *et al*., 2013; Khan *et al.*, 2009). In Bangladesh the yield of chilli is very low and however it 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.

Yield being a complex character, which is not only influenced by its associated traits but also governed by number of genes and influenced by environment. So, to make selection effective, it is necessary to separate genetic variability from total variability, which enables breeder to adopt suitable breeding programme. Mere variability studies will not be of much helpful for improvement of yield, as it is associated with number of yield component characters. Association analysis of quantitative attributes would help in choosing component characters that are positively correlated (Kadwey, 2014). Therefore, it is essential to know the degree of mutual association (correlation) prevailing between yield and its component characters, to form the basis for selecting desirable genotypes. Analysis of inter component correlation is very essential to expose the direct and indirect contribution of each of the component, which in turn is determined by path-coefficient analysis (Wright, 2007). To plan appropriate breeding programme and to evolve high yielding cultivars the plant breeders must possess adequate knowledge on variability, character association patterns, the extent of contribution of each character to fruit yield and genetic divergence.

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 (Syukur *et al.*, 2012; Poehlman and Sleper, 1995). 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 successful 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 for flowering, fruit set, yield and other qualitative attributes which provide great scope for improving fruit yield through systematic breeding (Maurya *et al.,* 2016*;* Rani, 1996). Estimation of genetic variability present in the germplasm of a crop is a pre-requisite for designing effective breeding programme (Parkash, 2012).

In order to benefit transgressive segregation, the knowledge of genetic distance between parents is necessary (Lahbib *et al.*, 2012; Khodadabi *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; 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 understand the degree and direction association between yield and yield components and their inter correlation among themselves;
- To assess the direct and indirect effects of component traits on yield of different chilli genotypes;
- 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 and yield contributing characters of chilli

2.1.1 Days to flower bud initiation

Several researches reports are available on chilli experiment and the researchers suggested their comments on days to flower bud initiation (Kaouther *et al*., 2015; Hasan *et al*., 2014). 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 Soma 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). In an another study carried out an experiment to study the performance of 22 diverse chilli genotypes collected from different parts of India including two controls 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 spp*.) at research farm of CIARI, South Andaman 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. Similar experiment was conducted by Kaouther *et al.* (2015) with five local accessions of chilli pepper (*Capsicum spp*.) 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. 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 Andaman 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 maximum number of branches (26.5/plant) from L_4 and minimum number of branches (21.5/plant) from L_3. Tembhurne *et al.* (2005) recorded maximum number of primary branches (5.73) in HCS G_8, minimum no of primary branches (4.33) in HCS G_2, maximum number of secondary branches (7.13) in HCS G_1 and minimum no of secondary branches (2.73) in 9626-6-1 among the 11 advanced lines.

2.1.4 Days to 50% flowering

Mohanty and Prusti (2005) observed that among the earliness parameters, while the days to fifty per cent flowering had significant negative (-0.209) association with total yield, While the early yield per plant had positive association (0.486) with total yield. Ahmed *et al. (*2006) and Hari *et al. (*2005) *and* had also reported negative association of days to 50 per cent flowering with yield and Krishna et al. (2007) had reported positive association of early yield with total yield. Hence, it would be rewarding for selection for early yield for improvement of the total yield rather than for selection for days to 50 per cent flowering as it has adverse effect on total yield. Similarly, Mishra *et al*. (2016) find that the earliest day to 1st lowering amongst genotypes was recorded with the Pusa Jawala (31.66) followed by LCA 301 (32), JCA 9(32.33) and the maximum days to 1st lowering were noticed in LCA 333 (41.66). Days to 50 per cent lowering was also observed significant among genotypes. Japani Long (58.00) and LCA 334 (57.33) took maximum days to 50 per cent lowering and the minimum days were recorded in SM 20 (51.66). Application of N @ 75% through vermicomposting and rest from urea induced advanced flowering in plants (T12) as compared to all other treatment.

2.1.5 Days to 1st fruiting

Mishra *et al*. (2016) experienced that significant differences were found for days to first green fruit harvest among various genotypes. The minimum days to first green fruit harvest was recorded in LCA 357 (79.00) followed by LCA 404 (80.66) and Pusa Jawala (81.33) while genotype LCA 301 (96.33) took maximum days to first green fruit harvest. Significantly the maximum weight of green fruit was recorded in EC 492576 (22.93g), followed by LCA 206 (18.88g), IC 38079 (18.65g) and JCA 9 (11.69g), while genotype Pusa Jawala (8.22g) was found to be with minimum weight of green fruit. Maximum fruit length was observed significant in IC 413702 (12.16cm) followed by SM 20 (11.50 cm), Pusa Jawala (10.5 cm) and LCA 206 (9.56cm) and the minimum fruit length was recorded in Pbc 1438 (4.33cm).

2.1.6 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 Yolo wonder 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 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 spp.*) over 3 years and found that 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 highest number of fruits per plant (144.2) among the 11 advanced lines that they evaluated.

2.1.7 Individual fruit weight

Jaisankar *et al.* (2015) conducted a varietal evaluation at research farm of CIARI, South Andaman with twelve varieties of Chilli and noted 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 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).

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 maximum individual fruit weight (1.12 g) in HCS (G_3) and minimum individual fruit weight (0.4 g) in HCS (G_8) among the 11 advanced lines. On the other hand, 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 20.31g.

2.1.8 Fruit length

Jaisankar *et al.* (2015) carried out a varietal evaluation at research farm of CIARI, South Andaman 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 Yolo wonder and found that Orobella rank first regarding hybrid produced highest (5.98 cm) value for fruit length. 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.

2.1.9 Yield per plant

The present experiment was carried out by Maurya *et al.* (2016) 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 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 (BograMorich) 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 Andaman 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). On the other hand, Kaouther *et al.* (2015) conducted an agronomic evaluation with five local accessions of chilli pepper (*Capsicum spp*.) namely, Tebourba, Soma, 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 Yolo wonder and observed that Orobella rank first regarding fruit weight/plant (1.96 kg). On the other hand, 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).

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.* (2016) 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.* (2016) 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 is 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 spp.* acquired from the Centre for Genetic Resources, the Netherlands (CGN) through Plant Genetic Resources Institute (PGRI), National Agricultural Research Centre (NARC) Islamabad 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 were 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%).

An investigation was carried out by Janaki *et al.* (2015) during kharif at Horticultural Research Station, Lam, Guntur with 63 genotypes of chilli (*Capsicum spp*.) 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, 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 Dipendra and Gautam (2003) 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 examined 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 weights, 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 spp*.) 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 and Sahu (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.* (2016) 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 fruits 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.

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 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-hierarchical 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 maximum to the total divergence followed by fruit length (21.6%) and yield/plant (21.1%). Cluster IV produced highest mean for fruit weight (4.48) and fruits/plan (149.90) and yield/plant (676.03). Cluster V produced highest mean for fruit length (10.23), pedicel length (4.94) and fruit diameter (10.36). Cluster I and III produced maximum 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 spp*.) 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 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 spp*.) genotypes of Indian origin at the research farm of Vegetable Science, College of Horticulture and Forestry, Central Agricultural University, Pasig hat, 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 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 character's capsaicin content and ascorbic acid contributed 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 maximum number (24) of genotypes and minimum with cluster III (1 genotype). The inter cluster distances (D values) ranged between 3.90 to12.68. Minimum inter cluster distance was between cluster II and IV (3.90) and maximum inter cluster distance was observed between cluster VII and VIII (12.68). The intra cluster divergence varied from 3.32 to 5.45. Maximum intra cluster distance was achieved in cluster VIII (5.45) and 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 maximum to the total divergence followed by fruit length (23.22%) and yield/plant (20.5%) and cluster IV produced highest mean for fruit weight (4.96) and fruits/plant (232.15) and yield/plant (453.33). It may be understood from the above reviews that different yield attributes significantly influence 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 multivariate 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 (33.4^0C) was recorded from April, 2016 and the minimum temperature (12.4^0C) 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. The purity and germination percentage were leveled as 95%. 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.

Table 1: Name of chilli genotypes used in the present study

Genotypes	Name of genotypes	Genotypes	Name of genotypes
G_1	DEB 1302	G_9	SRC06
G_2	Bogra Zhal Morich	G_{10}	SRC10
G_3	Bogra Special Morich	G_{11}	SRC14
G_4	Black Lady	G_{12}	C0611
G_5	CO 525	G_{13}	AC 542
G_6	SRC04	G_{14}	AC 578
G_7	SRC07	G_{15}	Dark Greem Papper
G_8	SRC03		

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 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 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. A view of seedbed preparation is shown in Plate 1A. Seeds were soaked in separate plastic glass for two days (Plate 1B). 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. Seed beds were watered when necessary and cleaned by removing weeds when emerged.

3.3.2 Land preparation

The plot selected for the study was opened in the 1st week of December 2016 with a power tiller, and left exposed to the sun for a week. Then the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain until good tilth. Weeds and stubbles were removed. 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 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).

Plate1: Growing of chilli plants in the experimental farm of Sher-e-Bangla Agricultural University. A. Seedbed preparation B. Soaking of chilli seeds before sowing in the seedbed C. Transplanted seedling in the main land D. Vegetative stage of the chilli plant E. Flowering stage of the chilli plant F-H. Fruiting stage of the chilli plants

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, 2015 with maintaining 60 cm distance from row to row and 40 cm from plant to plant (Plate 1C). This allowed an accommodation of 18 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. The vegetative stage, flowering stage and fruiting stage is illustrated in Plate 1(D-H).

3.3.5 Intercultural operations

After transplanting of seedlings, various intercultural operations such as irrigation, weeding and top dressing etc. were accomplished for better growth and development of the chilli seedlings. A view of intercultural operation and harvesting is shown in Plate 2.

3.3.5.1 Irrigation and drainage

Over-head irrigation was provided with a watering-can to the plots as per necessity. Excess water 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 and data collection

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

Plate 2. Intercultural operation and harvesting of fruits of chilli genotypes. A. Intercultural operation B. Harvesing

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 Days to 50% flowering

The number of days was counted from the date of sowing to 50 percent of plants flowered.

3.5.5 Days to 1st fruiting

Days required for sowing to 1st initiation of fruit was counted from the date of sowing to the initiation of fruiting and was recorded.

3.5.6 Days to 50% fruiting

The number of days was counted from the date of sowing to 50 percent of plants produce fruit.

3.5.7 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).

3.5.8 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.

3.5.9 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.

3.5.10 Fruit weight per plant

The weight of fruits from each picking was recorded from the five labeled plants of each experimental plot. Total yield per plant was worked out by adding yield of all harvests and was expressed in gram (g) per plant.

3.5.11 Fruit weight per plot

Total fruit weight of each plot was counted

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):

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

Where,

$\sum$ = Summation

x and y are the two variables

N = Number of observations

3.9 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 (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 parent's 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 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.

3.10.3 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.

3.10.4 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.

3.10.5 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= $\frac{\sum D_i^2}{n}$

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.

3.10.6 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= $\frac{\sum D_{ij}^2}{n_i \times n_j}$

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.

3.10.7 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.

3.10.8 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 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 Genetic variability, heritability and genetic advance

The mean values for each character of the genotypes are shown in Table 2. Performance of the genotypes is described below. The extent of variation among the genotypes in respect of fifteen characters was studied and mean sum of square, phenotypic variance (σ^2p), genotypic variance (σ^2g), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2b), genetic advance (GA), genetic advance in percent of mean and coefficient of variation (CV) presented in Table 3, Figure 1 and Figure 2.

