GENETIC VARIABILITY STUDIES OF GREEN CHILLI
(*Capsicum frutencens* L.)

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GENETIC VARIABILITY STUDIES OF GREEN CHILLI (*Capsicum frutencens* L.)

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CERTIFICATE

*This is to certify that thesis entitled, "**GENETIC VARIABILITY STUDIES OF GREEN CHILLI (Capsicum frutescens)"** submitted to the faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN GENETICS AND PLANT BREEDING**, embodies the result of a piece of bonafide research work carried out by Antara Kabiraj, Registration No.: 12-04906 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 her.

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Dated: June, 2018
Place: Dhaka, Bangladesh

(Prof. Dr. Md. Sarowar Hossain)
Supervisor

Dedicated

to

My belovedparents

And

My nephew Prottoy Kabiraj

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Dated: June, 2018.

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GENETIC VARIABILITY STUDIES OF GREEN CHILLI

(Capsicum frutescens L.*)*[1]

By

ANTARA KABIRAJ[2]

ABSTRACT

In order to evaluate the variability and genetic diversity of chilli the present experiment was carried out during the period from November 2017 to April 2018 at the experimental farm of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka. It was involved with 28 genotypes of chilli of different origin/sources. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Analysis of variance revealed highly significant differences among the accessions for all the characters studied. The phenotypic co-efficient of variation was higher than the genotypic coefficient of variation for all the characters. Highest genotypic coefficients of variation was recorded for number of fruits per plant (39.45) followed by fruit yield (36.46), plant height (31.95), fruit weight (19.55) and fruit length (18.05). The maximum genotypic and phenotypic variations were 1630.23 and 2601.77, respectively in fruit yield per plant. The highest estimated heritability amongst seven characters of chilli was 94.43% for days to first flowering and the lowest for 28.94% for number of primary branches per plant. The highest genetic advance amongst all the characters was found in fruit yield 65.84 and the lowest genetic advance was carried out in fruit weight (0.66). The maximum genetic advance in percent of mean was observed for number fruits per plant (66.02) followed by plant height (62.34) and fruit yield per plant (59.46). Whereas, the lowest was for primary branches per plant (16.67) followed by fruit length (29.27). Again, considering both genotypic and phenotypic correlation co-efficient among seven yield contributing characters of 28 chilli genotypes fruit yield was positively and significantly correlated with plant height, fruits number per plant and number of primary branches per plant. Finally findings of genetic parameters and cluster analysis revealed that the characters number of fruits per plant and fruit yield along with plant height, primary branches per plant and fruit length in cluster IV found most important for genotypic Coefficient of variance, phenotypic co-efficient of variance, heritability, genetic advance and maximum contribution towards genetic divergence in the respective chilli genotypes. Considering all, crossing between cluster IV and cluster II will give better performance because more divergence was present between these two clusters. Cluster IV can be selected for fruit yield, fruits number per plant, plant height, primary branches per plant and fruit length because it gave highest values for all the characters.

[1]Title of the thesis paper presented for the partial fulfilment of MS degree

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LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APENDICES

LIST OF ABBREVIATIONS

FULL NAME	ABBREVIATION
Fruit Weight	FL
Fruit Yield	FC
Fruit Number	FW
Genetic Advance	FY
Gram	Gm
Genotypic Coefficient of Variation	GCV
Genotypic Variance	σ^2g
Hectare	ha.
Heritability in Broad sense	h^2b
Journal	J.
Kilogram	Kg
Mean Sum of Square	MSS
Meter	M
Muriate of Potash	MP
Metric Tons	M. tons
Number	No.
Number of Primary Branches	PBN
Genetic Advance in Percent of Mean	GAPM
Genetic Advance	GA
Percent	PCV
Phenotypic Coefficient of Variation	PCV
Phenotypic Variance	σ^2P
Plant Height	PH
Principal Component Analysis	PCA
Randomized Complete Block Design	RCBD
Relative Humidity	RH
Sher-e-Bangla Agricultural University	SAU
Squire meter	m^2
Triple Super Phosphate	TSP
Fruit length	FL
Agro-Ecological Zone	AEZ
And Others	et al.
Bangladesh Bureau of Statistics	BBS
Bangladesh Agricultural Research Institude	BARI
Bang1adesh Rice Research Institute	BRRI

FULL NAME	ABBREVIATION
Centimeter	Cm
Coefficient of Variations	Cv
Dys to First Flowering	DF
Days to First Fruit Harvesting	DFH
Days after Transplanting	DAT
Degree Celsius	°C
Degrees of Freedom	d.f
Etcetera	Etc
Food and Agricultural Organization	FAO
Figure	Fig.

CHAPTER I

INTRODUCTION

Chilli (*capsicum sp*.) belongs to solanaceae family, originated in Mexico, with secondary centres in Guatemala and Bulgaria. Columbus introduced chilli in India in century . It is a common and widely distributed spices crop throughout the tropics. Over 100 species have been named under the genus Capsicum, but most workers recognize only two Species. *Capsicum annum* L. and *Capsicum frutescens L.* (Purseglove 1968, Cobley 1967).

Chilli is one of the most important ingredients used in the everyday diet of the people of South and South-east Asia. The *Capsicums* are the native of the tropical areas of Central America and the west Indies, but they quickly spread throughout the tropical world alter the discovery of America and west Indies. Chilli has high demand among the consumers due to its diversified uses. For the intensive cultivation and increased production of chilli, improved varieties/lines with desirable traits need to be identified through the world. It is an important spices crop in Bangladesh. It is also a cash crop of the country (Ahmed and Haque, 1980). It is cultivated on small family owned farms where sale of its produce serves as a ready source of cash income throughout the year. A large number of cultivars or landraces are under cultivation in different parts of the country. At present, the total cultivated area under spices and condiments is 793 thousands acres. Depending on yield and consumers preference, a number of chilli genotypes are being cultivated throughout the country. Winter chilli contributes about 90% of its total production (Annonnous, 1987). The actual area tinder chilli cultivation in Bangladesh is not available due to its seasonal nature of cultivation. The total cultivated area covered by chilli is about 352 thousands acres from (BBS. 2016) and total production of chilli is about 155 thousands of tons (BBS, 20016). In

Bangladesh. the harvest price of chilli is about 56100 Taka per M. tons (BBS, 2016).A wide genetic diversity is found here due to the availability of different land races and their wild relatives. In spite of its importance no major break through has been made and limited number of improved varieties are being grown on the country. Under this situation, new avenues for crop improvement require to be exploited. For achieving a substantial genetic improvement, a high knowledge of genetic diversity and variability is essential to improve new varieties of chilli in the country. Selection of better plant type either from local or exotic genotypes can he of immense value to the breeder. Keeping this view in mind. 30 germplasms of chilli from home and abroad were collected and there genetic diversity was assessed by this study.

Chilies are widely use throughout the tropics and are major ingredients of curry powder in the culinary preparations. In its powdered form, it constitutes red or caynee pepper. Extracts of chilies are used in the production of ginger beer and others beverages. Cayenne pepper is incorporated in poultry feeds. *Capsicum frutescens* is used in medicine as carminatives internally, besides being in external counter irritant. The green chillies are rich in routine Which is of immense pharmaceutical need (Purseglove, 1977). It is quite rich in nutritive value and supposed to contain certain medicinal properties. (Chawdhury, 1976) .Commercial cayenne pepper is the preparation of dried, linally grounded, mature of various highly pungent or hot' forms of *Capsicum frutescens*. These pungent are used in the manufacture of sauces and curry powders and in the preparations of pickles. The chief constituent of chilli (*Capsicum frutescense*) pericurp is a crystalline colorless pungent principle known as capsaicin (CIsH:7NO3) a condensation product of 3hydroxy-4-mcthoxy benzyl alanine which produces a highly irritating vapour on heating. Green chillies are rich in vitamin A and C and the seed contain (races of starch. The fruits also contain a fixed oil, red coloring matter which is non-pungent and yield 20-25 percent alcoholic extract, dry matter 22.02, ascorbic acid 131.06 mg/ l00 g (fresh weight) oleoresin 66.53 ASTA units, coloring matter

ASIA units. Capsaicin 0.34% (dry wt.) crude fibre 26.751%, and total ash 6.69%.

Crop improvement largely depends on existence of genetic variability. Improvement in any crop is based on the extent of genetic variation present in it. The present study was undertaken in 28 chilli genotypes with the objectives of obtaining information about variability, heritability and genetic advance among the genotypes. Genetic diversity is one of the most important criteria for parent selection. Genetic diversity is a prerequisite for an efficient plant breeding program. The availability of transgressive segregants in any breeding program depends upon the diversity of involving parents. The divergence analysis has a definite role to play in an efficient choice of divergent parents for hybridization to exploit maximum heterosis such as producing cultivar with increased yields, wider adaptation, desirable quality, pest and disease resistance. The importance of genetic diversity in the improvement of crop has been stressed in both self and cross-pollinated crops. (Griffin & Lindtorm, 1954). The quantification of' genetic diversity through biometrical procedure (Anderson, 1957) has made it possible to choose genetically diverse parents for a successful hybridization program. Genetic diversity is important to know the source of genes for a particular trait within the available germplasm (Tomooka, 1991). In order to increase the frequency of desired genotypes in breeding progenies superior parents with high breeding values are needed.

Variability and genetic diversity are the fundamental law of plant breeding which is major tool being used in parent selection for efficient hybridization program. Knowledge of the interrelationship between yield and yield components is desirable to know the magnitude and direction of changes expected during selection. More diverse the parents greater are the changes of obtaining high heterotic F1 and board spectrum variability in segregating generation (Arunachalam, 1991). The supreme parents having desired characters could be identified through divergence analysis. Several statistical methods are known for

discriminating purposes viz., Mahalanobis's generalized distance (Mahalanobis, 1936). Fisher's discriminant analysis.

