# VARIABILITY, CHARACTER ASSOCIATION AND PATH ANALYSIS OF YIELD AND YIELD CONTRIBUTING TRAITS IN GARLIC (*Allium sativum* L.)

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# CERTIFICATE

*This is to certify that thesis entitled, "Variability, Character Association and Path Analysis of Yield and Yield Contributing Traits in Garlic (Allium sativum 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 bona fide research work carried out by Ahmed Shahriar Anik, Registration No.: 11-04609 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.*

**Dated: June, 2018**
**Place: Dhaka, Bangladesh**

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***DEDICATED***

***TO***

***MY PARENTS***

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# SOME COMMONLY USED ABBREVIATIONS

| Full word | Abbreviations | Full word | Abbreviation |
|---|---|---|---|
| Agriculture | Agric. | | |
| And others | *et al.* | Genotypic coefficient of variation | GCV |
| Agricultural | Agril. | Harvest Index | HI |
| Agronomy | Agron. | Heritability in broad sence | |
| Agro Ecological Zone | AEZ | Indian Agricultural Research Institute | IARI |
| Analysis of variance | Anova | Journal | J. |
| At the rate | @ | Kilogram | Kg |
| Bangladesh Bureau of Statistics | BBS | Meter | M |
| Bangladesh | BD | Mean sum of square | MS |
| Bangladesh Agricultural Research Institute | BARI | Murate of potash | MP |
| Centimeter | cm. | Ministry of Agriculture | MOA |
| Cultivars | cv. | Square meter | $m^2$ |
| Degree celsius | $^oC$ | Percent | % |
| Degrees of freedom | Df | Phenotypic variance | |
| Environmental variance | | Percent of coefficient of variation | CV% |
| Etcetera | etc. | Phenotypic coefficient of variation | PCV |
| Food and Agricultural Organization | FAO | Randomized complete block design | RCBD |
| Genotypic variance | | Sher-e-Bnagla Agicultural University | SAU |
| Gram | g | Triple super phosphate | TSP |
| Degrees of freedom | Df | The third generation of a cross between two dissimilar | F3 |
| And others | *et al.* | | |
| Etcetera | etc. | | |
| Food and Agricultural Organization | FAO | | |
| Gram | G | | |
| Genotype | G | | |
| Genetic advance | GA | | |

# VARIABILITY, CHARACTER ASSOCIATION AND PATH ANALYSIS OF YIELD AND YIELD CONTRIBUTING TRAITS IN GARLIC (*Allium sativum* L.)

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## ABSTRACT

Ten genotypes of garlic (*Allium sativum* L.) were evaluated to study the evaluation of genotypes at Sher-e-Bangla Agricultural University farm, Dhaka during November 2017 to March 2018. In this experiment ten garlic genotypes were used as experimental materials. The experiment was laid out in Randomized Complete Block Design (RBCD) with three replications. Mean performance, variability, genotypic and phenotypic correlation coefficient and path analysis on different yield contributing characters and yield of garlic genotypes were estimated. The highest bulb yield/plant in gram (13.57) was recorded in the genotype of BARI Rosun-3, whereas the lowest bulb yield/plant in gram (9.007) from the genotype BARI Rosun-2. Phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the yield contributing traits. High heritability coupled with high genetic advance in percent mean was observed for bulb diameter. High heritability coupled with moderate genetic advance observes in plant height, root length, total no. of leaves, bulb length, and yield per plant. In correlation study, yield per plant positively and significantly correlated with root length (0.388* & 0.367*) and bulb diameter (0.474** & 0.467**) at both genotypic and phenotypic levels respectively. Path coefficient analysis revealed that positive direct effects on yield per plant were obtained by root length (0.168), leaf breath (0.131), bulb length (0.189) and bulb diameter (0.244).

# CHAPTER I

# INTRODUCTION

Garlic (*Allium sativum* L.) (2n=16) commonly known as garlic belongs to Amaryllidaceae family. Its close relatives include the onion, shallot, leek, chieve and rakkyo. Among cultivated alliums garlic is the 2nd most widely used vegetable after onion (*Allium cepa L.*). The origin of garlic is thought to be in Central Asia (India, Afghanistan, West China and Russia) and spread to other parts of the world through trade and colonization (Tindal, 1986). Garlic is grown for its edible bulbs. The bulbs can be eaten fresh, cooked, processed or saved for seed Hannan and Sorensen. The garlic bulb contains small bulblets called as cloves. It is easy to grow and can be grown year-round in mild climates. While sexual propagation of garlic is possible, nearly all of the garlic in cultivation is propagated asexually, by planting individual cloves in the ground. In colder climates, cloves are planted in the autumn, about six weeks before the soil freezes, and harvested in late spring or early summer. Garlic is the second most important spice crop in Bangladesh. The total production of garlic in Bangladesh is 3.88 lakh metric tons against the estimated demand of 3.42 lakh metric tons. But in Bangladesh the average yield of garlic is 4.40 t/ha (BBS, 2015), which is very low as compared to the world production.

World cuisines as well as in herbal medicine are occupied by garlic for thousands of years. It has been claimed to help prevent everything from high cholesterol to cancer (Rahman *et al.*, 2002). Among the species grown in Bangladesh, garlic is undoubtedly one of the important crops cultivated during cool season. However, the area and production of garlic have not been increased at desired level. The current production of garlic can't meet up the increasing demand of Bangladesh. We have to import a large amount of garlic from neighboring and other countries to meet up its demand. The leading garlic producing countries are China, South Korea, India, Thailand, Spain, Egypt, Turkey and Mexico (FAO, 2003).

Garlic plants can be grown closely together, leaving enough space for the bulbs to mature, and are easily grown in containers of sufficient depth. Garlic does well in loose, dry, well-drained soils in sunny locations, and is hardy throughout USDA climate zones 4–9. When selecting garlic for planting, it is important to pick large bulbs from which to separate cloves. Large cloves, along with proper spacing in the planting bed, will also increase bulb size. Garlic plants prefer to grow in a soil with a high organic material content, but are capable of growing in a wide range of soil conditions and pH levels.

Genotypes of garlic are categorized as non-bolting, semi-bolting, and bolting (Kamenetsky *et al.*, 2004; Etoh and Simon, 2002; Kamenetsky and Rabinowitch, 2001; Takagi, 1990) and differ considerably in bolting ability, scape length and seed production (Mathew *et al.*, 2010). In bolting accessions, specific combinations of temperature and photoperiod significantly influence the reproductive processes (Mathew *et al.*, 2010). Long-photoperiod conditions trigger the initial elongation of flower stalks (Kamenetsky *et al.*, 2004; Mathew *et al.*, 2010). Meanwhile, the bulbing and cloving of garlic are influenced by the length of the day and the temperature to which the dormant cloves or growing plants are exposed before bulbing begins (Bandara *et al.*, 2000). In general, low initial temperatures followed by long days are essential for bolting and the formation of bulbs and cloves (Kolev, 1962). However, the competition for resources by the simultaneously developing bulb and inflorescence sinks determines the fate of stalk elongation and bulbing (Etoh and Simon, 2002; Le Nard and De Hertogh, 1993). In onion bulbs, a strong sink in early bulb development stages suppresses the growth and differentiation of the young inflorescence with consequent drying out of the flower stalk (scape) (Mathew *et al.*, 2010). Hence, it was proposed that the influence of the temperature and photoperiod on scape and bulb development should be considered in the background of the simultaneous but competitive development of storage (bulb) and reproductive (scape) organs in garlic (Mathew *et al.*, 2010).

With respect to its production and economic value, garlic is one of the main *Allium* vegetable crops in the world and used as a seasoning in many foods throughout the globe. The oil of garlic is volatile and has sulfur combining compounds which is responsible for strong odor, its unique flavor and pungency as well as for healthful benefits (Salomon, 2002). Garlic is a basic flavoring in many types of dishes ranging from vegetable soup, meat, salad, tomato combination, spaghetti, sausages and pickles (Brewster, 1994). Similar to green onions, it is eaten as green and blenched tops in different ways as fresh and cooked as well as immature bulb consumption is common especially in tropics (Rabinowitch and Brewster, 1990). Bread and butter obtained from garlic have many uses in homes and restaurant cooking and food preparations (Nonnecke, 1989). Garlic has also medicinal value which is well recognized in the control and treatment of hypertension, worms, germs, bacterial and fungal diseases, diabetes, cancer, ulcer, rheumatism etc. (Kilgori *et al.*, 2007; Samavatean *et al.*, 2011). Many people perceived and appreciated garlic for its many medicinal attributes (Rabinowitch and Currah, 2002).

Increased garlic production largely depends on good variety, modern production technology and quality seeds. Inferior clovers may decrease production by 15-25%. Yield could be regarded as a complex character, which is dependent on a number of agronomic characters and is influenced by many factors, which could be genetic or environmental. It is an important spice crop in Bangladesh. The world production of garlic is 24,836,877 tons (FAO, 2015). It is in third position in world and in Bangladesh second after onion. Garlic is widely cultivated all over Bangladesh during winter. Farmers generally follow traditional method for cultivating garlic in Bangladesh. Although production of garlic is increasing day by day, but in a land hungry country like Bangladesh it may not be possible to meet the domestic demand due to increase in population. There is an acute shortage of garlic in relation to its requirement.

Genetic variability, character association pattern and direct and indirect effects of the yield attributing characters on bulb yield is helpful for effective selection in crop improvement. Knowledge of association of different components together with their relative contributions has immense value in selection. Since estimates of correlation coefficient indicate only the inter relationship of the characters but do not furnish information on the cause and effect, separation of correlation coefficient in to the components of direct and indirect effect through path analysis become important. The present investigation was, therefore, planned with the following objectives:

- To assess the variability for bulb yield and yield traits in garlic;
- To determine the direct and indirect effects of the yield attributing characters on the yield and
- To select the best genotype/variety.

