# CHARACTER ASSOCIATION AND PATH ANALYSIS BASED ON MORPHOGENIC TRAITS IN ONION (*Allium cepa* L.) GENOTYPES

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## *CERTIFICATE*

*This is to certify that thesis entitled, "character association and path analysis based on morphogenic traits in onion (Allium cepa L.) genotypes " 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 MD. MASHRUR HOSSAIN RIFAT, Registration No. 11-04459 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*

*(Prof. Dr. Mohammad Saiful Islam)*
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***DEDICATED TO MY BELOVED PARENTS AND BROTHER***

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# SOME COMMONLY USED ABREVIATIONS

| Full word | Abbreviation |
|---|---|
| Agriculture | Agril. |
| Agricultural | Agric. |
| Agro Ecological Zone | AEZ |
| Agronomy | Agron |
| Analysis of variance | ANOVA |
| And others | *et al* |
| At the rate | @ |
| Bangladesh | BD |
| Bangladesh Agricultural Research Institute | BARI |
| Bangladesh Bureau of Statistics | BBS |
| Centimeter | Cm |
| Cultivars | cv. |
| Degree Celsius | $0^c$ |
| Degrees of freedom | df |
| Environmental variance | $\sigma^2e$ |
| Etcetera | Etc |
| Food and Agricultural Organization | FAO |
| Genotypic variance | $\sigma^2g$ |
| Genetic advance | GA |
| Genotype | *G* |
| Genotypic coefficient of variation | GCV |
| Gram | gm |
| Harvest Index | HI |
| Heritability in broad sense | $h^2b$ |

## SOME COMMONLY USED ABREVIATIONS *(Continued........)*

| Full word | Abbreviation |
|---|---|
| Indian Agricultural Research Institute | IARI |
| International Center for Agricultural Research in Dry Areas | ICARDA |
| Journal | J. |
| Kilogram | Kg |
| Mean sum of square | MS |
| Meter | M |
| Ministry of Agriculture | MoA |
| Murate of potash | MoP |
| Percent | % |
| Percentage of coefficient of variation | CV% |
| Phenotypic coefficient of variation | PCV |
| Phenotypic variance | $\sigma^2p$ |
| Randomized complete block design | RCBD |
| Sher-e-Bangla Agricultural University | SAU |
| Square meter | $m^2$ |
| The third generation of a cross between two dissimilar homozygous parents | $F_3$ |
| Triple super phosphate | TSP |

# CHARACTER ASSOCIATION AND PATH ANALYSIS BASED ON MORPHOGENIC TRAITS IN ONION (*Allium cepa* L.) GENOTYPES

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## ABSTRACT

The experiment was conducted in the research field of Sher-e-Bangla Agricultural University, Dhaka during December 2017 to April 2018 to investigate the character association and path analysis based on morphogenic traits in onion (allium cepa l.) genotypes in field condition. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Variability, mean performance, heritability, genetic advance, genotypic and phenotypic correlation coefficient and path analysis on different yield contributing characters and yield of onion genotypes were estimated. The highest bulb yield/plant (47.93 g) was recorded in the genotype of Laltir King, whereas the lowest bulb yield/plant (6.44g) from the genotype of BARI Piaj 2. Phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the yield contributing traits. In case of different varieties following highest heritability order has found; yield per bulb followed by leaf length > root length > plant height > dry weight per bulb > bulb diameter > no. of leaf > root length > bulb length> leaf breadth. In correlation study, yield per bulb positively and significantly correlated with plant height (0.43 and 0.45), root length (0.59 and 0.60), no. of leaves (0.82 and 0.72), leaf length (0.44 and 0.45), leaf breadth (0.47 and 0.48), bulb length (0.84 and 0.78), bulb diameter (0.65 and 0.65) and dry weight per bulb (0.98 and 0.89) at both genotypic and phenotypic levels respectively. Path coefficient analysis revealed that plant height (1.853), no. of leaves (0.11), bulb length (0.59), bulb diameter (0.32) and dry weight per bulb (0.21) had direct positive effect on yield per bulb, indicating these are the main contributors to yield per bulb. The genotypes Laltir king and Faridpuri 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 I
# INTRODUCTION

The onion (*Allium cepa* L. from Latin cepa "onion", belongs to the family Liliaceae), also known as the bulb onion or common onion, is a vegetable that is the most widely cultivated species of the genus *Allium*. Its close relatives include the garlic, shallot, leek, chive,and Chinese onion.

Onion (*Allium cepa* L.) is probably originated from Central Asia between Turkmenistan and Afghanistan where some of its relatives still grow in the wild. Onion from Central Asia, the supposed onion ancestor had probably migrated to the Near East (Grubben and Denton, 2004; Bagali *et al*. 2012). The crop onion is a popular vegetable and its bulb is used raw, sliced for seasoning salads, and cooked with other vegetables and meat. Onion bulbs are essential ingredients in many African sauces and relishes. The leaves, whole immature plants called 'salad onion' or leafy sprouts from germinating bulbs are used in the same way. In some parts of West Africa, leaves still green at bulb harvest are propounded, and then used to make sun-dried and fermented balls, which are used later for seasoning dishes. Sliced raw onions have antibiotic properties, which can reduce contamination by bacteria, protozoa or helminthus in salads (Grubben and Denton, 2004).

Onions are day length sensitive, several onion types exist depending upon the latitude at which they grow. It is estimated that around the World, over 3,642,000 ha of onions are grown annually (FAO, 2013). On a worldwide scale, around 80 million metric tons of onions are produced per year. China is by far the top onion producing country in the world, accounting for approximately 28% of the world's onion production, followed by India, USA, Iran, Egypt, Turkey, Russia, Pakistan, Netherlands and Brazil. The worldwide onion exports are estimated at around 7 million Metric tons. The Netherlands is the world's largest onion exporter with a total of around 220,000 Metric tons followed at a distance by India (FAO, 2013).

The use of appropriate agronomic management has an undoubted contribution to increased crop yields. One of the major problems to onion production is improper agronomic practice used by farmers. The optimum level of any agronomic practice such as plant population, planting date, harvesting date, and fertilizer of the crop varies with environment, purpose of the crop and cultivar. As a result, Bangladesh has to import onion from other countries to meet its demand (Hossain and Islam 1994). The average yield of onion in Bangladesh is only 3.45 t/ha (FAO 2002). This is a very poor yield compared to other leading onion growing countries of the world. Lack of use of modern genotypes and optimum fertilizer dose may be a major constraint of maximum harvest (Shamima and Hossain 2000). Onion is a shallow rooted crop; a fairly high concentration of nutrient should normally be maintained at the surface of the soil for its optimum growth and yield.