Inspection of biomatric data and totals of grouped data (Whitehead, 1954). Among them Mahalanobis's D^2 statistics based on multivariate analysis appears to be a good index. This technique has been followed by many researchers on a wide range of crops. Based on the above informations. The present experiment was conducted to study the available variation, genetic nature and genetic diversity of 28 chilli genotypes collected from home and abroad for more promising and necessary to develop new varieties of chilli in the country. The specific objectives of the present study were as follows:

1. To estimate the genetic variability for different quantitative characters involved among 28 chilli genotypes
2. To estimate the genetic diversity among 28 chilli materials
3. To characterize and interrelationship among the genotypes on the basis of yield and yield contributing traits
4. To screen suitable diversed parents for the utilization in future hybridization programme.

CHAPTER II

REVIEW OF LITERATURE

Variability and genetic diversity are the fundamental law of plant breeding which is a major tool being used in parent selection for efficient hybridization programme. (Bhatt, 1973). It is a prerequisite for effective parent selection. The quantification of genetic diversity through biometrical procedures such as Mahalanobis's D-statistics and Canonical Variate Analysis has possible to choose genetically diversed parents. Recent work indicates that the Mahalanobis's generalized distance (D^2-statistics) may be an efficient tool in the quantitative estimation of genetic diversity. Genetic diversity is an essential tool to the diverge goals such as producing cultivars with increased yield, wider adaptation, desirable quality, disease and insect resistance. More diverse the parents exhibit high heterotic F1 and board spectrum variability in segregating generation (Arunachalam, 1981).

Therefore, relevant information available in the. Literature pertaining to the characterization, variability and diversity of the chilli and some other crops of the same family were reviewed in this section. Moreover literatures related to the efficient multivariate techniques for diversity analysis were also reviewed in the following headings.

Thirty-two accessions of hot chilli (*Capsicum chinense*) collected from different sources were evaluated at the College of Agriculture, Vellayani, Triyandrum during September 2000 to May 2001. The accessions were raised in randomized block design with three replications in plots of size 6.75 m, planted at a spacing of 0.75 x 0.60 m. The crop received timely management practices as per the package of practices recommendations of the Kerala Agricultural University. Five plants

were randomly selected per accession and observations recorded on plant height, primary branches per plant, plant spread, days to first flowering, pollen viability, days to maturity, fruits per plant, fruit length, pedicel length, fruit girth, fruit weight, seeds per fruit, 1000-seed weight, number of harvests and yield per plant. Analysis of variance in respect of various characters was done (Panse and Sukhatme, 1967). Genetic variability for the different characters was estimated as suggested by Singh and Choudhary (1985). Heritability (broad sense) and genetic advance as percentage of mean were calculated by Hanson *et al.* (1956).

Genetic variability, heritability, genetic advance and genetic advance as a percent over mean for twelve characters were assessed by field evaluation of eighty chilli accessions at Kittur Rani Channamma of Horticulture, Arabhavi (Kama taka) during 2002. 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 characters 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%), percent fruit set (70.70%), number of fruits per plant (81.10%), fruit length (92.40%), ten fruit weight (92.40%) and total green fruits per plant (88.40%). Most of these characters also had moderate to high estimates of genetic advances as a percent over mean except days to first flowering.

Singh *et al.* (2005) conducted an experiment on IS advance generation breeding lines of chilli including 4 control cultivars. To study the variation and heritability of' quality characteristics in chilli raised under normal and high temperature conditions. Data were recorded for total soluble solids (USS), pericarp, thickness, fruit firmness, acidity, lycopene content and dry matter content. There were significant differences among the genotypes under normal conditions, whereas differences were not significant under high temperature conditions. In general the

phenotypic coefficients of variation were higher than genotypic coefficients of variation indicating that the genotypic effect is less under the influence of the given environment. Heritability estimates (in broad sense) were high for all the traits for November planting except for lycopene content.

Wasule *et al.* (2004) carried out variability in 17 newly developed genotypes of chilli (*Capsicum aunnum L*.) in Akola, Maharastra, India and revealed that there were a wide range of variability among the genotypes for all the characters. They recorded variability for days to 50% flowering, plant height, number of primary branches per plant, number of fruits per plant, fruit length, fruit girth. 1000-seed weight, seed percentage and yield of red chillies per plant .They noted high genotypic co-efficient of variation, number of fruits per plant, wet red chilli yield, fruit girth, number of primary branches per plant ,They estimated heritability ranged from 27.60 to 92.70% and 9 characters showed high heritability (>700/0). They described the expected genetic advance ranged from 3.73 to 74.90. They observed high heritability (92.70%) was accompanied by high genetic advance (70%) in respect of number of fruits per plant, indicating prevalence of additive gene action which oilers good scope for further improvement.

Prabhakaran and Nataranjan (2004) conducted an experiment to study genetic variability. Heritability and genetic advance for 8 characters in chilli (*Capsicum annum*) in Coimbatore, Tamil Nadu, India with 97 genotypes of chilli. They recorded high genotypic co-efficient of variation for plant spread, number of fruits per plant, yield per plant, fruit length, mean fruit weight, placenta length and capsaicin. They observed that the heritability estimates were high for most of the characters. They found that the genetic advance as percentage of mean was high for yield per plan, mean fruit weight, placenta length and capsaicin. High heritability estimates coupled with high genetic advance as percentage of mean were recorded by them for yield per plant, mean fruit weight, placenta length and capsaicin.

High magnitude of heritability was noticed for days to 50% flowering (Sreelathakumary and Rajamony, 2004). The high heritability values in broad sense are also helpful in selection if coupled with high phenotypic performance. The reports of Sharma (1975) revealed high heritability for number of primary branches per plants. Whereas, Nandi (1992) observed low heritability for flowering characters. Moderate heritability was observed by Basavaraj (1997) for number of branches in chilli. Number of fruits per plant is the most important yield attributing character in capsicum. High heritability was reported for number of branches per plant indicating predominance of additive gene action which is amenable to improvement through selection and exploiting the additive variance (Verma *et al.,* 2004). High heritability estimates for fruit weight was observed by Sreelathakumary and Rajamony (2002) but, Rani and Singh (1996) reported that fruit weight was moderately heritable. Fruit size, in terms of length and width was reported to have high heritability (Sreelathakumary and Rajamony, 2002, Verma *et al.*, 2004), Whereas Munshi and Behera (2000) observed low heritability for fruit length and width. Number of seeds per fruit showed high heritability estimates as reported by Basavaraj (1997).

Sharma *et al*. (1975), reported high heritability and high genetic advance for average fruit weight, fruit yield per plant and fruit diameter indicating the role of additive gene action for the inheritance of these traits.

Sreelathakumary and Rajamony (2004) reported high estimates of heritability and genetic advance for fruit length and genetic advance for fruit length and number of fruits per plant. These characters could be effectively improved through selection. This could be treated as an indication of additive gene action and the consequent high expected genetic gain for selection from these characters. The fruit characters like size, length and width has been reported to have high genetic advance. fruit Verma et al. (2004) reported high genetic advance for fruit length, Shah et al. (1986) for fruit width. High genetic advance was reported for fruit number per

plant by Verma *et al.* (2004). Varalakshmi and Haribabu (1991) reported high genetic advance for number of seeds per fruit.

Fourty five lines of chilli were subjected to Mahalanobis analysis by Singh and Singh (1976) and the lines differed significantly for eight characters. The clustering pattern of lines followed geographical distribution. From a analysis of 27 varieties of chilli, Mehra and Peter (1980) reported that fruits per plant contributed maximum towards diversity (88.03). Sundaram *et al*. (1980) could not observe any relation between genetic and geographic diversity when they subjected 35 Indian and 15 exotic lines of *Capsicum frutescens* to analysis.

Pawar (2000) attempted to study the genetic diversity among and within the three native cultivars of chilli viz., *Byadgi dabbi, Byadgi kaddi and Sankeshwar* both at morphological and molecular level. The molecular polymorphism assessed employing the RAPD analysis using five random decamer primers generated 187 RAPD loci of which 97 were polymorphic. The level of polymorphism generated was 48.5 percent and highest number of polymorphic bands was recorded by the primer OPJ-10.

Yadwad *et al.* (2008) observed maximum diversity between Sankeshwar local and Byadgi dabbi varieties followed by LCA-312 and Byadgi dabbi and least diversity was noticed between VN-2 and Sankeshwar. Intra and inter varietal molecular polymorphism was studied using 5 primers of which the primer OPJ-01 amplified highest number of polymorphic bands with an average 9.12 bands per cultivar followed by OPJ-10 (8.00).

Vani *et al.* (2007) attempted to study the genetic diversity and observed maximum diversity between the accession IC-14 and IC-31 followed by Pusa Jwala and VN-2 and high similarity was observed between Byadgi dabbi and G-4. Forty-two genotypes representing all the fourteen clusters were selected to estimate the molecular diversity using twenty primers of which the primer OPJ-01 amplified

the highest number of polymorphic bands with an average nine bands per cultivars followed by OPJ-10 (8.00).

High GCV and PCV values were observed for number of fruits per plant and fruit diameter by Sreelathakumary and Rajamony (2004) and Verma et al. (2004). High GCV and PCV were observed for fruit length by Sreelathakumary and Rajamony (2004). Low variability for fruit length was reported by Basavaraj (1997). Significantly high variation was also observed for number of seeds per fruit. Acharya *et al.* (1992) suggested that improvement in capsicum should be made based on the selection for fruits per plant, yield per plant, fruit diameter, fruit length and seeds per fruit. Similarly, Verma et al. (2004) confirmed the statement for most of the characters.

