MORPHOLOGICAL CHARACTERIZATION AND GENETIC DIVERSITY OF ONION (*Allium cepa* L.)

BY

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CERTIFICATE

*This is to certify that thesis entitled, "**MORPHOLOGICAL CHARACTERIZATION AND GENETIC DIVERSITY OF ONION (Allium cepa L.)**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in GENETICS AND PLANT BREEDING**, embodies the result of a piece of bonafide research work carried out by **Nilufar Yasmin, Registration No. 07-02582** 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 duly been acknowledged.

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TO

HUSBAND AND SON

LIST OF ABBREVIATIONS AND SYMBOLS

Full Words	Abbreviations
Agro-Ecological Zone	AEZ
And Others	*et al.*
Bangladesh Agricultural Research Institute	BARI
Blooming Period	BP
Centimeter	Cm
Days Required for Visible Appearance of Shoot	DVAS
Diameter of Floral Stock	DFS
Days to Inflorescence Appearance	DIA
Days to Full Blooming of Inflorescence	DFBI
Days to Maturity	DM
Degree Celsius	C^0
Degrees of freedom	d.f.
Figure	Fig.
Genetic Advance	GA
Gram	g
Genotypic Coefficient of Variation	GCV
Genotypic Variance	(σ^2_g)
Heritability in broad sense	h^2b
Mean Sum of Square	MSS
Phenotypic Coefficient of Variation	PCV
Phenotypic Variance	(σ^2_p)
Randomized Complete Block Design	RCBD
Sher-e-Bangla Agricultural University	SAU
Sher-e-Bangla Agricultural University Bulb Germplasm	SAU-B-G
Square meter	m^2

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June, 2009 ***The Author***

SAU, Dhaka

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MORPHOLOGICAL CHARACTERIZATION AND GENETIC DIVERSITY OF ONION (*Allium cepa* L.)

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ABSTRACT

An experiment was conducted to study genetic divergence and morphological characterization and yield potentiality of ten different onion genotypes. The study was carried out at the experimental farm, Dept. of Genetics and Plant Breeding, SAU, during November, 2007 to April, 2008. The results indicated that different genotypes showed significant variation regarding all the characters studied. Maximum differences of genotypic and phenotypic variances and coefficient of variation as well as high heritability coupled with high genetic advance were observed for most of the traits. The maximum bulb yield (524.64 g) per plant was noticed in the genotype SAU-B-G-7. The same genotype also showed highest performance in respect of no. of bulb per plant. The genotype SAU-B-G-1 matured within minimum days (108.00) which showed the lowest (32.39 g) bulb yield among the materials under study. Cluster II comprised maximum number of genotypes (6) followed by cluster III, I, and IV. The highest inter genotypic distance was observed between genotypes SAU-B-G-1 and SAU-B-G-7 (3.483). The inter cluster distance was maximum between the cluster I and IV (9.083). Among the characters diameter of floral stock (1.1473) and days required for visible appearance of shoot (0.1220) were major characters that contributed mostly toward genetic divergence.

Chapter I
Introduction

CHAPTER I

INTRODUCTION

Herbaceous biennial plant (*Allium cepa*) of the lily family, probably native to South Asia but now grown worldwide for its edible bulb. Among the hardiest and oldest garden-vegetable plants, onions bear a cluster of small, greenish white flowers on one or more leafless stalks. The leaf base swells to form the underground mature edible onion. Onions are pungent; because they contain a sulfur-rich volatile oil, peeling or slicing them can cause a person's eyes to tear. Onions vary in size, shape, color and pungency. Though low in standard nutrients, they are valued for their flavor. Onions have been claimed to cure colds, earaches, and laryngitis and have been used to treat animal bites, powder burns, and warts; like their close relative garlic, they are being studied for other suspected beneficial qualities.

Onions, apparently native to Asia, were unknown to the American Indians. Early colonists first brought them to America. Wethersfield, Connecticut, soon became a noted onion-growing center. Records show that Wethersfield was shipping onions as early as 1710. A century later it was sending out a million bunches annually. Nonetheless, as onion culture spread to all parts of the country, Wethersfield lost its preeminence. Soon after 1900 extensive production of Bermuda onions began in Texas, California, and Louisiana. By 2002 Idaho, Oregon, Washington, and California had come to lead the United

States in onion production. In that year the American onion crop was worth between $3 billion and $4 billion retail.

Onion, plant of the family Liliaceae (lily family), of the same genus (*Allium*) as the chive (*A. schoenoprasum*), garlic (*A. sativum*, leek (*A. porrum*), and shallot (*A. ascalonium*). These plants are characterized by an edible bulb composed of food-storage leaves that are rich in sugar and are pungent oil, source of its strong taste. The above-ground green leaves, typically long and tubular, are also eaten. All these species are believed to be native to SW Asia and are known to have been cultivated since ancient times. Onion is classified in the division Magnoliophyta, class Liliopsida, order Liliales, family Liliaceae.

Onions, one of the oldest vegetables, are found in a large number of recipes and preparations spanning almost the totality of the world's cultures. They are now available in fresh, frozen, canned, caramelized, pickled, powdered, chopped, and dehydrated forms. Onions can be used, usually chopped or sliced, in almost every type of food, including cooked foods and fresh salads and as a spicy garnish. They are rarely eaten on their own, but usually act as accompaniment to the main course. Depending on the variety, an onion can be sharp, spicy, tangy and pungent or mild and sweet

Onions may be grown from seed or, more commonly today, from sets started from seed the previous year. Onion sets are produced by sowing seed very thickly one year, resulting in stunted plants that produce very small bulbs. These bulbs are very easy to set out and grow into mature bulbs the following year, but they have the reputation of producing a less durable bulb than onions grown directly from seed and thinned.

Either planting method may be used to produce spring onions or green onions, which are the leaves or immature plants. Green onion is a name also used to refer to another species, *Allium fistulosum*, the Welsh onion, which is said not to produce dry bulbs. The tree onion produces bulbs instead of flowers and seeds, which can be planted directly in the ground.

Morphological characterization is important to identify the species, to classify the species into different groups and give an idea about the crop canopy. Information on genetic divergence and morphological appearance among the plant materials is vital to a plant breeder for an efficient choice of parent for hybridization. Yield is a complex character and various morphological and physiological characters contribute to yield. It is essential to have knowledge on variability of different characters for the yield improvement.

A good knowledge of genetic resources might also help in identifying desirable cultivars for commercial cultivation. Lack of high yielding, disease and pest tolerant variety is the main constraints toward its production. Among the cultivated land races, a wide range of genetic variability exists in this crop that can be exploited for its improvement. It is the touchstone to a breeder to develop high yielding varieties through selection, either from the existing genotypes or from the segregates of a cross. Hence, information on variability in respect of yield and its contributing traits required to be properly assessed for its improvement.

Therefore, the above study was conducted on following objectives:

- To characterize the genotypes on the basis of different morphological and yield contributing characters
- To study the genetic diversity among the materials
- To select the genetically diverged materials for further onion improvement programme.

Chapter II

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Saleh, S. A. (2003) observed that the effects of intercropping sugar beet with onions in 60 and 120 cm ridges and the application of N fertilizers (20, 40 and 60 kg/fed) in combination with a biological fertilizer on the yield, yield components and chemical composition of sugar beet were determined in a field experiment conducted in Egypt during 2000-02. Intercropping sugar beet with onion at 60 cm ridges resulted in higher yield and yield components, as well as sucrose and soluble sugar content of the former compared to sole cropping or intercropping at 120 cm ridges. Onion yield and yield components were higher when grown 120 cm ridges apart. Application of N at 60 kg/fed increased all the sugar beet characters examined. Land equivalent ratio and net returns were higher when ridges were 120 cm wide.

Shahbazi, F. and Jafarzadeh, A. A. (2004) reported that land suitability evaluation (qualitative classification) was carried out for wheat, barley, Lucerne, onion, sugar beet and maize in an area of 400 ha in Khusheh-Mehr region of Bonab in East Azarbaijan, Iran. Eight soil profiles in different land units (1.1, 1.2, 2.1 and 2.2) were studied and two soil orders (Entisols and Inceptisols) were identified. Climatic data collected from Maragheh meteorological station were used. In addition, simple limitation method, limitation method regarding number and intensity and parametric methods

(Storie and square root) were selected and land suitability classes were determined. Regarding simple limitation method and limitation method based on number and intensity almost 60% of the area (240 ha) are moderately suitable (S2) and 40% (160 ha) are marginally suitable (S3) for wheat, barley, Lucerne, onion, sugar beet and maize, however, based on parametric method (Storie), almost 60% of the land are marginally suitable (S3) and 40% are actually unsuitable and potentially suitable (N1) for wheat, barley and sugar beet. For Lucerne, 25% of area is moderately suitable (S2), 35% is marginally suitable (S3) and the remaining 40% is actually unsuitable and potentially suitable (N1). Also 60% of the area is S3, 21% N1 and remaining 19% of the area is unsuitable (N2) for onion and maize. Using parametric method based on square root, 60% of the area is moderately suitable (S2) and 40% is marginally suitable (S3) for wheat, barley, Lucerne and sugar beet, 60% of area is S2, 21% S3 and 19% N1 for onion and 25% of area is S2 and 75% S3 for maize. Therefore, based on these results, the cultivation of wheat, barley, Lucerne and sugar beet in the first place and onion cultivation in the second place can be recommended. Comparison of the methods indicates that the parametric method based on square root is more realistic than the other methods.

Maliogka *et al.*, (2006) reported that an isometric virus ca. 25 nm in diameter with angular contour was isolated from onion plants showing yellow leaf striping and necrotic tips. The virus was mechanically transmitted onto 28 species of indicator plants belonging to five families, viz. Amaranthaceae, Chenopodiaceae, Cucurbitaceae, Leguminosae, and Solanaceae where it causes ring spots, malformations, and/or tip necrosis. Cytopathological studies in infected Nicotiana benthamiana tissues revealed cytoplasmic inclusions resembling those caused by Artichoke yellow ring spot virus (AYRSV), a member of the family Comoviridae. Host range and symptomatology of the onion virus were also similar to AYRSV. A high seed transmission rate (20%) was found in onion. Reverse transcription-polymerase chain reaction using degenerate primers specific for the family Comoviridae allowed amplification of RNA-dependent RNA polymerase sequences, which upon sequence analysis and comparison with AYRSV isolates from Cynara scolymus (AYRSV-AtG) and Vicia faba (AYRSV-F) were highly similar, thus providing evidence that the nepovirus AYRSV is infecting onion in the field.