# CHAPTER II

# REVIEW OF LITERATURE

This chapter aims at represent some review of the past research works that are related to the present study. A few researches have been done on garlic production in Bangladesh. Some important studies on garlic production, which have been conducted in the recent past, are discussed below:

## 2.1 General description

According to Figliuolo *et al.* (2001); Ipek *et al.* (2003) garlic belongs to the genus *Allium* family Alliaceae, which includes important vegetable crop such as onion (*Allium cepa*), leek (*A. ameloprisum*) and shallots (*A. asacloncum*). Garlic is a diploid species (2n = 2x = 16) of obligated apomixis and propagated vegetatively.

Hector *et al*., (2012) revealed that garlic is propagated asexually, but shows a high morphological diversity among cultivars. These cultivars have a wide range of adaptation to different environments. Like onion, garlic plants have thin tape shaped leaves about 30 cm long. Roots reach up to 50 cm depth or little more. Heads or bulbs are white skinned, divided into sections called cloves. Each head could have from 6 to 12 cloves, which are covered with a white or reddish papery layer or “skin”. Similarly Kamenetsky *et al.*, (2001) revealed that sexual propagation in garlic is expected to facilitate the exchange of genetic traits from one genotype to another and to improve garlic cultivars through classical breeding. Garlic does not produce true seed but it is propagated by planting cloves. Each bulb usually contains a dozen or more cloves and planted separately. Select only larger outer cloves of the best garlic bulbs for planting because larger cloves yield larger size and mature bulbs at harvest.

McLaurin, (2012) suggested not to divide the bulb until ready to plant; early separation decreases yields. Select “seed bulbs” that are large, smooth, fresh, and free from disease. To plant garlic properly, dig a hole or trench, place the unpeeled clove gently into the hole with the pointed side up (the scar [stem] end down) and cover the clove with soil. Setting the cloves in an upright position ensures a straight neck.

## 2.2 Growth and development

Garlic is a cool season plant; it makes all vitality and leaf growth while the temperatures are cool and the day is short. As the temperature becomes warm and the day is lengthen, the plant stops making leaves and begins to form bulbs. Cloves or young plants exposed to temperatures of between $0^oC$ and $10^oC$ for one to two months hastens subsequent bulbing under long days (Moore and Gough, 2010).

A study in the Netherlands conducted by Messiaen and Rouamba (2004) during the life cycle of plant under go successive stages of growth and development, the dormancy of mature cloves, induced by the temperature of 25-30 0C is eliminated most quickly at 6-7 $^oC$ vegetative growth is optimal at 18-20 $^oC$. When 12-14 leaves have been produced, bulb swelling is induced at temperature below 20 0C. There is considerable physiological variability amongst garlic cultivars. The total growing period varies from 4 months to about 9 months.

McLaurin, (2012) revealed that matured garlic cloves planted in the fall go through a dormant period. Garlic cloves require a period of 6-8 weeks of cool weather after planting (below 4.4 OC to undergo vernalization inducement to bulb) by low winter temperatures. During the fall and winter in Georgia, cloves will develop their root systems and initiate some top growth. The clove will swell considerably, forming a globular bulb with many fine roots. A pair of intertwined leaves will emerge from the terminal end of the bulb and will eventually break through the soil, depending on the weather and location. Leaf development will accelerate with flat, dark green leaves on stems reaching a height of 30 cm or more. Proper bulbing is a function of adequate growth, vernalization, and subsequent growth under longer days. As temperatures rise and day length increases, bulb formation begins.

Ledesma *et al.* (2001) conducted experiment results show the following development stages in garlic: Sprouting: from sowing to 20-30 days, adventitious roots, leaf emergence and total soluble carbohydrate assimilation in seed cloves are observed. Shoot growth: from the end of sprouting until 140 days after sowing. Translocation of photosynthesis to the bulb begins afterwards. Bulb growth: during the inductive stage, from sprouting, no increases in dry weight in total soluble carbohydrates can be observed up to 90 days.

Siktberg *et al*., (2006) suggested that a period of cold followed by a period of light and heat is needed for proper growth of garlic. Although garlic requires low temperatures in preparation for bulb development, increased day length and heat are necessary for bulbs to begin forming. Paredes *et al.*, (2007) revealed that garlic is a species of vegetative propagation, showing high morphological diversity. Besides, its clones have specific adaptations to different agro-climatic regions.

Garlic shows wide morphological and agronomic variations in characteristics such as color and size of the bulb, plant height, number and size of the cloves, days to harvesting, resistance to storage capacity, dormancy and adaptation to agro-climatic conditions (Figliuolo *et al.*, 2001)

McLaurin, (2012) found in his conducted experiment leaves will begin to turn brown and tops will fall, indicating maturity. Stop irrigation at this time to avoid bulb discoloration and bulb rots. To ensure bulbs are fully mature, remove the top layer of soil over the top of a few bulbs and check bulbs to make sure they are fully differentiated (division of bulb into distinct cloves). Harvest the garlic when 1/3 to 1/2 of the leaves have died back in this manner.

**2.3 Performance of genotypes:**

Sabur and Mollah (1993) under look a study on constraints of production and marketing of species in Bangladesh. The study revealed that the real price of garlic, onion and turmeric increased significantly by 3.83 percent, 3.58 percent and 3.17 percent respectively during the study period. They examined that the storage facilities for spices, particularly cold storage, were limited and seasonal price variations largely dependent on the perishability of spices.

Mahmood (1995) examined the relative profitability of selected spices, compared with their competing crops. Among all competing crops onion was the most profitable crop with net profit of tk 26673, which was followed by potato (Tk. 25875.30), lentil (Tk. 20652.1) and garlic (Tk. 16755.49) in respect of net return per hectare.

Chadha, K.I., (1990) conducted a study on onion and garlic in India. Area and production of onion and garlic in the world and India, export from other countries and factors limiting production and productivity in India are described. The research infrastructure, varietal improvement and production technology of onions and garlic in India, Kharif onion cultivation in North and East India, seed production and distribution, post harvest technology, all year round production of onions, disease and pest control and future research requirement are discussed.

Hossain (1996) carried out an experiment in Bangladesh Agricultural University, Mymensingh. Plant highest, leaf number, pseudo stem and bulb diameter, dry matter content of foliage, bulb weight and bulb yield were found significantly higher for mulched plants. Trevisan *et al.* (1996) reported that marketable yield and percentage of high quality clove were greatest with cloves planted on 18 may that 27 April and 14 June.

Shrivastava (1998) studied on economics of agro-forestry in Indo-Gangetic *alliums* of Uttar Pradesh in India. The study was managed under an agro-silvicultural system with Eucalyptus and a mixture of agricultural crops e.g. mustard, gram, coriander, onion, garlic and turmeric. Intercropping was to be carried out over the first 3 years. Detailed cost data were given including initial expenditure, actual and projected working costs of Eucalyptus plantation for the first 6 years and costs of intercropping. Total profit from the first and second cycles was predicted as Rs. 28362125 and Rs. 75548135 respectively with cost/benefit ratio of 4.0 and 7.2. the system generated 112960 man-days of employment in the first rotation.

Bhuyan (1999) conducted an experiment on the effect of planting time, mulch and irrigation on the growth and yield of garlic. In this experiment it was found that the highest yield was obtained from 25 October planting (3.92 t/ha) followed by 9 November (3.58t/ha), 25 November (3.55t/ha) and 8 December (3.08t/ha). December 23 planting gave the lowest yield (2.31t/ha). It was observed that earlier planting gave the highest plant height, highest total number of leafs per plant, diameter of bulb, weight of bulb, weight if individual bulb.

Rahman (2002) studied effect of spacing on the growth, yield and storability of some garlic germplasm. The pant spacing showed significant effect on most of the parameters studied. Wider spacing (20x20cm) give the maximum weight of bulb; the closest spacing (10x10cm) produced maximum yield of bulb ((9.19 t/ha), the lowest yield (3.67 t/ha) was obtained from wider spacing. The performance of garlic bulb during storage varied significantly due to spacing and different germplasm. Wider spacing showed the lowest result in percentage of insect infested bulbs and weight loss (4.92 percent and 24.01 percent respectively). The germplasm G21 showed minimum percentage of insect infestation and weight loss (8.91 percent and 25.24 percent respectively).

Harun-Or-Rashid (2002) studied the production potential and profitability in TPS-garlic intercropping system at different spacing and row arrangement. The spacing for TPS was 50x50cm, while that of garlic were 10x10cm, 15x10cm and 15x15cm. The row arrangements were single, double and alternative. The highest gross return (Tk. 169590/ha), Net return (Tk. 74782/ha), LER (1.38) and BCR (1.80) were recorded from potato+garlic at 15x15cm spacing as double row arrangement.

Large clove size showed taller plants in garlic as reported by Burba *et al.* (1982). Baten *et al.* (1990) showed that the tallest plant was produced when large seed cloves were used as propagules and the small seed cloves produced the shortest ones. Further, Rahim *et al.* (1984) stated that the plant height declined as the size of mother bulb reduced. Hossain (2008) and Talukder (2002) observed that plant height was positively corralled with the size of clove. The tallest plant was obtained from the large seed clove followed by medium and small ones. Similar result was also reported by most of the researchers (Ara *et al.*, 1998; Baten *et al.*, 1990; Duimovic and Bravo, 1979; El-Habbasha *et al.*, 1985).

## 2.4 The role of variety on garlic yield and yield components

According to Bishaw *et al.*, (2008) the variety must be selected from a list of recommended or local varieties. Apart from its adaptation, the variety should have high yield potential, tolerance to biotic and abiotic stresses, good marketability and high consumer preferences. Unless the variety meets the requirements of farmers and consumers, it is less likely to be widely adopted and therefore, the demand for seed cannot be addressed. The character of yield reflects the performance of all plant components and might be considered as the final result of many others i.e. every plant contains an inherent physiological production capacity that operates on energy required for normal plant performance though all accessions do not have the same inherent physiological capacity to yield. Breeders commonly find yield to be a very complex array of plant component interactions and by the manipulation of these genetic systems yield is improved as the result of plant efficiency improvement.