CHAPTER III

MATERIALS AND METHODOLOGY

This chapter includes the location, materials and methodology of the experiment conducted on chilli with different genotypes during the period from November 2017 to April 2018.

Location of the experimental site

The research work was conducted at the experimental site of Sher-e-Bangla Agricultural University, Dhaka- 1207.

Climate of the experimental site

The experimental area was under the sub-tropical monsoon climate zone, which is characterized by heavy rainfall, high humidity, high temperature and relatively long day during the Kharif season while hardly rainfall, low humidity, low temperature and short day during the Rabi season. Rabi season is favorable for capsicum cultivation. During the studying period, the crop received total rainfall of 26.50 mm. At that time, the average maximum and minimum temperatures were 28.42 degree C. and 16.36 degree C. respectively (appendix II). Details of the meteorological data in respect of temperature, rainfall, relative humidity, total sunshine and soil temperature during the period of experiment were collected from the Abhawa bhaban of Bangladesh. During the period the humidity was low, the temperature was mild with plenty of sunshine. The atmospheric temperature increased from February as the season proceeded towards summer.

Characteristics of soil

The selected plot was a medium high land. The pH of soil 4.47 to 5.63 while the amount organic carbon content, total N. available P and available K were 0.82%. 0.12%. 21 ppm and .27 mc per 100 gm of soil respectively (appendix I).

Genetic materials used for the experiment

The present study was performed with 28 genotypes of chilli of BARI. All the 28 genotypes were collected from Bangladesh Agricultural Research Institute (BARl), Gazipur.

Design and lay out of the experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) with 3 replications. The field was divided into 3 blocks then the blocks will be further sub-divided into 30 lines where genotypes wiere randomly assigned. The plot size was 3m with single tine. Row to Row distance was 50 cm and plant to plant distance was 50 cm. The genotypes were distributed to cacti line with each block randomly.

Preparation of the experimental field

Larger clods were broken into small particles and finally attained into a desirable tilth to ensure proper growing conditions. The plot was partitioned into the unit plots according to the experimental design as mentioned earlier. Recommended doses of well decomposed cowdung, manure and chemical fertilizers were applied and mixed well with the soil each plot. Proper irrigation and drainage channels were also prepared around the plots. Each unit plot was prepared keeping 5cm height from the drains. The bed soil was made friable and the surface of the bed was leveled.

Table 1. The code, name and source of collection of the 28 genotypes of chilli

Genotypes (code)	Name of the genotypes	Source of genotypes
V1	BD- 11109	BARI
V2	BD- 11110	BARI
V3	BD- 11111	BARI
V4	BD- 11112	BARI
V5	BD- 11113	BARI
V6	BD- 11114	BARI
V7	BD- 11115	BARI
V8	BD- 11116	BARI
V9	BD- 11117	BARI
V10	BD- 11118	BARI
V11	BD- 11119	BARI
V12	BD- 11120	BARI
V13	BD- 11121	BARI
V14	BD- 11122	BARI
V15	BD- 11123	BARI
V16	BD- 11124	BARI
V17	BD- 11125	BARI
V18	BD- 11126	BARI
V19	BD- 11127	BARI
V20	BD- 11128	BARI
V21	BD- 11129	BARI
V22	BD- 11130	BARI
V23	BD- 11131	BARI
V24	BD- 11132	BARI
V25	BD- 11133	BARI
V26	BD- 11134	BARI
V27	BD- 10478	BARI
V28	BD- 10481	BARI

Manure and fertilizers: Manure and fertilizers were applied at the doses indicated below following the methods shown in Table 2.

Table 2. Doses and methods of application of manure and fertilizers for the production of chilli.

Manure & Fertilizers	Doses Kg/ ha	Dose/ plant	Basal dose		Application per plot	
				1st top dressing at 30 DAP	2nd top dressing at 45 DAP	3rd dressing at 60 DAP
Cowdung	15000	15 kg	15 kg			
Urea	275	265 g	85 g	60 g	60 g	60 g
TSP	200	225 g	225 g			
MP	200	200 g	75 g	50 g	50 g	50 g
Zypsum	20	20 g	20 g			
ZnO	10	10 g	10 g			
Boric acid	10	10 g	10 g			
Furadon	10	10 g	10 g			

Four days before planting of *capsicum* seedlings the entire amount of well decomposed cowdung and TSP and other fertilizers were applied to the plots and well mixed with the bed soil. During final bed preparation one fourth of both Urea and MP were applied. The rest of the Urea and MP were top dressed in 3 equal installments, after 30, 45 and 60 days of planting (Table 2).

Planting of chilli seedlings

Forty five day old seedlings were transplanted in the experimental plots on 14 December, 2017. Planting was done at the afternoon. One seedling was planted in each hole. After planting, the bases of the seedlings were covered with soil and then pressed by hand.

Intercultural operations

The growing seedlings were always kept under care observation. After planting the seedlings, the following intercultural operations were accomplished for their better growth and development.

Irrigation

Immediately after transplanting the experimental plot was semi- flooded by irrigation. The crop was irrigated when needed depending on the moisture status of the soil and requirement of plants.

Gap filling

Plots with transplanted seedlings were regularly observed to find out any damage dead seedlings for its replacement. Gap filling was done as and when required.

Weeding and mulching

Weeding and mulching were necessary to keep the plots flee from weeds, easy aeration and for conserving soil moisture. When the plants were well established, the soil around the base of plants was pulverized.

Top dressing

The remaining doses of Urea and MP were applied as top dressing in each plot by 3 equal installments.

Plant protection measures

The established plants were infected with leaf curl disease. Confidor 70 WG and emidacloprid were applied in the infected field on 22 February, 2018. Chilli plants were infected with wilting disease and it was controlled by spraying Autostin. It was applied two times first on 28th February and second on 1st March, 2018. Few plants found to be infected by bacterial wilt were uprooted.

Harvesting

Harvesting of fruits was started at 75 DAP and continued up to 25 DAP with an interval of 25 days Harvesting was done usually by hand. First harvesting was done on 20 February, 2018; Second was done on 27 March, 2018 and Third harvesting was done on 29 April, 2018.

Data collection

In order to study the genetic divergence among the genotypes, the data were collected in respects of 7 parameters plant height, days to first flower number of primary branches per plant, fruit length, fruit weight, no. of fruits per plant and fruit yield per plant during the growth of plants and at the harvesting time of the crop. During the plant growth, 10 plants were selected randomly from each unit plot for data collection. The sampling was done iii such a way so that the border

effects were completely avoided. For this purpose, the outer two lines and the extreme end of the middle rows were excluded. Plate1 showing intercultural operations and data collection.

Plant height

The height of plant was taken in centimeter (cm) from ground level to the tip of the longest main stern of the plant. It was recorded at 25, 50, 75, 100 and 125 DAP.

Days to first flowering: Days to first flowering were recorded from transplanting date to the date of first flowering of every plant of every genotype.

Number of primary branches

Number of primary branches were recorded from the selected plants at final harvest .It was considered only main lateral shoots with main shoot.

Fruit length (cm):

The length of the fruits were recorded with a measuring tap in centimeter (cm) from the neck of the fruit to the bottom of the fruit. Ten selected fruits from each plant were measured and their average was taken as the length of the fruit (Plate 2).

3.11 5 Individual fruit weight:

Weight of individual fruit from the sample fruits were measured in gram at each harvest and the mean was recorded.

Number of fruits per plant

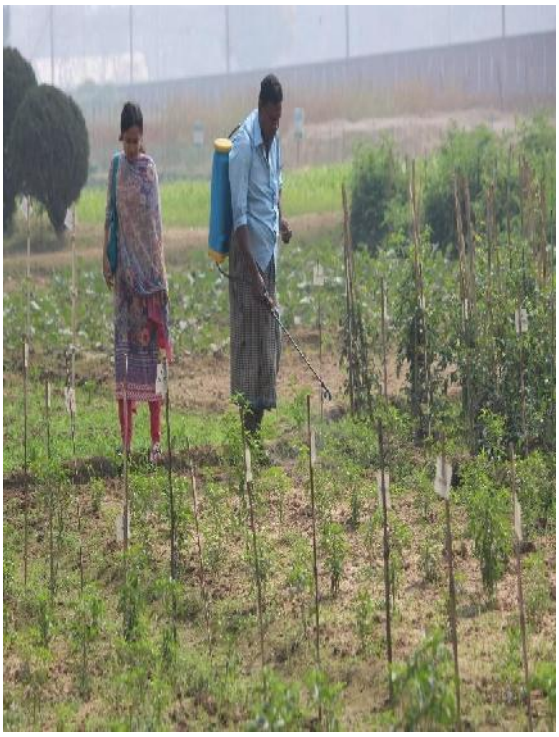
Fruits were collected in different dates from the selected plants and their average was taken as the number of fruits per plant.

Fruit yield per plant

Total weight (kg or gm) of all fruits per plant harvested at different periods was recorded by an electric balance.

Statistical Analysis of Data:

The data were analyzed for variance, different components of phenotypic and genotypic variance, heritability and genetic advance, correlation co - efficients and then the genetic diversity. According to Singh and Chaudhury (1985) ANOVA was done with the mean data of the replications subjected. Mean values for each character will he worked out by dividing the total corresponding number observations. While lowest and highest values of each character will be taken as range. Differences between genotypes for different character will be tested for significance by using analysis variance technique. Genetic diversity were subjected to both univariate and multivariate analysis using MSTAT and GENSTAT 5.13 Software program. Genetic diversity analysis involves several steps, i.e. estimation of distance between genotypes clustering and analysis of inter-cluster distance. The using MSTAT and GENSTAT 5.13 Software program. Genetic diversity analysis involves several steps, i.e. estimation of distance between genotypes, Clustering and analysis of inter-cluster distance. The data were analyzed for variance, different components of phenotypic and genotypic variance, heritability and genetic advance, correlation, coefficient and the genetic divergence. According to sing and chaudhury (1985), One-way ANOVA (Completely randomized design) was done with the mean data of all the replications subjected. Duncan,s New Multiple Range 1est (DMRT) was performed to test the differences between genotypes.