McCollum *et al.*, (2005) observed that the wide variation in onion bulb sulfur compounds associated with flavor and health attributes is well documented but poorly understood at the molecular level. We used a combination of genomic, agronomic and biochemical methods to dissect key factors underlying this variation. EST sequencing and homology-based cloning permitted the identification of cDNAs for most structural genes in the pathway of sulfate assimilation. We used these to develop markers for candidate gene mapping and measure gene expression at mRNA and protein level. Since earlier studies revealed significant differences in sulfur partitioning among onion cultivars, we compared the expression of the sulfur assimilation pathway in mild and pungent cultivars to determine whether sulfur uptake and flavor intensity differences are associated with differential regulation of the pathway. Results confirmed that there are significant differences in gene expression and enzyme activity between cultivars and significant changes on transition to bulbing. We optimized gas chromatographic analysis of the lachrymatory factor thiopropanal-S-oxide as a direct measure of a flavor bioactive. Our experience in field-based agronomic and mapping studies confirmed that this is a practical and economical way to profile flavor in large-scale genetic and agronomic studies.

Gent *et al.*, (2006) observed that Xanthomonas leaf blight has become an increasingly important disease of onion, but the diversity among Xanthomonas strains isolated from onion is unknown, as is their relationship to other species and pathovars of Xanthomonas. Forty-nine Xanthomonas strains isolated from onion over 27 years from 10 diverse geographic regions were characterized by pathogenicity to onion and dry bean, fatty acid profiles, substrate utilization patterns (Biolog), bactericide resistance, repetitive sequence-based polymerase chain reaction fingerprinting, rDNA internally transcribed spacer (ITS) region, and hrp b6 gene sequencing. Multiplication of onion Xanthomonas strain R-O177 was not different from X. axonopodis pv. phaseoli in dry bean, but typical common bacterial blight disease symptoms were absent in dry bean. Populations from each geographical region were uniformly sensitive to 100 micro g of CuSO4, 100 micro g of ZnSO4, and 100 micro g of streptomycin sulfate per ml. Biolog substrate utilization and fatty acid profiles revealed close phenoltypic relatedness between onion strains of Xanthomonas and X. axonopodis pv. dieffenbachiae (57% of strains) and X. arboricola pv. poinsettiicola (37% of strains), respectively. A logistic regression model based on fatty acid composition and substrate utilization classified 69% of strains into their geographical region of origin. Sequencing of a portion of the hrp B6 gene from 24 strains and ITS region from 25 strains revealed greater than 97% sequence similarity among strains. DNA fingerprinting revealed five genotype groups within onion strains of Xanthomonas and a high degree of genetic diversity among geographical regions of origin. Based on pathogenicity to onion, carbon substrate utilization, fatty acid profiles, rDNA genetic diversity, and genomic fingerprints, we conclude that the strains examined in this study are pathovar X. axonopodis pv. allii. Implications of genetic and phenotypic diversity within X. axonopodis pv. allii are discussed in relation to an integrated pest management program.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental Site

The experiment was carried out at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka-1207 during November, 2007 to April, 2008. The experimental site is located at 23°41' N latitude and 90°22' E longitude having an elevation of 8.6m from the sea level (Figure 1). The physical and chemical characteristics of the soil have been presented in (Appendix 1).

3.2 Soil and Climate

The experimental site was situated in the subtropical zone. The soil of the experimental site lies in Agro ecological region of "Modhupur" track. (AEZ No. 28) of Norda soil series. The soil is sandy loam in texture and olive gray with common fine to medium distinct dark yellowish brown mottles. The pH is 5.47 to 5.63 and organic carbon content is 0.82% (Appendix 1). The mean temperature during the re-search period was 24.21 degree centigrade with average maximum and minimum being 29.4 degree centigrade and 19.03 degree centigrade respectively. The record of air temperature, humidity and rain fall during the period of experiment were noted from the Bangladesh Meteorological Department, Agargaon, Dhaka (Appendix 2).

3.3 Genotypes

A total number of ten genotypes were used in this experiment. The bulb of the ten genotypes was collected from several area and market of Bangladesh.

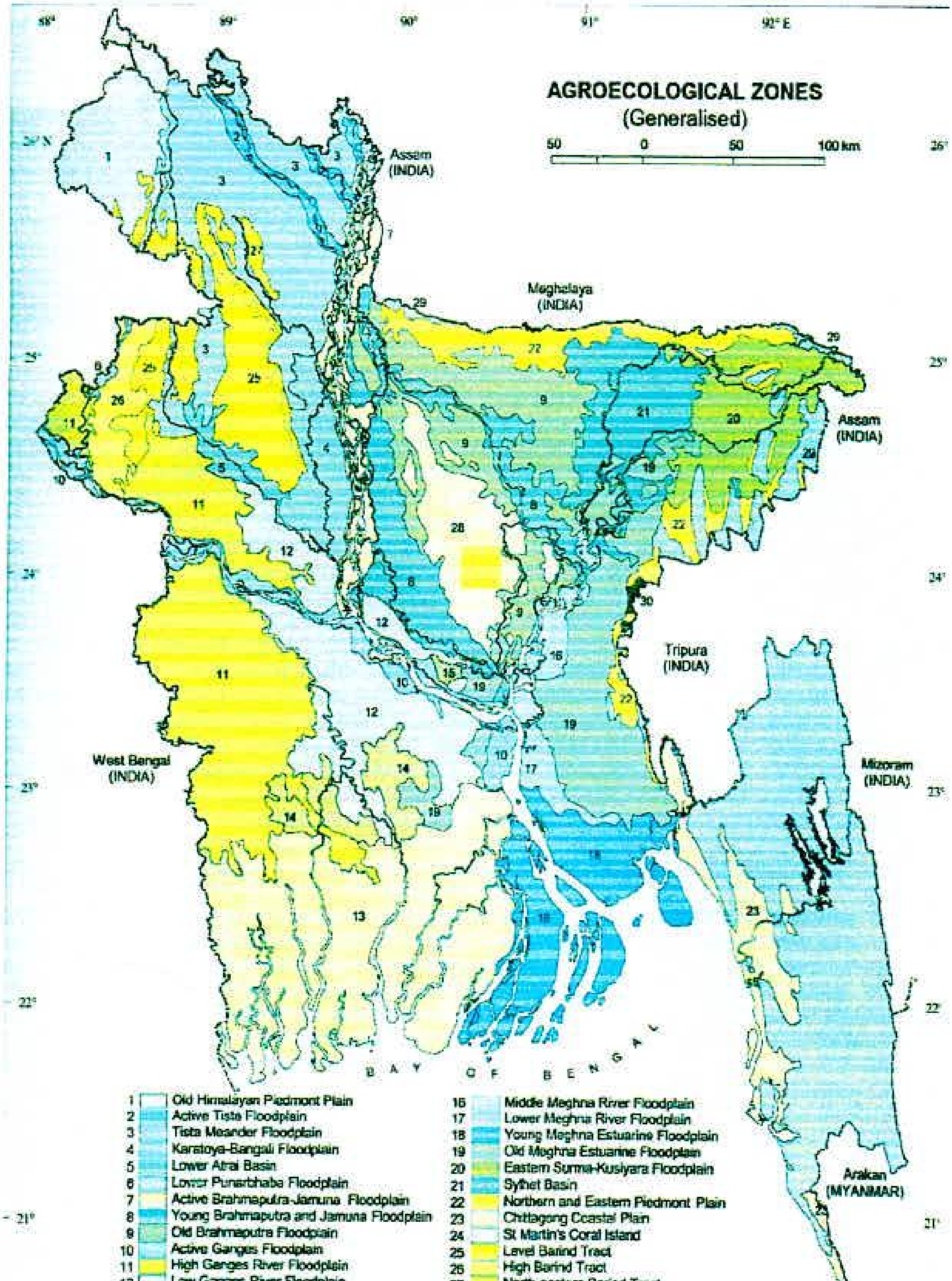

Figure 1. Location of the experimental field

3.4 Design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The whole experimental area was divided into three blocks, representing three replications. The total area of experiment was 5 m X 4 m = 20 square meter. Plant to plant distance was 10 cm and row to row distance was 15 cm.

3.5 Preparation of main land

The experimental plot was at a lower elevation with high water holding capacity. The land was prepared thoroughly by 3-4 times ploughing and cross ploughing followed by laddering to attain a good puddle. Weeds and stubbles were removed and land was finally prepared by addition of basal dose of fertilizers recommended by Anonymous (1999).

3.6 Sowing of Bulb

The bulb of different genotype was shown in lines in the experimental plots on November, 2007. The bulb was placed at about 5 to 10 cm depth in the soil. Field view of experiment was shown in Plate 1a and Plate 1b.

3.7 Application of Manures and Fertilizers

Manures and fertilizer was used in the experiment according to the recommendation of BARI which is shown in Table 1. The whole amount of well decomposed cow dung and all the fertilizer along with half of urea was applied at the time of final land preparation as a basal dose. The second half of Urea was top dressed at the time of initiation of flowers.

Table 1: Doses of manure and fertilizer used in the present study

Manures/Fertilizer	Doses/ha	Doses/Plot
Cow dung	5 ton	3 Kg
Urea	260 Kg	156 gm
TSP	220 Kg	132 gm
MP	200 Kg	120 gm
Gypsum	180 Kg	108 gm

Plate 1a. Field view of the experimental site

Plate 1b. Field view of the experimental field

3.8 Intercultural operation and after care

Necessary intercultural operation was taken during cropping period for proper growth and development of the plants.

3.8.1 Weeding: The first weeding was done after 15 days of sowing of bulb to keep the crop free from weeds. Weeding was also done several times when it was needed.

3.8.2 Irrigation and drainage: In the early stage, Irrigation was done twice daily with the help of hose pipe or watering cane. After rainfall excess water drained out when necessary.

3.9 Plant protection measures

Proper control measures were taken against pest of onion during cropping stage.