Onion is a momentous source of vitamin C and contains about 60 calories in a medium-sized bulb and has very low sodium content. The bulbs are major source of phytochemical called quercetin, which is effective in reducing the risk of cardiovascular disease, an anti-cancerous, and has promise to be an antioxidant (Smith, 2003). It`s pungency due to the presence of a volatile compound known as allyl-propyl di-sulphide. Onion bulbs and leaves are rich in minerals like Ca, K and P (Ullah *et al*., 2005). A single bulb provides 2.0 g protein, 72 mg calcium and 54 mg phosphorus (Ado, 2001). It also contains vitamins viz., thiamine, riboflavin and niacin. Eating of raw onion boost the immune system and regulate blood sugar level. It has been used for the treatment of various ailments such as skin diseases, ear pain and strokes and use also as heart problems (Mettananda and Fordham, 2001).Its main role in cooking is to provide flavor. The bulbs are boiled and used in soups and stews, fried or eaten raw in salads. It is hardy, bulbous rooted plant with small narrow rounded leaves and a white flower. Onion possesses typical pungent flavoring and it is useful mainly as a spice, seasoning and flavoring agent for foodstuff. It is grown by farmers in both for home use and source of income. Therefore, the introduction of new varieties represents an important axe to enhance production by increasing the number of cultivars available for growers, which is not only an advantage for the farming community but also for markets and processing industries. The farmers choose onion variety for planting depending on a number of factors which include production potential, market demand, regional adaptability and availability of seeds and their prices. Therefore, the perception of farmers is also important while selection and evaluating the varieties.

In fact, successful onion production depends mainly on the selection of varieties that are adapted to different conditions imposed by specific environment. Onion crop requires cool weather during the early development of bulbs. Environmental factors influence development, growth and biological yield of plants primarily by affecting their physiology. A cultivar crop performs differently under different agro-climatic conditions and various cultivars of the same species grown even in the same environment give different yields as the performance of a cultivar mainly depends on the interaction of genetic makeup and environment (Boukary *et al.*, 2012). The adequacy of germplasm collection is determined by the amount of genetic variability present in the germplasm. Existence of this natural variation even in respect of the plant parts that is economically important suggests the possibility of improvement in onion.

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 into 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 onion;
- To determine the correlation among yield and yield attributing traits;
- 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

A literature review is a summary of research that has been published about a particular subject. It provides the reader with an idea about the current situation in terms of what has been done and what we know. Sometimes it includes suggestions about what needs to be done to increase the knowledge and understanding of a particular problem. The present investigation was carried out to study the genetic variability, correlation and path coefficient analysis in onion (*Allium cepa* L.). The pertinent literature in relation to the proposed work is reviewed under the following sub heads:

2.1 Performance of genotypes

2.2. Genetic variability, heritability, genetic advance

2.3. Correlation analysis

2.4 Path coefficient analysis

## 2.1 Performance of genotypes

Patil (1997) reported vast diversity among the onion genotypes, the $D^2$ values ranged from 47.64 to 16173.41. He grouped 25 onion genotypes into 7 clusters with inter cluster distances of 26.89 and 127.17 respectively. The characters viz., bulb weight and marketable bulb yield are reported to contribute more to diversity; the pattern of genetic diversity was again not related to the geographical distribution of the genotypes.

Leeultai and Chaungdonghee (1996) measured varietal distances by applying $D^2$ statistics among 60 onion varieties based on the characters viz., plant height, length 21 and diameter of leaf sheath, bulb weight, bulb diameter and yield. The varieties were grouped into four clusters and these varietal groups were not associated with geographical origin, yield and bulb weight contributed largely to the D2 statistics.

El-Kafoury *et al.* (1996); observed that Hazera 7 cv. was the earliest in maturity, followed by other cultivars which did not show wide variations in between. The highest bulb weight, marketable and total bulb yields were produced from Composite 16 cv., whereas Composite 8 and Ben Shemen produced the lowest means for the previous mentioned traits. The highest culls yield was obtained from Hazera 7, followed by Giza20, Behairy No Pink and Ben Shemen. Bulbs of Composite 16, Giza 20 and Behairy No Pink proved to be the best in keeping quality, while Hazera 7 was the worst one in storability.

Randhawa *et al.* (1974); reported that variation for bulb yield (120.2-297.6q/ha), bulb weight (38.4-56.0g), plant height (38.5-50.5 cm) and number of scales leaves (5.3-7.3) in onion.

Vinutha (2000) reported that, among 17 characters included for $D^2$ analysis, the traits, bulb weight, split bulbs and marketable bulbs were the most important which contributed 82.33 per cent towards the divergence and also found that the parents with moderate to high divergence between them produced higher magnitude of heterotic crosses with higher frequency than the parents which had less divergence.

A cultivar crop performs differently under different agro-climatic conditions and various cultivars of the same species grown even in the same environment give different yields as the performance of a cultivar mainly depends on the interaction of genetic makeup and environment (Jilani and Ghafoor, 2003; Kimani *et al.* 1993).

Ijoyah *et al*. (2008) conducted a field experiment to evaluate the yield performance of four onion varieties and found that some other varieties performed better than the commonly grown onion varieties by the farmers.

Khar *et al*. (2006) studied 15 onion genotypes during kharif season for 10 economic characters. They grouped the accessions into 7 clusters. Maximum inter cluster difference observed was 35.11 between V and VI followed by ($D^2$ = 22.81) cluster IV and VII. The role of geographical distribution was reported to be least important in grouping the genotypes. They also reported that, marketable yield, total yield and TSS contributed maximum towards total divergence.

Shah *et al.* (2012) conducted an evaluation trial of three onion cultivars in Randomized Complete Block Design having three replications and concluded that onion cultivar performed differently and Parachinar local variety resulted in higher yield. Successful bulb production is depends upon selecting cultivars that will grow and bulb satisfactorily under the conditions imposed by a specific environment (Jones and Man, 1963). Wide variations in bulb characteristics were observed among the cultivated genotypes by several workers.

In a study of 43 onion varieties Padda *et al.* (1973) observed a wide variation for bulb size (25.00-71.80 g), total solids (7.4-17.5%) and yield (241.5-597.60 q/ha).

Azoom *et al*. (2014); were conducted a field experiment from September 2010 to July 2011 in Tunisia in order to evaluate the performance of seven onion varieties grown under field conditions. Results obtained showed that onion varieties were significantly different when it comes to the plant and bulb morphological characteristics. Variety 'Morada de Amposta' recorded the highest leaf length (68.06 cm), pseudo stem diameter (8.63 cm), number of leaves (8.71), plant height (76.95 cm), in addition to the greatest yields (32.88 t/ha) which were significantly ($p \leq 0.05$) increased by respectively 66.2, 88.8, 2.1, 61.2, 63, 27.9 and 28.4% compared to those obtained from the regular variety 'Blanc Hâtif de Paris'. Variety 'Blanc Hâtif de Paris' was the earliest to maturity and recorded the most preferment bulb weight (155.02 g) and diameter (8.21 cm). 'Keep Red' variety had the highest height of the bulb (7.19 cm). Variety 'Z6' recorded the minimum data in all measured parameters.

Dhotre *et al*. (2010) evaluated 14 onion genotypes during kharif season for 17 economic characters. They grouped the accessions into 5 clusters. Maximum inter cluster difference observed between IV and I (D2 = 206.33) followed by cluster IV and II ($D^2$ = 34.45). They also reported that, fresh bulb weight, equatorial diameter, double split, bulb per cent and bulb yield contributed maximum towards total divergence.

Mohamed and Gamie (1999) revealed that Giza 20 cultivars was the best in plant height, number of leaves/plant, bulb weight and total yield as compared to Shandaweel 1 and Giza 6, while, Shandaweel 1 cultivar was the best for the early bulb development. Leilah *et al*. (2003); cleared that local onion strains markedly differed in most of growth and yield characteristics.