According to Welsh, (1981) the yield performances of twenty five garlic germplasms were evaluated and gave quit satisfactory, yielding 6.5-9.4 t/ha in Bangladesh agricultural university (BAU). Garlic germplasm G-49 produced the highest yield (9.4 t/ha) followed by G-53 (7.9 t/ha) and G-27 (7.6 t/ha), the National Seed Board registered the G-49 garlic germplasm as garlic-3 variety for mass production. Allicin content of local germplasm (G-13) is quite high (2.4 mg/ml) (Rahim. M., 2011).

**2.5 Genetic variability**

The development of an effective plant breeding program is dependent upon the presence of genetic variability in the material. The efficiency of selection depends upon the magnitude of genetic variability present in the plant population. Thus, the success of genetic improvement in any character depends on the nature of variability present in the germplasm of that character. Hence an insight into the magnitude of variability present in the gene pool of a crop species is of almost important to a plant breeder for starting a judicious plant breeding programme.

Many biometrical techniques are available which are commonly used to assess the variability in plant population. These are simple measures of variability (range, mean, standard deviation, variance, standard error, coefficient of variation), variance component analysis, $D^2$ statistics and metroglyph analysis. The simple measures of variability especially the coefficient of variation partitions the variation into phenotypic, genotypic and environmental components and determines the magnitude of these components for various traits.

A knowledge of heritability for different component traits seems to be essential for any crop improvement programme, because the heritable component is the consequence of genotype and is inherited from generation to generation. Wright (1921) reported that heritability components comprised of additive and non additive portion and it was the former which responds to selection. Estimation of expected genetic advance is important to have an idea of effectiveness of selection. Burton and Devane (1953) suggested that genetic coefficient of variation together heritability estimates would give reliable indication of the amount of improvement to be expected from selection and further remarked that expected genetic gain under particular system supplies to a true practical information, which is needed by a breeder. Johnson *et al.* (1955) also found more useful to estimate the heritability values together with genetic advance in predicting the expected progress to be achieved through selection.

Korla and Rastogi (1979), studied eleven genotypes of garlic and reported that genotypes GC-8 and GC-9 had the maximum yield whereas, maximum bulb size and number of cloves per bulb were produced by genotype GC-11.

Korla *et al.* (1981), studied genetic variability in 11 cloves of garlic. The study revealed significant clonal differences for number of cloves per bulb and weight of 20 cloves in both years and for bulb yield per plot and bulb girth in one year. Clone X Year interactions were significant for the first three of these traits. Genotypic coefficient of variation and heritability estimates were highest for number of cloves per bulb and weight of 20 cloves.

Mehta and Patel (1985), studied genetic variability in 40 genotypes of garlic and reported that clove weight and bulb yield per plant had highest genotypic coefficient of variation with high heritability (> 90%) and genetic advance, suggesting there by involvement of additive gene action for the traits.

Pandey and Singh (1989), recorded maximum plant height, number of leaves per plant, number of cloves per bulb, weight of bulb and yield in genotype HG-1 .While studying genetic variability on 32 diverse genotypes of garlic by Shaha *et al.* (1990) and reported that high phenotypic coefficient of variation (PVC) and genotypic coefficient of variation (GCV) for weight of 50 cloves, plant height and bulb weight. High heritability along with high genetic advance was observed for plant height and weight of 50 cloves.

Yaso (2007), reported that high values of heritability, GCV%, and GS% were observed for total and marketable yield and bulb weight. While moderate to high estimates of heritability coupled with low GCV% noticed for days to maturity.

Ananthan and Balakrishnamoorthy (2007), evaluated range, phenotypic and genotypic coefficient of variance, heritability and genetic advance for thirteen characters of sixty two genotypes of onion and recorded higher estimates of genotypic and phenotypic coefficients of variation for bulb weight, reducing sugars, non-reducing sugars, total sugars, total loss and sulphur content.

## 2.6 Correlation analysis

The concept of correlation was given by Galton (1989) and later extended by Fisher (1918). Correlation coefficient is the important selection parameter in plant breeding. Correlation coefficient is used to find out the degree (strength) and direction of relationship between two or more variables. In plant breeding, correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement in yield. Yield is very complex phenomenon; it is not only polygenic in nature but is also affected by environment. Hence, the selection of superior plants based on the performance of yield as such is usually not very effective. For selection of superior genotypes the breeder has to choose from the material on the basis of its phenotypic expression. For most of the traits, the knowledge about degree of phenotypic and genotypic correlations of the traits is important (Robinson *et al.*, 1951).

Moravec *et al.* (1974), observed positive correlation between bulb yield and clove weight. They also recorded similar correlation between number of cloves per bulb and bulb weight of garlic.

Tripple and Chubrikova (1976), observed the significant positive correlation between bulb yield and bulb size of garlic. Korla and Rastogi (1979) reported that weight of 20 cloves and bulb weight were associated positively with bulb yield whereas cloves per bulb had negative correlation with weight of 20 cloves in garlic.

Kalloo *et al.* (1982), worked out correlation for some important yield components in garlic. They observed higher genotypic correlation than phenotypic correlation plant height, weight of bulb, diameter of bulb, average weight of clove, length of clove showed positive correlation with bulb yield.

Rahman and Das (1985), analyzed correlation coefficient in garlic and indicated that bulb yield/plant had highly positive significant correlation with number of leaves/plant, leaf length, and bulb diameter. Bulb diameter also had positive significant association with number of leaves/plant and leaf length.

### Path coefficient analysis

The path coefficient analysis is simply a standardized partial regression which may be useful in choosing the characters(s) that have direct and indirect effects on yield. Such a study may be useful and effective in selection for simultaneous improvement of the component characters that contribute towards yield. Path analysis was initially suggested by Wright (1921) but was applied for the first time in plant breeding by Deway and Lu (1959). The earlier research works conducted on correlation and path analysis in Garlic is being reviewed as under:

Yaso (2007), studied the phenotypic correlation and path coefficient analysis between bulb weight and various component characters. He recorded significant and positive correlation between bulb weight and each of plant height, number of leave per plant and time of maturing. Path coefficient analysis showed the plant height had high positive direct effect on bulb weight. The number of leaves per plant revealed moderate positive indirect effect on bulb weight.

# CHAPTER III

# MATERIALS AND METHODS

This chapter deals with the information on the subject of materials and methods that were used in conducting the experiment. It consists of a short explanation of locations of the experimental site, soil characteristics, climate, materials used in the experiment, layout and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural practices, harvesting, data recording procedure and statistical analysis etc., which are presented as follows:

## 3.1 Experimental site

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka-1207, AEZ-28 (Madhupur Tract) during December 2017 to April 2018. The location of the experimental site was situated at 230 74' N latitude and 900 35' E longitudes with an elevation of 8.6 meter from the sea level. Photograph showing the experimental site (Appendix I).

## 3.2 Soil and climate

The experimental site was situated in the subtropical zone. The soil of the experimental site belongs to the Agro-ecological zone of "The Modhupur Tract" (AEZ-28). The soil was clay loam in texture and olive gray with common fine to medium distinct dark yellowish brown mottles. The pH ranges from 5.47 to 5.63 and organic carbon content is 0.82% (Appendix II). The records of air temperature, humidity and rainfall during the period of experiment were noted from the Bangladesh Meteorological Department, Agargaon, Dhaka (Appendix III).

## 3.3 Experimental materials

The seeds were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.1700 and local market. The healthy seeds of ten garlic genotypes collected from the Siddik market in Dhaka and Bangladesh agricultural research institute (BARI), which were used as experimental materials. The materials used in that experiment is shown in Table 1.

**Table 1: Materials used in the experiment**

| Genotype | Names of genotype | Source |
|---|---|---|
| G1 | BARI Rosun-1 | BARI |
| G2 | BARI Rosun-2 | BARI |
| G3 | BARI Rosun-3 | BARI |
| G4 | BARI Rosun-4 | BARI |
| G5 | Faridpuri | local market (Faridpur) |
| G6 | China Rosun | local market |
| G7 | Natori | local market (Natore) |
| G8 | Ekdana | local market (Chittagong) |
| G9 | Khude | local market (Chittagong) |
| G10 | Manikganji | local market (Manikgonj) |

### 3.4 Methods

The following precise methods have been followed to carry out the experiment:

#### 3.4.1 Land preparation

The experimental plot was prepared by several ploughing and cross ploughing followed by laddering and harrowing with power tiller to bring about good tilth. Weeds and other stubbles were removed carefully from the experimental plot and leveled properly. Plate 1 showing land preparation.

#### 3.4.2 Application of manure and fertilizer

The recommended doses of fertilizer such as cowdung, Urea, TSP and MoP @ 10 ton, 130 Kg, 200 Kg, 75 Kg per ha, respectively were applied in the experimental field. The entire cowdung, TSP, half of Urea and half of MoP were applied at the time of final land preparation. The remaining urea and MoP were as top dressing in two installments.

**Plate 1: Showing land and plot  preparation**

### 3.4.3 Experimental design and layout

Field layout was done after final land preparation. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Total experimental area was 55 $m^2$. The spacing between row to row was 15 cm and plant to plant 10 cm. Seeds were sown in line in the experimental plots on 2 December 2017. The seeds were placed at about 1.5 cm depth in the soil. After sowing the seeds were covered with soil carefully so that no clods were on the seeds (Plate 2).