4.1.1 Plant height (cm)

The mean sum of squares (MS) (Table 3) revealed that there were significant differences among the genotypes for plant height which ranged from 107.57 cm (G3) to 175.10 cm (G6) with mean value 146.33 cm. (Table 2) Naz *et al*. (2013), Ravindra *et al*. (2003), Shravan *et al*. (2004) and Prasad *et al*. (1999) were also found similar significant variation for plant height. The phenotypic and genotypic variance was observed 461.64 and 424.78 respectively (Table 3) indicated environmental influence on the expression of the genes controlling these traits. The phenotypic co-efficient of variation (14.68) and genotypic co-efficient of variation (14.08) were moderate for plant height implying equal importance of additive and non- additive gene action (Table 3). The PCV is greater than GCV for this trait but narrow gap between PCV and GCV for this trait indicates less

Table 2: Mean analysis of growth, yield and yield contributing parameters

Genotypes	Plant height (cm)	No. of branches/plant	Days to 1st flowering	Days to 50% flowering	Days to 1st fruiting	Days to 50% fruiting	Fruit length (cm)	Single Fruit weight (g)	No. of fruits/ plant	Fruit weight/ plant (g)	Fruit weight/ plot (g)
G 1	153.20	20.00	66.67	87.67	79.33	105.67	4.77	2.31	51.67	119.34	716.01
G 2	145.33	23.00	58.33	83.33	77.67	104.67	8.00	3.25	55.06	178.73	1072.38
G 3	107.57	19.47	65.00	89.67	79.00	109.00	5.25	2.25	51.00	114.37	686.22
G 4	165.13	19.83	70.33	92.33	82.67	109.67	3.93	1.07	52.37	55.96	335.74
G 5	166.30	18.50	69.00	91.67	82.00	107.67	4.25	2.07	38.67	79.59	477.53
G 6	175.10	16.77	71.33	95.33	85.00	117.00	2.97	0.74	44.33	32.70	196.20
G 7	168.23	21.91	72.33	95.33	85.00	112.33	7.37	2.76	55.22	152.54	915.22
G 8	156.30	20.30	70.00	92.67	82.67	108.00	5.31	1.71	51.80	88.34	530.04
G 9	115.90	18.80	64.00	89.33	75.33	102.33	6.39	2.52	51.52	130.07	780.40
G 10	137.90	20.87	75.33	97.00	85.67	113.67	7.57	2.82	54.43	153.75	922.52
G 11	160.53	17.70	70.00	91.00	80.00	103.67	3.30	1.57	30.33	47.72	286.32
G 12	143.03	19.00	71.67	95.33	85.00	111.00	6.80	1.31	51.80	67.60	405.58
G 13	123.77	22.57	70.33	93.67	82.33	110.00	7.78	3.07	53.53	164.15	984.88
G 14	121.57	17.90	65.33	88.33	78.00	107.00	6.43	1.87	38.80	72.48	434.91
G 15	155.10	18.13	64.00	75.33	76.67	104.33	6.40	5.43	20.67	112.70	676.18
Mean	146.33	19.65	68.24	90.53	81.09	108.40	5.77	2.32	46.75	104.67	628.01
LSD	18.37	1.37	3.12	11.28	10.24	11.43	1.40	0.61	4.81	30.64	183.83
CV%	4.15	2.31	1.51	4.12	4.17	3.48	8.02	8.73	3.40	9.67	9.67

Table 3: Estimation of genetic parameters in eleven characters of fifteen genotypes in chilli

Parameters	MS	σ^2p	σ^2g	σ^2e	PCV	GCV	ECV	Heritability	Genetic advance (5%)	Genetic advance (% mean)	CV (%)
Plant Height	1311.20**	461.64	424.78	36.86	14.68	14.08	4.15	92.02	40.73	27.83	4.15
Branch per plant	10.04**	3.49	3.28	0.21	9.50	9.22	2.31	94.11	3.62	18.42	2.31
Days to 1st flowering	55.59**	19.24	18.18	1.06	6.43	6.25	1.51	94.49	8.54	12.51	1.51
Days to 50% flowering	91.75**	39.84	25.95	13.89	6.97	5.63	4.12	65.14	8.47	9.36	4.12
Days to 1st fruiting	33.59**	18.83	7.38	11.45	5.35	3.35	4.17	39.21	3.50	4.32	4.17
Days to 50% fruiting	48.91**	25.81	11.55	14.25	4.69	3.14	3.48	44.77	4.69	4.32	3.48
Fruit length	8.17*	2.87	2.65	0.21	29.35	28.23	8.02	92.53	3.23	55.94	8.02
Weight per fruit	3.83**	1.31	1.26	0.04	49.25	48.47	8.72	96.87	2.28	98.28	8.73
Fruits per plant	316.64**	107.23	104.71	2.52	22.15	21.89	3.40	97.65	20.83	44.56	3.4
Fruit yield per plant	6180.79**	2128.60	2026.10	102.50	44.08	43.00	9.67	95.18	90.47	86.43	9.67
Fruit yield per plot	222507.31**	76628.87	72939.22	3689.65	44.08	43.00	9.67	95.19	542.79	86.43	9.67

influence of environment on the phenotypic expression and is indicative of the heritable nature of the traits and high degree of genetic influence of environment on the phenotypic expression and is indicative of the heritable nature of the traits and high degree of genetic variability present on the expression of these characters. Kumari *et al*. (2007) obtained highest genotypic coefficient of variation which disagree with this result. Singh *et al.* (2002) showed that the phenotypic coefficient of variation was greatest for this character. Similar observations were made by Matin *et al.* (2001). The heritability estimates for this trait was high (92.02%) with high genetic advance in percent of mean (27.83%) (Table 2) revealed that this trait was governed by additive gene. Similar results were observed by several researchers (Bai and Devi, 1991; Kumari *et al.*, 2007; Mahesha *et al.,* 2006, Singh *et al.,* 2006, Singh *et al.,* 2005 and Joshi *et al*., 2004).

4.1.2 Number of branches per plant

Number of branches per plant in chilli showed significant difference where the number of branches (23) was found in Bogra Zhal Morich (G2) and the minimum was recorded 16.77 in SRC04 (G6) with mean value 19.65 (Table 2). The phenotypic variance (3.49) was higher than the genotypic variance (3.28) (Table 3). The genotypic co-efficient of variation and phenotypic co-efficient of variation were 9.22 and 9.50, respectively (Table 3) indicating that the phenotypic expression of this trait is slightly governed by the environment as because narrow gap was existing between PCV and GCV. Singh *et al*. (2002) also showed that the PCV was higher than GCV for this trait. The heritability estimates for this trait was high (94.11) indicated that the environmental influence is minimal on that character and selection could be fairly easy and improvement is possible using selection for this trait improvement. Genetic advance was low (3.62%) and genetic advance in per cent of mean was 18.42 (Table 3) were found moderate, revealed that this trait was governed by non-additive gene. Moderate heritability and low genetic advance for this character was observed by Kumar *et al.* (2004).

4.1.3 Days to first flowering

The variance due to days to first flowering showed that the genotypes differed significantly and ranged from 58.33 days after transplanting (DAT) in Bogra Zhal Morich (G6) to 75.33 DAT in SRC10 (G10) with mean value 68.24 days after transplanting (DAT) (Table 2). The genotypic variance and phenotypic variance for this trait were 18.18 and 19.24, respectively (Table 3). The phenotypic variance appeared to be high than the genotypic variance suggested considerable influence of environment on the expression of genes controlling this trait. The genotypic co-efficient of variation (GCV) (6.25) and phenotypic co-efficient of variation (PCV) (6.43) were more or less similar to each other, indicated presence of negligible influence of environment controlling this trait (Table 3). Therefore, selection based upon phenotypic expression of this character would be effective for the improvement of this crop. Similar findings were reported by Farzaneh *et al.* (2013) and Kumari *et al.* (2007). Matin *et al*. (2001) also found similar results in tomato. In contrast Monamodi *et al.* (2013) and Aditya *et al*. (1995) found in significant difference in days to first flowering. The heritability estimates for days to first flowering was high (94.49%) with low genetic advance (8.54%) and genetic advance in percentage of mean (12.51%) (Table 3). Thus, indicating this trait was mostly controlled by non-additive gene. Genetic advances in per cent of mean were low which is in accordance with the findings of Singh *et al.* (2009). Islam and Khan (1991) reported high heritability for days to first flowering. The variation in flowers of different genotypes is presented in Plate 4.

4.1.4 Days to 50% flowering

Significant variation was found for days to 50% flowering and it is ranged from 75.33 days after transplanting (DAT) in SRC10 (G10) to 97 DAT in Dark Green with mean value 90.53 days after transplanting (DAT) (Table 2). Present study observed low variance for days to 50% flowering. Similar findings for days to 50% flowering were also observed by Narolia (2012). On the other hand Nalla *et al*., (2014) found dissimilar result with very low variability for this trait. Genotypic co-efficient of variation (GCV) and phenotypic co-efficient of variation (PCV) were found low (5.63 and 6.97 respectively) (Table 3). The phenotypic variance appeared to be high than the genotypic variance advised significant influence of environment on the expression of genes governing days to 50% flowering. Many author also found higher PCV than GCV (Singh, 2005 and Samadia *et al*., 2006). Therefore, it can be referring that selection based upon phenotypic expression of this character wouldn't be productive for the improvement of chilli. The heritability estimates for this trait was moderate (65.14%) with low genetic advance (8.47%) and genetic advance in per cent of mean (9.36%), indicating this trait was controlled by non-additive gene (Table 3). Kumar *et al.* (2011) supported this finding.

4.1.5 Days to 1st fruiting

The studied genotypes showed significant difference in case of duration for days to fruiting. The maximum was found 85.67 DAT in SRC10 (G10) and the minimum was recorded 75.33 DAT in SRC06 (G9) with mean value 81.09 (Table 2). The genotypic variance (7.38) was lower than phenotypic (18.83) variance. Genotypic co-efficient of variation (3.35) and phenotypic co-efficient of variation (5.35) were also close to each other (Table 3). Suggesting environmental influence is minor on the expression of the genes controlling this trait. So, selection based upon phenotypic expression of this character would be effective for the improvement of this crop. Prashanth (2003) disagree with this result with high phenotypic coefficient of variation. The heritability estimates and genetic advance and genetic advance in per cent of mean were low for this trait indicated that this trait was controlled by non-additive gene. Low heritability of traits due to the influence of environment and limit the scope of improvement using selection. The variation in green and ripe fruits is shown in Plate 5.