Insecticide spraying

Sticking

Data collection

Harvesting

Plate 1: Intercultural operations and data collection

Genotype 1 to 28

Genotype 26 Genotype 24 Genotype 20

Plate 2: Different shapes and sizes of chilli genotypes

Variability of chilli genotypes:

Estimation of genotypic and phenotypic variances :

Genotypic and phenotypic variance were estimated according to the formula of Johonson *el al*. (1995).

Genotypic variance σ^2 = MSg - MSe / r

Where, MSg = Mean sum of squares for genotypes;

MSe = Mean sum of squares for error and

r = Number of replications

Phenotypic variance= σ^2g= σ^2g+ σ^2e

Where, σ^2g = Genotypic variance: and

σ^2g = Error mean square

Estimated of genotypic and Phenotypic co-efficient of variation:

Genotypic and phenotypic coefficient of variation were calculated.

Genotypic co-efficient of variation (CCV) = σ^2g/x × 100

Where, σ^2g / x = Genotypic variance: and

x = Population mean

Estimated of heritability

Heritability in board sense (h2b) was estimated by the following formula of Johnson *et al*. (1995).

Heritability, H^2b (%) = σ^2g/ σ^2p

Where, σ^2g = Genotypic variance and

σ^2p = Phenotypic variance.

Estimation of genetic advance

The expected genetic advance was estimated by the following given by Jhonson *et al*. (1995).

Genetic advance (GA) = h^2b. K. σ^2p

Where, h^2b = Heritability in board sense;

K = Selection intensity which is equal to 2.06 at S%; and

σ^2p = Phenotypic standard deviation

Estimated of genetic advance in percentage of mean, GA (%):

In percent of mean genetic advance was calculated by using the formula,

GA (%) = GA/ x × 100

Where, GA = Genetic advance and

X= Population mean

CHAPTER IV

RESULTS AND DISCUSSIONS

The knowledge of generic variability and genetic diversity within chilli genotypes would help to screen better genotypes .So, to generate information in the degree of diversity among 28 lines of chilli were raised in the field of Sher-e-Bangla Agricultural University. Dhaka. The data in respect of plant height, days to first flowering, primary branches per plant, fruit length, fruit weight, fruits per plant and fruit yield were recorded analysed and presented in this chapter. Performance of 28 genotypes of chilli was investigated in winter season and the findings of present study have been discussed under different morphological characters. The results of the study showed marked variation in different characters and the variation of different characters are presented in the following tables, figures and plates. The data pertaining to seven characters were computed, statistically analyzed and the results obtained are described below.

Variability among 28 chilli genotypes

I Heritability, genetic advance and genetic advance in percentage of mean

Correlation coefficients among seven yield contributing characters

Genetic diversity for 28 genotypes of chilli

4.1 Variability among 28 chilli genotypes

Mean square (MS) from analysis of variance for different characters are presented in (Table 3). The mean values of all characters for all the genotypes along with the least significant difference (LSD) are shown in (Table 5). The estimate of genotypes variance, phenotypic variance, genetic co-efficient of variation and phenotypic co-efficient of variation are summarized in (Table 6).

Table 3. Analysis of variance for different characters in chilli genotypes

Characters	Mean sum of square		
	Replication (r-1) = 2	**Genotype (g-1) = 27**	**Error (r-1)(g-1) = 54**
Plant height (cm)	63.01	1,884.30**	69.38
Days to first flowering	1.32	475.33**	9.17
Primary branches per plant	6.035	8.692**	3.912
Fruit length (cm)	0.36	2.94**	0.50
Individual fruit weight (g)	0.15	0.55**	0.08
Fruit per plant	451.34	1,744.99**	255.71
Yield per plant (g)	3,033.68	5,862.23**	971.53

** Denotes significant at 1% level of probability ns: non significant

Table 4: Range, mean, CV (%) and standard deviation of 28 genotypes

Parameters	Range		Mean	CV (%)	SD	SE
	Min	Max				
Plant height (cm)	10.00	114.00	76.99	10.82	8.33	3.15
Days to first flowering	34.33	84.00	59.00	5.13	3.03	1.14
Primary branches per plant	5.67	12.00	8.39	23.57	1.98	0.75
Fruit length	2.80	7.10	5.00	14.13	0.71	0.27
Individual fruit weight (g)	1.20	3.12	2.02	14.47	0.29	0.11
Fruit per plant	17.67	117.33	56.48	28.31	15.99	6.04
Yield per plant (g)	41.17	199.00	110.73	28.15	31.17	11.78

CV (%) = coefficient of variation, SD = standard deviation and SE = standard error

Table 5. Mean performance of different characters of 28 Chilli genotypes

Genotypes	PH	DFF	PBP	FL	IFW	FPP	YPP
G1	54.67lm	55.00fg	9.00a-d	5.50b-f	2.77ab	40.33g-l	87.95h-k
G2	43.33mn	51.67g	7.00c-e	5.80b-e	1.75e-j	37.33g-l	65.75i-k
G3	32n	60.00de	6.00de	5.63b-f	2.02c-i	44.00g-k	79.00h-k
G4	70i-l	53.00g	5.67e	6.10ab	3.05a	26.00kl	66.03i-k
G5	56.33lm	39.67hi	7.00c-e	4.23h-k	2.11c-g	55.00e-j	112.50e-i
G6	56.67k-m	60.67de	8.67b-e	4.71e-j	1.57l-j	83.67b-d	146.67b-g
G7	102.33a-d	58.00ef	7.00c-e	4.57f-j	1.64g-k	59.33d-i	113.00d-i
G8	73.67h-j	54.33fg	8.67b-e	4.00i-k	1.86c-j	87.00bc	169.00ab
G9	85f-h	61.67de	9.67a-c	6.40ab	1.62hh-k	54.67e-j	80.00h-k
G10	100b-e	43.67h	9.33a-c	4.20h-k	1.40jk	62.33c-g	98.92g-j
G11	82.33f-i	67.33c	10.33ab	5.33b-h	1.93c-i	31.00j-l	67.33h-k
G12	81f-j	38.67ij	9.00a-d	4.93c-i	2.25cd	45.67g-k	102.33f-j
G13	10op	60.00de	10.00a-c	4.67e-j	2.24cd	46.33g-k	117.13c-h
G14	77.67g-j	76.67b	10.33ab	4.53f-j	3.12a	17.67l	51.78jk
G15	94.33c-f	52.33g	12.00a	5.52b-f	2.31bc	73.00b-f	165.33a-c
G16	87.33e-g	80.67ab	5.67e	2.80l	1.96c-i	60.00d-h	117.67c-h
G17	81.67f-i	77.67b	9.00a-d	5.74b-e	2.20c-e	46.33g-k	101.67f-j
G18	105.67a-c	84.00a	10.00a-c	5.40b-g	1.67f-k	24.67kl	41.17k
G19	92.33c-f	80.33ab	10.00a-c	5.87b-d	2.07c-h	73.00b-f	163.67a-d
G20	90d-g	58.00ef	9.67a-c	3.30kl	2.05c-i	87.67bc	162.67a-e
G21	85.67f-h	63.33cd	7.67b-e	4.80d-j	2.13c-f	33.33i-l	86.94h-k
G22	84.67f-h	58.00ef	8.00b-e	5.49b-f	2.06c-h	49.33f-k	89.22h-k
G23	110ab	51.67g	6.00de	5.66b-f	2.20c-e	84.33b-d	188.40ab
G24	114a	34.33j	6.00de	7.10a	1.84c-j	77.67b-e	150.17a-f
G25	67.67j-l	51.67g	9.00a-d	4.30g-k	1.97c-i	88.67b	150.67a-f

Genotype	pH	DFF	BPB	FL	IFW	FPP	YPP
G26	102.33a-d	62.67c-e	10.00a-c	6.00a-c	1.81d-j	117.33a	199.00a
G27	78.67g-j	54.00fg	7.00c-e	3.80i-l	1.89c-i	35.47h-l	62.48i-k
G28	36.33n	63.00cd	7.33b-e	3.73j-l	1.20k	40.33g-l	64.00i-k

Table 6. Estimation of genetic parameters for different characters in Chilli

Parameters	$\pm^2$p	$\pm^2$g	$\pm^2$ e	PCV	GCV
Plant height (cm)	674.36	604.98	69.38	33.73	31.95
Days to first flowering	164.56	155.39	9.17	21.74	21.13
Primary branches per plant	5.51	1.59	3.91	27.96	15.04
Fruit length (cm)	1.32	0.82	0.50	22.92	18.05
Individual fruit weight (g)	0.24	0.16	0.09	24.33	19.55
Fruit per plant	752.14	496.43	255.71	48.56	39.45
Yield Per Plant (g)	2601.77	1630.23	971.54	46.06	36.46

σ^2p : Phenotypic variance
σ^2g : Genotypic variance
σ^2 e : Environmental variance

PCV : Phenotypic coefficient of variation
GCV : Genotypic coefficient of variation

4.1.1 Plant height

Significant difference was observed for plant height among the genotypes under study (Table 3). The significant varietal differences indicated that there was a wide range of variation among the genotypes for plant height with the mean values ranging from 10.00 cm to 114 cm (Table 4). The highest plant height G24 cm was recorded in G24 which was statistically similar with G23 (110 cm) and G18 105.67 cm (table 5). The smallest mean value for plant height 10.00 cm in G13 (10.00 cm). Manju *et al.* (2004) reported that analysis of variance showed significant differences among the accessions for plant height.