### 3.4.4 Intercultural operations

Intercultural operations, such as weeding, thinning and irrigation etc. were done uniformly in all the plots. Irrigation was given after sowing of seeds to bring proper moisture condition of the soil to ensure uniform germination of the seeds. The irrigation was done frequently on November 20, 23; 2, 8 December 2017; Jan 13, 11, 17, 22 and 30; 7, 13, February 2018. A good drainage system was maintained for immediate release of rainwater from the experimental plot during the growing period. The first weeding was done on 22 November 2017. At the same time, thinning was done for maintaining a distance of 10 cm from plant to plant in rows of 15 cm apart. Plate 3 showing different intercultural operations.

### 3.4.5 Crop harvesting

The crop was harvested on $9^{th}$ march, 2018 depending upon the maturity. 10 plants were selected at randomly from each replication. The plants were harvested by uprooting and then they were tagged properly. Data were recorded on different parameters from these plants. Plate 4 showing harvesting period of garlic.

**Plate 2:** Sowing of planting materials of garlic (Cloves)

**Plate 3:** Intercultural operations


**Plate 4:** Showing harvesting of garlic

### 3.4.6 Data collection

Eight characters were taken into consideration for studying different genetic parameters, association and path coefficient analysis. Data were recorded on ten selected plants for each genotype for each replication on following parameters. The details of data recording are given below on individual plant basis.

#### 3.4.6.1 Plant height (cm)

Data of plant height were recorded from 10 competitive plants selected randomly from each unit plot on the maximum vegetative stage. The height was measured in centimeter (cm) from the neck of the bulb to the tip of the largest leaf. Plate 5 (A) showing plant height data collection.

#### 3.4.6.2. Root length (cm)

Data of root length were recorded from 10 competitive plants selected randomly from each unit plot. The length was measured in centimeter (cm) from the base of the bulb root to the tip of the largest root.

#### 3.4.6.3. Total number of leaves

Number of leaves per plant was recorded by counting total number of leaves from each of the sampled plant at the time of maximum foliage stage at 90 days after sowing and mean value was obtained. It was denoted in number.

#### 3.4.6.4. Leaf length (cm)

Length of leaves was recorded from 10 randomly selected plants at maximum vegetative stage from each unit plot. Length of each leaf of individual plant was measured by a centimeter scale. Then the mean length of leaf was calculated as cm.

#### 3.4.6.5. Leaf breadth (cm)

Breadth of leaves was recorded from 10 randomly selected plants at maximum vegetative stage from each unit plot. Breadth of each leaf of individual plant was measured by a centimeter scale. Then the mean length of leaf was calculated as cm.

#### 3.4.6.6. Bulb length (cm)

The bulb length was measured after harvest with a slide calipers from bottom to top portion (from where leaves were removed) from 10 randomly selected bulbs and the average was calculated.

#### 3.4.6.7. Bulb diameter (cm)

The diameter of bulb was measure at harvest with a slide calipers at the middle portion of the bulb obtain from 10 randomly selected plants and the average was calculated.

#### 3.4.6.8. Yield per plant (g)

Ten randomly selected bulbs were dried in normal temperature until a constant weight was reached. Then weight all the dried bulb and the average were calculated as gram. Plate 5 (C) showing bulb weight data collection.

### 3.4.7 Statistical analysis

Mean data of the characters were used to statistical analyze like analysis of variance (ANOVA), mean, range were calculated by using MSTAT C software program. Genotypic and phenotypic variance was estimated by the formula used by Johnson et al. (1955). Heritability and genetic advance were measured using the formula given by Singh and Chaudhary (1985). Genotypic and phenotypic coefficient of variation was calculated by the formula of Burton (1953). Genotypic and phenotypic correlation coefficient was obtained using the formula suggested by Miller *et al.* (1958), Johnson *et al.* (1955) and Hanson *et al.* (1956); path coefficient analysis was done following the method outlined by Dewey and Lu (1959).

**A.** 

B. 

**C.** 

**Plate 5:** Data collection.

A. Plant height; B. weight; C. Root length data collection

### 3.7.1. Measures of genetic variability

According to formula given by Johnson *et al.* (1955).

**Genotypic Variance ($\sigma_g^2$),**

$$\sigma_g^2 = \frac{GMS - EMS}{r}$$

Where,

GMS = Genotypic mean sum of square

EMS = Error mean sum of square

r = No. of replication

**Phenotypic Variance ($\sigma_{ph}^2$),**

$$\sigma_{ph}^2 = \sigma_g^2 + \text{EMS}$$

Where,

$\sigma_g^2$ = Genotypic Variance

EMS = Error mean sum of square

**Environmental Variance ($\sigma_e^2$),**

$$\sigma_e^2 = \sigma_{ph}^2 - \sigma_g^2 - \sigma_{ge}^2$$

Where,

$\sigma_e^2$ = Environmental Variance

$\sigma_{ph}^2$ = Phenotypic variance

$\sigma_g^2$ = Genotypic Variance

$\sigma_{ge}^2$ = Interaction between genotype and environment

**Genotypic Coefficient of Variation,**

$$\text{GCV} = \frac{\sqrt{\sigma_g^2}}{\bar{x}} \times 100$$

Where,

$\sigma_g^2$ = Genotypic Variance

$\bar{x}$ = Population mean

**Phenotypic Coefficient of Variation,**

$$\text{PCV} = \frac{\sqrt{\sigma_{ph}^2}}{\bar{x}} \times 100$$

Where,

$\sigma_{ph}^2$ = Phenotypic variance

$\bar{x}$ = Population mean

**Environmental coefficient of variation,**

$$ECV = \frac{\sqrt{\sigma_e^2}}{\bar{x}} \times 100$$

Where,

$\sigma_e^2$ = Environmental Variance

$\bar{x}$ = Population mean

**Heritability in broad sense,**

$$h_b^2 = \frac{\sigma_g^2}{\sigma_{ph}^2} \times 100$$

Where,

$\sigma_g^2$ = Genotypic Variance

$\sigma_{ph}^2$ = Phenotypic variance

**Genetic advance,**

$$GA = h_b^2 \cdot K \cdot \sigma_{ph}$$

Where,

$h_b^2$ = heritability in broad sense

K = Selection differential, value is 2.06 at 5% selection intensity

$\sigma_{ph}$ = Phenotypic standard deviation

**Genetic advance in percent of mean,**

$$GA\ (\%) = \frac{GA}{\bar{x}} \times 100$$

Where,

GA = Genetic advance

$\bar{x}$ = Population mean

### 3.7.2. Estimation of correlation coefficients

According to formula given by Miller *et al.* (1958) and Johnson *et al.* (1955).

**Genotypic correlation,**

$$r_{g_{1.2}} = \frac{Cov.g_{1.2}}{\sqrt{\sigma_{g_1}^2 \times \sigma_{g_2}^2}}$$

Where,

$Cov.g_{1.2}$ = genotypic covariance between the trait $x_1$ and trait $x_2$

$\sigma_{g_1}^2$ = genotypic variance of the trait $x_1$

$\sigma_{g_2}^2$ = genotypic variance of the trait $x_2$

**Phenotypic correlation,**

$$r_{ph_{1.2}} = \frac{Cov.ph_{1.2}}{\sqrt{\sigma^2_{ph_1} \times \sigma^2_{ph_2}}}$$

Where,

$Cov.ph_{1.2}$ = Phenotypic covariance between the trait $x_1$ and trait $x_2$

$\sigma^2_{ph_1}$ = Phenotypic variance of the trait $x_1$

$\sigma^2_{ph_2}$ = Phenotypic variance of the trait $x_2$

### 3.7.3. Estimation of path coefficients

According to formula of Dewey and Lu (1959) quoted in Singh and Chaudhary (1985).

Assuming eight independent variable = $x_1$, $x_2$………and $x_8$ (yield components)

One dependant variable = $x_9$ (grain yield/plant)

The relationship between them can be represented as follows.

$P_{19} + r_{12}P_{29} + r_{13}P_{39} + r_{14}P_{49} + r_{15}P_{59} + r_{16}P_{69} + r_{17}P_{79} + r_{18}P_{89} = r_{19}$

$r_{12} P_{19} + P_{29} + r_{23}P_{39} + r_{24}P_{49} + r_{25}P_{59} + r_{26}P_{69} + r_{27}P_{79} + r_{28}P_{89} = r_{29}$

$r_{13} P_{19} + r_{23}P_{29} + P_{39} + r_{34}P_{49} + r_{35}P_{59} + r_{36}P_{69} + r_{37}P_{79} + r_{38}P_{89} = r_{39}$

$r_{14} P_{19} + r_{24}P_{29} + r_{43}P_{39} + P_{49} + r_{45}P_{59} + r_{46}P_{69} + r_{47}P_{79} + r_{48}P_{89} = r_{49}$

$r_{15} P_{19} + r_{25}P_{29} + r_{53}P_{39} + r_{54}P_{49} + P_{59} + r_{56}P_{69} + r_{57}P_{79} + r_{58}P_{89} = r_{59}$

$r_{16} P_{19} + r_{26}P_{29} + r_{63}P_{39} + r_{64}P_{49} + r_{65}P_{59} + P_{69} + r_{67}P_{79} + r_{68}P_{89} = r_{69}$

$r_{17} P_{19} + r_{27}P_{29} + r_{73}P_{39} + r_{74}P_{49} + r_{75}P_{59} + r_{76}P_{69} + P_{79} + r_{78}P_{89} = r_{79}$

$r_{18} P_{19} + r_{28}P_{29} + r_{83}P_{39} + r_{84}P_{49} + r_{85}P_{59} + r_{86}P_{69} + r_{87}P_{79} + P_{89} = r_{89}$

Where,

$P_{19}$, $P_{29}$…..$P_{89}$ = Path coefficient of the variables $x_1$, $x_2$……$x_8$ on variable $x_9$, respectively.

$r_{19}$, $r_{29}$……..$r_{89}$ = correlation coefficient of the variables $x_1$, $x_2$……$x_8$ on variable $x_9$, respectively.