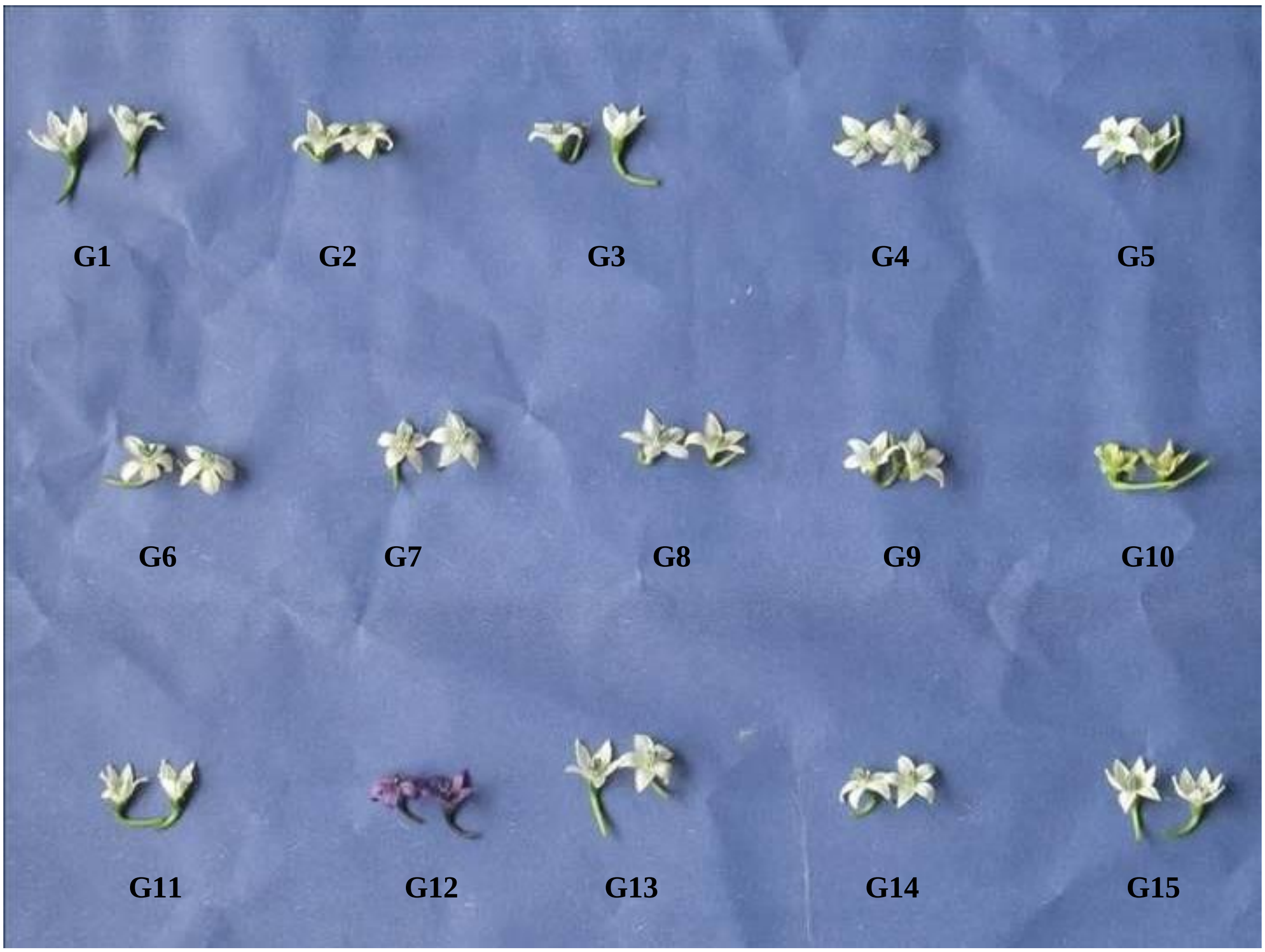


Plate 4: Variation in flowers of fifteen chilli genotypes used in the study

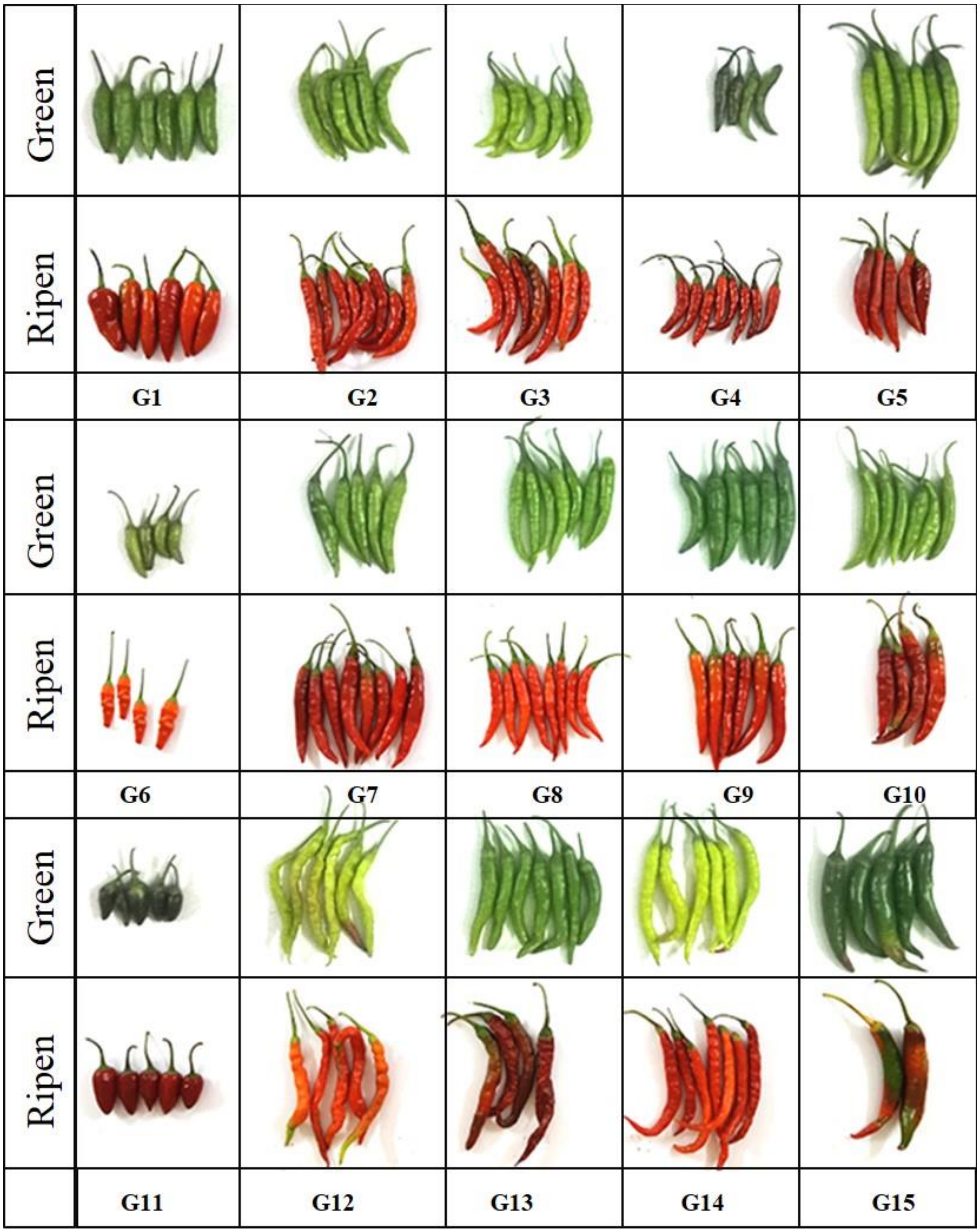

Green
Ripen
G1
G2
G3
G4
G5
Green
Ripen
G6
G7
G8
G9
G10
Green
Ripen
G11
G12
G13
G14
G15

Plate 5 : Green and ripen fruit of fifteen chilli genotype used in the study

4.1.6 Days to 50% fruiting

The significant difference was observed in case of days to 50% fruiting. The maximum was found 117 DAT in SRC04 (G6) and the minimum was recorded 102.33 DAT in SRC06 (G9) with mean value 108.40 (Table 2). The genotypic variance (11.55) was lower than phenotypic (25.81) variance. Genotypic co-efficient of variation (3.14) and phenotypic co-efficient of variation (4.69) were also close to each other (Table 3). 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.

4.1.7 Fruit Length (cm)

The mean fruit length was noticed as 5.77 cm with a range of 2.97 cm to 8.00 cm. The genotype G_6 showed the minimum fruit length and the maximum fruit length was recorded in the genotype G_2 (Table 2). The genotypic and phenotypic variance were low (2.65 and 2.87 respectively) and genotypic co-efficient of variation (28.23) and phenotypic co-efficient variation (92.53) were close to each other (Table 3), indicating minor environmental influence on this character that would be effective for the improvement of this crop. Singh *et al*. (2002) showed that the phenotypic coefficient of variation was greatest for this character which does not support the present study. High heritability estimates (92.53%) with low genetic advance (3.23%) over percent of mean (55.94%) (Table 3) indicate that effective selection may be made for fruit length. Moderate heritability and moderate genetic gain for this character was observed by Joshi *et al.* (2004).

4.1.8 Single fruit weight (g)

The maximum single fruit weight was recorded 5.43 g in G_{15} where the minimum was recorded 0.74 g in G_6 with mean value 46.75 g (Table 2). The genotypic variance (1.26) and phenotypic variance (1.31) for fruit weight was low (Table 3). The genotypic co-efficient of variation and phenotypic co-efficient of variation were high (48.47 and 49.25 respectively) and close to each other, proved that environment has little influence of the expression of this character (Table 3). Therefore, selection based upon phenotypic expression of this character would be effective for the improvement of this crop. High GCV and PCV for average fruit weight were also noticed by Manivannan *et al*. (2005). High heritability (96.87%) associated with low genetic advance in percent of mean (2.28%) and moderated Genetic advance (98.28%) (Table 4) was observed indicating fruit weight governed by additive gene. Pandit *et al.* (2010), Ara *et al.* (2009) and Singh *et al.* (2006) also supported the present findings.

4.1.9 Number of fruits per plant

From the current study we observed that the maximum range for number of fruits per plant was found 55.22 in SRC06 (G9) and the minimum was recorded 20.67 in 'Dark Green Papper (G15) (Table 2). The difference between genotypic (104.71) and phenotypic (107.23) variances indicate environmental influence existed in controlling this trait (Table 3). The phenotypic coefficient of variation (22.15) and genotypic coefficient of variation (21.89) was moderate, which indicated presence of low variability among the genotypes (Table 3). Singh *et al.* (2002), Saeed *et al.* (2007) and Joshi *et al*. (2003) supported the findings. The heritability estimates for this trait was high (97.65%), genetic advance (20.83%) and genetic advance in percent of mean (44.56%) were found high, revealed that this character was governed by additive gene and selection for this character would be effective (Table 3). This character showed high heritability coupled with high genetic gain which is supported by Ara *et al.* (2009) and Saeed *et al.* (2007).

4.1.10 Fruit yield per plant (g)

The highest fruit yield per plant was found 178.73 g in G_2 and the lowest was recorded 32.70 g in G_6 with mean value 628.01 g (Table 2). The phenotypic variance (2128.60) found higher than genotypic variance (2026.10) (Table 4), suggested considerable influence of environment on the expression of the genes controlling this character. The phenotypic coefficient of variation and genotype coefficient of variation were 44.08 and 43.00, respectively for fruit yield per plant, which indicating that significant variation exists among different genotypes which made the trait effective for selection (Table 3). Similar findings supported by Singh *et al.* (2006) and Manivannan *et al.* (2005). Estimation of high heritability (95.18%) for fruit yield per plant with high genetic advance (90.47%) and genetic advance at % mean (86.43%) (Table 3) revealed that this character was governed by additive gene and provides opportunity for selecting high valued genotypes for breeding programme. High heritability and high genetic advance was also observed by Ara *et al.* (2009) and Anupam *et al.* (2002).

4.1.11 Fruit yield per plot (g)

The highest fruit yield per plot was found 1072.38 g in G2 and the lowest was recorded 196.20 g in G6 with mean value 628.01 g (Table 2). The phenotypic variance (76626.87) found higher than the genotypic variance (72939.22) (Table 3), suggested considerable influence of environment on the expression of the genes controlling this character. The phenotypic coefficient of variation and genotype coefficient of variation were 44.08 and 43.00, respectively for fruit yield per plot, which indicating that significant variation exists among different genotypes which made the trait effective for selection (Table 3). High heritability (95.19%) was found in yield/plot of fruit attached with high genetic advance (542.79) and high genetic advance in percentage of mean (86.43). 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. Jogi *et al*. (2015) also reported the high estimates of heritability for total yield (91.37%). Similar results also reported earlier by Amit *et al*. (2014) and Chattopadhyay *et al*. (2011).

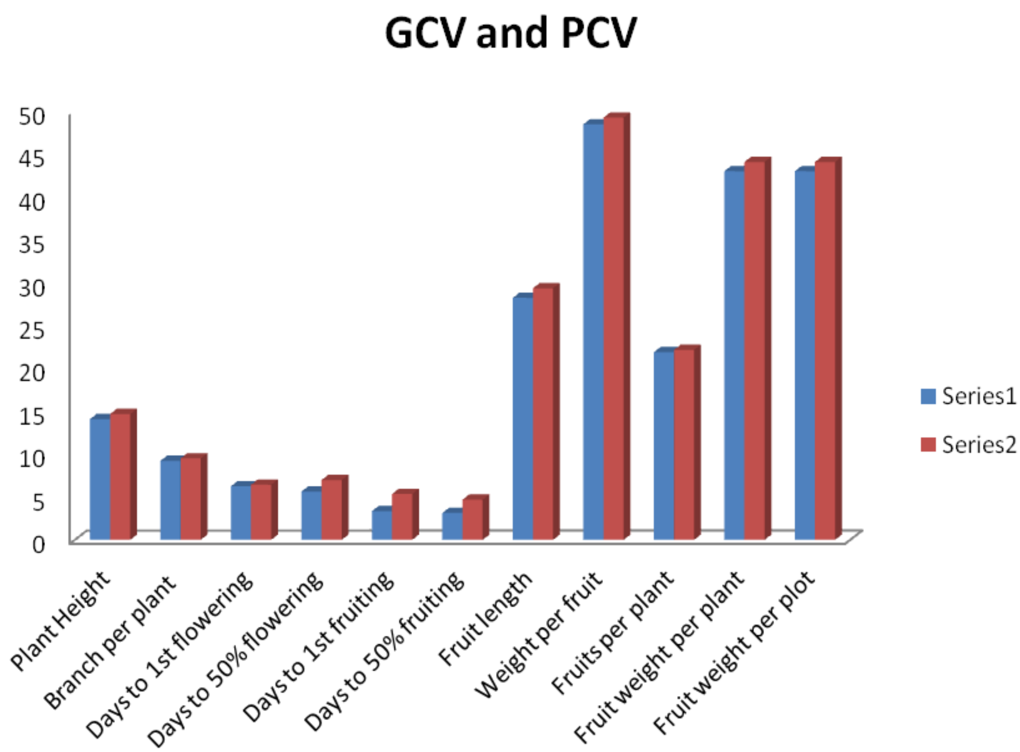
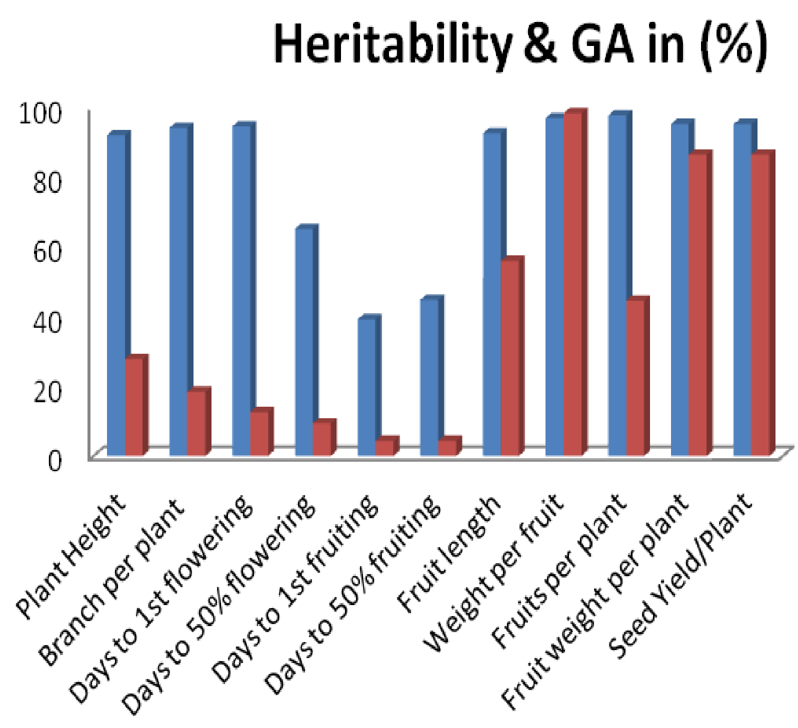


Figure 1: Comparison between GCV and PCV



4.2 C

Figure 2. Comparison between heritability and genetic advance in

Correlation studies along with path analysis provide a better understanding of the association of different characters with fruit yield. Simple correlation was partitioned into phenotypic (that can be directly observed), genotypic (inherent association between characters) components as suggested by (Singh and Chaudhary, 1985). As we know yield is a complex product being influence by several inter-dependable quantitative characters. So selection may not be effective unless the other contributing components influence the yield directly or indirectly. When selection pressure is applied for improvement of any character highly associated with yield, it simultaneously affects a number of other correlated characters. Hence knowledge regarding association of character with yield and among themselves provides guideline to the plant breeders for making improvement through selection with a clear understanding about the contribution in respect of establishing the association by genetic and non-genetic factors (Dewey and Lu 1959). Genotypic and phenotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotype of chilli are given in Table 4 and Table 5.