Gamie and Yaso (2007) stated that the genotypes of Giza 20 Pink Flesh, Giza 20 White Flesh and Giza 20 Original were the tallest in plant height. Giza 20 Original was the highest in total soluble solids (TSS %) among the tested genotypes, while, Giza 20 White Flesh showed the greatest potential for storage.

Mohanty and Prusti (2001) studied the behavior of 12 varieties of onion during kharif season. They concluded that ArkaKalyan recorded the highest yield (21.06 t/ha) followed by ArkaNiketan (19.64 t/ha) and PusaMadhavi (18.96 t/ha), while Agri. found Dark Red and N 53 displayed moderately high yield of 18.06 and 17.85 t/ha, respectively.

Singh and Dubey (2011) studied twenty six onion genotypes and were grouped into 6 clusters based on $D^2$ values and concluded that the differences in cluster means existed for almost all 14 characters studied. Cluster- VI had highest value of plant height (65.96 cm), bulb diameter (5.5 cm), bulb size index (23.31 cm2), gross yield (394.97 q/ha), marketable yield (378.96 q/ha) and minimum doubles (1.60%). Cluster-V was for highest number of leaves per plant (9.06) and minimum bolters (1.35%) and days taken for in harvesting (107.33). Cluster III was characterized by high TSS (13.44) and dry matter (14.31%).

Yaso (2007) reported that Giza 20 and Red Giza and (Giza 20 x TEYG) genotypes had the highest means for plant height and No. of leaves/plant, while Comp. 13 Oblong gave the lowest ones. Compo. 13 Ob. was the earliest in bulb maturity, while Giza 20 and Red Giza were the latest ones. Giza 20, Red Giza, (Giza 20 x TEYG) and Group of Composites were the highest in total and marketable yield and average bulb weight.

**2.2. Genetic variability, Heritability, Genetic Advance**

The genetic and environmental components of variation were described in the early part of this century by Johansen (1909) who attributed the variation in segregating population to both heritable and non-heritable factors and the variation in a pure line due to only environmental factors.

Charles and Smith (1939) and Powera *et al*. (1950) partitioned genetic variance from total variance in non-segregating populations. The heritable variation was further divided into additive and non-additive components and the latter fraction included dominance and inter-allelic interaction (Falconer, 1981).

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.

Different types of 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. 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.

In the early of 1889, Galton observed that a part of continuous variation is due to heredity. The study of heritable and non-heritable component of variability has its inception in the finding of Johannson (1909). The degree to which the variability of quantitative character is transmitted to the progeny is referred as heritability.

Krishna Prasad *et al*. (2005) reported significant variation in plant height among 209 onion lines. Plant height had high heritability associated with low genetic advance (Vidyasagar *et al*. 1993)

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.

Randhawa *et al.* (1974); found that the phenotypic and genotypic coefficient of variation was maximum for bulb yield followed by bulb weight. Heritability was moderate for bulb yield (55.7%), plant height (54.1%) and bulb weight (50.1%), whereas, it was low for number of scales leaves (25%). Genetic advance was moderate for bulb yield (44.1%). In general, the red varieties outstanding yielded over the white varieties. 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.

McCollum (1968), reported that variability for bulb shape (extremely flat to oblong) in onion was low. He further recorded variability for other characters (bulb weight and diameter), intermediate (plant height) and high (total solids).

In a study of 43 onion varieties Padda *et al.* (1973) observed the genotypic coefficient of variation (GCV) for these characters was moderate (16.1-20.6%). Heritability (broad sense) for bulb size and total solids was high (more than 80%) whereas; it was low for bulb yield (30.6%). Genetic advance expressed as percent of mean was low (bulb yield) to moderate (bulb size and total solids).

Patil (1997) reported polar and equatorial diameter ranged between 3.99 and 6.46 with a mean of 3.63-6.08 cm, while GCV and PCV was low to moderate and high heritability associated with moderate GAM for this trait.

Korla and Rastogi (1979b) 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. El-Shafie and Ahmed (1977), studied the F2 population of two onion crosses and reported that the heritability was 37.80 per cent (cross A) and 52.75 per cent (cross B) for earliness and the corresponding figures for bulb weight were 77.77 and 48.53 per cent respectively.

Singh and Dubey (2011) observed wide variability in onion for diameter of bulb which is ranged from 5.14 to 5.62 cm and mean of 5.37 cm. The estimate of GCV (1.56%) and PCV (2.94%) were low. Heritability was low (28.20%) with low GAM (1.67%).

Ram *et al.* (2011) reported that, the variability was ranged from 4.84 to 6.12 cm. The estimate of GCV (5.65%) and PCV (8.32%) were low. Heritability was moderate (46.2%) with low GAM (7.85%).

Dhotre (2009) reported a significant variation for polar and equatorial diameter and it was ranged between 38.2 and 47.8 mm. while low GCV (8.49%) and PCV (9.38%), high heritability (80.88%) associated with moderate GAM (15.74%) for diameter of bulb.

Bulb diameter (polar and equatorial) showed very low heritability (Madalgeri, 1983; Veeregouda, 1988 and Patil *et al*., 1986, while some other reports indicated (Sidhu *et al*. 1986 and Vidyasagar *et al*., 1993) high heritability coupled with very low genetic advance, indicating non-additive gene action. It also showed wide variation among genotypes (Sidhu *et al*., 1986).

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.

Sindhu *et al.* (1986) studied 30 genotypes of onion and observed variation for total yield (105.8-368.1q/ha), days to bulb maturity (119.3-137.0 days), diameter of bulb (4.3-6.7cm), shape index (0.75-0.96), bulb weight (30.3-63.3g), bolting (0.0-36.7%) and TSS (6.77-10.0%). Phenotypic and genotypic coefficient of variation, genetic advance and heritability estimates were high for total yield and bolting and low for other characters studied.

Dhotre (2009) reported significant variation in plant height among 14 genotypes range varied between (40.39-52.17 cm), low GCV (6.46%) and PCV (8.33%), high heritability (61.34%) coupled with low GAM.

Patil *et al.* (1986) made a comprehensive study on the genetic variability involving 45 cultivars of onion and observed wide range of variation for bulb weight (59.33-150.00 g), polar diameter (4.06-5.38 cm), equatorial diameter (5.0-6.77 cm), neck thickness (1.21-1.48 cm), plant height (55.33-74.50 cm), number of leaves per plant (14.23-17.50), TSS at harvest (7.80-12.70%), bolting (8.00-92.10%) and losses due to sprouting (0.0-31.5%). Genotypic and phenotypic coefficient of variation were moderate to high (15-30%) for bolting, bulb weight and sprouting whereas, these were low for other characters (<15%). Heritability was high for bulb weight, number of leaves per plant and bolting; medium for plant height and low for other characters. Expected genetic advance was high for bulb weight and bolting; moderate for sprouting, rotting and total losses and low for other characters.

Kadams and Nwasike (1986) reported high heritability for solids and low for bulb weight in Nigerian white onions.