3.10 Data collection

Data were collected from 10 randomly selected plant of each genotype on individual plant basis.

3.10.1 Days required for visible appearance of shoot

Days required for visible appearance of shoot was recorded from the date of sowing of bulb to date of visible appearance of shoot.

3.10.2 Leaf length (cm)

The length was recorded in cm from node of the leaf to tip of the leaf.

3.10.3 Length of floral stock (cm)

The length was recorded in cm from first node of the rachis to tip of the top most flowers.

3.10.4 Diameter of floral stock (cm)

Diameter of floral stock was recorded by slide calipers.

3.10.5 Days to inflorescence appearance

Days to inflorescence appearance was recorded from the date of sowing of bulb to date of inflorescence appearance.

3.10.6 Days to full blooming of inflorescence

Days to full blooming of inflorescence was recorded from the date of sowing of bulb to date of full blooming of inflorescence.

3.10.7 Blooming period

Blooming period was measured from the time of the start of anthesis to close of the opened flower. It was recorded in hours and minutes.

3.10.8 Days to maturity

Days to maturity was recorded from the date of sowing of bulb to date of harvesting.

3.10.9 Number of seeds per plant

The number of seeds per plant was measured during heading stage of onion.

3.10.10 Thousand seed weight (g)

1000 seed weight was measured after harvesting.

3.10.11 Bulb weight (g)

Bulb weight was measured after harvesting.

3.10.12 Number of bulbs per plant

Number of bulbs per plant was measured after harvesting.

3.10.13 Yield per plant (g)

All the seeds of ten plants were dried in the sun (drying continued until reaches 14% moisture content), weighed in gram and measured by dividing it by ten.

3.11 STATISTICAL ANALYSIS

All the collected data of the present study were statistically analyzed. The statistical analyses for various characters under investigation were done and the analysis of variance for each of the characters was performed by F test and mean values were separated by DMRT (Steel and Torrie, 1980).

The analysis of variance was done according to Goulden's methods (1959). Genotypic and phenotypic coefficients of variations were computed using the formula suggested by Burton (1952). Heritability in broad sense and genetic advance were calculated according to methods given by Allard (1960).

3.11.1 Variability of Onion Genotypes

3.11.1.1 Estimation of Phenotypic and Genotypic Variance

Genotypic and phenotypic variances were estimated by Johnson *et al.* (1995). Genotypic variance (σ^2g) was obtained by subtracting genotype mean sum of squire to error mean sum of squire and dividing by the number of replication as given below:

$$\text{Genotypic Variance } (\sigma^2_g) = \frac{\text{GMS} - \text{EMS}}{\text{Number of replication(r)}}$$

Where,

GMS = Genotypic mean sum of square

EMS = Error mean sum of square

The phenotypic variances (σ^2_p) were come from by adding genotypic variances (σ^2_g) with error variance (σ^2_e) as shown by the given formula:

$$(\sigma^2_p) = (\sigma^2_g) + (\sigma^2_e)$$

3.11.1.2 Estimation of Genotypic and Phenotypic Coefficient of variation

According to the Johnson *et al.* (1955) genotypic and phenotypic coefficient of variation were estimated.

$$\text{Genotypic coefficient of Variation (GCV)} = \frac{\sigma_g}{\text{Grand Mean}}$$

Where,

σ_g = Genotypic standard deviation

$$\text{Phenotypic Coefficient of variation (PCV)} = \frac{\sigma_p}{\text{Grand Mean}}$$

Where,

σ_p = Phenotypic standard deviation

3.11.1.3 Estimation of Heritability

Johnson *et al.* (1955) was suggesting a formula for estimating broad sense heritability.

$$\%h^2b = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where, h^2b = Heritability in broad sense

σ^2_g = Genotypic variance
σ^2_p = Phenotypic variance

3.11.1.4 Estimation of Genetic Advance

The expected genetic advance for different characters under selection was estimated using the formula suggested by Johnson *et. al.*, (1955)

$$\text{Genetic Advance (GA)} = \frac{\sigma^2_g}{\sigma^2_p} \times k \times \sigma_p$$

Where,

K = Selection intensity, the value of which is which is 2.06 at 5% selection intensity.

σ_p = Phenotypic standard deviation

σ^2_g = Genotypic variance
σ^2_p = Phenotypic variance

3.11.1.5 Estimation of Genetic Advance in Percentage of Mean

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

$$\text{Genetic Advance in Percentage of Mean} = \frac{\text{Genetic Advance}}{\text{Grand Mean}} \times 100$$

3.11.2 Genetic Diversity Analysis

3.11.2.1 Principal Component Analysis (PCA)

Principal components were computed from the correlation matrix and genotypic scores obtain for the first component and succeeding components with latent roots greater than unity (Jager *et al.* 1983).

3.11.2.2 Principal Coordinate Analysis (PCO)

Principal coordinate analysis is equivalent to PCA but it is used to calculate inter-unit distances. Through the use of all dimensions of it gives the minimum distance between each pair of n points using similarity matrix (Digby *et al.*, 1989). Inter-distance between genotypes was studied by PCO.

3.11.2.3 Clustering Analysis (CLSA)

Genotypes were divided into groups on the basis of data set into some number of mutually exclusive groups. The clustering was done using hierarchical classification. In Genstat, the algorithm is used for searching. The optimal values of the criteria followed by some initial classification of the genotypes into required number of groups, the algorithm repeatedly transfers 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 swapping two genotypes of different classes, and so on.

3.11.2.4 Canonical Variate Analysis (CVA)

The canonical variate analysis is based upon the roots and vectors of W-1B, where w is the pooled with in groups covariance matrix and B is the among groups covariance matrix. It provides two-dimensional plots, which helped in separating different populations involved.

3.11.2.5 Computation of Average Intra-cluster Distances

Once the clusters were formed, the average intra-cluster distance for each cluster was calculated by taking all possible D^2 values within the numbers of cluster obtained from PCO. The formula used was D^2/n, where D^2 is the sum of distances between all possible combinations (n) of the genotypes included in a cluster. The square root of the average D^2 values, represent the distances (D^2) with in cluster.

3.11.2.6 Computation of Average Inter-cluster Distances

The procedure for calculating inter-cluster distance between cluster II and I and between cluster III and I and between I and IV, between II and IV and so on. The clusters taken one by one and their distances from other clusters were calculated.

3.11.2.7 Cluster Diagram

Using the values of intra-and inter-cluster distance, cluster diagram was drawn. It gives a brief idea of the pattern of diversity among the genotypes included in a cluster.

3.11.2.8 Selection of Genotypes for Future Hybridization Programme

Genotypes were selected from the study for future hybridization progrmme considering genetic variability and other performances related to yield (gm), number of bulb per plant, color of bulb, weight of bulb, days to first flowering, and days to maturity.

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises the presentation and discussion of the findings obtained from the study. The data pertaining to 13 morphological as well as yield and its contributing characters were computed and statistically analyzed and the results thus obtained are discussed below:

4.1 Characterization of onion

4.1.1 Morphological characterization

4.1.2 Characterization of onion genotypes on the basis of yield and yield contributing characters.

4.2 Genetic Variability, heritability and genetic advance in onion genotypes

4.3 Genetic diversity presents among the onion genotypes

4.1 Characterization of onion

4.1.1 Morphological Characterization

The results of the morphological characteristics of ten genotypes of onion are presented in (Table 2) and discussed bellow under the following headings:

4.1.1.1 Bulb color

Eight types of bulb color viz. light brown, dark red, reddish, light pink, purple, brown, pink and pale orange were observed among the genotypes. Light brown was observed in SAU-B-G-1, dark red was observed in SAU-B-G-2, reddish was observed in SAU-B-G-3 and BARI Onion 1, light pink was observed in

Table 2. Morphological characterization of ten genotypes of onion

Sl. No.	Name of Genotypes	Bulb		Leaf		Floral Stock		Seed	
		Color	Shape	Color	Shape	Color	Shape	Color	Shape
1	SAU-B-G-1	Light Brown	Elongated	Dark Green	Long Erect	Dark Green	Round Cylindrical	Black	Irregular
2	SAU-B-G-2	Dark Red	Round	Green	Medium Erect	Green	Round Cylindrical	Black	Irregular
3	SAU-B-G-3	Reddish	Round to Oval	Green	Long Erect	Green	Round Cylindrical	Black	Irregular
4	SAU-B-G-4	Light Pink	Round	Green	Long Erect	Green	Round Cylindrical	Black	Irregular
5	SAU-B-G-5	Light Pink	Elongated	Light Green	Medium Erect	Green	Cylindrical	Black	Irregular
6	SAU-B-G-6	Purple	Round	Light Green	Long Erect	Light Green	Flat Cylindrical	Black	Irregular
7	SAU-B-G-7	Brown	Globe	Pale Green	Medium Erect	Light Green	Flat Cylindrical	Black	Irregular
8	SAU-B-G-8	Pink	Flat Round	Pale Green	Short Erect	Yellowish Green	Round Cylindrical	Black	Irregular
9	SAU-B-G-9	Pale Orange	Round to Elongated	Yellowish Green	Medium Erect	Light Green	Round Cylindrical	Black	Irregular
10	BARI Onion 1	Reddish	Round	Light Green	Medium Erect	Light Green	Round Cylindrical	Black	Irregular

SAU-B-G-4 and SAU-B-G-5, purple was observed in SAU-B-G-6, brown was observed in SAU-B-G-7, pink was observed in SAU-B-G-8 and pale orange were observed in SAU-B-G-9 among the genotypes. Currah and Proctor, 1990 find similar result and it was morphologically significant.

4.1.1.2 Shape of bulb

Elongated bulb shape was observed in SAU-B-G-1 and SAU-B-G-5 among the genotypes (Table 2). Round bulb shape were observed in SAU-B-G-2, SAU-B-G-4, SAU-B-G-6 and BARI Onion 1 among the genotypes. Round to oval were observed in SAU-B-G-2 among the genotypes. Globe, Flat Round and Round to Elongated was observed in SAU-B-G-7, SAU-B-G-8 and SAU-B-G-9, respectively among the genotypes.