The genotypic variance was (604.98) considerably lower than the phenotypic variance (674.36) for plant height in chilli genotypes suggesting moderate influence of environment of this trait (table 6 and figure 1). Genotypes co-efficient of variation (31.95) was also lower than phenotypic co-efficient of variation (33.73). The wide range of variation between genotypic and phenotypic variance for plant height indicated that the genotypes responded differently even when grown under the same environment.

Days to first flowering

The analysis of variance for days to first flowering showed highly significant variation among the genotypes (Table 3). Raikar *et al*. (2005) and Manju *et al.* (2004) also reported significant differences among different genotypes of tomato for its trait. The maximum days 84.00 required for first flowering was recorded in G18 followed by 80.67 in G16, 80.33 in G19 (table 4). On the other hand the variety (G24) required the minimum number of days to first flowering (34.33)

Phenotypic Variance (164.56) was considerably higher than genotypic variance (155.39) while phenotypic co-efficient of variation (21.74) was slightly higher than genotypic co-efficient of variation (Table 6). From the result it is revealed that environmental effect for this trait was low.

Primary branches per plant

The mean squares due to number of primary branches per plant were found statistically significant at 1% level including highly significant variation among the genotypes selected for the study (Table 3). The mean value for this trait ranged between 5.67 and 12.00 (Table 4). The highest number of primary branches per plant 12.00 was observed in G15 followed by G11 with 10.33. The least branch 5.67 genotype was G4 (Table 5). Similar significant differences were reported for this trait by Raikar *et al.* (2005), Smitha *et al.* (2006). Phenotypic variance (5.51) was relatively higher than genotypic variance (1.59). Phenotypic coefficient of variation (27.96) was considerably higher than genotypes co-efficient of variation (15.04) indicating a moderate influence of environment of expression of this characters (Table 6). But Wasule *et al* (2004) noted high genotypes co-efficient of variation for primary branches per plant.

Fruit length

Highly significant variation for the fruit length was observed among the genotypes (Table 3). The genotypes (G24) gave the highest mean value of fruit length 7.10 cm which was significantly superior to all other varieties (Table 6). The lowest fruit length was observed in (G16) 2.80 cm that was statistically different from all other lines/varieties (Table 6) The average mean value for fruit length ranged between 2.80 cm to 7.10 cm (Table 6). Senapoti *et al.* (2003) suggested that fruit length were the chief contributors towards genetic divergence.

Phenotypic variance (1.32) was slightly higher than genotypic variance (0.82) (Table 6). Phenotypic coefficient of variation (22.92) was also slightly higher than genotypes co-efficient of variation (18.05) indicating a moderate influence of environment of expression of this characters. Sreelathakumary *and* Rajmony (2004) recorded high genotypic and phenotypic coefficient of variation for fruit length. Khurara *et al.* (2003) observed a highly significant variation among the genotypes in terms of fruit length and recorded a high genetic coefficient of variation for fruit length and had high values of heritability. Prabhakaran and nataranjan (2004) recorded high genotypic co-efficient of variation for fruit length.

Individual fruit weight

The analysis of variance for this character showed highly significant differences among the genotypes (Table 3). The genotype (G14) gave the highest mean value of individual fruit weight 3.12 g which was statistically similar with G4 (3.05 g) and significantly superior to all other lines (Table 5). The lowest individual fruit weight 1.20 g was observed in G28 that was statistically similar with some of lines and different from all other lines (Table 5). Phenotypic variance (0.24) and genotypic variance (0.16) were for this trait with little differences in genotypic co-efficient of variation (19.55) and phenotypic co-efficient of variation (24.33) indicating negligible environmental effect (Table 6). Sudre *et al.* (2005), Smitha *et al.* (2006) recorded high genotypic and phenotypic coefficient of variation for fruit weight.

Number of fruits per plant

Highly significant variation for the number of fruits per plant was observed among the genotypes (Table 3). Manju *et al.* (2004) reported that the number of fruits per plant showed highly significant differences among the cultivars and on an average ranged from 82.0 to 532.2. The genotype (G26), produced the highest number of fruits per plant 117.33 (Table 5). The genotype G14 produces the lowest number

of fruits per plant 17.67. Number of fruits per plant showed a wide range from 117.33 to 17.67 (Table 4). Senapoti *et al.* (2003) suggested fruit number per plant were the chief contributors towards genetic divergence. The environmental influence was considerable for this trait, which could not be realized from the difference between genotypic variance (496.43) and phenotypic variance (752.14) and also the difference between genotypic coefficient of variation (39.45) and phenotypic co-effiicient of variation (48.56) (Table 6). Sreelathakumary *et al.* (2004) recorded high genotypic and phenotypic coefficient of variation for fruits per plant. Khurana *et al*. (2003) and Prabhakaran *et al.* (2004) observed a highly significant variation among the genotypes and recorded a high genetic coefficient of variation for number of fruits per plant had high values of heritability.

4.1.7 Yield per plant

Highly significant difference was observed among the genotypes for yield per plant (Table 3). According to mean values the maximum yield per plant 199.00 g was produced by the line G26 which statistically similar and followed by G23 (188.40 g), G8 (169.00 g) and G15 (165.33 g). Whereas minimum yield per plant was 41.17 g was produced by the line G18. The ranged of yield per plant was from 41.17 g to 199.00 g. (Table 4) reported that the genotype 94-3 showed the highest fruit yield of 200.82 g per plant. The phenotypic variance (2601.77) was considerably higher than genotypic variance (1630.23) indicating environmental influence on this trait (Table 6) and genotypic co-efficient variation (36.46) to that of phenotypic coefficient variation (46.06) was considerable which indicated environmental influence on yield per plant (Table 6).

Heritability and genetic advance in percentage of mean

The estimate of heritability, genetic advance and genetic advance in percentage of mean are presented in Table 7.

Plant height

Plant height exhibited heritability estimates (89.71%) along with values of genetic advance in percentage of mean 62.34 (Table 7) that indicated a high degree of genetic variability for this characters i.e. there is a good scope of isolating some good genotypes.

Table 7. Estimation of genetic parameters for different characters in Chilli

Parameters	h^2b	GA	GA (% of mean)
Plant height (cm)	89.71	47.99	62.34
Days to first flowering	94.43	24.95	42.29
Primary branches per plant (No.)	28.94	1.40	16.67
Fruit length (cm)	61.98	1.46	29.27
Individual fruit weight (g)	64.59	0.66	32.37
Fruit per plant	66.00	37.29	66.02
Yield per plant (g)	62.66	65.84	59.46

h^2 : Heritability

GA : Genetic advance

GA (% mean) : Genetic advance (% mean)

Days to first flowering:

Days to first flowering exhibited high heritability (94.43%) in hoard sense (h^2b) coupled with high genetic advance 24.95 and genetic advance in percentage of mean 42.29 (Table 7) indicated the possibility of additive genes effect for the expression of this character. Therefore selection would he effective for producing varieties with reduced days to first flowering from the genotypes tinder study.

Number of primary branches per plant:

The magnitude of heritability 28.94% in board sense (h^2b) for number of primary branches per plant was low with considerably moderate genetic advance in percentage of mean 16.67 (Table 7) which indicated non additive gene action i.e. there is no or limited scope of isolating superior genotypes.

Fruit length:

Fruit length exhibited high heritability (61.98%) in board sense (h^2) coupled with low genetic advance (1.46) and high genetic advance in percentage of mean 29.27 (Table 7) indicated the possibility of additive genes effect for the expression of this character. Therefore, selection would be effective and there is a good scope of isolating some good genotypes on the basis of this trait.

Individual fruit weight:

Individual fruit weight showed high heritability (64.59%) coupled with low genetic advance (0.66) and high genetic advance in percentage of mean (32.37) (Table 7). The results of individual fruits weight through selection would be effective.

Number of fruits per plant:

The estimates of heritability and genetic advance in percentage of mean were 66.00% (high) and 66.02 (high) respectively (Table 7) indicating high degree of genetic variability for this character. Therefore, there is a good scope of isolating some good genotypes on the basis of this trait.

Yield per plant

High heritability (62.66%) along with high genetic advance (65.84) and high genetic advance in percentage of mean (59.46) (Table 7) were obtained for yield per plant. The scope of selection on the basis of this parameter would be good of its high heritability, high genetic advance and high genetic advance in percentage of mean.

Correlation coefficients among eight yield contributing characters

Estimation of genotypic and phenotypic correlation co-efficient was made among yield and seven yield contributing characters of the 28 chilli lines in all possible one way paired combinations. Genotypic correlation co-efficient were higher than phenotypic correlation coefficient in all most of cases were suggested that character association had not been largely influenced by environment in this cases.

Plant height

Interrelationships among the yield contributing traits showed that plant height had highly significant and positive correlated with fruits per plant (0.323 and 0.307) and yield per plant (0.321 and 0.309) at both genotypic and phenotypic levels. Plant height was exhibited significant positive correlation with fruit length (0.223) at genotypic level. It was correlated insignificantly with primary branches per

plant (0.085 and 0.112) and days to first flowering (0.049 and 0.030). This result indicated that taller plants enhanced more vegetative growth like by more primary branches per plant and ultimately produced more fruits resulting increased yield.

Days to first flowering

Days to first flowering exhibited highly significant and positive association with primary branches per plant (0.375) at genotypic level but it was positive insignificant with primary branches per plant (0.189) at phenotypic level.