The residual effect was estimated as follows:

Residual effect, R = $\sqrt{1 - (r_{19}P_{19} + r_{29}P_{29} + \cdots\cdots\cdots\cdots\cdots + r_{89}P_{89})}$

# CHAPTER IV

# RESULTS AND DISCUSSIONS

The present study was conducted to find out of genetic variability, character association and path analysis in garlic genotypes during Rabi season 2017-18 are illustrated in the following sections.

## 4.1 Evaluation of performance of garlic genotypes

### 4.1.1 Analysis of variance

The analyses of variance of different garlic genotypes for yield and yield contributing traits are shown in Table 2. Analysis of variance indicated that the highly significant difference among genotypes for all eight traits under study viz., plant height (cm), root length (cm), total no. of leaves, leaf length (cm), leaf breadth (cm), bulb length (cm), bulb diameter (cm) and yield per plant(g). This results suggest that the presence of variation among the genotypes for all these traits.

### 4.1.2 Performance of the genotypes for yield and yield contributing traits

Univariate statistical analysis gave an excellent opportunity to identify and group the genotypes into different categories with respect to various traits individually. The mean performances of the ten Garlic genotypes for their traits are shown in Table 3&4.

#### 4.1.2.1 Plant height (cm)

Plant height among the genotypes ranged from 39 cm to 63.8 cm with a mean value of 48.326 cm. The highest plant height was observed in genotype BARI Rosun-1 and lowest in genotype BARI Rosun-2.

#### 4.1.2.2 Root length (cm)

Root length was exhibited the variation with the ranged from 8.7 cm to 12.5 cm with an average of 10.927 cm. The genotype BARI Rosun-3 represented the longest root which was significantly different with Khude. While the shortest root were observed by the genotype China.

**Table 2. Analysis of variance for different characters in Garlic (*Allium sativum* L.) genotypes**

| Characters | Mean sum of square | | |
|---|---|---|---|
| | Replication (r-1)=2 | Genotypes (g-1)=9 | Error (r-1)(g-1) =18 |
| Plant height (cm) | 3.186 | 143.541** | 1.676 |
| Root length (cm) | 0.200 | 2.87** | 0.078 |
| No. of leaves | 0.052 | 2.197** | 0.088 |
| Leaf length (cm) | 5.226 | 46.384** | 4.287 |
| Leaf breath (cm) | 0.001 | 0.035** | 0.002 |
| Bulb length (cm) | 0.014 | 0.294** | 0.006 |
| Bulb diameter (cm) | 0.017 | 3.248** | 0.009 |
| Dry weight per bulb(g) | 0.689 | 9.212** | 0.075 |

**Table 3. Range, mean, CV (%) and standard deviation of 10 garlic (*Allium sativum* L.) genotypes**

| Parameter | Range | | Mean | CV (%) | SD | SE |
|---|---|---|---|---|---|---|
| | Min | Max | | | | |
| Plant height (cm) | 39 | 63.8 | 48.326 | 2.68 | 6.77 | 0.7474 |
| Root length (cm) | 8.7 | 12.5 | 10.927 | 2.55 | 0.97 | 0.1610 |
| No. of leaf | 6.75 | 9.5 | 8.311 | 3.56 | 0.86 | 0.1708 |
| Leaf length (cm) | 28.1 | 47.9 | 33.792 | 6.13 | 4.17 | 1.1954 |
| Leaf breadth (cm) | 1.25 | 1.6 | 1.433 | 3.25 | 0.11 | 0.0269 |
| Bulb length (cm) | 2.4 | 3.6 | 2.7627 | 2.79 | 0.309 | 0.0445 |
| Bulb diameter (cm) | 1.9 | 4.9 | 2.963 | 3.15 | 1.007 | 0.0539 |
| Dry weight per bulb (g) | 8.7 | 11.5 | 10.917 | 2.51 | 1.718 | 0.1579 |

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

#### 4.1.2.4 Leaf length (cm)

Leaf length was exhibited the variation with the ranged from 28.1 cm to 47.9 cm with an average of 33.792 cm. The genotype BARI Rosun-3 represented the longest leaf and the shortest leaf length was observed in the genotype BARI Rosun-2 which is genetically similar with BARI Rosun-1, Faridpuri, China, Natore and manikgonj.

#### 4.1.2.5 Leaf breath (cm)

Leaf breath was exhibited the variation with the ranged from 1.25 cm to 1.6 cm with an average of 1.433 cm. The genotype BARI Rosun-3 represented the highest leaf breadth which was significantly similar with genotype BARI Rosun-4. While the shortest leaf breadth was observed by the genotype Natori, khude which is statistically similar with BARI Rosun-2.

#### 4.1.2.6 Bulb length (cm)

Bulb length (cm) Bulb length was exhibited the variation with the ranged from 2.4 cm to 3.6 cm with an average of 2.7627 cm. The genotype BARI Rosun-1 showed the highest bulb length. While the shortest bulb length was observed by the genotype Manikgonji which are genetically similar with BARI Rosun-2, Natore respectively.

#### 4.1.2.7 Bulb diameter (cm)

Bulb diameter was exhibited the variation with the ranged from 1.9 cm to 4.9 cm with an average of 2.963 cm. The genotype BARI Rosun-3 represented the highest bulb diameter and the lowest bulb diameter was observed in the genotype BARI Rosun-2.

#### 4.1.2.8 Yield per plant (g)

The important yield contributing trait yield per plant was ranged from 8.7 g to 11.57 g with a mean value of 10.917 g. The highest yield per plant was exhibited by the genotype BARI Rosun-3. The lowest yield per plant was exhibited by the genotype BARI Rosun-2 which is statistically similar with BARI Rosun-4. Since, greater yield per plant is one of the major criteria which contribute to higher bulb yield and it could be utilized in further program.

**Table 4. Mean performance of different characters of 10 garlic (*Allium sativum* L.) genotypes**

| | Plant Height (cm) | Root length (cm) | Total no. of leaves | Leaf length (cm) | Leaf breath (cm) | Bulb length (cm) | Bulb diameter (cm) | Yield per plant (g) |
|---|---|---|---|---|---|---|---|---|
| BARI Rosun-1 | 63.58 a | 10.867c | 9.300a | 30.67d | 1.400d | 3.653 a | 2.353d | 11.07 bc |
| BARI Rosun-2 | 40.17 f | 11.30 b | 8.110 d | 30.62 d | 1.293 e | 2.543 ef | 1.950 f | 9.077 f |
| BARI Rosun-3 | 52.43 c | 12.30 a | 6.833 e | 43.70 a | 1.580 a | 2.800 c | 4.716 a | 15.17 a |
| BARI Rosun-4 | 42.45 e | 10.00 d | 8.20c d | 31.04 cd | 1.573 a | 2.673 cde | 3.71 c | 9.257 ef |
| Faridpur (local variety) | 46.80 d | 11.33 b | 8.867 abc | 34.13 bcd | 1.533 ab | 3.000 b | 4.067 b | 11.17 bc |
| China (local variety) | 45.30 d | 9.133 e | 8.567 bcd | 32.08 bcd | 1.410 cd | 2.713 cd | 2.187 de | 9.637 de |
| Natori (local variety) | 42.90 e | 12.00 a | 8.667 abc | 31.18 cd | 1.310 e | 2.510 f | 2.170 e | 10.90 c |
| Ekdana (local variety) | 62.43 a | 10.73 c | 9.217 ab | 35.00 bc | 1.433 cd | 3.000 b | 3.783 b | 9.900 d |
| Khude (local variety) | 56.63 b | 12.17 a | 6.817 e | 35.20 b | 1.317 e | 2.667 cde | 3.933 b | 11.40 bc |
| Manikgang (local variety) | 40.57 f | 11.43 b | 8.733 ab | 34.30 bcd | 1.483 bc | 2.517 f | 2.320 de | 11.20 bc |
| SD | 6.77 | 0.97 | 0.87 | 4.17 | 0.11 | 0.309 | 1.007 | 1.718 |
| CV (%) | 2.68 | 2.55 | 3.56 | 6.13 | 3.25 | 2.79 | 3.15 | 2.51 |
| Mean | 48.326 | 10.927 | 8.311 | 33.792 | 1.433 | 2.763 | 2.963 | 10.917 |

### 4.2 Estimation of genetic parameters of Onion genotypes

Genotypic variances, phenotypic variances, genotypic co-efficient of variation (GCV), phenotypic co-efficient of variation (PCV), heritability, genetic advance and genetic advance in percent of mean (GA % mean) for all yield and the yield contributing traits are presented in Table 5.

#### 4.2.1 Variability parameters

The perusal of data revealed that most of the variance for all traits was non-significant (Table 5). Significant genetic variation in various component traits exhibited by the genotypes indicated these traits might be effective for further improvement in garlic. Phenotypic variance was higher than the genotypic variances for all the traits that were supported by Pavlović *et al.* (2003) and Gurjar and Singhania (2006). This was indicated the influences of environmental factor on these traits. Coefficient of variation studied indicated that estimates of phenotypic coefficient of variation (PCV) were higher than the corresponding genotypic coefficient of variation (GCV) for all the traits. That indicates they all interacted with the environment to some extent. Among the all traits, high GCV and PCV were found for bulb diameter (35.072 and 35.213, respectively) followed by yield per plant (15.986 and 16.181%), plant height (14.230 and 14.400%) bulb length (11.214 and 11.556%), no. of leaves (11.085 and 11.666%), total number of leaf (10.090 and 10.699%), root length (8.838 and 9.199%) and leaf breath (7.249 and 7.996%). Randhawa et al. (1974) found that the phenotypic and genotypic coefficient of variation was maximum for bulb bulb diameter. Patil *et al.* (1986) reported the GCV and PCV were moderate to high (1530%) for bulb yield. Singh *et al.* (1995) reported bulb weight, bulb yield/ha and leaves per plant had high genotypic coefficients of variation (21.95, 20.72 and 20.28 respectively). Hossain *et al.* (2008) recorded higher genotypic coefficients of variations in plant height, fresh weight of bulb and bulb length.