Madalageri *et al*. (1986) reported high genetic variability and genetic advance for total soluble solids. 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 plant height and bulb weight. High heritability along with high genetic advance was observed for plant height and weight of 50 cloves. Singh *et al.* (1995), conducted a field experiment and studied genetic variability and correlation in nine cultivars of onion. Bulb weight, bulb yield/ha and leaves per plant had high genotypic coefficients of variation (21.95, 20.72 and 20.28 respectively), heritability (97.88, 96.95 and 95.92 per cent, respectively) and genetic advance (44.80, 42.85 and 40.96 per cent, respectively). Bulb yield showed strong positive correlation with bulb weight and neck girth.

Gowda *et al.* (1998), informed on genotypic and phenotypic coefficient of variation, heritability, genetic advance are derived from data on 8 yield related traits in 14 varieties of onion (*Allium cepa*).

Mohanty (2001a) evaluated onion cultivars in Orissa, India during the kharif 1997 and 1998 for genetic variation in yield and its components and found genotype x environment interactions were significant for all characters, except bulb diameter. The highest genetic variation was observed in bulb yield (150.80-210.60 q/ha). Phenotypic variation was high for neck thickness (22.72%), but moderate for plant height (13.07%), bulb weight (10.65%) and number of leaves per plant (10.61%). High values of heritability coupled with moderate to high genotypic coefficient of variation and genetic gain were observed for the number of leaves per plant, neck thickness, plant height and bulb weight.

Rajalingam and Haripriya (1998) studied genetic variability in onion and estimated that phenotypic coefficient of variation was high as compared to genotypic coefficient of variation. Very high values of heritability were observed for the bulb volume (96.50%) and bulb yield (91.62%). All other characters showed high heritability except for pyruvic acid content (14.99%). Weight of plant, bulb length, bulb diameter, volume of bulb and bulb yield per plant recorded very high heritability estimates coupled with high genetic advance.

Rashid *et al*. (2012) showed significant differences among the 30 genotypes and ranged between 23.95 to 40.09 cm, moderate GCV (11.64%) and PCV (11.93%), high heritability (94.86%) associated with high GAM (29.80%) for this trait.

Mohanty and Prusti (2001) studied 12 onion cultivars in Orissa and evaluate the heritability and genetic advance of important economic characters and found high values of heritability associated with moderate to high genotypic coefficient of variation and genetic gain were manifested by bulb yield, bulb weight, plant height, number of leaves per plant and neck thickness, which might be attributed to additive gene action regulating their inheritance and phenotypic selection.

Vidyasagar *et al*. (1993) observed low heritability in combination with low genetic advance for number of leaves per plant. Non-significant variation among 106 genotypes for number of leaves per plant was reported by Monpara *et al*. (2005). Whereas, Patil (1997) recorded wide range between 4.00-15.6, moderate PCV (35.05%) and GCV (43.28%) and high heritability (65.60) for number of leaves per plant.

Monpara *et al*. (2005) reported that the polar diameter had higher positive direct and indirect contribution towards bulb weight through equatorial and polar diameter, days to maturity and bolting, although its negative indirect contribution was through total soluble solids. Days to maturity, bulb girth and total soluble solids expressed negative direct effects. He advocated that, for improving bulb yield and important component traits (bulb weight, polar and equatorial diameter) in onion, the generation of genetically broad base population using diverse genotypes in breeding programme.

Ram et al. (2011) reported significant variation in number of leaves per plant ranged between 8.00 to 9.77, low GCV(4.70%), PCV(6.50%), and have high heritability(63.8%) associated with low genetic advance(0.16%) coupled with low genetic advance as percentage of mean (11.85%).

Pavlovic *et al.* (2003); cleared that the phenotypic coefficient of variation (PCV) for bulb yield of onion was greater than genotypic coefficient of variation (GCV). They added that heritability confirmed that the genotypic variability was strong in the overall phenotypic variability.

Hosamani *et al*. (2010) reported the significant difference for this character indicating existence of genetic difference among the 21 genotypes. Plant height ranged from 23.33 cm (Agrifound White) to 32.00 cm (PRO-6) with a mean of 27.70 cm. Low GCV (7.34%), PCV (10.69%), medium heritability (49.09%) and low genetic advance (2.87) associated with low GAM (10.36) in plant height.

Degewione *et al*. (2011) conducted a study on 25 shallot onion accession reported wide variability for leaf length ranged from 23.77 to 42.46 cm, low genotypic (8.47%), moderate phenotypic (11.25%) coefficient of variation and heritability (56.69%) coupled with moderate GAM (13.33%).

Gurjar and Singhania (2006), evaluated 30 varieties and local land races of onion and revealed that PCV was higher than GCV and genetic gain were recorded for neck thickness, bulb weight and bulb yield which could be improved by simple selection. Moderate to high heritability with low GCV and genetic gain were observed for plant height, days to maturity, number of leaves per plant, equatorial bulb diameter and dry matter content.

Golani *et al*. (2006) noticed significant differences among 32 onion genotypes for bulb weight and reported low genetic and phenotypic coefficient of variation. Patil (1997) also reported the same results.

Haydar *et al.* (2007); examined genetic variability in different parameters in 10 onion varieties and found that plant height, bulb yield and bulb length shown high broad sense heritability. Bulb yield per hectare and number of green leaves per plant had high broad sense heritability estimates with high genetic gain.

In onion, Singh and Dubey (2011) observed number of leaves per plant in the range of 8.20 to 9.80 cm, with a mean of 61.80 cm. The estimate of GCV (2.91%) and PCV (4.29%) was low. Heritability in broad sense was moderate (46.00%) with low GAM (4.08%).

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.

Dhotre (2009) reported the range values from 31.32 to 93.86 g, high estimates of genotypic coefficient of variation (31.32%) phenotypic coefficient of variation (32.58%) and high heritability (92.37%) with high genetic advance mean (62.02%) for this trait.

Ram *et al*. (2011) observed that, moderate genotypic coefficient of variation (11.57%) and phenotypic coefficient of variation (12.00%) and high heritability (93.00%), high genetic advance (11.38%) associated with genetic advance as percentage over mean (22.99%).

Dhotre (2009) reported the range values from 31.32 to 93.86 g, high estimates of genotypic coefficient of variation (31.32%) phenotypic coefficient of variation (32.58%) and high heritability (92.37%) with high genetic advance mean (62.02%) for this trait.

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% and GS% were noticed for days to maturity.

Studying genetic variability on seven varieties of onion, Hossain *et al.* (2008) recorded higher genotypic coefficients of variations in number of seeds per scape (NSPS), final plant height (FPH), final height, fresh weight of bulb and bulb length. These characters also exhibited high heritability along with high genetic advance as percentage of mean.

Santra *et al.* (2017) studied genetic variability, heritability and genetic advance in ten kharif onion. They were found significant differences among genotypes for all traits. Pooled mean performances showed that Agrifound Dark Red had highest plant height (51.42 cm), average bulb weight (75.06 g), total bulb yield (306.42 q ha-1) and marketable bulb yield (295.09 q ha-1). Superior genotypes like Agrifound Dark Red (313.49 q ha-1 and 299.35 q ha-1) and Gota (287.43 q ha-1 and 275.93 q ha-1) exhibited high total yield in both the locations Kalyani and Bankura of West Bengal, India. High GCV was recorded for plant height, number of leaves, polar diameter, equatorial diameter, neck thickness, average marketable bulb weight, marketable yield, days to maturity, total soluble solids, pyruvic acid and phenol content in bulbs. High heritability was observed for most of the characters.