Primary branches per plant

Correlation co-efficient revealed that primary branches per plant were and positively significant relationship with yield per plant (0.029) at phenotypic level. It was positively correlated with fruit length (0.151) and fruit weight (0.167) at only genotypic level but positively significant correlation with fruits per plant (0.237) at phenotypic level (Table 8). The result indicated more primary branches per plant enhanced more vegetative growth and produced more fruit yield.

Table 8. Genotypic and phenotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotype of Chilli.

Traits		Plant height (cm)	Days to first flowering	Primary branches per plant	Fruit length (cm)	Individual fruit weight (g)	Fruit per plant	Yield per plant (g)
Plant height (cm)	G	1						
	P	1						
Days to first flowering	G	0.049	1					
	P	0.030	1					
Primary branches per plant	G	0.085	0.375**	1				
	P	0.112	0.189	1				
Fruit length (cm)	G	0.223*	-0.125	0.151	1			
	P	0.158	-0.097	-0.048	1			
Individual fruit weight (g)	G	-0.101	0.056	0.167	0.226*	1		
	P	-0.043	0.037	-0.041	0.109	1		
Fruit per plant	G	0.323**	-0.263*	-0.026	-0.009	-0.350**	1	
	P	0.307**	-0.206	0.237*	-0.013	-0.275*	1	
Yield per plant (g)	G	0.321**	-0.243*	0.029	0.043	-0.093	0.946**	1
	P	0.309**	-0.187	0.220*	0.007	-0.098	0.928**	1

** = Significant at 1% level * = Significant at 5% level.

Fruit length

Significant and positive correlation was observed of fruit length with fruit weight (0.226) at genotypic level. While it showed non-significant positive association with fruit weight (0.109) at phenotypic level and with yield per plant (0.043 and 0.007) at both levels. So fruit length promoted fruit weight resulting increased fruit yield. It was negatively correlated with fruits per plant (-0.009 and -0.013) at both levels. When fruit length was increased the number of fruits per plant was decreased.

Fruit weight:

Interrelationships among the yield contributing traits showed that fruit weight had highly significant and negative correlation with fruits number per plant (-0.350 and -0.275) at both genotypic and phenotypic level and insignificant negative correlation with yield per plant (-0.093 and -0.098). The correlation showed when fruit weight was increased the fruit yield decreased.

Number of fruits per plant:

Number of fruits per plant showed a highly significant and positive correlation with fruit yield (0.946 and 0.928) at genotypic and phenotypic level. It was indicated that if fruits per plant was increased the yield was highly increased.

Study of genetic divergence among the genotypes of chilli

The genetic diversity of 28 genotypes of chilli carried out based on seven characters. Genetic divergence among the varieties/lines was assessed on multivariate scale by using Mahalanobis's D^2-statistic. Based on this variation D^2 estimate was predicted accurately. The Mahalanobis's D^2 values were estimated by Singh and Chaudhury (1985).

Nature and magnitude of genetic diversity

The genotype were grouped into distinct clusters by using Mahalanobis's D^2-statistics. Based on D^2 values the genotypes were grouped into four distinct clusters. (Table 9).The genotypes belonging to the same cluster had smaller D2 values than those belonging to different cluster. The principal component analysis (PCA) showed that the first to components accounted for more than 80% of the total variation and a two dimensional scatter diagram was constructed using component 1 as X axis and component 2 as Y axis, reflecting the relative position of the genotypes. The 28 chilli genotypes were apparently distributed into four groups according to the scatter diagram. The 28 chilli genotypes were also constellated into four cluster comparing D^2-values for all possible pairs of populations (Table 9). The clustering pattern reflected by principal component analysis has been confirmed by D^2 analysis. Same trend was reported by Masud *et al*. (1995). Among four clusters, cluster II and cluster IV contained the highest number of 9 genotypes each. The other two clusters viz, cluster 1 and cluster V contained five genotypes each. Plate 3 to plate 6 showing different genotypes under four clusters.

Cluster distance

The average intra and inter cluster distances values are presented in Table 10. From the Table 10 it could he revealed that the inter cluster distances in most of cases were higher than intra cluster distances, reflecting wider diversity among the genotypes of the different groups (Table 10). In respect of inter cluster distance, the maximum inter cluster distance was observed between genotypes of cluster III and IV (7.60) followed by clusters I and IV (6.46) and clusters 11 and IV (4.50) suggesting wider diversity between them and the genotypes in these clusters could be used as parents in hybridization program for getting transgressive segregants.

Table 9. Distribution of 28 genotypes of Chilli in different clusters

Cluster no.	Accession No.	No. of populations
I	G1, G2, G3, G13, G28	5
II	G5, G7, G9, G10, G12, G16, G17, G21, G22	9
III	G4, G11, G14, G18, G27	5
IV	G6, G8, G15, G19, G20, G23, G24, G25, G26	9
Total		28

Genotype 3

Genotype 13

Genotype 28

Genotype 2

Plate 3. Chilli genotypes of cluster I

Genotype 21

Genotype 12

Genotype 10

Genotype 16

Plate 4. Chilli genotypes of cluster II

	
Genotype 4	Genotype 14
	
Genotype 27	Genotype 11

Plate 5. Chilli genotypes of cluster III

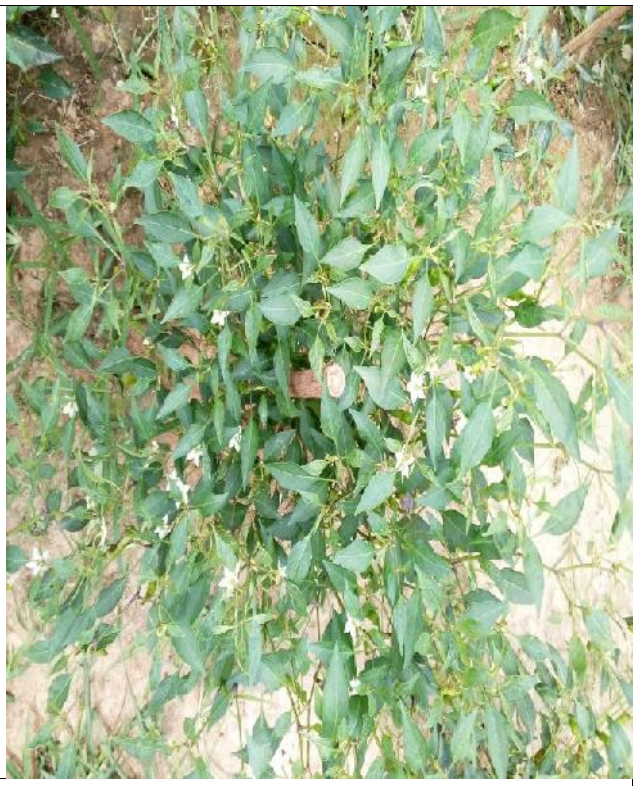
	
Genotype 6	Genotype 25
	
Genotype 19	Genotype 24

Plate 6: Chilli genotypes of cluster IV

	
Genotype 23	Genotype 15
	
Genotype 26	Genotype 20

Plate 6: Chilli genotypes of cluster IV

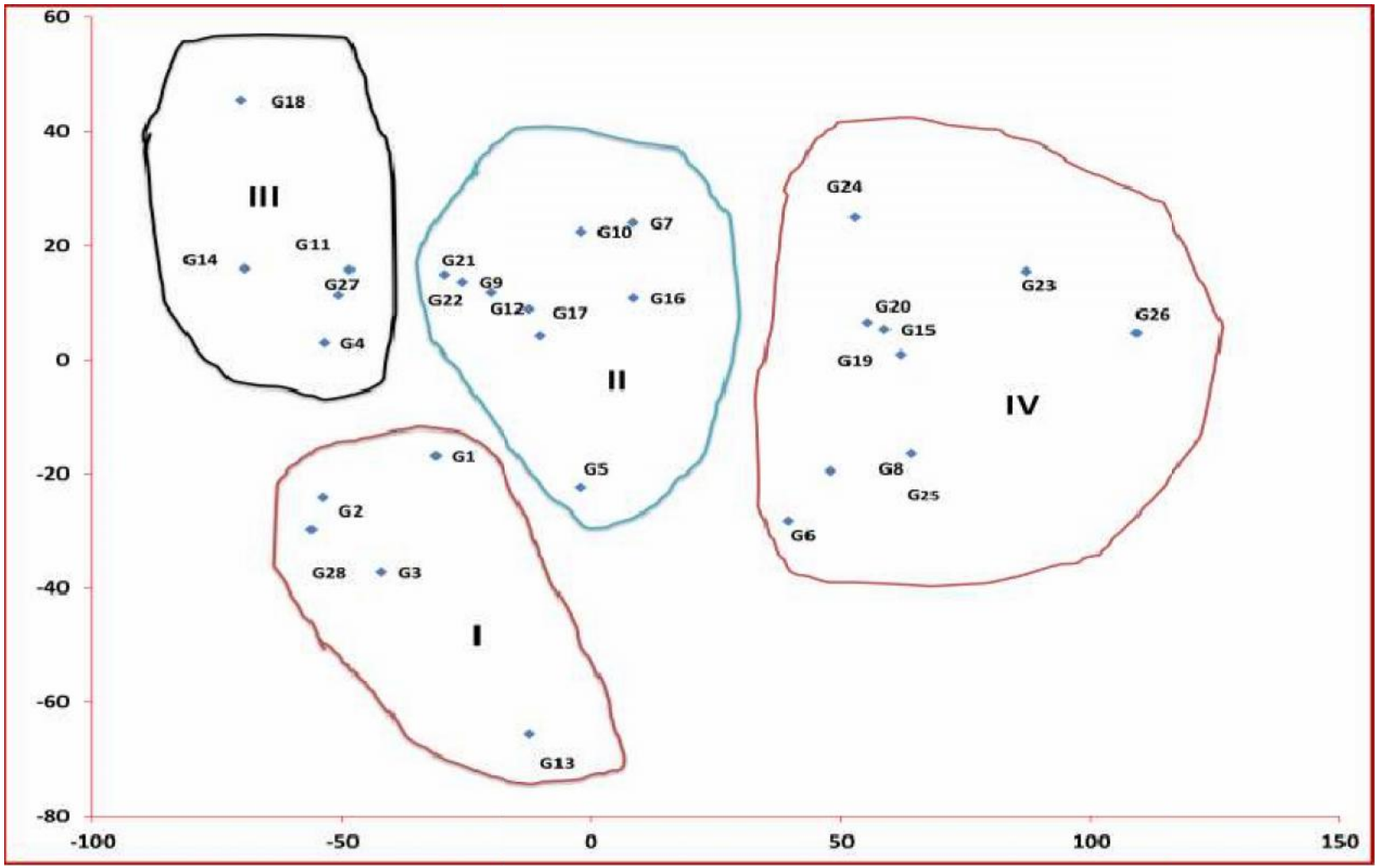


Figure 4: Cluster diagram of ***Capsicum frutescens*** genotypes based on their principal component scores.