4.1.1.3. Leaf color

Out of ten genotypes, 3 genotypes had green leaves and 3 genotypes had light green leaves. Among the rest genotypes, genotype SAU-B-G-1 had dark green, SAU-B-G-7 and SAU-B-G-8 had pale green and SAU-B-G-9 had yellowish green color leaf.

4.1.1.4 Shape of leaf

Among the genotypes of this study 4 had long erect and 5 medium erect leaf shape. Only one genotype SAU-B-G-8 had short erect leaf shape.

4.1.1.5 Color of floral stock

Green colored floral stock was observed in SAU-B-G-2, SAU-B-G-3, SAU-B-G-4 and SAU-B-G-5. Light green floral stock color was observed in SAU-B-G-6, SAU-B-G-7, SAU-B-G-9 and BARI Onion 1 among the genotypes. Dark green floral stock color was observed in SAU-B-G-1 and yellowish green floral stock color was observed in SAU-B-G-8 among the genotypes.

4.1.1.6 Shape of floral stock

Maximum 7 genotypes of this study had round cylindrical and 2 flat cylindrical type floral stock shapes. Only one genotype SAU-B-G-5 had cylindrical floral stock shape.

4.1.1.7 Seed color

Seed color of all the genotypes was black.

4.1.1.8 Shape of seeds

Seeds of all the genotypes were irregular in shape.

4.1.2 Characterization of onion genotypes on the basis of yield and yield contributing characters

4.1.2.1 Days required for visible appearance of shoot

Significant variation on days required for visible appearance of shoot was observed among the genotypes (Table 3). The genotype BARI Onion 1 flowered early (4.00 days) which was statistically similar with genotype SAU-B-G-3 (4.33 days) and SAU-B-G-9 (4.33 days). Genotype SAU-B-G-8 required maximum days required for visible appearance of shoot (9.67 days) followed by the genotype SAU-B-G-5 (8.33 days). Days required for visible appearance of shoot in different genotypes varied may be due to inherent characteristics of genotypes. The present result was also supported by the findings of Ramamoorthy *et al*., (1999).

Table 3: Mean performance of thirteen characters of ten genotypes of onion

Name of Genotypes	DVAS	LL(cm)	LFS(cm)	DFS(cm)	DIA	DFBI	BP	DM	NSP	TSW (g)	BW(g)	NBP	Y /P (g)
SAU-B-G-1	4.67cd	38.00bc	39.67d	5.08bc	47.00a	57.33a	10.33a	108.00d	225.00d	2.36de	10.76g	3.00e	32.39f
SAU-B-G-2	4.67cd	36.67bc	63.33a	4.68d	42.33bc	52.67b	10.33a	114.33bc	355.67c	2.00e	16.28ef	3.67de	59.49ef
SAU-B-G-3	4.33d	31.67cd	57.67abc	5.33b	46.33a	55.67ab	9.33ab	113.33c	393.33abc	2.07e	18.08e	5.33bc	96.48de
SAU-B-G-4	5.67c	41.00b	55.00abc	5.51ab	45.00ab	53.67ab	8.67bc	108.00d	375.67bc	1.92e	15.59efg	6.667a	104.05de
SAU-B-G-5	8.33b	34.33bcd	49.33bcd	6.01a	48.00a	56.67ab	8.67bc	121.33a	392.00abc	2.71bcd	30.43d	4.33cd	131.76d
SAU-B-G-6	9.33ab	28.33d	48.67bcd	5.08bc	39.67cd	48.33c	8.67bc	112.33c	370.00bc	2.74bcd	12.56fg	6.33ab	79.33e
SAU-B-G-7	5.00cd	34.33bcd	49.33bcd	5.51ab	48.00a	55.00ab	7.00d	116.67b	386.33abc	2.57cd	78.78a	6.67a	524.64a
SAU-B-G-8	9.67a	42.00b	59.67ab	5.08bc	45.33ab	52.33bc	7.00d	121.33a	418.00abc	2.99bc	43.50c	6.33ab	276.39c
SAU-B-G-9	4.33d	50.00a	48.00cd	5.33b	48.00a	55.67ab	7.67cd	121.33a	431.67ab	3.06ab	54.80b	6.67a	365.16b
BARI Onion 1	4.00d	35.00bcd	63.00a	5.33b	36.67d	43.00d	6.33d	112.00c	447.00a	3.47a	16.51ef	6.00ab	99.04de
LSD	1.03	7.17	10.26	0.23	3.64	4.12	1.32	2.82	56.31	0.42	4.67	1.03	44.68
CV (%)	10.04	11.26	11.20	6.50	4.75	4.53	9.19	1.43	8.65	9.45	9.16	10.95	14.72

DVAS=Days required for visible appearance of shoot; LL=Leaf length; LFS=Length of floral stock; DFS=Diameter of floral stock; DIA=Days to inflorescence appearance, DFBI=DAYS to full blooming of inflorescence; BP=Blooming period; DM=Days to maturity; NSP=Number of seed per plant; TSW=Thousand seed weight; BW=Bulb weight; NBP=Number of bulb per plant. Y/P = Yield per plant. According to DMRT (Duncan Multiple Range Test) a, b, c, d, e, f indicate the ranking of the mean value.

4.1.2.2 Leaf length

Remarkable difference among the genotypes for leaf length was observed (Table 3). It ranged from 28.33 cm to 50.00 cm. The highest leaf length was measured in SAU-B-G-9 (50.00 cm) and the lowest one was measured from SAU-B-G-6 (28.33 cm). The variation in leaf length may be due to the inherent genetic differences among the genotypes. This result is agreed with the findings of Rashid and Rashid (1976). Different leaf morphology of ten genotypes of Onion is shown in Plate 2a.

4.1.2.3 Length of floral stock

The length of floral stock among the ten genotypes ranged from 39.67 to 63.33 cm (Table 3). The genotype SAU-B-G-2 had the highest (63.33 cm) length of floral stock which was statistically similar with BARI Onion 1 (63.33 cm). The lowest length of floral stock was found in the genotype SAU-B-G-1 (39.67 cm). Different floral stock morphology of ten genotypes of Onion is shown in Plate 2b.

4.1.2.4 Diameter of floral stock

Significant difference among the genotypes for diameter of floral stock was observed (Table 3). It ranged from 1.83 cm to 2.37 cm. The highest diameter of floral stock was measured in SAU-B-G-5 (2.37 cm). Lowest one was measured from SAU-B-G-2 (1.83 cm). The variation in diameter of floral stock may be due to the inherent genetic differences among the genotypes. These findings are in agreement with the result of Rahman (2004).

Plate 2a. Different leaf morphology of ten genotypes of Onion

Plate 2b. Different floral stock morphology of ten genotypes of Onion.

4.1.2.5 Days to inflorescence appearance

Significant variation on days to inflorescence appearance was observed among the genotypes (Table 3). The genotype BARI Onion 1 flowered early (36.67 days) followed by SAU-B-G-2 (42.33 days). Genotype SAU-B-G-9 required maximum time for inflorescence appearance (48.00 days) which was statistically similar with genotype SAU-B-G-7 (48.00 days), SAU-B-G-5 (48.00 days), SAU-B-G-3 (46.33 days) and SAU-B-G-1 (47.00 days). Days required for inflorescence appearance in different genotypes varied may be due to inherent characteristics of genotypes.

4.1.2.6 Days to full blooming of inflorescence

Significant variation on days to full blooming of inflorescence was observed among the genotypes (Table 3). The genotype BARI Onion 1 bloomed early (43.00 days) followed by SAU-B-G-6 (48.33 days). Genotype SAU-B-G-1 required maximum time for full blooming of inflorescence (57.33 days). Days required for full blooming of inflorescence in different genotypes varied may be due to inherent characteristics of genotypes.

4.1.2.7 Blooming period

Results on blooming period showed that the genotypes were significantly different (Table 3). Early blooming period (6.33 days) was observed incase of genotype of BARI Onion 1 which was statistically similar with genotype SAU-B-G-7 (7.00 days) and SAU-B-G-8 (7.00 days). The genotype SAU-B-

G-1 was late in blooming and required maximum time for blooming period (10.33 days) which was statistically identical with the genotype SAU-B-G-2 (10.33 days).

4.1.2.8 Days to maturity

Significant variation on days to maturity was observed among the genotypes (Table 3). The genotype SAU-B-G-1 flowered early (108.00 days) which was statistically similar with SAU-B-G-4 (108.00 days). Genotype SAU-B-G-8 required maximum time for maturity (121.33 days) which was statistically similar with genotype SAU-B-G-9 (121.33 days) and SAU-B-G-5 (121.33 days). Days required for maturity in different genotypes varied may be due to inherent characteristics of genotypes.

4.1.2.9 Number of seeds per plant

The significant differences in number of seeds per plant among the genotypes were observed (Table 3). Among the ten genotypes BARI Onion 1 produced maximum number of seeds (447.00) per plant. The minimum number of seeds per plant (225.00) was obtained from the genotypes SAU-B-G-1.

4.1.2.10 Thousand seed weight (g)

The weight of 1000 seed differed significantly among the genotypes (Table 3). They showed wide variation within the genotypes. The genotype BARI Onion 1 produced the maximum weight of 1000 seed (3.47 g). The minimum weight of 1000 seed (1.92 g) measured from the genotype SAU-B-G-4 which was statistically similar with genotype SAU-B-G-2 (2.00 g) and SAU-B-G-3 (2.07 g). Wide variation in 1000 seed weight might be due to different seed size.

4.1.2.11 Bulb weight (g)

The weight of bulb differed significantly among the genotypes (Table 3). They showed wide variation within the genotypes. The genotype SAU-B-G-7 produced the maximum weight of bulb (78.77 g) which was significantly different from others. The minimum weight of bulb (10.76 g) measured from the genotype SAU-B-G-1. Galmarini *et al.* (1995) found that the increasing number of plant density decreased the bulb size. Bulb appearance of different Onion Genotypes is shown in Plate 3.

4.1.2.12 Number of bulbs per plant

The significant differences in number of bulbs per plant among the genotypes were observed (Table 3). Among the ten genotypes, SAU-B-G-4 produced maximum number of bulb per plant (6.67) which was statistically similar with genotype SAU-B-G-7 (6.67) and SAU-B-G-9 (6.67). The minimum number of bulb per plant (3.00) was obtained from the genotypes SAU-B-G-1.