### 2.3 Correlation analysis

Correlation concept 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.

Bharti *et al*. (2011) reported that bulb size had positive and highly significant correlation with bulb diameter, plant height at genotypic and phenotypic level. Bulb yield showed significant and positive association with most of the morphological characters. Positive association of plant height with bulb yield has been reported by Vidyasagar and Monika (1993); Mohanty (2004); Ananthan and Balakrishnamoorthy (2007); Trivedi *et al*. (2006) and Netrapal *et al.* (1988).

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).

Buso and Costa (1979) reported negative phenotypic as well as genotypic correlations amongst bulb weight, bulb diameter and TSS in onion. Singh (1981) reported that bulb weight per plant was positively and significantly correlated with clove length, leaf length, plant height, leaves per plant and number of cloves per bulb. In addition, high and positive inter correlation was observed among yield components both at genotypic and phenotypic levels.

Vadival *et al.* (1981) was observed that positive association of plant height & bulb weight with bulb yield in multiplier onion.

Mohanty (2001 a) showed a negative association of plant height with the bulb yield. Whereas no association was reported between plant height and bulb yield (Patil, 1997). Aliyu *et al*. (2007) also found significant positive correlation of bulb yield with plant height, number of leaves per plant. Whereas, Hosamani *et al*. (2010) reported negative relationship between vegetative growth like number of leaves per plant with dry matter content and bulb yield.

Tripple and Chubrikova (1976) observed the significant positive correlation between bulb yield and bulb size of garlic.

Number of leaves have both positive and negative association with bulb yield. The positive association was reported by Mohanty (2001 b); Mohanty (2004); Mahanthesh *et al*. (2007) and Netrapal *et al*. (1988). Whereas, negative correlation for number leaves with bulb yield was reported by Padda *et al*. (1973). Bharti *et al*. (2011) observed bulb diameter showed positive and highly significant association with number of leaves per plant, plant height and neck thickness at genotypic and phenotypic level only.

Korla and Rastogi (1979a) 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.

Padda *et al.* (1973) observed negative correlation of total solids with bulb size (-0.31) and yield (-0.33) whereas, yield was positively correlated with bulb size [0.99] in onion.

The correlation between number of leaves per plant and plant height at both the levels and with bulb length, bulb girth and 10-bulb weight at genotypic level only was observed to be significant and positive (Golani *et al*. 2006).

The relationship between bulb yield and various bulb characters have been reported by Netrapal *et al*. (1988); Vidyasagar and Monika (1993); Singh *et al*. (1995); Trivedi *et al*. (2006 a), Ananthan and Balakrishnamoorthy (2007); Mahanthesh *et al*. (2008), Mohanty (2004) and Hosamani *et al*. (2010).

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.

Patil *et al.* (1987) observed positive correlation of bulb weight with bulb diameter, neck thickness and number of leaves, percent sprouting loss with bulb diameter and neck thickness with present total loss on onion.

In a diallel studies, Netrapal *et al.* (1988) observed positive correlation of bulb yield with bulb weight, diameter of bulb and plant height in onion.

Bulb diameter showed to be positively correlated with bulb yield (Pavlovic *et al*., 2007 b; Trivedi *et al*., 2006 a; and Mohant y, 2004). Monpara *et al*. (2005) reported that the chief yield attributing factor, bulb weight was positively associated with polar and equatorial diameter of bulb. Positive and significant association of bulb yield with bulb weight has also been reported by Mahanthesh *et al*. (2007) and Mahanthesh *et al*. (2008). Several workers have also reported positive association between number of rings per bulb and the bulb yield (Vidyasagar and Monika, 1993 and Mahanthesh *et al*. 2008).

Suthanthira Pandian and Muthukrishan (1982) studied the progenies of 30 crosses obtained from line x tester mating system in multiplier onion (*Allium cepa* L.) and reported significant positive correlation of number of leaves and number of bulb with bulb yield (0.41 and 0.36 respectively) and between themselves (0.74). Bulb maturity and plant height showed positive correlation but these were not associated with bulb yield.

Rajalingam and Haripriya (2000) studied 20 aggregatum onion (*Allium cepa* var. aggregatum) and showed that the yield components, including plant height leaf length, leaf breadth, number of !eaves, weight of plant, number of bulbs, bulb length, bulb diameter and volume of bulb exhibited significant positive association with 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.

Bulb yield was significantly and highly correlated with equatorial bulb diameter, quantity of marketable bulbs and polar bulb diameter. It also had a positive relationship with the number of rings per bulb and bulb neck thickness. Sprouting and split percentage in bulb production were negatively correlated with bulb yield (Mohammed-Ibrahim *et al*., 2000).

Vidyasagar and Monika (1993) worked out correlation and path coefficient among seven bulb and leaf characters in 22 diverse onion cultivars grown at Palampur during rabi season. Bulb yield in general was significantly and positively associated with bulb size, equatorial and polar diameter, plant height, leaf breadth and neck thickness.

In an experiment Baiday and Tiwari (1995) reported that G-61 had the maximum bulb yield and IC 25599 the minimum. Yield was highly correlated with bulb weight, bulb diameter, neck diameter and plant height.

Golani *et al*. (2006) observed that the bulb yield in onion showed significant and positive association with number of leaves per plant, bulb length, bulb girth and 10-bulb weight at phenotypic and genotypic levels.

Mohanty (2001a) evaluated onion cultivars in Orissa during the kharif 1997 and 1998 for interrelationship between yield and its components and found bulb yield was significantly and positively correlated with the number of leaves per plant and bulb weight at phenotypic and genotypic levels. Neck thickness was positively correlated with plant height and bulb diameter, but was negatively correlated with bulb weight and yield at both levels.

Mohanty (2001b) studied the genetic variability, interrelationship and path coefficients in 12 onion cultivars in a field experiment conducted in Orissa during the kharif season of 1997 and recorded bulb yield manifested positive and significant phenotypic and genotypic correlation with plant height and diameter and weight of bulb.

Hosamani *et al*. (2010) showed that, the yield is negatively associated with TSS in both phenotypic and genotypic correlations. Days to maturity described by positive association with bulb yield (Sidhu *et al*. 1986 and Patil, 1997) but negative association with the bulb yield was reported (Vadivel *et al*. (1981 and Monpara *et al*. 2005).

Mohanty (2002) reported positively significant phenotypic and genotypic association of bulb yield with plant height, number of leaves/plant, diameter and weight of bulb but significantly negative with neck thickness in onion.

Bharti *et al*. (2011) neck thickness had positive and significant association with plant height at genotypic level only. Similarly neck thickness also showed to be associated positively with bulb yield (Mahanthesh *et al*. 2008 and Singh *et al*. 1995) whereas, some workers (Mohanty, 2001 a; Mohanty, 2002 and Mohanty 2004) reported that, the bulb neck thickness was negatively associated with the bulb yield. Trivedi *et al*. (2006) and Patil (1997) reported no association between neck thickness and bulb yield.

Mohanty (2004) evaluate 12 varieties of onion over four years revealed that phenotypic and genotypic associations of bulb yield were significantly positive with plant height, number of leaves/plant, diameter and weight of bulb but significantly negative with neck thickness.