On the other hand, the minimum inter cluster distance was found between the genotypes of cluster Il and III (3.28) followed by I and III (3.55) which showed low divergence. The intra cluster distances of cluster I. II, Ill and IV were 1.76, 0.62, 0.94 and 1.96 respectively. The averages intra and inter cluster distances (Table 10) have been used to denote cluster distances. The intra cluster distance was maximum in cluster IV (1.96) and minimum in cluster II (0.62), indicating the genotypes of cluster IV were the most heterogeneous and those in cluster II were comparatively homogeneous. Therefore, the genotypes of the widely divergent cluster IV with high yield potential would likely to produce heterotic combination and wide variability in segregating generation.

In a close similar, Senapoti *et al.* (2003) conducted an experiment in order to estimate genetic divergence in chilli by using Mahalanobis's D^2 statistics was studied for 11 characters in a collection of 20 diverse chilli genotypes and were grouped into six clusters. Karad *et al.* (2002) studied genetic divergence in chilli using Mahalanobis's D^2 statistics among 40 genotypes and noted that the genotypes were grouped into eight clusters. Sudre *et al.* (2005) evaluated genetic divergence and reported eight distinct groups between 56 chilli and sweet pepper accessions by using multivariate techniques. They used Mahalanobis's distance (D^2) as dissimilarity measure. Canonical variate analysis, cluster analysis using Toeher's method and distances in the plan was applied to assess genetic diversity. They also reported that the magnitude of intra-cluster distance was comparatively lower than that of inter cluster distances which supports the findings of the present study. Smitha *et al.* (2006) reported the presence of a high degree of genetic divergence in 40 genotypes of chilli (*Capsicum annum* L.) consisting of eight clusters.

Table 10. Intra (Bold) and inter cluster distances (D^2) for 28 genotypes

Cluster	I	II	III	IV
I	**1.76**	3.55	4.20	6.46
II		**0.62**	3.28	4.50
III			**0.94**	7.60
IV				**1.96**
V				

Table 11. Nearest and farthest cluster distances

Cluster	Nearest cluster distance	Farthest cluster distance
I	II (3.55)	IV (6.46)
II	III (3.28)	IV (4.50)
III	II (3.28)	IV (7.60)
IV	II (4.50)	III (7.60)

Genotypic distance

High genotypic distance

Table 12. Ten highest and ten lowest inter genotypic distance among the 28 genotypes of Chilli

Lowest distance				Highest distance			
Sl No.	**Genotype**		**Distance**	**Sl No.**	**Genotype**		**Distance**
01	G8	G25	0.17	01	G13	G18	2.6
02	G8	G20	0.285	02	G13	G24	2.545
03	G6	G25	0.295	03	G13	G26	2.49
04	G9	G22	0.309	04	G13	G23	2.483
05	G17	G22	0.345	05	G13	G14	2.346
06	G6	G8	0.359	06	G14	G26	2.345
07	G20	G25	0.383	07	G10	G13	2.286
08	G11	G21	0.397	08	G7	G13	2.285
09	G21	G22	0.411	09	G13	G20	2.247
10	G7	G10	0.42	10	G13	G15	2.246

Relative contribution of individual character towards divergence

The present study was carried out on seven characters viz. plant height, days to first flowering, primary branches per plant, fruit length, fruit weight, number of fruits per plant and fruit yield per plant were used to estimate genetic divergence. The plant height contributed maximum (32.48%) to the total diversity. Days to first flowering contributed (18.88%), primary branches per plant (17.43%), fruit length (12.75%), fruit weight (10.30%), number of fruits per plant (7.66%) and yield per plant (0.50%) to the total diversity. So, on the basis of the priority in contribution the order of the characters were as plant height, days to first flowering, primary branches per plant, fruit length, fruit weight, number of fruits per plant and yield per plant among them first four characters accounted more than 80% of the total divergence. Senapati *et al.* (2003) suggested that four characters, namely fresh fruit weight, fruit girth, fruit length and fruit number per plant were the chief contributors towards genetic divergence. Karad *et al.* (2002) revealed that the variances of cluster means were fresh fruit weight and fruits per plant had the highest contribution towards diversity. Smitha *et al.* (2006) recorded the maximum relative contribution to the total divergence was for NF (28.08% *),* FY (21.15%), P13 (15.00%) and SB (10.00%), S (10.00%), PS(6.67%), FW (5.26%) and FL (3.44%), confirming the existence of ample amount of divergence genotypes with respective to the traits and hence the selection of best genotypes for such traits would be helpful in utilizing the maximum heterosis in the future breeding programs. They also suggested that PH (0.51%). FD (0.381%), DAF (0.131%) and AAC (0.38%) contributed lower, indicating that these traits will not help in yield improvement through hybridization until variability are created in these traits. Chowdhury *et al.* (1994) reported that plant height, days to maturity and pods per plant had maximum contribution towards divergence in groundnut. Hossain and Alam (1989) also reported same results.

Principal component analysis (PCA)

Table 13. Eigen values and yield percent contribution of 7 characters of 28 genotypes

Principle component axis	Eigen values	Percent variation	Cumulative % of percent variation
I	2.273	32.48	32.48
II	1.321	18.88	51.36
III	1.220	17.43	68.79
IV	0.892	12.75	81.54
V	0.720	10.30	91.84
VI	0.536	7.66	99.5
VII	0.034	0.50	100

Characterization of individual clusters

The cluster means of seven characters for 28 genotypes of chilli are given in Table 14. There was a wide range of variation in the cluster mean values for all the characters. From the range and mean values of all cluster for the respective character were categorized into low (L), intermediate (I) and high (H) classes. To facilitate the characterization of each cluster in relation of those characters regards to plant height cluster IV showed high value (89 cm). Cluster Ill showed intermediate value (82.82 cm) and clusters I showed low (35.27 cm) values. With regard to days to first flowering cluster III showed high value (67) and lowest valu by the cluster IV (56.22). For primary branches per plant cluster IV showed high value (8.89) whereas cluster II showed intermediate values (8.04) and cluster I showed low value (7.87). For fruit length cluster I, Ill and IV showed high value (5.0-5.16 cm) whereas cluster II showed low value (4.80 cm). For fruit weight cluster I and cluster III showed high value (2.00 g and above) whereas cluster II showed low value (1.93 g). For number of fruits per plant cluster IV showed high value (85.82) while cluster I and II showed intermediate value (41.66 and 51.78) and cluster III showed low value (26.96). For fruit yield per plant cluster IV showed high value (166.18 g), whereas cluster II showed intermediate value (100.25 g) and cluster III showed low value (57.76 g). Masud *et al.* (1995) found a single genotype in cluster II having highest cluster mean for fruit weight, sex-ratio, seeds per fruit, dry weight etc in pumpkin. Sumabai *et al.* (1987) reported significant variation among varieties for days to flowering, plant height and fruit length in chilli.

The highest cluster mean was in cluster IV for fruit yield per plant, fruits number per plant, plant height, primary branches per plant and fruit length. Mean performance of different clusters also revealed that the highest cluster mean value for fruit yield, fruits number per plant, plant height, primary branches per plant, fruit length and lowest days to first flowering in cluster IV, while lowest value of

fruit yield, fruits number per plant and highest value of days to first flowering in cluster III indicated the maximum distance of these characters between cluster IV and III. For the plant height the maximum distance between the cluster IV (highest) and cluster I (lowest).

Relationship between genetic diversity and geographical distribution

The present study was performed with 28 genotypes of chiIli of different origin/source. From the clustering pattern (Table 14), it could be revealed that thegeographic divergence did not follow the same trend as the genotypes belonging the same cluster originated from different locations. Therefore, the clustering pattern of the genotypes indicated that the genotypes originated from the same locations did not group in the same clusters indicating that there was no parallel relationship between clustering pattern and their geographic origin. The clustering pattern of the accessions under this study revealed that the genotypes collected from the same area were grouped into different clusters. These findings fully agree with those of Mannan *et al.* (1993) in Panikachu *(Colocasia esculenta*) and Singh and Singh (1979) in okra.

Proposed to selection of genotypes for future hybridization programme

Multivariate analysis is a useful tool to quantify the degree of divergence among biological populations at genotypic level and in assessing relative contribution of different components to the total divergence both at intra and inter cluster levels (Sudre *et al.,* 2005; Manju *et al.,* 2004; Senapati *et al.,* 2003 and Karad *et al.,* 2002). Varietal distant genotypes are able to produce higher heterosis (Smitha *et al.,* 2006 and Patil *et al.,* 2004). Based on the study of genetic diversity of chilli, the genotypes having the different performance and located in the distant clusters.