**Table 5. Estimation of genetic, phenotypic and environmental variance and coefficient of variations**

| Parameter | $\sigma^2p$ | $\sigma^2g$ | $\sigma^2e$ | GCV | PCV | PCV:GCV |
|---|---|---|---|---|---|---|
| Plant height (cm) | 48.964 | 47.288 | 1.676 | 14.230 | 14.400 | 0.988 |
| Root length (cm) | 1.01 | 0.932 | 0.078 | 8.838 | 9.199 | 0.961 |
| Total No. of leaves | 0.791 | 0.703 | 0.088 | 10.090 | 10.699 | 0.943 |
| Leaf length (cm) | 18.319 | 14.0323 | 4.287 | 11.085 | 11.666 | 0.950 |
| Leaf breadth (cm) | 0.012 | 0.011 | 0.002 | 7.249 | 7.46 | 0.972 |
| Bulb length (cm) | 0.102 | 0.096 | 0.006 | 11.214 | 11.556 | 0.971 |
| Bulb diameter (cm) | 1.008 | 1.079 | 0.009 | 35.072 | 35.213 | 0.996 |
| Yield per plant (g) | 3.115 | 3.04 | 0.075 | 15.986 | 16.181 | 0.988 |

Values with same letter(s) are statistically identical at 5% level of probability.

$\sigma^2p$ = Phenotypic variance, $\sigma^2g$ = Genotypic variance and $\sigma^2e$ = Environmental variance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, ECV = Environmental coefficient of variation

### 4.2.2. Heritability and genetic advance

The heritability in broad sense, genetic advance at 5% selection intensity and genetic advance in percent of mean for eight characters of 10 garlic genotypes were presented in Table 6.

#### 4.2.2.1. Plant height (cm)

Plant height showed very high heritability (96.578%) with moderate genetic advance in percent of mean (28.808%) which indicated that this trait was controlled by additive gene.

#### 4.2.2.2. Root length (cm)

Root length showed very high heritability (92.305%) with moderate genetic advance in percent of mean (17.492%) which indicated that this trait was controlled by additive gene.

#### 4.2.2.3. Total no. of leaves

Total number of leaves showed high heritability (88.928%) with moderate genetic advance in percent of mean (19.600%) which indicated that this trait was controlled by additive gene.

#### 4.2.2.4. Leaf Length (cm)

Leaf Length (cm) showed moderate heritability (76.597%) with moderate genetic advance in percent of mean (19.986%) which indicated that this trait was controlled by additive gene.

#### 4.2.2.5. Leaf Breath (cm)

Leaf Breath showed moderate heritability (83.231%) with low genetic advance in percent of mean (13.624%) which indicated that this trait was controlled by non-additive gene.

#### 4.2.2.6. Bulb length

Bulb length showed very high heritability (94.174%) with moderate genetic advance in percent of mean (22.418%) which indicated that this trait was controlled by additive gene.

**Table 6. Estimation of heritability and genetic advance of ten garlic genotypes**

| Parameter | Heritability | Genetic advance (5%) | Genetic advance (% mean) |
|---|---|---|---|
| Plant height (cm) | 96.578 | 13.921 | 28.808 |
| Root length (cm) | 92.305 | 1.911 | 17.492 |
| No. of leaf | 88.928 | 1.629 | 19.600 |
| Leaf length (cm) | 76.597 | 6.754 | 19.986 |
| Leaf breadth (cm) | 83.231 | 0.195 | 13.624 |
| Bulb length (cm) | 94.174 | 0.619 | 22.418 |
| Bulb diameter (cm) | 99.199 | 2.132 | 71.957 |
| Yield per plant (g) | 97.603 | 3.552 | 32.534 |

#### 4.2.2.7. Bulb diameter

Bulb diameter showed high heritability (99.199%) with high genetic advance in percent of mean (71.957%) which indicated that this trait was controlled by additive gene.

#### 4.2.2.8. Yield per plant (g)

Yield per plant showed high heritability (96.603%) with moderate genetic advance in percent of mean (32.534%) which indicated that this trait was controlled by additive gene.

### 4.3. Relationship among yield and yield contributing traits

#### 4.3.1. Correlation coefficient analysis

Yield being a complex character was influenced by several inter-dependable quantitative traits. Selection for this trait would not be effective unless the influence of other yield components were taken into consideration. Selection pressure for improvement of any character highly associated with yield would affect other correlated characters simultaneously. Therefore knowledge regarding association of yield and yield components provides guideline to select the character for improvement with a clear understanding. In this regard, phenotypic and genotypic correlation coefficient among different pair of yield and yield contributing characters for ten garlic genotypes were shown in Table-7. Correlation coefficient analysis had shown that genotypic correlation coefficient was slightly higher than the corresponding phenotypic correlation coefficient for most of the characters. It revealed that, phenotypic expression was modified due to the strong inherent association and environmental effect by reducing their phenotypic correlation value.

#### 4.3.1.1 Plant height (cm)

Plant height had shown highly significant and positive correlation with leaf length (0.559** and 0.506**), bulb length (0.748** and 0.730**) and bulb diameter (0.878** and 0.858**) which indicated that if plant height was increased, then leaf length and bulb diameter would also be increased.

It had shown non-significant positive correlation for root length (0.185 & 0.144), leaf breath (0.089 and 0.039) and yield per plant (0.132 and 0.121) non-significant negative correlation with total number of leaves (0.089 and 0.039).

#### 4.3.1.2. Root length (cm)

Root length had shown significant and positive correlation with dry weight per bulb (0.388* and 0.367*) which indicated that if root length was increased, then yield per plant would also be increased. It had shown non-significant positive correlation with leaf length (0.320 and 0.280), bulb diameter (0.311 and 0.300). It had shown non-significant negative correlation with total number of leaves (-0.402 and-0.399) leaf breath (-0.289 and -0.254) and bulb length (-0.130 and -0.123) at both genotypic and phenotypic level, respectively.

#### 4.3.1.3. Total number of leaves

Total number of leaves had shown negatively significant at root length (-0.402 and-0.399) and leaf length (-0.636 and -0.539) which indicated that if total number of leaves was increased then root length and leaf length would be decreased. Non-significantly negative correlation with plant height (-0.166 and -0.138), leaf breath (-0.032 and -0.042) and bulb diameter (-0.161 and -0.143) which associations was largely influenced by environmental factors

**Table 7. Genotypic and phenotypic correlation coefficients among different pairs of yield and yield contributing characters for 10 garlic genotypes**

| | | **Plant height** | **Root length** | **No of leaves** | **Leaf length** | **Leaf breath** | **Bulb length** | **Bulb diameter** |
|---|---|---|---|---|---|---|---|---|
| Root length | G | 0.185$^{NS}$ | | | | | | |
| | P | 0.144$^{NS}$ | | | | | | |
| No of leafs | G | -0.166$^{NS}$ | -0.402$^{NS}$ | | | | | |
| | P | -0.138$^{NS}$ | -0.399$^{NS}$ | | | | | |
| Leaf length | G | 0.559$^{**}$ | 0.320$^{NS}$ | -0.636$^{NS}$ | | | | |
| | P | 0.506$^{**}$ | 0.280$^{NS}$ | -0.539$^{NS}$ | | | | |
| Leaf breath | G | 0.089$^{NS}$ | -0.289$^{NS}$ | -0.032$^{NS}$ | 0.541$^{**}$ | | | |
| | P | 0.039$^{NS}$ | -0.254$^{NS}$ | -0.042$^{NS}$ | 0.419$^{*}$ | | | |
| Bulb length | G | 0.748$^{**}$ | -0.130$^{NS}$ | 0.304$^{NS}$ | 0.292$^{NS}$ | 0.305$^{NS}$ | | |
| | P | 0.730$^{**}$ | -0.123$^{NS}$ | 0.258$^{NS}$ | 0.278$^{NS}$ | 0.213$^{NS}$ | | |
| Bulb diameter | G | 0.878$^{**}$ | 0.311$^{NS}$ | -0.161$^{NS}$ | 0.617$^{**}$ | 0.245$^{NS}$ | 0.826$^{**}$ | |
| | P | 0.858$^{**}$ | 0.300$^{NS}$ | -0.143$^{NS}$ | 0.554$^{**}$ | 0.227$^{NS}$ | 0.793$^{**}$ | |
| Yield per plant | G | 0.132$^{NS}$ | 0.388$^{*}$ | 0.016$^{NS}$ | 0.335$^{NS}$ | 0.321$^{NS}$ | 0.146$^{NS}$ | 0.474$^{**}$ |
| | P | 0.121$^{NS}$ | 0.367$^{*}$ | 0.016$^{NS}$ | 0.288$^{NS}$ | 0.300$^{NS}$ | 0.144$^{NS}$ | 0.467$^{**}$ |

[

****= Significant at 1%; *=Significant at 5%; NS= Nonsignificant**

#### 4.3.1.4. Leaf length

Leaf length had shown highly significant and positive correlation with plant height (0.559** and 0.506**) leaf breath (0.541** and 0.419*) and bulb diameter (0.617** and 554**) which indicated that if leaf length was increased then plant height, leaf breath and bulb diameter would also be increased. It had shown highly significant and negative correlation with total number of leaves (-0.636** and -0.539**) which indicated that if leaf length was increased then total number of leaves would be decreased. It had shown non-significant positive correlation with root length (0.320 and 0.280) bulb length (0.292 and 0.278) and yield per plant (0.335 and 0.288) at both genotypic and phenotypic level, respectively.

#### 4.3.1.5. Leaf breath

Leaf breath had shown highly significant and positive correlation with leaf length (0.541** and 0.419*) at both genotypic level, respectively which indicated that if leaf breath was increased then leaf length would also be increased. It had shown non-significant positive correlation with plant height (0.089 and 0.039), bulb length (0.305 and 0.213), bulb diameter (0.245 and 0.227) and yield per plant ( 0.321 and 0.300) at both genotypic and phenotypic level, respectively. It had shown non-significant negative correlation with root length (-0.289 and -0.254), leaf length (-0.032 and -0.042). Association between these traits was largely influenced by environmental factors.