4.2.1 Plant height

Plant height had significant positive correlation with days to 1^{st} fruiting (0.578) at genotypic level and non-significant positive correlation (0.461) at phenotypic level. Days to 1^{st} flowering (0.363 and 0.353), days to 50% flowering (0.107 and 0.102), days to 50% fruiting (0.339 and 0.277) showed non-significant positive association with plant height at both genotypic and phenotypic level (Table 4 and Table 5) which is supported by Mohanty (2003). Plant height had also non-significant negative correlation with number of branch per plant, fruit length, single fruit weight, number of fruits per plant, fruit yield per plant and fruit yield per plot at both levels (Table 4 and Table 5).

Table 4. Genotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotype of chilli

	PH	BP	1st F	50% F	1st Fr	50% Fr	FL	WF	FP	FWP	FWPL
PH		-0.165	0.363	0.107	0.578*	0.339	-0.498	-0.201	-0.231	-0.414	-0.414
BP			-0.072	0.090	0.187	0.029	0.711**	0.319	0.679**	0.845**	0.845**
1st F				0.860	1.000**	0.817**	-0.183	-0.422	0.180	-0.284	-0.284
50% F					0.872**	0.729**	-0.134	-0.785**	0.637*	-0.203	-0.203
1st Fr						0.950**	-0.102	-0.563*	0.484	-0.218	-0.218
50% Fr							-0.074	-0.458	0.449	-0.161	-0.161
FL								0.592*	0.371	0.847**	0.847**
FW									-0.332	0.656**	0.656**
FP										0.440	0.440
FWP											1.000**

* = Significant at 5%, ** = Significant at 1%

PH- Plant height (cm), **BP**- No. of branches/plant,, **1st F** - Days to 1st flowering, **50% F**- Days to 50% flowering, **1st Fr**- Days to 1st fruiting, **50% Fr**-Days to 50% fruiting **FL**- fruit length (cm), **FW**- Single Fruit weight (g), **FP**-No. of fruits/plant, **FWP**= Fruit Weight per plant, **FWPL**- Fruit weight per plot.

Table 5. Phenotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotype of chilli

	PH	BP	1st F	50% F	1st Fr	50% Fr	FL	WF	FP	FWP	FWPL
PH		-0.1607	0.353	0.102	0.461	0.277	-0.481	-0.194	-0.224	-0.398	-0.398
BP			-0.072	0.094	0.139	0.035	0.698**	0.315	0.667**	0.831**	0.831**
1st F				0.801**	0.877**	0.705**	-0.179	-0.415	0.175	-0.280	-0.280
50% F					0.806**	0.692**	-0.114	-0.709**	0.577*	-0.18	-0.18
1st Fr						0.870**	-0.071	-0.454	0.375	-0.181	-0.181
50% Fr							-0.053	-0.391	0.365	-0.153	-0.153
FL								0.581*	0.361	0.827**	0.827**
FW									-0.330	0.659**	0.659**
FP										0.436	0.436
FWP											1**

* = Significant at 5%, ** = Significant at 1%

PH- Plant height (cm), **BP**- No. of branches/plant,, **1st F** - Days to 1st flowering, **50% F**- Days to 50% flowering, **1st Fr**- Days to 1st fruiting, **50% Fr**-Days to 50% fruiting **FL**- fruit length (cm), **FW**- Single Fruit weight (g), **FP**-No. of fruits/plant, **FWP**= Fruit Weight per plant, **FWPL**- Fruit weight per plot.

4.2.2 Number of branches per plant

The number of branches per plant had positive and strong significant correlation with fruit length (0.711 and 0.698), number of fruits per plant (0.679 0.667), fruit yield per plant (0.845 and 0.831), fruit yield per plot (0.845 and 0.831) at both genotypic and phenotypic levels (Table 4 and Table 5). Monamodi *et al*. (2013) found more branch number in a plant will produce more fruits. But a negative correlation between the number of branches per plant and number of fruits per plant was noticed by Singh *et al*. (2005). It had non-significant positive correlation with days to 50% flowering (0.090 and 0.094), days to 1st fruiting (0.187 and 0.139), days to 50% fruiting (0.029 0.035), single fruit weight (0.319 and 0.315) at both levels. Days to 1st flowering showed non-significant negative relation for number of branch per plant (-0.072 and -0.0722) at both levels indicated that the association between this trait is largely influenced by environmental factors. A positive correlation between yield of fruits per plant and number of branches per plant was observed by Ara *et al*. (2009) and Singh *et al*. (2006)

4.2.3 Days to first flowering

Days to first flowering had highly significant positive correlation with 1st fruiting (1.000), 50 % fruiting (0.817) at genotypic and phenotypic level (Table 5) and 50% flowering (0.8015) only phenotypic level. Patil and Bojappa (1993), Mayavel *et al.* (2005) and Samadia *et al.* (2006) observed positive correlation which supports the present findings. This character also showed non-significant positive association at genotypic levels with 50% flowering (0.860) and fruits per plant (0.180) and phenotypic level only fruits per plant (0.1752). This trait had non-significant negative correlation at both levels for fruit length, single fruit weight, fruit weight per plant and fruit weight per plot.

4.2.4 Days to 50% flowering

Days to 50% flowering showed non-significant negative association at both levels with fruit length (-0.134 and -0.114), fruit weight per plant (-0.203 and -0.18), fruit weight per plot (-0.203 and -0.18) (Table 4 and Table 5). Dhankhar *et al.* (2006) and Samadia *et al.* (2006) observed positive correlation. It showed highly significant positive association with 1st fruiting (0.872 and 0.806) and 50% fruiting (0.729 and 0.692) (Table 5 and Table 6). Days to 50% flowering exhibited strongly significant negative relationship with single fruit weight (-0.785 and -0.709) and significant positive correlation with fruits per plant at genotypic and phenotypic level (Table 4 and Table 5). Yield improvement can be achieved by selection for days to 50% flowering were reported by Wright *et al*. (2007).

4.2.5 Days to 1st fruiting

Days to 1st fruiting had highly significant positive correlation with 50% flowering (0.950 and 0.870) and non-significant positive correlation with fruit per plant (0.484 and 0.375) at genotypic and phenotypic levels (Table 4 and Table 5). It had also significant negative association with single fruit weight (-0.563) at genotypic level and non-significant negative association (-0.454) at phenotypic level (Table 4 and Table 5). Fruit length, fruit weight per plant and fruit weight per plot had non-significant negative association with days to 1st fruiting at both genotypic and phenotypic correlation. A significant and positive correlation observed by Singh *et al.* (2002) and Mohanty (2003) between days to maturity and fruit yield per plant and. This doesn't support the present findings.

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Days to 50% fruiting had non-significant positive correlation with No. of fruits per plant (0.449 and 0.365) and non-significant negative correlation with fruit length, single fruit weight, fruit yield per plant and fruit yield per plot at both genotypic and phenotypic level. In this case no highly positive or negative correlation was found (Table 4 and Table 5).

4.2.7 Fruit length (cm)

Fruit length showed powerfully significant positively correlation fruit yield per plant (0.847 and 0.827) and fruit yield per plot (0.847 and 0.8275) at both genotypic and phenotypic levels (Table 5 and Table 6). Fruit length (FL) also showed significant positive correlation with single fruit weight (0.592 and 0.581) and non-significant positive correlation with number of fruits per plant (0.371 and 0.361) at both levels. (0.223 and 0.189) (Table 4 and Table 5). There is no negative correlation showed with this parameter.

4.2.8 Single fruit weight (g)

Fruit weight showed highly significant and positive correlation with fruit yield per plant (0.656 and 0.659) and fruit yield per plot (0.656 and 0.659) for both levels (Table 4 and Table 5). Matin *et al*. (2001) found that individual fruit weight had significant positive correlations with yield per plant. Arun *et al*. (2004) and Joshi *et al.* (2004) observed that in case of chilli yield per plant was positively and significantly correlated with average fruit weight. Megha *et al*. (2006) also found similar results for this trait in chilli. It had non-significant negative effect (-0.332 and -0.330) at both levels for number of fruits per plant. Matin *et al*. (2001) found significant negative correlations between number fruits per plant and individual fruit weight.

4.2.9 Number of fruits per plant

The number of fruits per plant had non-significant and positive association with fruit yield per plant (0.440 and 0.436) and fruit yield per plot (0.440 and 0.436) at genotypic and phenotypic levels respectively (Table 4 and Table 5). Rani *et al.* (2010) reported that the number of fruits per plant was negatively associated with yield per plant.

4.2.10 Fruit yield per plant

In general, fruit yield is the main target of improvement breeding. Thereby its correlation study is utmost important. From Table 4 and 5 it is observed that, fruit yield per plant (FYP) was strongly and positively correlated with fruit weight per plot at both genotypic and phenotypic level (1.000 and 1.000), significant at 1% level of significance. Rani *et al*. (2010) conducted an experiment with chilli and found average fruit weight was positively and significantly associated with fruit yield per plant. Findings' of Weber *et al.* (2010) also evidenced the positive and strong association between FYP and AFW. Singh and Cheema (2006) reported positive indirect effects through AFW mainly contributed towards its strong association with yield. This study also revealed positive and significant correlation between FYP and fruit length (FL) and fruit diameter (FD) at genotypic level (0.105 and 0.110 respectively). Strong association between FYP and FD and FL were reported earlier (Susic. 2002).

Inconsistently, number of fruits per plant (FPP) manifested strong positive association with fruit yield per plant (FYP) in several earlier investigations (Kumar *et al*., 2004; Kumar *et al*., 2003 and Singh *et al*., 2004). Dhankar and Dhankar (2006) reported number of fruit per plant had the highest direct effect on yield per plant. But, in more recent study, Rani *et al*. (2010) investigated negative association between numbers of fruit per plant with fruit yield. It is assumed that, less fruit number enabled high single fruit weight and thereby high positive correlation between single fruit weight and fruit yield per plant had already been established in the present study.

4.3 Path coefficient analysis

The direct and indirect effects of yield contributing characters on yield were worked out by using path analysis. Here fruit weight per plant was considered as effect (dependent variable) and plant height (cm), branches per plant, days of first flowering, days 50% flowering, days to first fruiting, days to 50% fruiting, fruit length (cm), fruits per plant, single fruit weight (g) were treated as independent variables. Path coefficient analysis was showed direct and indirect effects of different characters on yield of chilli in Table 6.

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Table 6. Path coefficient analysis showing direct and indirect effects of different characters on yield of chilli

Characters	Direct effect	Indirect effect										Genotypic correlation with yield
		PH	BP	1st F	50% F	1st Fr	50% Fr	FL	WF	FP	FWP	
PH	**-0.035**		-0.002	-0.036	-0.057	-0.074	-0.039	-0.042	-0.043	-0.045	-0.041	-0.414
BP	**0.009**	0.095		0.103	0.112	0.102	0.155	0.105	0.097	0.100	-0.032	0.845**
1st F	**-0.026**	-0.007	0.019		-0.001	0.028	-0.053	-0.001	-0.006	-0.003	-0.235	-0.284
50% F	**-0.011**	-0.056	-0.083	-0.055		-0.050	-0.038	-0.065	-0.054	-0.059	0.266	-0.203
1st Fr	**-0.099**	-0.023	-0.020	-0.016	-0.028		0.032	-0.023	-0.026	-0.027	0.014	-0.218
50% Fr	**0.069**	-0.015	-0.075	-0.004	-0.007	-0.065		-0.009	-0.015	-0.014	-0.025	-0.161
FL	**-0.028**	0.002	0.023	0.005	0.018	0.008	-0.014		0.006	-0.003	0.831**	0.847**
FW	**0.008**	-0.001	0.006	0.000	-0.002	0.002	-0.001	-0.018		0.004	0.659**	0.656**
FP	**-0.013**	0.002	0.017	0.003	0.018	-0.007	-0.006	-0.011	-0.003		0.439	0.440
FWP	**0.999**	0.000	0.011	0.005	0.014	-0.003	-0.001	-0.025	0.005	-0.006		1.000**

Residual effect: 0.439

4.3.1 Plant height

Plant height had negative direct effect (**-0.035**) on yield per plant (Table 6). It had positive indirect effect through BP (0.095), FL (0.002), FP (0.002) and neutral on FWP (0). On the other hand, plant height showed negative indirect effect on yield per plant through 1^{st} F (-0.007), 50%F (-0.056), 1^{st} Fr (-0.023), 50% Fr (-0.015) and WF (-0.001) (Table 7). Matin *et al*. (2001) reported that plant height had negative direct effect on yield per plant.