4.1.2.13 Yield per plant (g)

Wide variation on yield (g) was observed among the genotypes (Table 3). The genotype SAU-B-G-7 produced the highest yield (524.64 g) which was statistically different from the other genotypes. This may be due to higher number of bulb per plant as well as maximum bulb weight in SAU-B-G-7.

Plate 3. Bulb appearance of different Onion genotypes

The second highest yield (365.16 g) was produced by the genotype SAU-B-G-9. The minimum yield (32.38 g) was recorded from SAU-B-G-1. The observed differences in yield among the genotypes might be due to the inherent characteristics of the genotypes. Khandelural and Maith (1971) found that the widest spacing increased the yield.

4.2 Genetic Variability, heritability and genetic advance in onion genotypes

The analysis of variance (ANOVA) indicated the existence of highly significant variability for all the characters studied (Table 4). Grand mean, range and co-efficient of variation of ten onion genotypes in respect of thirteen characters are presented in (Table 5). The mean sum of square, variance components, coefficients of genotypic and phenotypic variations, heritability, genetic advance and genetic advance in percent of mean (GAPM) are presented in (Table 6). The results are discussed character wise as follows:

4.2.1 Days required for visible appearance of shoot

Mean sum of square for days required for visible appearance of shoot was highly significant due to onion genotypes (Table 4) indicating existence of considerable difference for this trait. The maximum days required for visible appearance of shoot were found as 9.67 and the minimum was recorded as 4 with mean value of 6 (Table 5). The σ^2_g (4.79), σ^2_p (5.15), GCV (79.88) and PCV (85.93) were close to each other indicating less environmental influence in case of days required for visible appearance of shoot (Table 6). Heritability

Table 4. Mean sum squares from the ANOVA of ten onion genotypes in respect of thirteen characters

Source of variation	df	Mean sum of square												
		Days required for visible appearance of shoot	Leaf length (cm)	Length of floral stock (cm)	Diameter of floral stock (cm)	Days to inflorescence appearance	Days to full blooming of inflorescence	Blooming period	Days to maturity	Number of seeds per plant	Thousand seed weight (g)	Bulb weight (g)	Number of bulbs per plant (g)	Yield /plant
Replication	2	0.40	36.23	85.63	0.06	8.13	5.63	0.30	2.03	953.03	0.06	15.48	0.40	1100.74
Genotypes	9	14.74	110.90	174.70	0.06	45.51	57.74	5.76	80.09	11232.46	0.77	1523.36	5.57	76776.90
Error	18	0.36	17.49	35.74	0.09	4.50	5.78	0.60	2.70	1077.74	0.06	7.41	0.36	678.28

Table 5. Grand Mean, Range and co-efficient of variation of ten onion genotypes in respect of thirteen characters

Parameter	Days required for visible appearance of shoot	Leaf length (cm)	Length of floral stock (cm)	Diameter of floral stock (cm)	Days to inflorescence appearance	Days to full blooming of inflorescence	Blooming period	Days to maturity	Number of seeds per plant	Thousand seed weight (g)	Bulb weight (g)	Number of bulbs per plant	Yield /plant (g)
Grand mean	6.00	37.13	53.37	5.29	44.63	53.03	8.40	114.87	379.47	2.59	29.73	5.50	176.87
Range	4-9.67	28.33-50	39.67-63.33	1.83-2.37	36.67-48	43-57.33	6.33-10.33	108-121.30	225-44	1.92-3.47	10.76-78.78	3-6.67	32.4-524.60
Co-efficient of variation	10.04	11.26	11.20	6.50	4.75	4.53	9.19	1.43	8.65	9.45	9.16	10.95	14.72

Table 6. Genetic parameters of different characters of genotypes of Onion

Parameter	Days required for visible appearance of shoot	Leaf length (cm)	Length of floral stock (cm)	Diameter of floral stock (cm)	Days to inflorescence appearance	Days to full blooming of inflorescence	Blooming period	Days to maturity	Number of seeds per plant	Thousand seed weight (g)	Bulb weight (g)	Number of bulbs per plant	Yield /plant (g)
Mean sum of square	14.74**	110.90**	174.70**	0.06*	45.51**	57.74**	5.76**	80.09**	11232.46**	0.77**	1523.36**	5.57**	76776.90**
σ^2_g	4.79	31.14	46.32	0.01	13.67	17.32	1.72	25.79	3384.91	0.24	505.32	1.74	25366.21
σ^2_e	0.36	17.49	35.74	0.02	4.50	5.78	0.59	2.70	1077.74	0.06	7.41	0.36	678.28
σ^2_p	5.15	48.63	82.06	0.03	18.17	23.10	2.31	28.49	4462.64	0.29	512.73	2.10	26044.49
h^2_b	92.96	64.03	56.44	43.75	75.22	74.97	74.29	90.52	75.85	79.87	98.55	82.71	97.40
GA (5%)	43.48	91.98	105.33	1.61	66.06	74.23	23.30	99.54	1043.80	8.98	459.70	24.69	3237.98
GAPM	724.72	247.71	197.36	77.40	148.00	139.97	277.38	86.66	275.07	346.91	1546.26	448.93	1830.71
GCV	79.88	83.85	86.79	0.67	30.63	32.66	20.50	22.46	892.02	9.19	1699.69	31.58	14341.72
PCV	85.93	130.96	153.77	1.54	40.72	43.56	27.60	24.81	1176.03	11.51	1724.61	38.18	14725.22
ECV	6.05	47.11	66.98	0.86	10.09	10.90	7.10	2.35	284.01	2.32	24.92	6.60	383.49

** = Significant at 1% level, σ^2_g = Genotypic variance, σ^2_e = Environmental variance, σ^2_p = Phenotypic variance, h^2b = Heritability in broad sense, GA = Genetic advance, GAPM = Genetic advance in Percent Mean, GCV = Genotypic Coefficients of Variations, PCV = Phenotypic Coefficients of Variations and ECV = Environmental Coefficients of Variations estimates for this trait was medium, GA and GAPM was found moderate, indicated that selection for this character would be effective.

4.2.2 Leaf length

Mean sum of square for leaf length was highly significant due to onion genotypes (Table 4) indicating existence of considerable difference for this trait. The maximum leaf lengths were found as 50 cm and the minimum was recorded as 28.33 cm with mean value of 37.13 cm (Table 5). The σ^2_g (31.14), σ^2_p (48.65), GCV (83.85) and PCV (130.96) were close to each other indicating less environmental influence in case of leaf length. Heritability (64.03%) estimates for this trait was medium, GA and GAPM was found moderate, indicated that selection for this character would be effective.

4.2.3 Length of floral stock

Mean sum of square for length of floral stock was highly significant due to onion genotypes (Table 4) indicating existence of considerable difference for this trait. The maximum length of floral stock was found as 63.33 cm and the minimum was recorded as 39.67 cm with mean value of 53.37 cm (Table 5). The σ^2_g (46.32), σ^2_p (82.06), GCV (86.79) and PCV (153.77) were close to each other indicating less environmental influence in case of length of floral stock (Table 6). Heritability (56.44%) estimates for this trait was moderate together with considerable low GA and GAPM indicated that selection for this character would not be effective.

4.2.4 Diameter of floral stock

Mean sum of square for diameter of floral stock was highly significant in different onion genotypes (Table 4) indicating existence of considerable variability for this trait. The maximum diameter of floral stock was found as 6.01 cm and the minimum was recorded as 4.68 cm with mean value of 5.29 cm (Table 5). The σ^2_g (0.01), σ^2_p (0.03), the GCV (0.67) and PCV (1.54) were close to each other indicating less environmental influence (Table 6). Heritability (43.75%) estimates for this trait was moderate. GA and GAPM was also found very high, indicated that selection for this character would be more effective.

4.2.5 Days to inflorescence appearance

Mean sum of square for days to inflorescence appearance was highly significant due to onion genotypes (Table 4) indicating existence of considerable difference for this trait. The maximum inflorescence appearance were found as 48 days and the minimum was recorded as 36.67 days with mean value of 44.63 days (Table 5). The σ^2_g (13.67), σ^2_p (18.17), the GCV (30.63) and PCV (40.72) were close to each other indicating less environmental influence in case of days to inflorescence appearance (Table 6). Heritability (75.22%) estimates for this trait was high together with considerable moderate GA and GAPM indicated that selection for this character would be effective.

4.2.6 Days to full blooming of inflorescence

Mean sum of square for days to full blooming of inflorescence was highly significant due to onion genotypes (Table 4) indicating existence of considerable difference for this trait. The maximum days to full blooming of inflorescence were found as 57.33 and the minimum was recorded as 43 with mean value of 53.03 days (Table 5). The σ^2_g (17.32), σ^2_p (23.10), the GCV (32.66) and PCV (43.56) were close to each other indicating less environmental influence in case of days to full blooming of inflorescence (Table 6). Heritability (74.97%) estimates for this trait was moderate, GA and GAPM was found moderately high, indicated that selection for this character would be effective.

4.2.7 Blooming period

Mean sum of square for blooming period was highly significant due to onion genotypes (Table 4) indicating existence of considerable variation for this trait. The maximum blooming period were found as 10.33 days and the minimum was recorded as 6.33 days with mean value of 8.40 days (Table 5). The σ^2_g (1.72), σ^2_p (2.31), the GCV (20.50) and PCV (27.60) were close to each other indicating less environmental influence in case of blooming period (Table 6). Heritability (74.29%) estimates for this trait was high, GA and GAPM was found moderately high, indicated that selection for this character would be effective.

4.2.8 Days to maturity

Mean sum of square for days to maturity was highly significant due to onion genotypes (Table 4) indicating existence of considerable variability for this trait. The maximum days to maturity were found as 121.30 and the minimum was recorded as 108 with mean value of 114.46 days (Table 5). The σ^2_g (25.80), σ^2_p (28.50), the GCV (22.46) and PCV (24.81) were close to each other indicating less environmental influence in case of days to maturity (Table 6). Heritability (90.52%) estimates for this trait was high, GA and GAPM (86.66) indicated that selection for this character would be effective.