#### 4.3.1.6 Bulb length

Bulb length had shown highly significant and positive correlation with plant height (0.748** and 0.730**) and bulb length (0.826** and 0.793) at both genotypic and phenotypic level which indicated that if bulb length was increased then plant height and bulb length would also be increased.

It had shown non-significant and positive correlation with total no of leaves (0.304 and 0.258), leaf length (0.292 and 0.278), leaf breath (0.305 and 0.213) and bulb length (0.146 and 0.144). It showed non-significant negative correlation with root length(-0.130 and -0.123). Association between these traits was largely influenced by environmental factors.

#### 4.3.1.7. Bulb diameter

Bulb diameter had shown highly significant and positive correlation with plant height (0.878** and 0.858**), leaf length (0.617** and 0.554**), bulb length (0.826** and 0.793**) and yield per plant (0.474** and 467**). It had shown non-significant positive correlation with root length (0.311 and 0.300) and leaf breath (0.245 and 0.227) which indicated that if bulb diameter was increase root length and leaf breath would also be increase. It had shown non-significant negative correlation with total number of leaves (-0.161 and -0.143). Association between these traits was largely influenced by environmental factors.

#### 4.3.1.8. Yield per plant

Dry weight per bulb had shown highly significant and positive correlation with bulb diameter (0.474** and 0.467**); significant and positive correlation with root length (0.388* and 0.367*) at genotypic and phenotypic level. Which indicated that if dry weight per bulb was increased then bulb diameter and root length would also be increased. It had shown non-significant positive correlation with plant height (0.132 and 0.121), total number of leaves (0.016 and 0.016), leaf length (0.335 and 0.288), leaf breath (0.321 and 0.300) and bulb length (0.146 and 0.144).

### 4.3.2. Estimation of path co-efficient

The correlation coefficient alone is inadequate to interpret the cause and effect relationships among the traits and ultimately with yield. Path analysis technique furnishes a method of partitioning the correlation coefficients into direct and indirect effects provide the information on actual contribution of the independent variables on the dependent variable. In the present study, all the eight traits were considered as causal variables of yield. Genotypic correlations coefficients of these traits with yield per bulb were partitioned into the direct and indirect effects through path coefficient analysis. The results are shown in Table 8.

#### 4.3.2.1 Plant height (cm)

Path coefficient analysis had shown that, plant height had negatively direct effect (-0.812) on dry weight per plant. It had positive indirect effect via root length, total number of leaves, leaf breath, bulb length, bulb breath, bulb diameter, yield per plant.

On the other hand, it had negative indirect effect on leaf length (Table 8). Plant height finally made negatively correlation with yield per plant (-0.132) (Table 8).

#### 4.3.2.2. Root length

Path coefficient analysis had shown that, root length had positively direct effect (0.168) on dry weight per plant. It had positive indirect effect via total no. of leaves, bulb diameter, dry weight per bulb. On the other hand, it had negative indirect effect on plant height, leaf length, leaf breath, bulb length (Table 8). Root length finally made positively correlation with yield per plant (0.388) (Table 8).

#### 4.3.2.3. Total no. of leaves

Path coefficient analysis had shown that, total number of leaves had negatively direct effect (-0.425) on yield per plant. It had positive indirect effect via plant height, leaf length, bulb length, and yield per plant. On the other hand, it had negative indirect effect on root length, leaf breath, bulb diameter, (Table 8). Total number of leaves finally made positively correlation with yield per bulb (0.016) (Table 8).

#### 4.3.2.4. Leaf length

Path coefficient analysis had shown that, leaf length had negatively direct effect (-0.543) on yield per bulb. It had positive indirect effect via root length, total no. of leaves, leaf breath, bulb length, bulb diameter and yield per plant.. On the other hand, it had negative indirect effect on plant height. Leaf length finally made positively correlation with yield per bulb (0.335) (Table 8).

#### 4.3.2.5. Leaf breath

Path coefficient analysis had shown that, leaf breath had positively direct effect (0.131) on yield per plant. It had positive indirect effect via total no. of leaves, leaf breath, bulb diameter and yield per bulb. On the other hand, it had negative indirect effect on plant height, root length, leaf length, Leaf breath finally made positively correlation with yield per plant (0.321) (Table 8).

#### 4.3.2.6. Bulb length

Path coefficient analysis had shown that, bulb length had positively direct effect (0.189) on yield per plant. It had positive indirect effect via leaf breath, bulb diameter and dry weight per bulb. On the other hand, it had negative indirect effect on plant height, root length, total no. of leaves, leaf length. Bulb length finally made positively correlation with yield per plant (0.146) (Table 8).

#### 4.3.2.7. Bulb diameter

Path coefficient analysis had shown that, bulb diameter had positively direct effect (0.244) on yield per plant. It had positive indirect effect via leaf length, total no. of leaves, bulb length and yield per plant. On the other hand, it had negative indirect effect on plant height. Bulb diameter finally made positively correlation with yield per plant (0.474) (Table 8).

#### 4.3.2.8. Yield per plant

Path coefficient analysis had shown that, dry weight per bulb had positively direct effect (0.334) on yield per plant.  It had positive indirect effect via root length, leaf length, leaf breath, bulb length, bulb diameter and yield per bulb. Yield per plant finally made positively correlation with yield per plant (0.137) (Table 8).

**Table 8. Partitioning of genotypic correlations into direct (bold) and indirect effects of eight important characters by path analysis of garlic (*Allium sativum* L.).**

| | Effect via | | | | | | | | Genotypic correlation with yield per plant (g) |
|---|---|---|---|---|---|---|---|---|---|
| | Plant height | Root length (cm) | Total no. of leaves | leaf length (cm) | leaf breath | Bulb length | Bulb diameter | Weight per bulb | |
| **Plant height (cm)** | **-0.812** | 0.031 | 0.070 | -0.303 | 0.011 | 0.141 | 0.092 | 0.044 | -0.132$^{NS}$ |
| **Root length (cm)** | -0.150 | **0.168** | 0.171 | -0.174 | -0.038 | -0.024 | 0.387 | 0.129 | 0.388$^{*}$ |
| **No. of leaf** | 0.134 | -0.068 | **-0.425** | 0.345 | -0.004 | 0.058 | -0.200 | 0.005 | 0.016$^{NS}$ |
| **Leaf length (cm)** | -0.454 | 0.054 | 0.270 | **-0.543** | 0.071 | 0.055 | 0.768 | 0.111 | 0.335$^{NS}$ |
| **Leaf breadth (cm)** | -0.072 | -0.048 | 0.013 | -0.294 | **0.131** | 0.058 | 0.305 | 0.107 | 0.321$^{NS}$ |
| **Bulb length (cm)** | -0.608 | -0.022 | -0.129 | -0.158 | 0.040 | **0.189** | 0.027 | 0.049 | 0.146$^{NS}$ |
| **Bulb diameter (cm)** | -0.714 | 0.052 | 0.068 | -0.335 | 0.032 | 0.157 | **0.244** | 0.158 | 0.474$^{**}$ |
| **Yield per plant (g)** | -0.1073 | 0.065 | -0.007 | -0.182 | 0.042 | 0.028 | 0.590 | **0.334** | 0.137 |

****= Significant at 1%; *=Significant at 5%; NS= Non-significant**

# CHAPTER V
# SUMMARY AND CONCLUSION

The present study was undertaken at Sher-e-Bangla Agricultural University farm, Dhaka-1207, Bangladesh with ten garlic genotypes during the period from Mid November 2017 to March 2018. Cloves of garlic were sown to the main field in Randomized Complete Block Design (RCBD) with three replications. Data on various agro-morphological traits such as plant height (cm), root length(cm), total number of leaves, leaf length(cm), leaf breath (cm), bulb length (cm), bulb diameter(cm), dry weight per bulb (g).

The analysis of variance showed significant differences among the genotypes for all the traits viz. plant height (cm), root length (cm), total no. of leaves, leaf length (cm), leaf breadth (cm), bulb length (cm), bulb diameter (cm) and dry weight per bulb (g). Genotype BARI Rosun-1 shows highest plant height where BARI Rosun-4 and Local variety Natori shows lowest value. The BARI Rosun-3 represented the longest root which is genetically similar with local genotype Khude and Natori where the shortest root was observed by the local genotype China rosun. Genotype BARI Rosun-3 was showed lowest number of leaves and the genotypes BARI Rosun-1, Faridpuri, Natori and manikgonji showed the highest value. The genotype BARI Rosun-3 represented the longest leaf and the shortest leaf length was observed in the genotype BARI Rosun-1, BARI Rosun-2. The genotype BARI Rosun-3, BARI Rosun-4, Local genotype Manikgonji represented the longest leaf breadth while the shortest leaf breadth was observed by the genotype BARI Rosun-2, local genotype Natori and Khude. The genotype BARI Rosun-1 showed the highest bulb length and the shortest bulb length was observed by the genotype Manikgonji. The genotype BARI Rosun-3 represented the highest bulb diameter and the significant lowest bulb diameter was observed in the genotype BARI Rosun-2. The highest dry weight per bulb was exhibited by the genotype BARI Rosun-3 and the lowest dry weight per bulb was exhibited by the genotype BARI Rosun-2. Phenotypic variance was higher than the genotypic variances for all the traits. Phenotypic coefficient of variation (PCV) was higher than the corresponding genotypic coefficient of variation (GCV) for all the traits. Among the all traits, high GCV and PCV were found for bulb diameter (35.072

and 35.213, respectively) followed by dry weight per bulb (15.986 and 16.181%), plant height (14.230 and 14.400%) bulb length (11.214 and 11.556%), no. of leaves (11.085 and 11.666%), total number of leaf (10.090 and 10.699%), root length (8.838 and 9.199%) and leaf breath (7.249 and 7.996%).