4.3.2 Number of branches per plant

Number of branches per plant had positive direct effect on yield per plant (0.009) and it had also highly significant positive correlation with yield per plant (0.845). This trait had positive indirect effect on 1^{st} F (0.019), FL (0.023), WF (0.006), FP (0.017), FWP (0.011). On the other hand, negative indirect effect was found on PH (-0.002), 50%F (-0.083), 1^{ST} Fr (-0.020), 50%Fr (-0.075) (Table 6). Singh *et al.* (2005) also reported that number of branches per plant had direct negative effects on yield which is not supported by present findings. This disagreement with present findings might be due to environmental variation.

4.3.3 Days to first flowering

Days to first flowering had negative direct effect on fruit weight per plant (**-**0.026) which is contributed to result non-significant negative genotypic correlation with yield per plant (-0.284). Matin *et al*. (2001) reported dissimilar result with the present study and they stated that days to first flowering had negative direct effect on fruit weight per plant. It had positive indirect effect on BP (0.103), FL (0.005), FP (0.003) and FWP (0.005). Negative indirect effect was also found on PH (-0.036), 50%F (-0.055), 1^{st} Fr (-0.016), 50%Fr (-0.004) (Table 6).

4.3.4 Days to 50% flowering

Days to 50% flowering had negative direct effect (**-0.011**) on fruit weight per plant. Days to 50% flowering had positive indirect effect on number of BP

(0.112), FL (0.018), FP (0.018), FWP (0.014). But it had negative indirect effect on, PH (-0.057), 1st F(-0.001), 1 st Fr (-0.028), 50% Fr (-0.007) , WF (-0.002) (Table 7), Singh *et al.* (2004) showed that days to 50% flowering had high positive direct effect on yield, which is supported by present findings.

4.3.5 Days to 1st fruiting

Days to maturity had negative direct effect on yield per plant (-0.099) and it had also significant negative correlation with yield per plant -0.218) at genotypic level. Singh *et al.* (2005) also reported that days to maturity had high negative direct effects on yield in tomato. Days to maturity had positive indirect effect on BP (0.102), 1st F (0.028), FL (0.008) and WF (0.002). This trait had also negative indirect effect on PH (-0.074), 50% Fr (-0.065), FP (-0.007), FWP (-0.003) (Table 6).

4.3.6 Days to 50% fruiting

Days to 50% fruiting had positive direct effect (0.069) on yield per plant and non-significant negative correlation with yield per plant (-0.161). It had positive indirect effect on BP (0.155), 1st Fr (0.032). This trait showed negative indirect effect on PH (-0.039), 1st F (-0.053), 50 % FF (-0.038), FL (-0.014), WF (-0.001), FP (-0.006) and FWP (-0.001) (Table 6). Similar findings reported by Singh *et al.* (2005).

4.3.7 Fruit Length

Fruit length showed negative direct effect (**-0.028**) on yield per plant and highly significant positive correlation (0.847) at genotypic level. It also showed positive indirect effects through BP (0.105) (Table 6). It also showed negative indirect effects on PH (-0.042), 1st F (-0.001), 50% F (-0.065), 1st Fr (-0.023), 50% Fr (-0.09), WF (-0.018), FP (-0.011) and FWP (-0.025). Mayavel *et al.* (2005) also reported that number of fruits per cluster had negative direct effects on fruit yield.

4.3.8 Single Fruit weight

Single Fruit weight showed positive direct effect (**0.008**) on yield per plant. It had also highly significant positive correlation with yield per plant (0.656). Number of fruits per plant had positive indirect effects on BP (0.097), FL (0.066), FWP (0.005). It had negative indirect effect on PH (-0.043), 1st F (-0.006), 50% F (-0.054), 1st Fr (-0.026), 50% Fr (-0.015), FP (-0.003) (Table 6). Singh *et al.* (2006) and Kumar *et al.* (2003) also observed fruits per plant had direct positive effects on fruit yield at the genotypic and phenotypic levels. Ara *et al.* (2009) also found similar results for this trait in chilli. This is not supported by present findings. This discrepancy with present findings might be due to environmental variation.

4.3.9 Fruit weight per plant

Path analysis revealed that Fruit weight per plant had direct negative effect (-**0.013**) on yield per plant and nonsignificant positive correlation with yield per plant (0.440). This trait had also indirect positive effect on BP (0.100), WF (0.004). Further, fruit weight showed indirect negative effect on PH (-0.0045), 1st F (-0.003), 50% F (-0.059), 1st Fr (-0.027), 50% Fr (-0.014), FL (-0.003) and FWP (-0.006) (Table 6). Significant genotypic correlation between fruit weight and yield further strengthened their reliability in the process of selection for higher yield. Rani *et al.* (2010), Singh *et al.* (2006) and Manivannan *et al.* (2005) also reported positive direct effects on fruit yield.

4.3.10 Fruit weight per plot

Fruit weight per plot had positive direct effect (**0.999**) on yield per plant. It had also highly significant positive correlation with yield per plant (1.000). This trait had also indirect positive effect on 50%F (0.266), 1st Fr (0.014), FL (0.831)**, WF (0.659)**, FP (0.439). Fruit length showed indirect negative effect on PH (-0.041), BP (-0.032), 1st F (-0.235), 50% Fr (-0.025) (Table 6). Padda *et al.* (2007), Singh *et al.* (2004) revealed that fruit length exhibited positive effect on yield per plant at the genotypic and phenotypic levels.

4.4 Multivariate analyses

The genetic diversity of chilli advanced lines is presented in Table 7 to 11.

4.4.1 Principal component analysis (PCA)

Principal component analysis was carried out with fifteen genotypes of chilli which gives Eigen values of principal component axes of coordination of genotypes with the first axes totally accounted for the variation among the genotypes. First three Eigen values for three principal coordination axes of genotypes accounted for 87% variation (Table 7).

4.4.2 Non-Hierarchical Clustering

Fifteen *Capsicum spp*. genotypes were grouped into three different clusters non-hierarchical clustering (Table 8). These results confirmed the clustering pattern of the genotypes obtained through principal component analysis. Shashikanth *et al.* (2010) reported ten clusters, Mahesha *et al.* (2006) reported nine clusters, Sharma and Verma (2001) reported five clusters in chilli. Cluster I had highest number of eight genotypes followed by cluster III and cluster II constitute by four and three genotypes, respectively (Table 8).

According to the cluster means (Table 9), cluster I had the highest cluster mean value for six characters namely Branches per plant (20.60), Fruit length (6.70 cm), Single fruit weight (3.10 g), Fruits per plant (49.10), Fruit weight per plant (140.70 g), Fruit weight per plot (844.20 g). This indicates that, genotype of cluster I could be used for parent in future hybridization program for Branches per plant, Fruit length, Single fruit weight, Fruits per plant, Fruit weight per plant, Fruit weight per plot.

Cluster II had high value for Plant height (166.9) Days of first flowering (≈70), Days to 50% flowering (≈93), Days to 1st fruiting (≈83), Days to 50% fruiting (≈110).

Table 7. Eigen values and yield percent contribution of chilli

Components	Eigen values	Percent variation	Cumulative % of Percent variation
I	4.82	44	44
II	3.57	32	76
III	1.18	11	87
IV	0.69	6	93
V	0.34	3	96
VI	0.20	2	98
VII	0.09	1	99
VIII	0.07	1	100
IX	0.02	0	100
X	0.01	0	100
XI	0.00	0	100

Table 8. Distribution of fifteen genotypes in different clusters

Cluster	Number of population	Genotypes	Name/Acc No.
I	8	G1, G2, G3, G7, G9, G10, G13 and G15	DEB 1302, Bogra Zhal Morich, Bogra Special Morich, SRCO 7, SRCO 9, SRCO 10, AC542, and Dark Green Papper
II	3	G4, G6 and G11	Black Lady, SRCO 4 and SRCO 14
III	4	G5, G8, G12 and G14	CO 525, SRCO 3, CO 611 and AC 578

Table 9. Cluster mean values of 11different characters of 15 genotypes

Parameters	**I**	**II**	**III**
Plant Height	138.4	166.9	146.8
Branch per plant	20.6	18.1	18.9
Days to 1st flowering	66.9	70.3	69
Days to 50% flowering	88.9	92.7	92
Days to 1st fruiting	80.1	82.7	82
Days to 50% fruiting	107.7	110.3	108.5
Fruit length	6.7	3.4	5.7
Weight per fruit	3.1	1.1	1.7
Fruits per plant	49.1	42.3	45.3
Fruit weight per plant	140.7	45.5	77
Fruit weight per plot	844.2	272.8	462

4.4.3 Canonical variate analysis

Canonical Variate Analysis (CVA) was done to compute the inter-cluster distances. The scatter distribution of 15 chilli genotypes based on their principal component score superimposed with cluster is presented in Figure 3. The intra and inter-cluster distance (D^2) values were shown in Figure 4. In this experiment, the inter-cluster distances were higher than the intra-cluster distances thus indicating broader genetic diversity among the genotypes of different groups. Islam and Islam (2000) reported that the inter-cluster distances were larger than the intra-cluster distances.

The highest inter-cluster distance was observed between clusters I and II (11.862), followed by between clusters I and III (9.091), II and III (3.796) (Figure 4). However, the maximum inter-cluster distance was observed between the clusters I and II (11.862) indicating genotypes from these two clusters, if involved in hybridization may produce a wide spectrum of segregating population. On the other hand, the maximum intra-cluster distance was found in cluster II (0.752), which contained of 3 genotypes, while the minimum distance was found in cluster III (0.496) that comprises 4 genotypes. Cluster I consist of nearest cluster with D^2 values cluster III (9.091) and farthest cluster with D^2 values II (11.862) (Table 10). Cluster II consists of nearest cluster with D^2 values cluster III (3.796) and farthest cluster with D^2 values I (11.862). Cluster III consists of nearest cluster with D^2 values cluster II (3.796) and farthest cluster with D^2 values I (9.091) (Table 10).

Principal coordination analysis (PCO) indicated that the maximum inters genotypic distance between genotype G2 and G6 (2.7178), the minimum distance was showed between genotype G13 and genotype G10 (.1989) (Table 11).

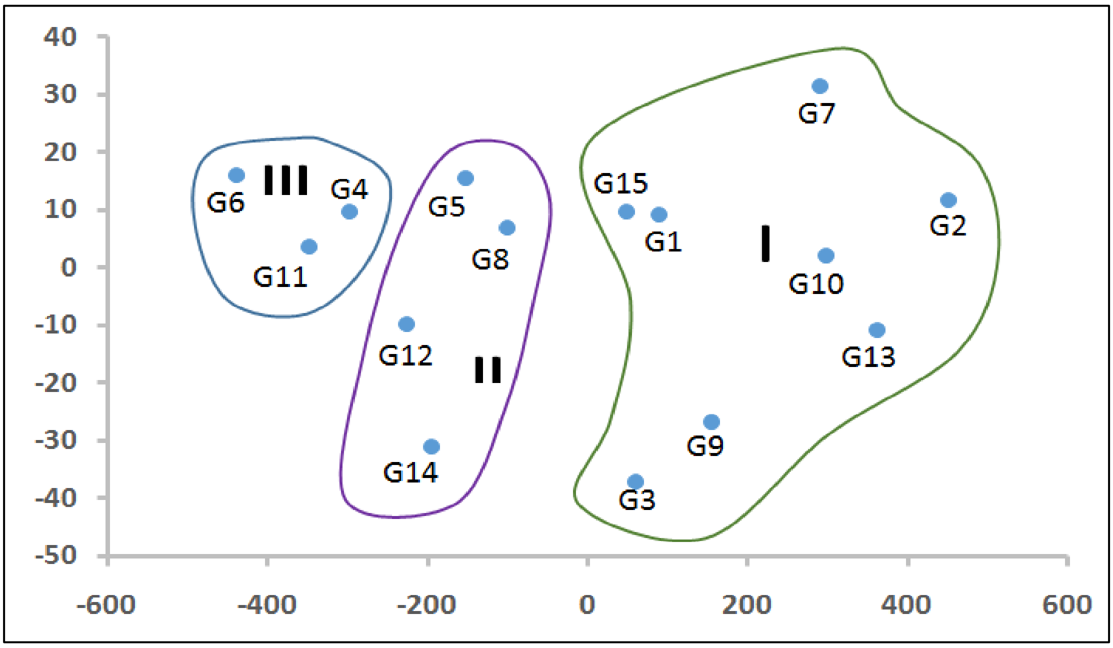


Figure 3. Scatter distribution of 15 chilli genotypes based on their principal component score superimposed with cluster