4.2.9 Number of seeds per plant

Mean sum of square for number of seeds per plant was highly significant due to onion genotypes (Table 4) indicating existence of considerable difference for this trait. The maximum numbers of seed per plant were found as 447 and the minimum was recorded as 225 with mean value of 379.47 (Table 5). The σ^2_g (3384.91), σ^2_p (4462.64), the GCV (892.02) and PCV (1176.03) were close to each other indicating less environmental influence in case of number of seed per plant (Table 6). Heritability (75.85%) estimates for this trait was high, GA and GAPM (275.07) indicated that selection for this character would be effective.

4.2.10 Thousand seed weight

Mean sum of square for thousand seed weight was highly significant due to onion genotypes (Table 4) indicating existence of considerable difference for this trait. The maximum thousand seed weights were found as 3.47 g and the minimum was recorded as 1.92 g with mean value of 2.59 g (Table 5). The σ^2_g (0.24), σ^2_p(0.30), the GCV (9.19) and PCV (11.51) were close to each other indicating less environmental influence in case of thousand seed weight (Table 6). The heritability value (79.87%) was high.

4.2.11 Bulb weight

Mean sum of square for bulb weight was highly significant due to onion genotypes (Table 4) indicating existence of considerable difference for this trait. The maximum bulb weight was found as 78.78 g and the minimum was recorded as 10.76 g with mean value of 29.73 g (Table 5). The σ^2_g (505.32), σ^2_p (512.73), the GCV (1699.69) and PCV (1724.61) were close to each other indicating less environmental influence in case of bulb weight (Table 6). The heritability value (98.55%) as well as genetic advance and genetic advance in percentage of mean were observed high.

4.2.12 Number of bulbs per plant

Mean sum of square for number of bulbs per plant was highly significant due to onion genotypes (Table 4) indicating existence of considerable difference for this trait. The maximum number of bulb per plant was found as 6.67 and the minimum was recorded as 3.00 with mean value of 5.50 (Table 5). The σ^2_g (1.74), σ^2_p (2.10), the GCV (31.58) and PCV (38.18) were close to each other indicating less environmental influence in case of number of bulb per plant

(Table 6). The heritability value (82.71%) as well as genetic advance and genetic advance in percentage of mean were observed high. The very high heritability with moderate genetic advance in percentage of mean provided opportunity for selecting high valued genotypes for breeding programme.

4.2.13 Yield per plant

Mean sum of square for yield per plant (g) was highly significant due to onion genotypes (Table 4) indicating existence of considerable difference for this trait. The maximum yield per plant was found as 524.60 g and the minimum was recorded as 32.40 g with mean value of 176.87 g (Table 5). The σ^2_g (25366.21), σ^2_p (26044.49), the GCV (14341.72) and PCV (14725.22) were close to each other indicating less environmental influence in case of yield per plant (g) (Table 6). The heritability value (97.40%) was high. Similar result was found by Verma *et al.* (1972).

4.3 Diversity of the onion Genotypes

Genetic divergence in onion was analyzed by using GENSTAT software programme. Genetic diversity analysis involved reversal steps i.e., estimation of distance between the genotypes, clusters, and analysis of inter-cluster distance. Therefore, more than one multivariate technique was required to re-present the results more clearly and it was obvious from the results of many researchers (Bashar, 2002; Uddin, 2001; Juned *et al.*, 1998 and Aria, 1987). In the analysis of genetic diversity in onion multivariate techniques were used.

4.3.1 Principal component analysis (PCA)

Principal component analysis was carried out with 10 onion genotypes. First four eigen values for four principal coordination axes of genotypes accounted for 80.64 % variation (Table 7). A two dimensional scattered diagram was developed on the basis of the principal component score of two principal coordinates axes I and II (Figure 2 and Figure 3).

4.3.2 Principal coordinates analysis (PCO)

The result obtained from principal coordinate analysis showed that the highest inter genotypic distance was observed between genotypes SAU-B-G-1 and SAU-B-G-7 (3.483) followed by SAU-B-G-1 and SAU-B-G-9 (3.039) (Table 8). The lowest distance were observed (0.437) between genotypes SAU-B-G-3 and SAU-B-G-4 followed by the distance (0.633) between genotypes SAU-B-G-2 and SAU-B-G-3. The difference between the highest and the lowest inter genotypic distance indicated the moderate variability among the 10 onion genotypes. These inter genotypic distances were used in computation of intra-cluster distances on the basis of the suggestion forwarded by Singh and Chaudhary (1977). The highest intra-cluster distance was recorded in cluster II (0.861) (Table 11 and Fig. 4) containing six genotypes (SAU-B-G-2, SAU-B-G-3, SAU-B-G-4, SAU-B-G-5, SAU-B-G-6 and BARI Onion 1). The lowest intra-cluster distance was observed in cluster I & IV (0.000) having one genotype viz. SAU-B-G-1 and SAU-B-G-7, respectively. It favored to decide that intra-group

Table7. Eigen values and percentage of variation for corresponding thirteen component characters in ten onion genotypes

Principal component axis	Eigen values	% of total variation accounted for	Cumulative percent
Days required for visible appearance of shoot	4.64	35.71	35.71
Leaf length (cm)	3.45	26.57	62.28
Length of floral stock (cm)	1.36	10.47	72.75
Diameter of floral stock (cm)	1.03	7.89	80.64
Days to inflorescence appearance	0.92	7.11	87.75
Days to full blooming of inflorescence	0.76	5.85	93.60
Blooming period	0.60	4.66	98.26
Days to maturity	0.17	1.31	99.57
Number of seeds per plant	0.05	0.43	100
Thousand seed weight (g)	0	0	100
Bulb weight (g)	0	0	100
Number of bulbs per plant	0	0	100
Yield per plant (g)	0	0	100

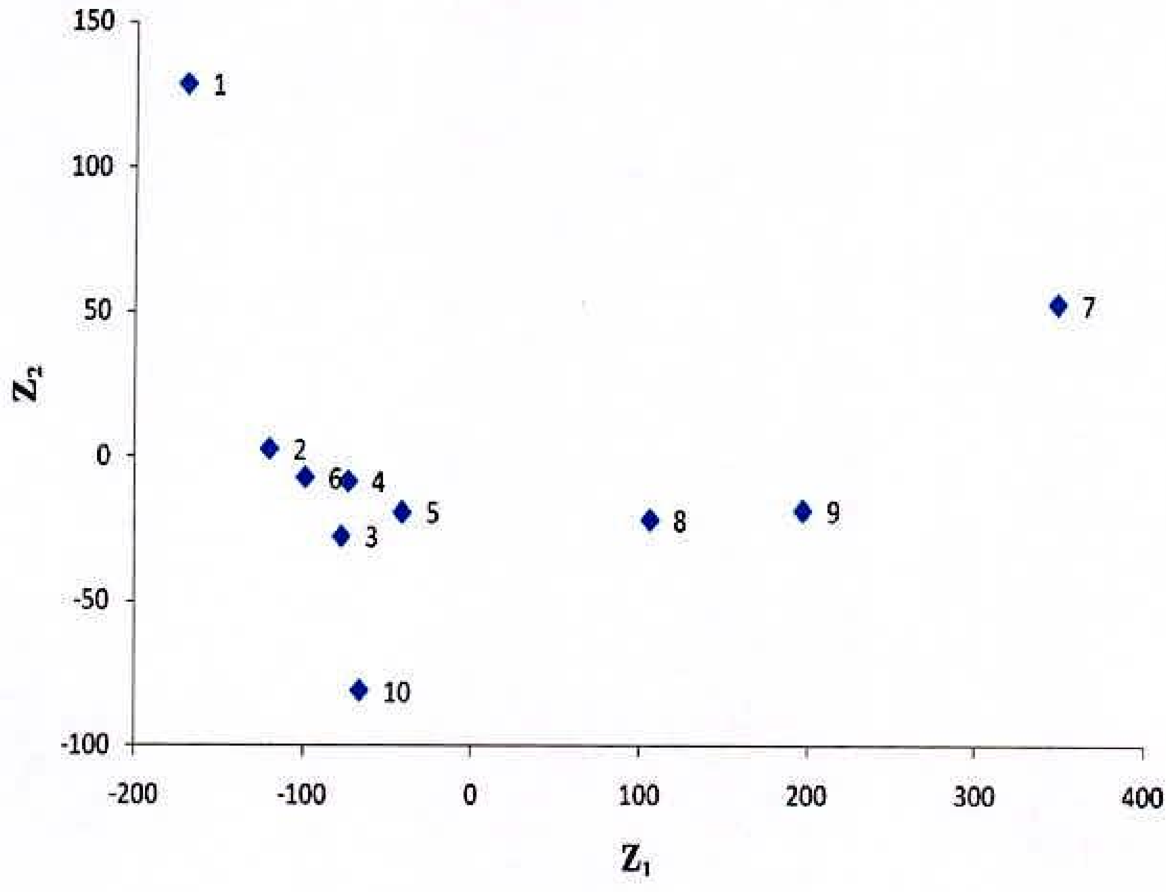

Figure 2. Scatter diagram of 10 onion genotypes based on their principal component scores