Table 14. Cluster mean values of 7 different characters of 28 genotypes

Characters	**I**	**II**	**III**	**IV**
Plant height (cm)	35.27 (L)	84.89	82.87 (I)	89.00 (H)
Days to first flowering	57.93 (I)	57.93 (I)	67.00 (H)	56.22 (L)
Primary branches per plant	7.87 (L)	8.04 (I)	8.67	8.89 (H)
Fruit length (cm)	5.07	4.80 (L)	5.03 (I)	5.16 (H)
Individual fruit weight (g)	2.00	1.93 (L)	2.33 (H)	1.96 (I)
Fruit per plant	41.66	51.78 (I)	26.96 (L)	85.82 (H)
Yield per plant (g)	82.77	100.25 (I)	57.76 (L)	166.18 (H)

H = High

I = Intermediate

L = Low

could be utilized for hybridization programme to develop desired high yielding varieties. Clusters by D^2-statistics are useful in the matter. The genotypes grouped together are less divergent than the ones which into different clusters.Three important points are considered while selecting the genotypes-1) Choice of the particular cluster from which genotypes are to be used as parents 2) Selection of particular genotype from the selected cluster and 3) Relative contribution of characters to total divergence (Singh and Chaudhary, 1985). Contribution of individual characters towards divergence was also observed in this study. In respect of cluster mean performance of different clusters revealed that cluster IV can be selected for high yield, high fruits number per plant, tall plant height, high primary branches per plant, high fruit length and early flowering. Cluster Ill is important for more fruit weight and late flowering in while lowest value of' fruit yield and fruits number per plant.

Finally findings of genetic parameters and cluster analysis revealed that the characters number of fruits per plant and fruit yield along with plant height, primary branches per plant and fruit length in cluster IV found most important for genotypic co-efficient of variance, phenotypic co-efficient of variance, heritability, genetic advance and maximum contribution towards genetic divergence in the respective chilli genotypes. Therefore, considering the magnitude of genetic distance and agronomic performance the genotypes from cluster IV along with cluster III should be prioritized in future breeding program for having higher fruit yield. The greater genetic distance among the genotypes due to these characters in such clusters would also offer prime score for the development of high yielding chilli varieties. Considering magnitude of genetic distance, contribution of different characters towards the total divergence, magnitude of cluster means for different characters and field performance the genotype G13 cluster I; genotypes G14 and G4 from cluster III and genotypes G26, G23 and G24 from cluster IV would be considered as better parents for release as open pollinated variety or further use in future hybridization program.

Table 15. Salient features of selected genotypes under clusters

Cluster No.	Genotypes	Main features
I	G13	Early maturing Short plant statue
III	G14	Late maturing High fruit weight
IV	G26, G23, G24	Early flowering and maturity Highest yield per plant Highest fruits per plant Highest plant height Early maturing Highest fruit length

CHAPTER V

SUMMARY AND CONCLUSION

In order to evaluate the variability and genetic diversity of chilli the present experiment was carried out during the period from November 2017 to April 2018 at the experimental farm of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka. It was involved with 28 varieties/lines of chilli of different origin/sourees. The experiment was conducted to study the genetic divergence considering seven important yield and yield contributing characters, viz., plant height, days to first flowering, primary branches per plant, fnut length, fruit weight, number of fruits per plant and fruit yield per plant. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and seeds of the different genotypes were sown in separate seedbeds and thirty five days old seedlings were transplanted in the main field. The results of the present study are summarized as follows:

Analysis of variance revealed highly significant differences among the accessions for all the characters studied. Characters like plant height, days to first flowering, number of primary branches per plant, fruit length, fruit weight, fruits number per plant and fruit yield exhibited high genotypic and phenotypic co-efficient of variation. The phenotypic variance was higher than the corresponding genotypic variance for all the characters indicating greater influence of environment for the expression of these characters. The phenotypic co-efficient of variation was higher than the genotypic coefficient of variation for all the characters. The maximum difference between phenotypic and genotypic coefficient of variation were 27.96 and 15.04, respectively which indicated that the number of primary branches per plant was mostly depended on the environmental condition. Highest genotypic coefficients of variation was recorded for no. of fruits per plant (39.45) followed

by fruit yield (36.46), plant height (31.95), fruit weight (19.55) and fruit length (18.05). The maximum genotypic and phenotypic variations were 1630.23 and 2601.77, respectively in fruit yield per plant.

The highest estimated heritability amongst seven characters of chilli was 94.43% for days to first flowering and the lowest for 28.94% for no. of primary branches per plant. The highest genetic advance amongst all the characters was found in fruit yield 65.84 and the lowest genetic advance was carried out in fruit weight (0.66). The maximum genetic advance in percent of mean was observed for no. of fruits per plant (66.02) followed by plant height (62.34) and fruit yield per plant (59.46). Whereas, the lowest was for primary branches per plant (16.67) followed by fruit length (29.27). Again, considering both genotypic and phenotypic correlation co-efficient among seven yield contributing characters of 28 chilli genotypes fruit yield was positively and significantly correlated with plant height, fruits number per plant and number of primary branches per plant.

To estimate genetic diversity, multivariate analysis was performed through principal component analysis, principal coordinate analysis, cluster analysis and canonical variate analysis using GENSTAT 513 software programme. The first two principal component characters with egen values were greater than unity contributed a total of 68.79% variation towards divergence. As per as principal component analysis (PCA), D^2 and cluster analysis, the genotypes were grouped into four different clusters.. Cluster I and cluster III contain five genotypes each. The clustering pattern of the accessions collected from the same area was grouped into different clusters. The maximum inter-cluster divergence was observed between cluster III and IV (7.60) followed by the distances between cluster I and IV. It was found that the genotypes of the cluster- IV had usually higher intra cluster distance than the genotypes of other groups. It is suggested that the genotypes selected from the more diversified cluster-I and cluster Ill and IV could be used as parents for future breeding programs. On the other hand, the minimum inter-cluster divergence was observed between cluster ll and IIII (3.28).

Contribution of individual characters towards divergence was also observed in this study.

In respect of cluster mean performance of different clusters revealed that cluster IV can be selected for fruit yield, fruits number per plant, plant height, primary branches per plant and fruit length in while lowest value of fruit yield, fruits number per plant, plant height, primary branches per, plant fruit length and fruit weight in cluster III indicated the maximum contribution of these characters towards divergence between cluster III and IV. Finally findings of genetic parameters and cluster analysis revealed that the characters number of fruits per plant and fruit yield along with plant height, primary branches per plant and fruit length in cluster IV found most important for genotypic coefficient of variance, phenotypic co-efficient of variance, heritability, genetic advance and maximum contribution towards genetic divergence in the respective chilli genotypes. It is suggested that selection of genotypes from these more diversified groups would give better segregation when they are crossed. The greater genetic distance among the genotypes due to these characters in clusters would also offer prime score for the development of high yielding chilli variety.

CONCLUSION

In the conclusion, considering magnitude of genetic distance, contribution of different characters towards the total divergence, magnitude of cluster means for different characters and field performance the genotype G13 cluster I; genotypes G14 and G4 from cluster III and genotypes G26, G23 and G24 from cluster IV would be considered as better parents for release as open pollinated variety or further use in future hybridization program.

CHAPTER VI

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CHAPTER VII

APPENDICES

Appendix I. Morphological, physical and chemical characteristics of initial soil (0 - 15 cm depth)

A. Physical Composition of the Soil

Sl no.	Soil Separates	Percentage (%	Methods Employed
1	Sand	36.90	Hydrometer methods
2	Silt	26.40	same
3	Clay	36.66	Same
4	Texture class	Clay loam	Same

B. Chemical Composition of the Soil

Sl. No.	Soil Characteristics	Analytical data	Methods Employed
1	Organic Carbon (%)	0.82	Alkley and Black, 1947
2	Total Nitrozen (Kg/ha)	1790	Bremner and Mulvaney. 1965
3	Total S (ppm)	225	Bardsley and Lanester, 1965
4	Total Phosphorus (ppm)	840	Olsen and Sommers, 1982
5	Available Nitrozen (kg/ha)	54	Bremner. 1965
6	Available Phosphorus (kg/ha)	69	Olsen and Dean, 1965
7	Exchangeable K (Kg/ha)	89	Pratt, 1965
8	Available S (kg/ha)	16	Hunter, 1984
9	pH (1:2.5 Soil to Water)	5.55	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Appendix II. Monthly average temperature, no. of rainy days, relative Humidity

Year	Months	Maximum Temperature	Minimum temperature	Mean	Number of Rainy Days	RH %
2017	October	32.3	24.7	28.50	07	72
2017	November	29.7	20.1	24.90	04	65
2017	December	26.9	15.8	21.35	00	68
2018	January	24.6	12.5	18.50	00	66
2018	February	27.1	16.8	21.95	00	64
2018	March	31.5	19.6	25.55	00	47
2018	April	33.7	23.7	28.70	12	65
Total		205.80	133.3	169.5	33	--

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

Appendix iii. Nutritive value per 100 gums edible portion of chilli (*Capsicum frutescens)*

Nutrients	Value (mg)	Nutrients	Value (mg)
Moister	85.6	Phosphorous	80
Protien	2.9	Iron	1.2
Fat	0.6	Sodium	6.5
Minerals	1.0	Potasium	212
Fibre	6.9	Copper	1.50
Carbohydrate	3.5	Sulfer	34
Calcium	30	Chlorine	15
Magnesium	24	Thiamin	0.19
Riboflavin	0.36	Vitamin A	292 I.U.
Oxalic acid	67	Vitamin C	112