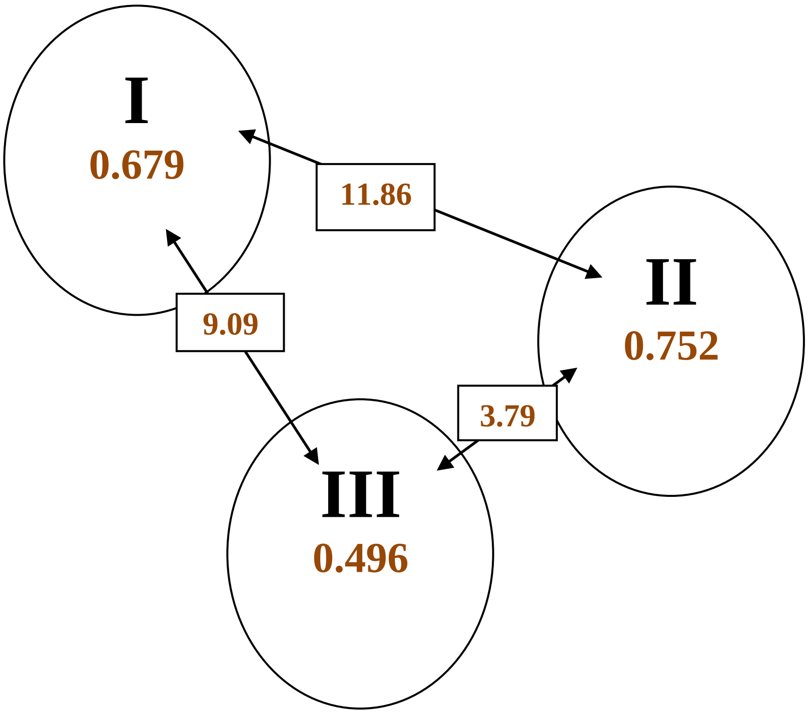


Figure 4. Intra and inter cluster distance between different clusters

Table 10. Nearest and farthest cluster

Cluster	Nearest with D^2 values	Farthest with D^2 values
I	III(9.091)	II (11.862)
II	III (3.796)	I (11.862)
III	II (3.796)	I (9.091)

Table 11. Ten highest and lowest inter and genotypic distances

10 highest inter genotypic distances				**10 lowest inter genotypic distances**			
Sl	Genotypes	Genotypes	Values	Sl	Genotypes	Genotypes	Values
1	G6	G2	2.7178	1	G13	G10	0.1989
2	G13	G6	2.5896	2	G10	G7	0.2116
3	G10	G6	2.4621	3	G9	G3	0.2849
4	G7	G6	2.4339	4	G13	G2	0.312
5	G15	G6	2.3979	5	G13	G7	0.3411
6	G9	G6	2.2074	6	G3	G1	0.3693
7	G11	G2	2.1664	7	G8	G5	0.4058
8	G13	G11	2.0404	8	G9	G1	0.4076
9	G6	G3	1.9907	9	G7	G2	0.4098
10	G6	G1	1.9828	10	G10	G2	0.4172

CHAPTER V
SUMMARY AND CONCLUSION

The present study was undertaken at the Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh with fifteen genotypes of chili (*Capsicum spp.*) during November 2015 to April 2016. Seeds were sown in seed bed then transferred to the main field in Randomized Complete Block Design (RCBD) with three replications. Data on various yield attributing characters such as plant height (cm), number of branch per plant, days to first flowering, days to 50% flowering, days to first fruiting, days to 50% fruiting, fruit length (cm), fruit weight (g), number of fruit per plant, fruit weight per plant (g), fruit weight per plot (g). Analysis of variance revealed significant differences among all the genotypes for all the characters under study.

The analysis of variances showed significant mean squares for different characters indicated the presence of sufficient variation among the genotypes for all the characters. The number of fruit weight per plant showed highest range of variation (178.73-32.70) that means wide range of variation present for this character.

In case of branch per plant, days to 1st flowering, fruit length, fruit weight per plant, number of fruit per plant showed higher influence of environment for the expression of these characters. On the other hand plant height, branch per plant, days to 1st flowering, fruit length, weight per fruit, fruit per plant, fruit weight per plant, fruit weight per plot showed least difference in phenotypic and genotypic variance suggesting additive gene action for the expression of the characters. All the characters under the present study exhibit the highest value of heritability.

Correlation coefficients among the characters were studied to define the association between yield and yield components. In general, most of the characters showed the genotypic correlation co-efficient were higher than the corresponding phenotypic correlation co-efficient suggesting a strong inherent association between the characters under study. The highly significant positive correlation with seed yield per plant was found in branch per plant, fruit length, fruit weight at genotypic and phenotypic level. In addition, there were non-significant positive correlation with fruit yield per plot was also found in number of fruits per plant at genotypic and phenotypic level, respectively. On the other hand, the non-significant negative correlation with yield per plot was also found in plant height, days to 1st flowering, days to 50% flowering, days to 1st fruiting, days to 50% fruiting at genotypic and phenotypic level, respectively.

Path coefficient analysis showed that branch per plant had the positive correlation with fruit yield per plot. Coherently, this trait contributes to the yield through direct effect (0.009) indicating selection will be judicious and more effective for these characters in future breeding program. It was also showed that fruit weight per plant had the highest positive correlation (1.000) with fruit yield per plot and this trait contributes to the yield through direct effect (0.999) indicating selection will be judicious and more effective for these characters in future breeding program. Plant height, days to 1st flowering, days to 50% flowering, days to 1st fruiting, fruit length, number of fruits per plant had negative direct effect with fruit yield per plant. Plant height had a high negative correlation to fruit yield per plot as (-0.414). Fruit weight per plant had positive direct effect on yield (0.999) and it had a positive correlation to fruit length as (0.847). Positive indirect effect was also found in 50% flowering, 1st Fruting.

Genetic diversity among chilli genotypes was performed through Principal Component Analysis (PCA), Cluster Analysis, Canonical Variate Analysis (CVA) using GENSTAT computer program. The first three principal component axes accounted for 87% variation towards the divergence. Among three clusters, cluster I contained maximum number of genotypes (8) while cluster II had only three genotypes. According to PCA, D^2 and cluster analysis, the genotypes grouped into three divergent clusters obtained from principal component scores. The highest inter-cluster distance was observed between clusters I and II (11.86) indicating genotypes from these two clusters, if involved in hybridization may produce a wide spectrum of segregating population while the lowest inter-cluster distance was observed between cluster II and III (3.796). On the other hand, the maximum intra-cluster distance was found in cluster II (0.752), which contained of 3 genotypes, whereas the minimum distance was found in cluster III (0.496) that comprises 4 genotypes. Therefore, crossing between the genotypes belonging cluster I with cluster II, cluster II with cluster III, might produce high heterosis in respect of yield, single fruit weight and higher number of fruit per plant. Also the crosses between genotypes from cluster I with cluster III might produce high level of segregating population. So the genotypes belonging to cluster I and cluster II, cluster II and cluster III, cluster I and cluster III selected for future hybridization program. Considering the magnitude of cluster mean and agronomic performance the genotype G_2 for maximum branches per plant, fruit length, fruits per plant, fruit weight per plant, fruit weight per plot, G_{10} for days to 1st flowering, days to 50% flowering, days to 1st fruiting were found promising. Therefore, considering group distance and other agronomic performance the inter-genotypic crosses between G_4, G_7, and G_{15} and also other improved variety and/or high yielding variety might be suggested for future hybridization program.

From the findings of the present study, the following conclusions could be drawn:

i. Technique of selection would be applied for desired characters such as lowest days to first flowering, increase number of fruits per plant, fruit length, fruit weight, fruit weight per plant and fruit weight per plot to develop high yielding varieties.

ii. Considering group distance and other agronomic performance the inter-genotypic crosses between G4, G11, G6, G10 and G15 might be suggested for future hybridization program.

iii. G2, G7, G9, G10 and G13 genotypes could be recommended to the farmers for getting higher yield.

REFERENCES

Abdullah, M.H., Qasim, U. and Nawab, N.N. (2006). Variability and path-coefficient analysis in chilli (*Capsicum annuum* L). *Intl. J. Agril. Sci*. **2**(1): 90-92.

Abu, N.E. and Uguru, M.I. (2006). Evaluation of genetic variations in growth and yield components of aromatic pepper lines in a derived savanna ecology of Nigeria. *Agron. Sci*. **5**(1): 1-7.

Acharya, P., Sengupta, S. and Mukhserjee, S. (2007). Genetic variability in pepper (*Capsicum annuum* L.). *Env. Ecol*. **25**(4): 808-812.

Aditya, P.M. and Phir, K. (1995). Studied on genetic variability in chilli. *Progr. Hort*. **32**(2): 172-182.

Agong, S.G. Schittenhelm, S. and Friedt, W. (2001). Genotypic variation of Kenyan chilli germplasm. *J. Food Technol.* **6**(1): 13-17.

Ahmed, N., Bhat, M.A., Tanki, M.J. and Singh, A.K. (2006). Correlation and path coefficient analysis in paprika (*Capsicum annuum* L.). *Indian J. Hort*. **63**(1): 92-95.

Ajjapplavara, P.S., Patil, S.S., Hosamani, R.M., Patil, A.A. and Gangaprasad, S. (2005). Correlation and path coefficient analysis in chilli. *Karnataka J. Agril. Sci*. **18**(3): 748-751.

Akbar, N., Ahmad, H., Ghafoor, S., Begum, K., Afridi, S.G., Muhammad, I. and Khan, I.A. (2010). Estimation of genetic diversity in *capsicum* germplasm using Randomly Amplified Polymorphic DNA. *Asian J. Agric. Sci.* **2**: 53-56.

Allard, R.W. (1960). Principles of plant breeding. John Willey and Sons, Inc, New York. p. 36.

Amit, K., Ahad, I., Kumar, V. and Thakur, S. (2014). Genetic variability and correlation studies for growth and yield characters in chilli (*Capsicum annuum* L.). *J. Spices Aromatic Crops*. **23**(2): 170-177.

Anupam B., Jain, B.P. and Verma, A.K. (2002), Genetic variability heritability and genetic advance in chilli (*Capsicum annuum*(L.) Karst.). *J. Res. Birsa Agril.Uni.* **14**(2): 249-252.

Anupam P., and Suddhasuchi D. (2016). Response of Chilli (Capsicum annuum L.) to Different Sources and Combination of Nitrogen. *Intl. J.Curr. Microbiol. App. Sci* .**6**(4): 972-976.

Ara, A.R., Narayan, N and Khan, S.H., (2009). Genetic variability and selection parameters for yield and quality attributes in chilli. *Indan. J. Hort*. **66**: 73-78.

Bai, N.R. and Devi, D.S. (1991). Study on genetic parameters in chilli hybrids. *Orissa J. Agric. Res*. **4**: 27-29.

BBS. (2014). Year Book of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning, Govt. of the Peoples Republic of Bangladesh, Dhaka. p. 156.

BBS. (2015). Statistical Pocket Book, Statistics Division, Ministry of Planning, Govt. of the Peoples Republic of Bangladesh, Dhaka. p. 34.

Bello, O.B., Ige, S.A., Azeez, M.A., Afolabi, M.S., Abdulmaliq, S.Y. and Mahamood, J. **(**2014). Heritability and genetic advance for yield and its component character in chilli. *Intl. J. Plant Res.* **2**: 138-145.

Benchaim, A. and Paran, I. (2000). Genetic analysis of quantitative traits in pepper (*Capsicum annuum* L.). *J. American Soc. Hort. Sci*. **125**(1): 66-70.

Bendale, V.W., Palsuledesai, M.R., Bhave, S.G., Sawant, S.S. and Desai, S.S. (2006). Genetic evaluation of some economic traits in chilli. *Crop Res.* **31**: 401-403.

Bhalekar, M.N., Warded, S.D. and Gupta, NS. (2002). Path coefficient analysis in chilli. National Seminar on opportunity and potential of spices for crop diversification held at JNKVV, Jabalpur. pp. 265-266.

Bharadwaj, D.N., Singh, S.K. and Singh, H.L. (2007). Genetic variability an association of component characters for yield in chilli. *Intl. J. Plant Sci.* **2**: 93-96.

Bhattacharya, A., Chattopadhyay, A., Mazumdar, D., Chakravarty, A. and Pal, S. (2010). Antioxidant constituents and enzyme activities in chilli peppers. *Intl. J. Veg. Sci*. **16**(3): 201-211.

Bijalwan, P. and Madhvi, P. (2016). genetic variability, heritability and genetic advance of growth and yield components of Chilli (*Capsicum annuum* L.) Genotypes. *Intl. J. Sci. Res*. **5**(7): 1305-1307.

Burton, G.W. (1952). Quantitative inheritance in grasses. *Proceedings of Proc. 6th Intl. Grassland Cong.* **1**: 277-283.

Chattopadhyay, A., Sharangi, A.B., Dai, N. and Dutta, S. (2011). Diversity of genetic resources and genetic association analysis of green and dry Chillies of Eastern India. *Chilean J. Agric. Res*. **71**(3): 350-356.