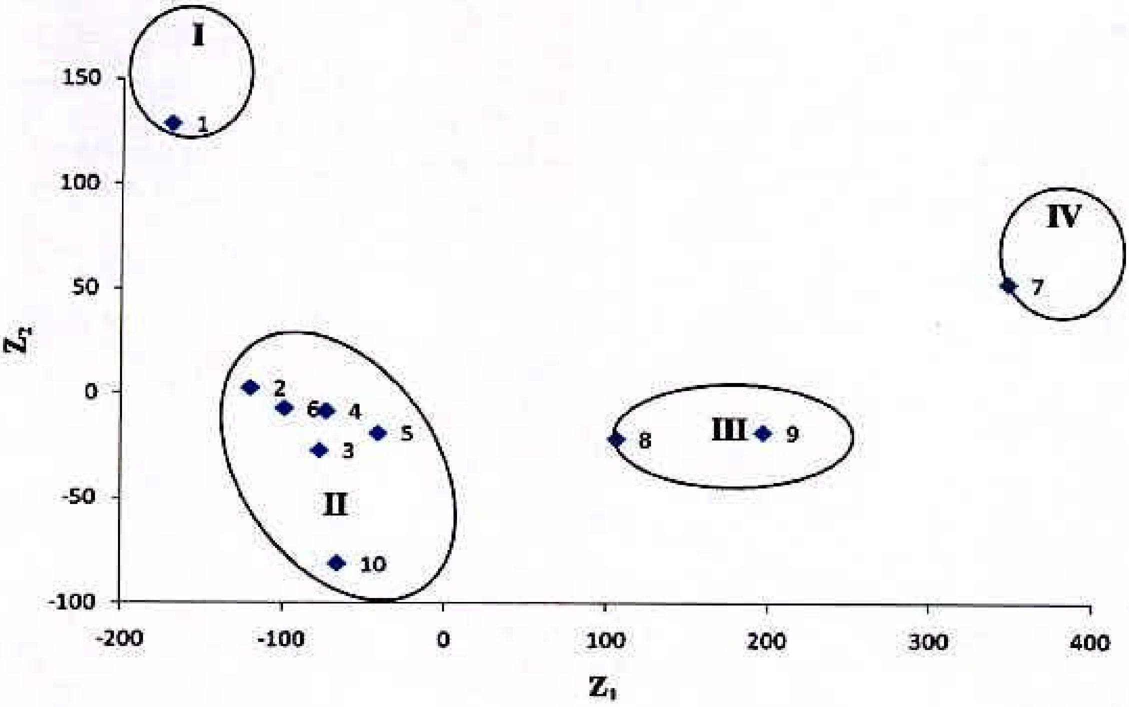

Figure 3. Scatter distribution of 10 onion genotypes based on their principal component scores superimposed with clusters

Table 8. Ten highest and ten lowest inter genotypic distance among the ten onion genotypes

Sl. No.	Genotypic combination	Distances
A. 10 highest inter genotypic distance		
01	SAU-B-G-1 – SAU-B-G-7	3.483
02	SAU-B-G-1 – SAU-B-G-9	3.039
03	SAU-B-G-1 – SAU-B-G-8	2.783
04	SAU-B-G-2 – SAU-B-G-7	2.742
05	SAU-B-G-6 – SAU-B-G-7	2.664
06	SAU-B-G-7 – BARI Onion 1	2.315
07	SAU-B-G-2 – SAU-B-G-9	2.294
08	SAU-B-G-4 – SAU-B-G-7	2.280
09	SAU-B-G-6 – SAU-B-G-9	2.270
10	SAU-B-G-3 – SAU-B-G-7	2.249
B. 10 lowest inter genotypic distance		
01	SAU-B-G-3 – SAU-B-G-4	0.437
02	SAU-B-G-2 – SAU-B-G-3	0.633
03	SAU-B-G-3 - BARI Onion 1	0.657
04	SAU-B-G-7- SAU-B-G-9	0.667
05	SAU-B-G-4 - BARI Onion 1	0.718
06	SAU-B-G-4 – SAU-B-G-6	0.737
07	SAU-B-G-2 – SAU-B-G-4	0.812
08	SAU-B-G-8 – SAU-B-G-9	0.837
09	SAU-B-G-3 – SAU-B-G-6	0.862
10	SAU-B-G-3 – SAU-B-G-5	0.878

diversity was the highest in cluster II and the lowest in cluster I & IV. Cluster III having two genotypes viz. SAU-B-G-8 & SAU-B-G-9 and had an intra-cluster distance 0.837 (Table 9 and Table 11).

4.3.3 Non-hierarchical clustering

The computations from covariance matrix gave non-hierarchical clustering among 10 onion genotypes and grouped them into four clusters. The clustering pattern obtained coincided with the apparent grouping patterns performed by PCA. So the results obtained through PCA were confirmed by non-hierarchical clustering (Table 9) represents the clusters occupied by 10 onion genotypes. It explains that's cluster II contained the highest number of genotypes (six), cluster III constitute by two genotypes and cluster I and IV constitute by one genotypes respectively. Intra cluster mean for 13 traits are presented in (Table 10). These clusters were able to lead in respect of the highest cluster mean value for maximum characters. Among 13 characters cluster I stood first for two characters viz. days to full blooming of inflorescence (57.33) and blooming period (10.33) (Table 10).

Cluster II was formed by six genotypes viz. SAU-B-G-2, SAU-B-G-3, SAU-B-G-4, SAU-B-G-5, SAU-B-G-6 and BARI Onion 1. Among them BARI Onion 1 were collected from BARI and rest are originated from SAU. Having six genotypes, this cluster was unable to lead in respect of cluster mean value of 13 characters. The highest cluster mean value was achieved for only one characters viz. length of floral stock (56.17) (Table 10).

Table 9. Distribution of ten onion genotypes in four clusters

Cluster	Number of members	Onion Genotypes
I	1	SAU-B-G-1
II	6	SAU-B-G-2, SAU-B-G-3, SAU-B-G-4, SAU-B-G-5, SAU-B-G-6 & BARI Onion 1
III	2	SAU-B-G-8 & SAU-B-G-9
IV	1	SAU-B-G-7

Table 10. Cluster mean for thirteen characters of ten onion genotypes

SL. No.	Characters	Cluster			
		I	II	III	IV
01	Days required for visible appearance of shoot	4.67	6.06	7.00	5.00
02	Leaf length (cm)	38.00	34.50	46.00	34.33
03	Length of floral stock (cm)	39.67	56.17	53.83	49.33
04	Diameter of floral stock (cm)	2.00	2.09	2.05	2.17
05	Days to inflorescence appearance	47.00	43.00	46.67	48.00
06	Days to full blooming of inflorescence	57.33	51.67	54.00	55.00
07	Blooming period	10.33	8.67	7.33	7.00
08	Days to maturity	108.00	113.56	121.33	116.67
09	Number of seeds per plant	225.00	388.94	424.83	386.33
10	Thousand seed weight (g)	2.36	2.49	3.02	2.57
11	Bulb weight (g)	10.76	18.24	49.15	78.78
12	Number of bulbs per plant	3.00	5.39	6.50	6.67
13	Yield per plant (g)	32.39	95.02	320.77	524.64

Genotypes SAU-B-G-8 and SAU-B-G-9 established cluster III. The genotypes of this cluster are originated from SAU. The highest cluster mean value was achieved for five characters viz. days required for visible appearance of shoot (7.00), leaf length (46.00), days to maturity (121.33), number of seed per plant (424.83) and thousand seed weight (3.02).

Cluster IV had one genotypes named SAU-B-G-7. The genotype is originated from SAU. The highest cluster mean value was achieved for five characters viz. diameter of floral stock (2.17 cm), days to inflorescence appearance (48.00), bulb weight (78.78 g), number of bulb per plant (6.67) and yield per plant (524.64 g). Bulb view of different onion genotypes of cluster I, II, III, IV was shown in Plate 4a. Plate 4b, Plate 4c, Plate 4d.

Plate 4a. Bulb view of different onion genotypes of Cluster I

Plate 4b. Bulb view of different onion genotypes of Cluster II

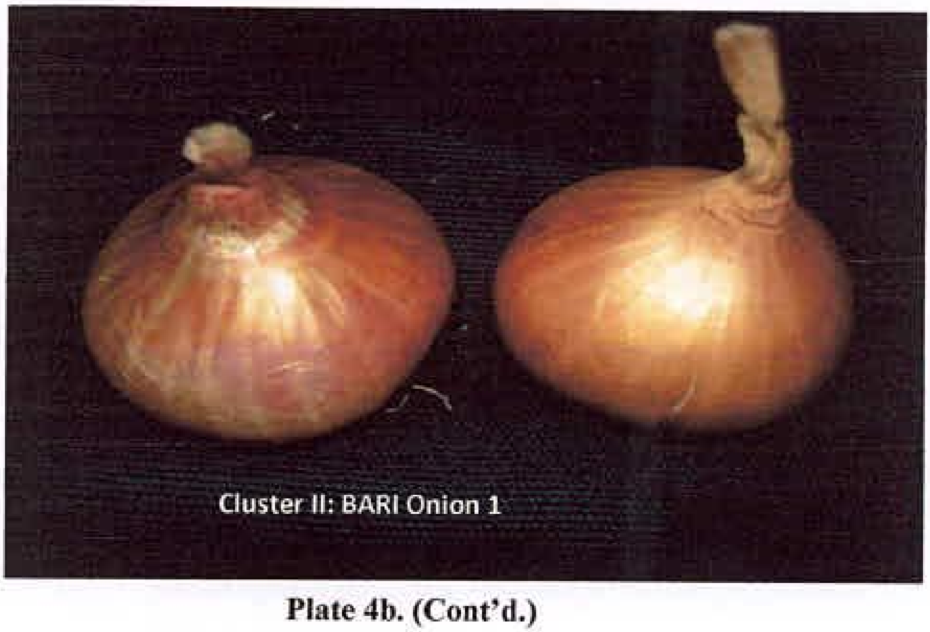

Plate 4b. (Cont'd.)

Cluster II: SAU 5

Cluster II: SAU 6

Plate 4b. Bulb view of different onion genotypes of Cluster II

Cluster III: SAU BG 8

Cluster III: SAU BG 9

Plate 4c. Bulb view of different onion genotypes of cluster III

Cluster IV: SAU BG 7

Plate 4d. Bulb view of different onion genotypes of cluster IV

4.3.4 Canonical variate analysis

The highest inter-cluster distance was observed (Table 11 or Figure 4) between cluster I and IV (9.083). The intra cluster distance was the highest (0.861) in cluster II. The lowest inter-cluster distance was observed between cluster III and IV (3.781). The inter cluster distances were higher than the intra cluster distances suggesting wider genetic diversity among the genotype of different groups. No parallel relationship was found between genetic and geographic divergence, which may be due to continuous exchange of germplasm from one place to another. Differently originated genotypes found in same cluster or genotypes from same origin were dispersed in different clusters. Genotypes from BARI and SAU being in different clusters, indicating the broad genetic variability. There was evidence from Shanmugam and Rangasamy (1982) that materials from same origin distributed in different clusters is an indication of broad genetic base of the genotypes belonging to that origin.