Gurjar and Singhania (2006) evaluated of 30 varieties and local land races of onion revealed that bulb yield expressed positive and significant phenotypic and genetic association with plant height, number of leaves per plant, bulb neck thickness, bulb weight, equatorial and polar bulb diameter.

While studying correlation coefficient in onion Correlation coefficient in 10 varieties of onion was conducted by Haydar *et al.* (2007). They were indicated that bulb yield had highly positive significant correlation with bulb length and bulb diameter. Bulb diameter also had positive significant association with plant height, fresh weight/bulb and bulb length. Hossain *et al.* (2008); conducted an experiment using seven varieties of onion on character association of onion and recorded positive and significant phenotypic correlation coefficient of bulb length, bulb diameter and scape diameter with fresh weight of bulb. The number of seeds per scape, final scape height, final plant height and number of pseudo stem branches at maximum flowering stage were also positively and significantly correlated with seed yield.

Santra *et al.* (2017) studied character association among parameters in ten kharif onion. They were revealed that total bulb yield was positively and significantly correlated with plant height (0.802), number of leaves (0.630), polar diameter (0.572), equatorial diameter (0.919) and average bulb weight (0.974).

### 2.4 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 onion and its related species are being reviewed as under:

Rajalingam and Haripriya (2000) studied 20 aggregatum onion ecotypes (*Allium cepa* var. aggregatum) and path coefficient analysis indicated that plant height, leaf breadth, weight of plant, bulb length, shape index, days to maturity and harvest index, had direct positive effect on yield, while leaf length, number of leaves, number of bulbs, bulb diameter, volume of bulb and storage life had negative direct effects.

Monpara *et al*. (2005) reported that the polar diameter had higher positive direct and indirect contribution towards bulb weight through equatorial and polar diameter, days to maturity and bolting, although its negative indirect contribution was through total soluble solids. Days to maturity, bulb girth and total soluble solids expressed negative direct effects. He advocated that, for improving bulb yield and important component traits (bulb weight, polar and equatorial diameter) in onion, the generation of genetically broad base population using diverse genotypes in breeding programme.

Suthanthira Pandia and Mathukrishnan (1982) reported in multiplier onion that number of leaves (0.16), weight of plant (0.98), bulb maturity (0.34) and shape index (0.12) had direct positive effects on yield. They concluded that weight of plant and days to bulb maturity are dependable indices of selection in identifying the yield potential of individual lines in multiplier onion.

Dehdari *et al.* (2002) conducted an experiment in Iran to determine the path coefficient analysis among the different traits in onion and revealed that bulb diameter had the highest direct positive effect on bulb yield, while plant height, through bulb diameter exhibited the highest indirect effect.

Rahman *et al.* (2002) observed that bulb diameter, plant height and leaf number per plant were the principal components of yield in onion.

Mohanty (2002) studied path analysis in onion and reported that number of leaves/ plant, diameter and weight of bulb had positive direct effect on yield.

Mohanty (2004) evaluated 12 varieties of onion over 4 years and path analysis showed that weight and diameter of bulb produced positive direct effect on yield and positive indirect effect through each other on yield. Plant height and number of leaves/plant also exerted positive indirect effects via these traits on yield suggesting giving emphasis on such traits while making selection for bulb yield in onion.

Gurjar and Singhania (2006) evaluated of 30 varieties and local land races of onion revealed that path analysis showed that plant height, number of leaves per plant, bulb neck thickness, bulb weight, equatorial and polar bulb diameter had high positive direct effect through each other on yield. The path analysis was studied in 10 genotypes of onion and revealed that plant height, bulb length and bulb diameter is the major components of bulb yield in onion (Haydar *et al*., 2007).

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. Higher estimates of genotypic and phenotypic coefficient of variation were recorded for bulb weight, reducing sugars, total sugars, total loss at end of storage period and sulfur content. Path coefficient analysis indicated that the reducing sugars, protein and total loss at end of storage period had the strongest positive direct effect on storage loss.

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.

A similar opinion was put forth by Aliyu *et al.* (2007) who studied path coefficient analysis in onion and indicated that bulb diameter, plant height and number of leaves per plant were the principal component of yield.

# CHAPTER III

# MATERIALS AND METHOD

The details of the experiment with respect to material used and techniques adopted in the present investigation are presented in this chapter. 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 field experiment was directed at the experimental field of Sher-e-Bangla Agricultural University, Dhaka-1207 during December 2017 to April 2018. The location was situated at $23^{0}74$ N latitude and $90^{0}35'$ E longitude. Photograph showing the experimental site (Appendix I).

### 3.2 Soil

The experimental site is in "Madhupur Tract" (AEZ No. 28). The soil of the experimental site comprised of clay loam in texture and olive gray with common fine to medium distinct dark yellowish brown mottles. The pH was 4.47 to 5.63 and organic carbon content was 0.82%.Morphological, physical and chemical characteristics of initial soil (0-15 cm depth) of the experimental site were shown in (Appendix II).

### 3.3 Climate and weather conditions

The experimental site has sub-tropical climate. It was characterized by high temperature accompanied during kharif season (April to September) and low temperature in the Rabi season (October to March). Details of the metrological data including maximum and minimum mean monthly temperature ($0^{c}$), relative humidity and sunshine (hours/day) for growing season was collected from the Bangladesh Metrological Department (Climate division), Agargaon, Dhaka-1207, which is presented in Appendix 1II.

### 3.4 Experimental materials

The healthy seeds of ten onion 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 for the experiment**

| Genotype | Variety Name | Source |
|---|---|---|
| G1 | BARI Piaj 1 | BARI |
| G2 | BARI Piaj2 | BARI |
| G3 | BARI Piaj3 | BARI |
| G4 | BARI Piaj4 | BARI |
| G5 | BARI Piaj5 | BARI |
| G6 | Taherpuri | Local |
| G7 | Faridpuri | Local |
| G8 | Nath Royal | Sheikh company ltd |
| G9 | Laltir King | Laltir Seed company ltd |
| G10 | Annex N-53 | Sheikh company ltd |

### 3.5 Design of experiment

After completing final land preparation, field lay out was done. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Total experimental area was $40m^2$. Seeds were sown in line in the experimental plots on 3 December 2017. The seeds were placed at about 1.5 cm depth in the soil.

### 3.6 Methods

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

#### 3.6.1 Land preparation

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

#### 3.6.2 Application of manure and fertilizer

The recommended doses of fertilizer such as cow dung, Urea, TSP and MoP @ 10 t, 130 Kg, 200 Kg, 75 Kg per ha, respectively were applied in the experimental field. The entire cow dung, 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.

#### 3.6.3 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 December 30; Jan 7, 11, 17, 22 and 30; February 7, 13, 22 and 28; March 8 and March 15, 2018. A good drainage system was maintained for immediate release of rainwater from the experimental plot during the growing period. Gap filling was done properly on 13 February 2018. The first weeding was done on 22 February 2018. Second weeding was done on March 14, 2018. A pictorial view of experimental field at growing stages is presented in plate 1 and 2.