Chowdhury, M.S.N., Hoque, F., Mehraj, H. and Jamal Uddin, A.F.M. (2015). Vegetative Growth and Yield Performance of Four Chilli (Capsicum frutescens) Cultivars. *American-Eurasian J. Agric. Env. Sci*. **15**(4): 514-517.

Comstock, R.E. and Robinson, H. F. (1952). Genetic Parameters their estimation and significance. Proc. Of 6th Int. Grassland Cong. **1**:128-291.

Datta, S. and Jana, J.C. (2010). Genetic variability, heritability and correlation in chilli genotypes under Terai zone of West Bengal. *SAARC J. Agric*. **8**(1): 33-45.

Devi, D.S. and Arumugam, R. (1999). Correlation and path coefficient analysis in chilli. *Crop Res. Hisar*. **17**(1): 90-93.

Dewey, D.R. and Lu, K.H. (1959). A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J*. **51**: 515-18.

Dhankar, S.K., Dhankar, B.S. and Sharma, N.K. (2001). Correlation and path analysis in chilli under normal and high temperature conditions. *Haryana J.Hort. Sci*.**30** (1-2): 89-92.

Dhankhar, S.K. and Dhankar, S.S. (2006). Variability, heritability, correlation and path coefficient studies in chilli. *Haryana J. Hort. Sci*. **35** (1-2): 179-181.

Dipendra, G. and Gautam, B.P. (2003). Correlation and path coefficient analysis in chilli (*Capsicum spp*.). *Agril. Sci. Digest.* **23**(3): 162-166.

El-Ghoraba, A.H., Javedb, Q., Anjumb, F.M., Hamedc, S.F. and Shaabana, H.A. (2013). Pakistani bell pepper (*Capsicum annum* L.): Chemical compositions and its antioxidant activity. *Intl. J. Food Prop*. **16**(1):18-32.

FAO. (2010). FAOSTAT Database. Food and Agriculture Organization, Roma, Italy. Available online at URL: www.fao.org

Farooq, M., Ramzan, A., Chattha, M.R., Qasim, U., Nawab, N.N. and Hidyatulllah. (2015)**.** Studies on the performance of sweet pepper (*Capsicum annum* L.) hybrids under plastic tunnel. *J. Sci. Technol. Dev*. **34**(3): 155-157.

Farzaneh, A., Nemati, H., Arouiee, H., Kakhki, A.M. (2013). Genetic analysis of traits associated with yield and earliness in nine chilli (*Capsicum annuum L*) lines using diallel crossing method. *J. Seed Plant. Improv.* **29**(4): 693-710.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research. 2nd Ed. A. John Wiley Inter Sci. Pub. p. 130-240.

Gupta, A.M., Singh, D. and Kumar, A. (2009). Genetic variability, genetic advance and correlation in chilli. *Indian J. Agril. Sci.* **79**: 221-223.

Hari, G.S., Rao, P.V. and Reddy, Y. N. (2005). Evaluation of paprika (*Capsicum annuum*L.) germplasm and its utility in breeding for higher yield and better quality grown under irrigated condition. *Res. Crops*. **6**(2): 266-269.

Hasan R., A.K.M., Hossain, M.K. and Alam, N. (2015). Assessment of genetic divergence in chilli (*Capsium annum* L.) genotypes. *Plant Genet. Trait.* **6**(3): 1-5.

Hasan, M.J., Kulsum, M.U., Ullah, M.Z., Hossain, M.M. and Mahmud, M. E. (2014). Genetic diversity of some chilli (*Capsicum annuum* L.) Genotypes. *Int. J. Agril. Res. Innov. Tech*. **4**(1): 32-35.

He, S., Maurya, S.K. and Nair, R. (2013). Evaluation of chilli genotypes for vegetative and fruit characters under kymore plateau region of madhya pradesh. *An Intl. Quarterly J. Env. Sci*. **6** : 121-125.

Hosmani, R.M. and Nandadevi. (2003). Variability correlation and path analysis in kharif grown chilli genotypes for different characters. *Capsicum and Eggplant Newsletter*. **22**: 43-46

Ibrahim, M., Ganiger, V.M. and Yenjerappa, S.T. (2001). Genetic variability, heritability, genetic advance and correlation studies in chili. *Kamataka J. Agric. Sci.* **14**: 784-787.

Islam, M.S. and Khan, S. (1991). Variability and character association in chilli (*Capsicum annuum*). *Bangladesh J. Plant. Breed.Genet*. **4**(1-2): 49-53.

Islam, P., and Islam, A.K. (2000). Variability studies in chilli (*Capsicum annuum*). *Bangladesh J. Plant. Breed. Genet*. **4**(1-2): 49-53.

Jaisankar I., Singh, S., Goutham, R.K., Velmurugan, A., Singh, A.K., Roy, S.D., Parisa, D. and Soan, S. (2015). Performance of chilli genotypes for green fruit yield in Andaman and Nicobar Islands. *AVT J. Andaman Sci. Assoc.* **20**(1): 39-42.

Janaki, M., Aram, L.N, Naidu, C. Venkata, R. and Paratpara, R. (2015). Assessment of genetic variability, heritability and genetic advance for quantitative traits in chilli (*Capsicum annuum* L.). *The Bioscan*. **10**(2): 729-733.

Jogi, M.Y., Madalageri, M.B. Pujari, R.J. and Mallimar, M.S. (2015). Genetic Variability Studies in Chilli (*Capsicum annuum* L.) for Yield and Quality Attributes. *Indian J. Ecol.* **42**(2): 536-539.

Johnson, H.W., Robinson, H.F. and Comstock, R.E. (1955). Estimation of genetic and environmental variability in soybeans. *Agron. J*. **47**: 314-318.

Joshi, A., Vikram, A. and Thakur, M.C. (2004). Studies on genetic variability, correlation and path analysis for yield and physico- chemical traits in schilli (*Solanum lycopersicum* L.). *Progr. Hort*. **36**(1): 51-58.

Jyothi, S., Kumari, S. and Ramana, C.V. (2011). Variability studies in chilli (*Capsicum annuum* L.) with reference to yield attributes *J. Hort. Sci.* **6**(2): 133-135.

Kadwey, S., Ashwini, D. and Sunil, P. (2016). Genotypes performance and genetic variability studies in Hot Chilli. *Indian J. Agril. Res.* **50**(1): 56-60.

Kannan, D., Singh, D.K., Singh, S.K. and Palanisamy, A. (2016). Genetic variability and agronomic performance studies in chilli *(Capsicum annum* L.*) SAARC J. Agril.* **14**(2): 56-62.

Kaouther, Z., Hamdi, W., Sedraoui, S., Fendri R., Lajimi, O. and Hannachi, C. (2015). A comparative study of morphological characterization of Tunisian accessions of Chilli pepper (*Capsicum frutescens* L.). *IRJET*. **2**(4): 87-94.

Karungi, J., Obua, T., Kyamanywa, S., Mortensen, C.N. and Erbaugh, M. (2013). Seedling protection and field practices for management of insect vectors and viral diseases of hot pepper (*Capsicum chinense* Jacq.) in Uganda. *Intl. J. Pest Manage*. **30**(2): 84-92

Khan, H.A., Ayub, C.M., Pervez, M.A., Bilal, R.M., Shahid, M.A., Ziaf, K. (2009). Effect of seed priming with NaCl on salinity tolerance of hot pepper (*Capsicum annum* L.) at seedling stage. *Environ. Expt. Bot*. **60**: 77-85.

Khodadabi, M., Fotokian, M.H. and Miransari, M. (2011). Genetic diversity of wheat genotypes based on cluster and principal component analyses for breeding strategies. *Australian J. Crop Sci*. **5**(1): 17-24.

Krishna, U., Patil, M.P., Madalageri, M.B., Mulge, R. and Jagadeesha, R.C. (2007). Character association and path analysis studies in green chilli for yield and yield attributes. *Karnataka J. Agril*. *Sci*. **20**(1): 99-101.

Krishna, U.C., Madalageri, M.B., Patil, M.P., Ravindra, M. and Kotlkal, Y.K. (2007). Variability Studies in Green Chilli (*Capsicum annuum* L.). *Karnataka J. Agril. Sci*. **20**: 102-104.

Kumari, N., Srivastava, J.P., Shekhavat, A.K.S., Yadav, J.R. and Singh, B. (2007). Genetic variability and heritability of various traits in chilli (*Capsicum annuum L*). *Progr. Agric***.** **7**(1-2): 80-83.

Kumar, N., Srivastava, J.P., Shekhavat, A.K.S., Yadav, J.R. and Singh, B. (2016). Genetic variability and heritability of various traits in chilli (*Capsicum annuum L*). *Progr. Agric***.** **7**(1-2): 80-83.

Lahbib, K., Bnejdi, F. and Gazzah, E.I. (2012). Genetic diversity evaluation of pepper in Tunisia based on morphologic characters. *African J. Agric. Res*. **7**(23): 3413-3417.

Mahesha, D.K., Apte, Y.B. and Jadhav, B.B. (2006). Studies on genetic divergence in chilli. *Crop Res*. **32**(2): 401-402.

Manivannan, K., Natarajan, J. and Irulappan, I. (2005). Correlation studies in chilli. *South Indian Hort*. **34**: 70-73.

Matin, K., and Kuddus, M. (2001). varietal resistance to bacterial wilt in chilli. *Plant Disease. Rep.***60**: 120-123.

Maurya, A.K., Kushwaha, M.L. and Singh, B.K. (2015). Genetic Studies in Chilli (*Capsicum annuum* L.). *Intl. J. Sci. Tech*. **3**(8): 289-291.

Maurya, A.K., Kushwaha, M.L., Jain, V.K. and Singh, N. (2016). Evaluation of chilli (*Capsicum annuum* L.) genotypes for yield and performance against diseases. *Prog. Res. Intl. J*. **11**(7): 4615-4617.

Maurya, A.K., Kushwaha, M.L., Maurya, S.K. and Ankit, P. (2016). Estimation of *Per se* performace of chilli (*Capsicum annuum* L.) genotypes for yield and quality traits. *J. Pharma. Phytoche*. **6**(1): 333-335.

Mayavel, A., Balakrishnamurthy, G. and Natarajan, S. (2005). Variability and heritability studies in chilli hybrids. *South Indian Hort*. **53**(1-6): 262-266.

Megha, U., Singh, J.P., Singh, A. and Joshi, A. (2006). Studies on genetic variability in chilli. *Progr. Hort*. **3**(2): 463- 465.

Mishra, R.S. and Sahu, G.S. (2001). Genetic divergence in chilli. *Mysore J. Agric. Sci.* **29**: 5-8.

Mohanty, B.K. (2003). Genetic variability, correlation and path coefficient studies in chilli. *Indian J. Agril. Res*. **37**(1): 68-71.

Mohanty, B.K. and Prusti, A.M. (2005). Assessment of chilli varieties in western undulating zone of Orissa. *Indian J. Agril. Res.* **39**: 76-78.

Monamodi, E.L., Lungu, D.M. and Fite, G.L. (2013). Analysis of fruit yield and its components in determinate chilli using correlation and path coefficient. *Bots. J. Agric. Appl. Sci*. **9**(1): 29-40.

Munshi, A.D., Behra, T.K. and Singh, G. (2000). Correlation and path coefficient analysis in chilli. *Bangladesh J. Hort*. **57**(2): 157-159.

Nalla, M.K., Rana, M.K., Singh, S.J., Sinha, A.K., Reddy, P.K. and Mohapatra, P.P. (2014). Assessment of genetic diversity through D^2 analysis in chilli *Intl. J. Innovation and App. Studies*. **6**(3) 431-438.

Narolia, R.K., Reddy, R.V., Sujatha, M. (2012). Genetic architecture of yield and quality in chilli. *Agric. Sci. Digest*. **32**(4): 281-285.

Naz, S., Zafrullah, A., Shahzadhi, K. and Munir, N. (2013). Assessment of genetic diversity within germplasm accessions in chilli using morphological and molecular markers. *J. Animal Plant Sci.* **23**(4):1099-1106.

Nsabiyera, V., Logose, M., Ochwo-Ssemakula, M., Sseruwagi, P., Gibson, P., Ojiewo, C.O. (2013). Morphological Characterization of Local and Exotic Hot Pepper (*Capsicum annuum* L.) Collections in Uganda. *Bioremediation, Biodiversity Bioavailability*. **7**(1): 22-32.

Osuna-García, J.A., Wall, M.W. and Waddell, C.A. (1998). Endogenous levels of tocopherols and ascorbic acid during fruits ripening of New Mexican-type chilli *(Capsicum annuum L.)* cultivars. *J. Agril Food Chem.* **46**(12): 5093-5096.

Padda, D.S., Saibhi, M.S. and Singh, S. (2007). Genotypic and phenotypic variabilities and correlations in quality characters of chilli. *Indian J. Agric. Sci*. **41**: 199-202.

Pandit, A., Rai, V. and Bal, S. (2010). Combining QTL mapping and transcriptome profiling of bulked RILs for identification of functional polymorphism for salt tolerance genes in rice (*Oryza sativa* L.). *Mol. Genet. Genomics.* **284**:121-36.