Among the traits, highest heritability was recorded by bulb diameter (99.199%) followed by dry weight per bulb (97.603%), plant height (96.578 %), bulb length (94.174%), no. of leaves (88.928%), leaf breath (83.231%) and leaf length (76.597).
The highest genetic advance value is for bulb diameter (71.957) followed by dry weight per bulb (32.534), plant height (28.808), bulb length (22.418), leaf length (19.986), no of leaves (19.600), root length (17.492) and lowest for leaf breath (13.624) among yield and yield contributing traits. High heritability along with high genetic advance provided opportunity for selection of high yielding genotypes. Genotypic correlation coefficients were of higher in magnitude than the corresponding phenotypic correlation coefficients in most of the associations which might be due to masking or modifying effect. Very close genotypic and phenotypic correlations were observed the traits, plant height with bulb diameter, leaf length with bulb diameter and leaf length with dry weight per bulb, which might be due to reduction in error (environmental) variance, thus selection for higher yield on the basis of above traits would be reliable.

Dry weight per bulb positively but non significantly correlate with plant height (1.132 and 1.121), root length significantly at (0.388 and 0.367), no. of leaves non significantly at (0.016 and 0.016), leaf length non significantly at (0.335 and 0.288), leaf breath non significantly at (0.321 and 0.300), bulb length non significantly at (0.146 and 0.144), bulb diameter significantly at (0.474 and 0.467) at both genotypic and phenotypic levels respectively. Highly significant positive correlations at both the levels were recorded for plant height with bulb diameter (0.878 and 0.858), bulb length (0.826 and 0.793), leaf length (0.617 and 0.554), bulb length (0.874 and 0.740). Leaf length was correlated as positively highly significant with bulb diameter (0.617 and 0.554) leaf breadth (0.541 and 0.419). Bulb diameter was highly significant positive correlated with bulb length. Highly significant and positive correlation of bulb length at genotypic and phenotypic level with plant height (0.748 and 0.730). Highly significant positive correlation of no. of leaves with leaf length, bulb length, bulb diameter and dry weight per bulb at both genotypic and phenotypic levels. Highly significant and positive correlation of bulb length at genotypic and phenotypic level with bulb diameter and dry weight per bulb. Positive and highly significant correlation was observed of bulb diameter with dry weight per bulb at both genotypic and phenotypic levels.

Path analysis revealed Root length, leaf breath, bulb length, bulb diameter; yield per plant had direct positive effect on yield per plant, indicating these are the main contributors to yield per plant. The highest positive indirect effects on yield per plant (0.334), bulb diameter (0.244), bulb length (0.189), root length (0.168) and lead breath (0.131). Plant height, number of leaves, leaf length total number of leaves, yield per plant and bulb diameter had positive and higher indirect effect on yield per bulb through yield per plant.

High heritability coupled with high genetic advance in percent of mean was observed in bulb diameter, Dry weight per bulb, plant height, bulb length. So, yield per bulb in garlic would be achieved through selection of these traits.
The traits root length, bulb length, bulb diameter and dry weight per bulb showed positive and significant correlation with yield per bulb. So, yield per bulb of garlic can be increased by improving these traits. Path coefficient indicated maximum direct contribution towards Plant height, number of leaves, leaf length total number of leaves, dry weight per bulb and bulb diameter.

Based on the results of the study, the following recommendations may be drawn:

- The genotypes BARI Rosun-3 and BARI Rosun-1 may be selected for high yield, more dry weight of bulb, maximum bulb length, bulb diameter, no. of leaves, leaf length and plant height.

# CHAPTER V

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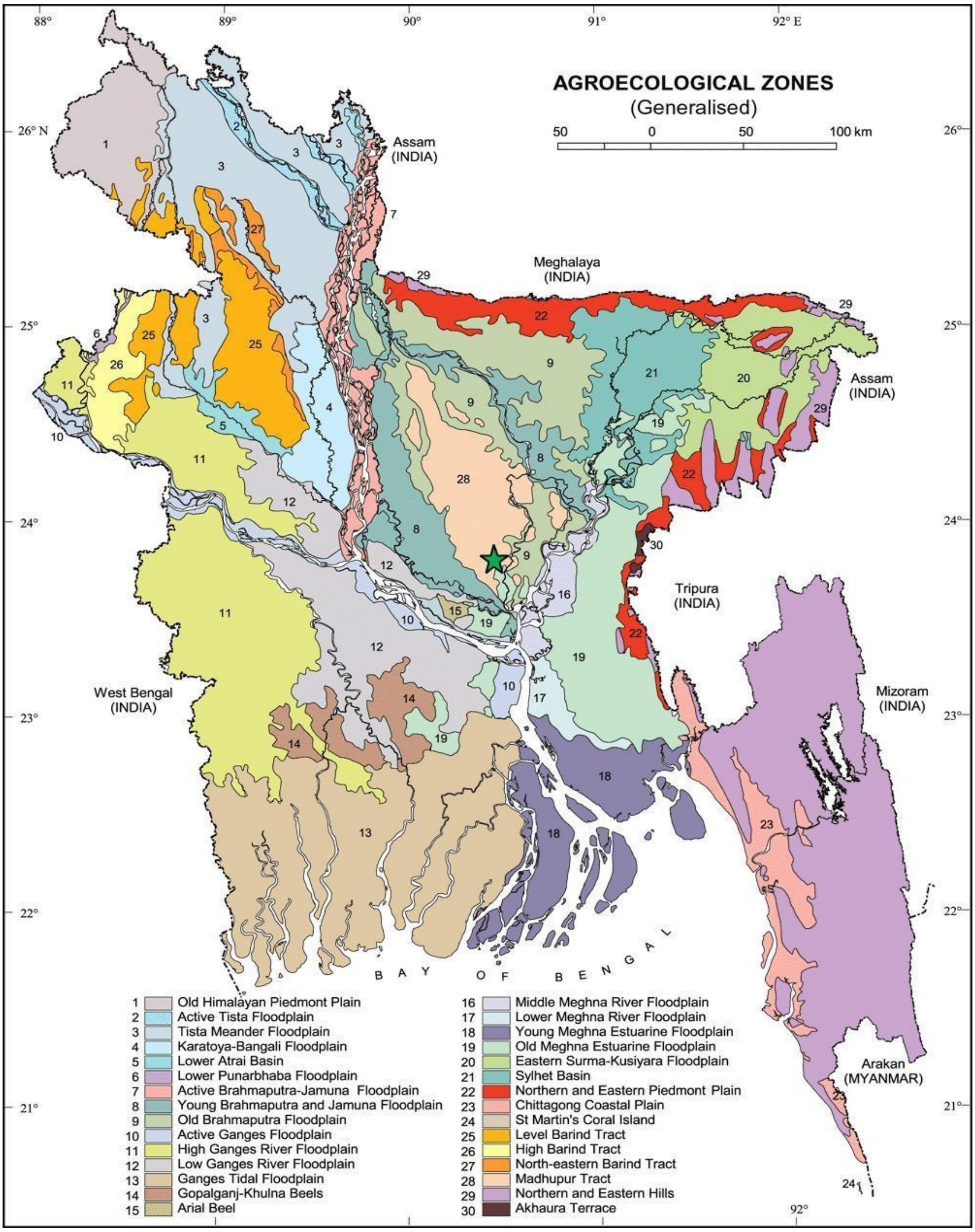
# APPENDICES

## Appendix I. Map showing the experimental site under the study




☆Shows the experimental site under the study

**Appendix II: Morphological, physical and chemical characteristics of initial soil (0-15 cm depth) of the experimental site**

**A. Physical composition of the soil**

| Soil separates | % | Methods employed |
|---|---|---|
| **Sand** | 36.90 | Hydrometer method (Day, 1915) |
| **Silt** | 26.40 | Do |
| **Clay** | 36.66 | Do |
| **Texture class** | Clay loam | Do |

**B. Chemical composition of the soil**

| Sl. No. | Soil characteristics | Analytical data | Methods employed |
|---|---|---|---|
| 1 | Organic carbon (%) | 0.82 | Walkley and Black, 1947 |
| 2 | Total N (kg/ha) | 1790.00 | Bremner and Mulvaney, 1965 |
| 3 | Total S (ppm) | 225.00 | Bardsley and Lanester |
| 4 | Total P (ppm) | 840.00 | Olsen and Sommers, 1982 |
| 5 | Available N (kg/ha) | 54.00 | Bremner, 1965 |
| 6 | Available P (kg/ha) | 69.00 | Olsen and Dean, 1965 |
| 7 | Exchangeable K (kg/ha) | 89.50 | Pratt, 1965 |
| 8 | Available S (ppm) | 16.00 | Hunter, 1984 |
| 9 | pH (1:2.5 soil to water) | 5.55 | Jackson, 1958 |
| 10 | CEC | 11.23 | Chapman, 1965 |

**Source:** Central library, Sher-e-Bangla Agricultural University, Dhaka.

**Appendix III. Monthly average temperature, relative humidity and total rainfall and sunshine of the experimental site during the period from November, 2017 to February, 2018.**

| Month | Air temperature (ºc) | | Relative humidity (%) | Rainfall (mm) (total) | Sunshine (hr) |
|---|---|---|---|---|---|
| | **Maximum** | **Minimum** | | | |
| **November, 2017** | 34.7 | 18.0 | 77 | 227 | **5.8** |
| **December, 2017** | 32.4 | 16.3 | 69 | 0 | **7.9** |
| **January, 2018** | 29.1 | 13.0 | 79 | 0 | **3.9** |
| **February, 2018** | **28.1** | **11.1** | **72** | **1** | **5.7** |

**Source:** Bangladesh Meteorological Department (Climate & Weather Division), Agargoan, Dhaka – 1212