4.3.5 Contribution of characters towards divergence of the genotypes

The values of Vector I and Vector II are presented in (Table 12). Vector 1 obtained from PCA expressed that days required for visible appearance of shoot (0.1220), length of floral stock (0.0729), diameter of floral stock (1.1473), days to inflorescence appearance (0.0489), days to full blooming of inflorescence (0.0246), number of seed per plant (0.0005) and number of bulb per plant (0.0267) were major characters that contribute to the genetic divergence. In vector 2, days required for visible appearance of shoot (0.1220),

Table 11. Average intra and inter cluster distances (D^2) for ten onion genotypes

Clusters	I	II	III	IV
I	**0.000**			
II	4.758	**0.861**		
III	5.369	4.732	**0.837**	
IV	9.083	7.964	3.781	**0.000**

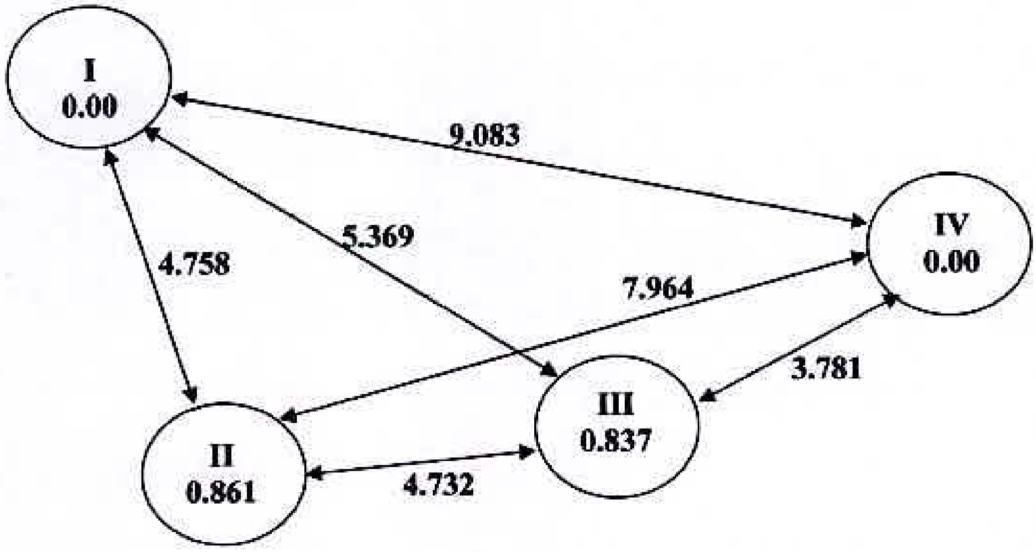

Figure 4. Diagram showing intra and inter-cluster distances of 10 onion genotypes

Table 12. Latent vectors for thirteen principal component characters of ten onion genotypes

SL. No.	Chacters	Vector 1	Vector 2
01	Days required for visible appearance of shoot	0.1220	0.1816
02	Leaf length (cm)	-0.0284	0.1842
03	Length of floral stock (cm)	0.0729	-0.0483
04	Diameter of floral stock (cm)	1.1473	-1.2592
05	Days to inflorescence appearance	0.0489	-0.0936
06	Days to full blooming of inflorescence	0.0246	-0.0582
07	Blooming period	-0.1431	0.1010
08	Days to maturity	-0.0243	0.0073
09	Number of seeds per plant	0.0005	-0.0226
10	Thousand seed weight (g)	-0.4806	0.2107
11	Bulb weight (g)	-0.0406	0.0166
12	Number of bulbs per plant	0.0267	-0.1775
13	Yield per plant (g)	-0.0127	-0.0006

leaf length (0.1842), blooming period (0.1010), days to maturity (0.0037), thousand seed weight (0.2107) and bulb weight (0.0166) showed their important role toward genetic divergence. The value of Vector I and Vector II revealed that both Vector had positive values for days required for visible appearance of shoot (0.1220) indicating the highest contribution of this traits towards the divergence among 10 onion genotypes. Negative values in both vectors had lower contribution towards the divergence.

4.3.6 Selection of genotypes as parent for hybridization programme

Among the inter cluster distance, distance between I and IV were the highest (9.083) and other clusters were more or less intermediate distance. Intermediate diverse parents have the more chance to contribute heterosis in the subsequent generations.

To select cluster to obtain more heterotic genotype four pairs of clusters to be considered for this purpose, they are I and II, I and III, I and IV, II and IV. Cluster I had the highest cluster mean for days to full blooming of inflorescence and blooming period, but average to below average for number of bulb per plant that were most important yield contributing character. The cluster I comprised with the genotype SAU-B-G-1. Hybridization between the genotypes of cluster I and cluster II will manifest maximum heterosis and create wide genetic variability.

Genotype included in the cluster I was important for days to full blooming of inflorescence and blooming period; cluster II for anther length of floral stock;

cluster III important for days required for visible appearance of shoot, leaf length, days to maturity, number of seed per plant and thousand seed weight, cluster IV important for days to inflorescence appearance, bulb weight, number of bulb per plant and yield per plant.

Considering cluster distance and cluster mean, the genotype SAU-B-G-1 from cluster I, genotype SAU-B-G-2, SAU-B-G-4 and SAU-B-G-6 from cluster II, genotype SAU-B-G-8 and SAU-B-G-9 from cluster III, genotype SAU-B-G-7 from cluster IV may be considered better parents for future hybridization program.

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The present experiment was undertaken to study the genetic parameters of 13 characters of 10 onion genotypes and multivariate analysis of 13 characters of onion genotypes. The salient findings of the present study have been summarized on the basis of the characters studied.

Eight types of bulb color viz. light brown, dark red, reddish, light pink, purple, brown, pink and pale orange were observed among the genotypes. Among the genotypes six types of shape of bulb was found such as elongated, round, round to elongated, round to oval, flat round and globe shape. Out of ten genotypes, five types of leaf color was found such as dark green, green, light green, pale green and yellowish green. Among the genotypes, three types of shape of leaf was found viz. long erect, medium erect and short erect. Four types color of floral stock viz. dark green, green, light green, yellowish green was observed. Different types of shape of floral stock was also observed in this study such as round cylindrical, cylindrical, flat cylindrical. Seeds of all the genotypes was black in color and irregular in shape.

Mean sum of square for days required for visible appearance of shoot, leaf length, length of floral stock, diameter of floral stock, days to inflorescence appearance, days to full blooming of inflorescence, blooming period, days to maturity, number of seeds per plant, thousand seed weight, bulb weight, number of bulbs per plant and yield per plant were highly significant due to genotype indicating wide range of variability among the onion genotypes for this traits. The σ^2_g and σ^2_p and the GCV and PCV were close to each other for all the traits, indicating less environmental influence and additive gene action for this trait. For most of the characters selection would be effective due to their high and moderate heritability with high and moderate genetic advance and genetic advance in percentage of mean.

Considerable $\sigma^2_{g,}$ σ^2_{p}; considerable difference of GCV and PCV; high heritability with high GA and GAPM were observed for days required for visible appearance of shoot, days to maturity, bulb weight and yield per plant. These four traits might be considered for the improvement of yield of onion genotypes.

Ten onion genotypes were evaluated for 13 agronomic characters in a randomized complete block design to study the genetic divergence through multivariate analysis. Genotypes were grouped into 4 different clusters. Cluster II comprised maximum number of genotypes (six) followed by cluster III, I, and IV. PCA showed 80.64% variation against first four Eigen values. Cluster III, I, and IV contain two, one and one genotypes, respectively. The highest inter genotypic distance was observed between genotypes SAU-B-G-1 and SAU-B-G-7 (3.483) followed by SAU-B-G-1 and SAU-B-G-9 (3.039) and the lowest distance were observed (0.437) between genotypes SAU-B-G-3 and SAU-B-G-4 followed by the distance (0.633) between genotypes SAU-B-G-2 and SAU-B-G-3. The inter cluster distance was larger than the intra cluster distances. The inter cluster distance was maximum between the cluster I and IV (9.083) followed by the distance between II and IV (7.964), I and III (5.369). The lowest inter cluster distance was found between the cluster III and IV (3.781). The intra cluster distance in the entire four clusters was more or less low indicating the genotypes with in the same cluster were closely related. Among the characters visible appearance of shoot (0.1220), diameter of floral stock (1.1473), and days required for visible appearance of shoot (0.1220) were major characters that contribute mostly toward genetic divergence.

Depending on the genetic distance, 10 onion genotype constitute four clusters in which SAU-B-G-1, SAU-B-G-7, SAU-B-G-8 and SAU-B-G-9 are most diverse genotype these can be used for future hybridization program. Visible appearance of shoot, diameter of floral stock and days required for visible appearance of shoot had maximum contribution towards genetic divergence of onion genotypes. Divergent genotypes are recommended to use as parent in future hybridization program which may produce desirable segregants.

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Appendices

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	%	Methods Employed
01	Sand	36.90	Hydrometer Methods (Day, 1915)
02	Silt	26.40	Same
03	Clay	36.66	Same
04.	Texture Class	Clay Loam	Same

B. Chemical Composition of the Soil

Sl No.	Soil Characters	Analytical Data	Methods Employed
01	Organic Carbon (%)	0.82	Walkley And Black, 1947
02	Total Nitrogen (Kg/ha)	1790.00	Bremner and Mulvaney, 1965
03	Total S (ppm)	225.00	Bardsley and Lanester, 1965
04	Total Phosphorous	840.00	Olsen and Sommers, 1982
05	Available Nitrogen (Kg/ha)	54.00	Bremner, 1965
06	Available Phosphorous	69.00	Olsen and dean, 1965
07	Exchangeable K (Kg/ha)	89.50	Pratt, 1965
08	Available S (Kg/ha)	16.00	Hunter, 1984
09	pH (1:2.5 Soil to Water)	5055	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Appendix II: Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from November, 2007 to April 2008

Year	Months	* Air temperature (^{0}C)		* Relative Humidity (%)	* Total Rainfall (mm)	* Sun-shine (hr)
		Maximum	Minimum			
2007	November	31.8	16.8	67	111	5.7
	December	28.2	11.3	63	0	5.5
2008	January	29.0	10.5	61.5	23	5.6
	February	30.6	10.8	5 + ·5	56	5.8
	March	3 + ·6	16.5	61.5	45	5.8
	April	36.9	19.6	59.5	91	8.3

*** Monthly Average**

Source: Bangladesh Meteorological Department (Climate) Division, Agargaon, Dhaka- 1207.