Pandit, M.K., Muthukumar, P. and Mukhopadhyay, T.P. (2009). Genetic variability, character association and path analysis in chilli (*Capsicum annuum* L.) genotypes. ICH p. 41.

Parkash, C. (2012). Estimation of genetic variability and implications of direct effects of different traits on leaf yield in bathua (*Chenopodium album*). *Indian J. Agril. Sci*. **82**: 71-74.

Patil, A.A. and Bojappa, K.M. (1993). Studies on phenotypic and genotypic correlation on growth yield and quality attributes in chilli (*Capsicum annuum L*). Karnataka *J. Agric. Sci*. **6**:133-136

Poehlman, J.M. and Sleper, D.A. (1995). Field Crops. *Iowa State University Press*, United States of America.

Prashanth, S.J. (2003). Genetic variability and divergence study in chilli (*Capsicum annuum* Mill). M. Sc. (Agric.). Thesis, UAS, Dhanwad, India.

Quresh, W., Alam, M., Ullah, H., Ahmad, H., Jatoi and Khan, W.U. (2015). Evaluation and characterization of Chilli (*Capsicum annuum* L.) germplasm for some morphological and yield characters. *Pure Appl. Biol.* **4**(4): 628-635.

Raika, P. (2005). Variability, heritability and genetic advance in chilli (*Capsicum spp.*). *Agril. Sci. Digest*. **22**(2): 107-110.

Rani, C.I., Muthuvel, I., Veer, D. (2010). Correlation and path coefficient for yield components and quality traits in chilli (*Capsicum annuum L*). *Agric. Sci. Digest*. **30**(1): 11-14.

Rani, P.U. (1996). Fruit seed weight and seed attributes on the quality characteristics in chilli. *Madras Agric. J*. **83**: 259-264

Rathod, R.P., Deshmukh, D.T., Ghode, P.B. and Gonge, V.S. (2002). Correlation and path analysis studies in chilli (*Capsicum annuum* L.). *Haryana J. Hort. Sci*. **31**(1-2): 141-143.

Ravindra, M., Aravinda, S. and Kumar, J.S. (2003). Stability, analysis for growth and earliness in chilli. *Indian. J. Hort*. **60**(4): 353-356.

Rosmaina, S., Hasrol, F. Yanti, J. and Zulfahmi. (2016). Estimation of variability, heritability and genetic advance among local chili pepper genotypes cultivated in peat lands. *Bulgarian J. Agril. Sci.* **22**(3): 431-436.

Saeed, A., Hayat, K., Khan, A.A., Iqbal, S. and Abbas, G. (2007). Assessment of genetic variability and heritability in *Capsicum annuum L. Intl. J. Agric. Biol*. **9** (2): 375-377.

Samadia, D.K., Aswani, R.C. and Dhandar, G. (2006). Genetic analysis for yield components in chilli land races. *Haryana J. Hort. Sci*. **35**(1-2): 116-119.

Sarkar, S., Murmu, D., Chattopadhyay, A. and Hazra, P. (2009). Genetic variability, correlation and path analysis of some morphological characters in chilli. *J. Crop Weed*. **5**(1): 157-161.

Segnou, J., Amougou, A., Youmbi, E. and Njoya, J. (2013). Effect of Chemical Treatments on Pests and Diseases of Pepper (*Capsicum annuum* L.). *Greener J. Agril. Sci*. **3**(1): 12-20.

Sharma, K.C. And Verma, S. (2001). Analysis of genetic divergence in chilli. *Annals Agric. Res.* **22**(1): 71-73.

Shashikanth, P., Das, K. and Mulal, K. (2010). Studies on chilli leaf curl virus. *Indian. J. Virol*. **15**: 115-117.

Shirshat, S.S., Giritammannavar, V.A. and Patil, S.J. (2007). Analysis of Genetic Variability for Quantitative Traits in Chilli. *Karnataka J. Agric. Sci.* **20**(1): 29-32.

Singh, H. and Cheema, D.S. (2006). Correlation and path coefficient studies in chilli (*Capsicum annuum L*). *Haryana J. Hort. Sci*. **35**(1-2): 126-129.

Singh, J.K., Singh, J.P., Jain, S.K., Joshi, A. and Joshi, K. (2002). Studies on genetic variability and its importance in chilli. *Progr. Hort*. **34**(1): 77-79.

Singh, J.P., Singh, A. and Joshi, A. (2005). Studies on genetic variability in chilli (*Capsicum annuum L*). *Prog. Hort*. **37**(2): 463-465.

Singh, M.D. and Singh. M.G. (2004). Correlation and path analysis studies in selected local chillies (*Capsicum annuum* L.). *Env. Ecol*. **22**(4): 672-675.

Singh, P.K., Singh, B. and Pandey, S. (2006). Genetic variability and character association analysis in chilli. *Indian. J. Plant Genet. Res.* **19**(2): 180-183.

Singh, R.K. and Chaudhury, B.D. (1985). Biometrical method in quantitative genetics analysis. Kalyain Publishers, New Delhi, India. p. 78-85.

Sreelathakumary, I. and Rajamony, L. (2004). Variability, heritability and genetic advance in chilli (*Capsicum annuum* L.). *J. Trop. Agric*. **42**(1-2): 35-37.

Srinivas, B., Thomas, B., Gogineni, S. (2013). Genetic Divergence for Yield and its Component Traits in Chilli (*Capsicum frutescens*L) Accecessions of Kerala. *Intl. J. Sci. Res*. **6**(14): 442-446.

Susic, Z., Pavlovic, N., Cvikic, D. and Rajicic, S.T. (2002). Studies of correlation between yield and fruit characteristics of (*Capsicum annuum L*) hybrids and their parental genotypes. *Acta Hort*. **579**: 163-166.

Syukur, M., Sujiprihati, S. and Yunianti, R. (2012). Estimation of genetic parameter for quantitative characters of pepper (*Capsicum annuum* L.). *J. Trop. Crop Sci*. **1**: 4-8

Tairu, F.M., Olufolaji, A.O., Abdul, R.M.A. and Kouame, C. (2013). Comparative study on the performance of some exotic chilli pepper accessions in ibadan, southwestern Nigeria. *Acta Hort*. **1007**: 29-35.

Tembhurne, B.V., Revanappa, P. and Kuchanur, P.H. (2004). Varietal Performance, Genetic Variability and Correlation Studies in Chilli (*Capsicum annuum* L.). *Karnataka J. Agric. Sci.* **21**(4): 541-543.

Tembhurne, B.V., Revanappa, P. and Kuchanur, P.H. (2005). Performance of Chilli Genotypes in Upper Krishna Project Command Area. *Karnataka J. Agric. Sci.* **21**(4): 594-596.

Usman, M.G., Rafii, M.Y., Ismail, M.R., Malek, M.A. and Latif, M.A. (2014). "Capsaicin and dihydrocapsaicin determination in chili pepper genotypes using ultra-fast liquid chromatography. *Molecules*. **19**(5): 6474-6488.

Vani, S.K., Sridevi, O. and Salimath, P.M. (2007). Genetic divergence in chilli (*Capsicum annum* L.). *Annals Biol*. **23**(2): 123-128.

Verma, S.K. and Sarnaik, D.A. (2000). Path analysis of yield components in chilli (*Capsicum annuum* L). *J. Appl. Biol*. **10**(2): 136-138.

Vikram A., Warshamana I.K., and Gupta M. (2014) Genetic correlation and path coefficient studies on yield and biochemical traits in chilli (*Capsicum annuum* L). *Intl. J. Farm Sci.* **4**(2): 70-75

Wahyuni, Y., Ballester, A.R., Tikunov, Y., De Vos, R.C., Pelgrom, K.T., Maharijaya, A., Sudarmonowati, E., Bino, R.J. and Bovy, A.G. (2013). Metabolomics and molecular marker analysis to explore pepper (*Capsicum sp.)* biodiversity. *Metabolomics*. **9**: 130-144.

Warade, S.D., Dhumal, M.M. and Shinde, K.G. (1997). Correlation studies in chilli. *J. Maharashtra Agril. Univ*. **21**(1): 55-57.

Weber, C.R. and Moorthy, H.R. (2010). Heritable and non-heritable relationship and variability of oil content and agronomic characters in the F2 generation of soybean crosses. *Agron. J*.**44**: 202-209.

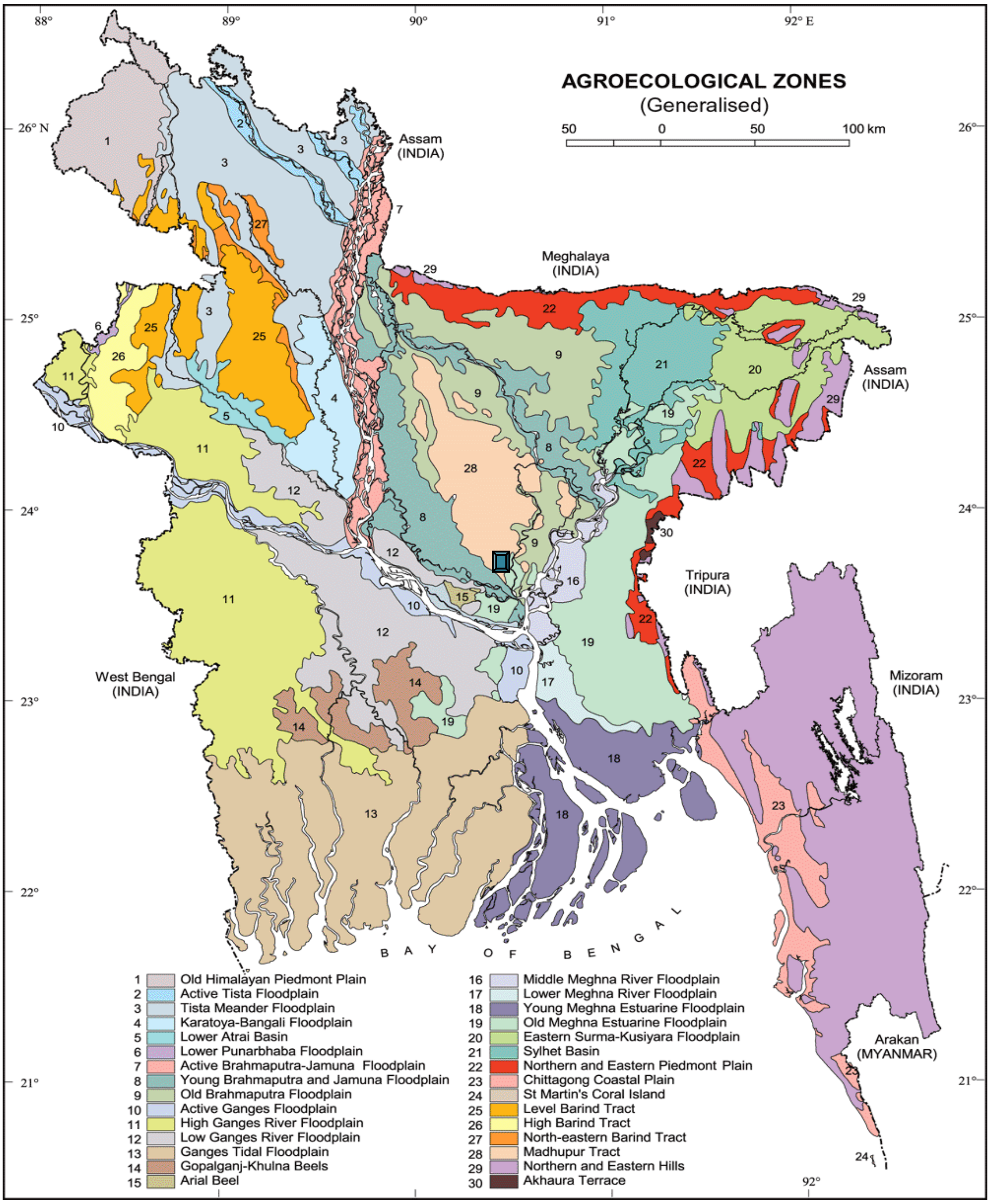
Wilson, D. and Philip, D. (2009). Genetic variability and genetic divergence in paprika. pp.16.

Wright, S. (2007). Correlation and causation. *J. Agric. Res*. **20**: 202-209.

Yatung, T., Dubey, R.K., Singh, V., and Upadhyay, G. (2014). Genetic diversity of chilli (*Capsicum annuum* L.) genotypes of India based on morpho-chemical traits. *Australian J. Crop Sci*. **8**(1):97-102.

Zhani, K., Hermans, N., Ahmad, R. and Hannachi, C. (2013). Evaluation of Salt Tolerance (NaCl) in Tunisian Chili Pepper (*Capsicum frutescens* L.) on Growth, Mineral Analysis and Solutes Synthesis. *J. Stress Physio. Biochem*. **9**(1): 209-228.

Appendix I. Map showing the experimental site under the study



The experimental site under study

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 (ºc)		*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, 2015	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	36.4	20.2	72	78	6.9

* Monthly average,

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