**Plate 1.** Showing growing onion in the field


**Plate 2.** Showing growing onion in the field

### 3.6.4 Crop harvesting

Depending upon the maturity, harvest was started on April 20, 2018. Ten representative plants were selected randomly from each genotype and were tagged for identification. Average from these ten plants was worked out for the statistical computation and further used for the genetic variability and diversity study.

### 3.6.5 Data collection

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.

#### 3.6.5.1 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.

#### 3.6.5.2 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.

#### 3.6.5.3 Total no. of leaves

Numbers 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.

#### 3.6.5.4 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.

#### 3.6.5.5 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.

#### 3.6.5.6 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.

#### 3.6.5.7 Dry weight per bulb (g)

Ten randomly selected bulbs were dried in an oven at $65^0$c temperature until a constant weight was reached. Then weight all the dried bulb and the average were calculated as gram.

#### 3.6.5.8 Yield per bulb (g)

The top of the 10 randomly selected plants was removed by cutting the pseudo stem, keeping only 2.5 cm above bulb. It was done after harvest. The weight of the bulbs and the average was calculated as gram.

### 3.7 Statistical analysis

Mean data of the characters were used to statistical analyze like analysis of variance (ANOVA), mean, range were calculated by using OPSTAT online 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 (1952). 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).

#### 3.7.1 Mean:

It was calculated by using following formula.

$$Mean = {}^{\Sigma x}/_{n}$$

Where,
$\Sigma x$ = The sum of all the observations
n = Number of observations

### 3.7.2 Analysis of variance

The data based on the mean of individual plants selected for observations were statistically analyzed to find out overall total variability present in the material under study for each character and for all the populations. The first and foremost step is to carry out analysis of variance to test the significance of differences among the populations. The analysis of variance was carried out as per methods suggested by Panse and Sukhatme (1967). The skeleton of analysis of variance used was as follows:

**Table 2: ANOVA for Randomized Completely Block Design:**

| Source of Variation | d. f. | Sum of Square | Mean sum of Square | F value | $F_t$ 5% or 1% table value |
|---|---|---|---|---|---|
| Replications | r-1 | RSS | RMS | RMS/EMS | - |
| Genotypes | g-1 | GSS | GMS | GMS/EMS | - |
| Error | (r-1)(g-1) | ESS | EMS | - | - |
| Total | rg-1 | TSS | - | - | - |

Where,

r = Number of replications

g = Number of genotypes

d.f. = Degree of freedom

RSS = Replication sum of squares

GSS = Genotype sum of squares

ESS = Error sum of squares

TSS =Total sum of squares
RMS = Replication mean sum of squares

GMS = Genotype mean sum of square

EMS = Error mean sum of square

**Estimation of mean, components of variance, phenotypic, genotypic and environmental coefficient of variation, heritability, genetic advance and genetic advance as percentage of mean:**

The mean of different characters were calculated by conventional method:-

$$Mean = \Sigma xi / n$$

Where,

$\Sigma x_i$ = The sum of all the observation for $i^{th}$ character.

n = Number of observations.

Range was recorded by observing the lowest and the highest mean values for each character.

**Table 3: The component of variance was calculated as follows:-**

| Source of Variation | M. S. S. | Expected M. S. S. |
|---|---|---|
| Replication | - | - |
| Genotypes | $M_i$ | $\sigma^2_{ei} + r.\sigma^2_{gi}$ |
| Error | $E_i$ | $\sigma^2_{gi}$ |

$\sigma^2_{gi}$ = Mi- Ei

$\sigma^2_{pi} = \sigma^2_{ei} + \sigma^2_{gi}$

$\sigma^2_{ei}$ = Ei

where,

$\sigma^2_{gi}$ = Genotypic variance for $i^{th}$ character.

$\sigma^2_{ei}$ = Environmental variance for $i^{th}$ character.

$\sigma^2_{pi}$ = Phenotypic variance for $i^{th}$ character.

Phenotypic and genotypic coefficient of variation (expressed in %) were calculated by using the formula given by Burton (1952). Genotypic coefficient of variation (GCV) was calculated as below:

$$GCV\% = \frac{\sqrt{\sigma^2 g_i}}{x_i} \times 100$$

Phenotypic coefficient of variation (PCV)

$$PCV\% = \frac{\sqrt{\sigma^2 P_i}}{x_i} \times 100$$

Where,

Xi =General mean of the $i^{th}$ character under consideration.

$\sigma^2_{gi}$ and $\sigma^2_{pi}$ = Genotypic and phenotypic variances of the $i^{th}$ character respectively.

### 3.7.3 Heritability and genetic advance

Heritability (broad sense) which is ratio of genotypic variance to the total phenotypic variance is symbolized as $h^2$ (BS) and expressed in percentage. Estimation of heritability was done as per the formula given by Hanson *et al.* (1956).

$$h^2(BS) = \frac{\sigma^2 g_i}{\sigma^2 p_i} \times 100$$

Or

$$= \frac{\text{Genotypic variance of ith character}}{\text{Phenotypic variance of ith character}}$$

Expected genetic advance was calculated by using the method suggested by Johnson *et al.* (1955) at 5% selection intensity.

Genetic advance (GA) = K. $P_i$ .$h^2_i$

Genetic advance as percentage of mean was calculated as follows:

$$\frac{\text{Genetic Advance}}{\bar{x}}$$

Where,
K = Selection intensity its value at 5% selection level is 2.06
$P_i$ =Phenotypic standard deviation of the I th

### 3.7.4 Correlation coefficient

Correlation coefficients were calculated in all possible combination staking all the characters into consideration at genotypic, phenotypic and environmental levels by using the formula as proposed by Miller *et al.* (1958).

$$R= \frac{\sum xy - \frac{\sum xy}{n}}{\sqrt{(\sum x^2 - \frac{(\sum x)^2}{2})\,(\sum y^2 - \frac{(\sum y)^2}{2})}}$$

Where,

r = Correlation coefficient

n = Number of treatments

x and y = Characters under study

Genotypic, phenotypic and environmental correlations were computed by substituting corresponding variance and covariance in the following formula:

$$r_G\,(X_iX_j) = \frac{\text{Cov G (Xi Xj)}}{\sqrt{\text{VG (Xi). VG (Xj)}}}$$

$$r_P\,(X_iX_j) = \frac{\text{Cov P (Xi Xj)}}{\sqrt{\text{VP (Xi). VP (Xj)}}}$$

$$r_E (X_i X_j) = \frac{Cov\ E\ (Xi\ Xj)}{\sqrt{VE\ (Xi).\ VE\ (Xj)}}$$

**Testing of correlation coefficient**

The phenotypic correlations were tested for their significance by using the following formula based on "t" test:

$$t = \sqrt{n-2}\ \frac{r}{\sqrt{(1-r^2)}}$$ at (n-2) d. f.

Where,

n= Number of treatments.

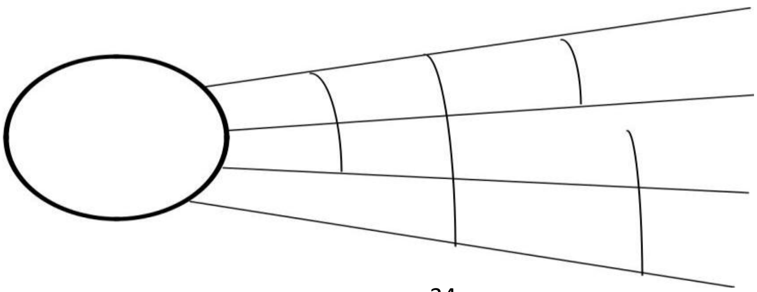
r= phenotypic correlations coefficient.

The calculated value of "t" is compared with table of "t" at (n-2) d. f. If the calculated value is equal to or greater than table value, it is significant at given probability level. If $t_c < t_T$, it is non-significant.

**3.7.5 Path coefficient analysis**

Path coefficient are standardized partial regression coefficient and as such these provide the means to direct influence of one character upon another character upon another character and also permit portioning of correlation coefficient into direct and indirect effect via other character. The direct indirect contribution of various independent characters on a dependent character yield were calculated through path coefficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959). The following set of simultaneous equation were formed and used for the estimation of direct and indirect effects.

Y



$r_{1y} = p_{1y} + r_{12}\, p_{2y} + r_{13}\, p_{3y}$ + ------------------------------------------- $r_{1y}\, p_{1y}$

$r_{2y} = r_{2y}\, p_{1y} + r_{2y} + r_{23}\, p_{3y}$ + ------------------------------------------- $r_{21y}\, p_{1y}$

$r_{ky} = r_{ki}\, p_{1y} + r_{k-1}\, p_{2y} + r_{k3} p_{3y}$ + -----------------------------------------$p_{ky}$

$r_{xky} = r_{xk1}\, p_{1y} + r_{xk2}\, p_{2y} + r_{xk3}\, p_{3y}$ + ----------------------------------- $p_{xky}$

Where,

$r_{xky}$ = Coefficient correlation between independent character

$P_{iy}$ to $P_{3y}$ = Direct effect of character 1 to 3 character y

**Direct effect**

The direct effects were calculated as follows:

$$P_{ky} = \sum_{i=1}^{k} C_{krik} Y$$

**Indirect effect**

Indirect effect of any independent traits on the dependent one (=yield) via other independent traits are computed by multiplying the direct effects ($P_{ky}$) of that independent variables with the corresponding correlation coefficient as follows:

$$K^{th} \text{ traits via } (n-1) = rk\,(n-1)\, P\,(n-1)\, Y$$

Where,

$r_{xky}$ = Coefficient correlation between independent character

$P_{iy}$ to $P_{3y}$ = Direct effect of character 1 to 3 character y

# CHAPTER IV

# RESULTS AND DISCUSSIONS

The present study was conducted to find out of genetic variability, character association and path analysis in Onion genotypes during Rabi season 2017-2018 are illustrated in the following sections.

## 4.1 Evaluation of performance of onion genotypes

### 4.1.1 Analysis of variance

The analyses of variance of different Onion genotypes for morphogenic traits are shown in Table 4. Analysis of variance indicated that the highly significant difference among genotypes for all nine 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), dry weight per bulb (g) and yield per bulb (g). This results suggest that the presence of variation among the genotypes for all these traits. Previous studies in Onion also found significant variation for these traits (Azoom *et al.*, 2014 and Santra *et al.* 2017).

### 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 Onion genotypes for their traits are shown in Table 5&6.

#### 4.1.2.1 Plant height (cm)

Plant height among the genotypes ranged from 20.19 cm to 53.47cm with a mean value of 36.77cm. Highest plant height was observed in genotype Laltir King and it was statistically similar with the genotype Faridpuri (51.73 cm) while lowest in genotype Taherpuri (20.19 cm). Azoom *et al.* (2014) reported that the variety 'Morada de Amposta' recorded the highest plant height (76.95 cm). Plant height in onion is a complex character and has several genetically controlled factors (Cheema *et al.*, 1987).

**Table 4. Analysis of variance for nine characters in onion (*Allium cepa* L.) genotypes**

| Characters | Mean Sum of Square | | |
|---|---|---|---|
| | Replication | Genotype | Error |
| | (r-1) = 2 | (g-1) = 9 | (r-1)(g-1) = 18 |
| Plant height (cm) | 30.27 | 311.86** | 5.01 |
| Root length (cm) | 1.49 | 29.14** | 0.46 |
| No. of leaves | 0.03 | 7.44** | 0.55 |
| Leaf length (cm) | 23.73 | 208.69** | 3.09 |
| Leaf breath (cm) | 0.84 | 2.79** | 0.07 |
| Bulb length (cm) | 2.44 | 4.57** | 0.29 |
| Bulb diameter (cm) | 6.14 | 25.87** | 1.01 |
| Dry weight per bulb (g | 10.16 | 195.96** | 3.72 |
| Yield per bulb (g) | 42.43 | 477.21** | 6.71 |

****** Denote significant at 1% level of probability.

**Table 5: Range, mean, CV (%) and standard error of ten onion (*Allium cepa* L.) genotypes**

| Parameters | Range | | Mean | CV (%) | SE |
|---|---|---|---|---|---|
| | Min. | Max. | | | |
| **Plant height (cm)** | 20.19 | 53.47 | 36.77 | 6.09 | 1.83 |
| **Root length (cm)** | 2.32 | 12.33 | 6.11 | 7.43 | 0.55 |
| **No. of leaf** | 6.00 | 10.33 | 7.37 | 10.09 | 0.61 |
| **Leaf length (cm)** | 15.64 | 41.93 | 30.47 | 5.77 | 1.44 |
| **Leaf breadth (cm)** | 1.01 | 4.62 | 2.49 | 10.33 | 0.21 |
| **Bulb length (cm)** | 4.16 | 8.43 | 6.46 | 6.39 | 0.44 |
| **Bulb diameter (cm)** | 5.28 | 14.60 | 9.10 | 11.01 | 0.82 |
| **Dry weight per bulb (g)** | 3.22 | 30.36 | 13.90 | 13.87 | 1.58 |
| **Yield per bulb (g)** | 6.44 | 47.93 | 21.89 | 11.84 | 2.12 |

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

**Table 6: Mean performance of nine characters of ten onion (*Allium cepa* L.) genotypes**

| Genotype | Plant Height (cm) | Root Length (cm) | No of Leaf | Leaf Length(cm) | Leaf Breadth (cm | Bulb Length(cm) | Bulb Diameter(cm) | Dry Weight per Bulb(gm) | Yield per Bulb(gm) |
|---|---|---|---|---|---|---|---|---|---|
| **BARI Piaj1** | 27.77 | 3.69 | 6.00 | 24.63 | 1.57 | 4.82 | 7.98 | 5.54 | 9.36 |
| **BARI Piaj2** | 39.63 | 4.28 | 6.33 | 34.54 | 2.54 | 4.96 | 10.02 | 4.76 | 8.58 |
| **BARI Piaj3** | 31.12 | 2.97 | 6.33 | 24.44 | 2.13 | 5.39 | 6.19 | 6.73 | 11.71 |
| **BARI Piaj4** | 39.41 | 5.23 | 6.67 | 32.90 | 2.58 | 5.58 | 11.26 | 14.01 | 18.31 |
| **BARI Piaj5** | 41.72 | 7.89 | 6.67 | 33.68 | 2.62 | 7.38 | 11.71 | 22.66 | 37.07 |
| **Taherpuri** | 22.25 | 3.72 | 9.67 | 20.54 | 1.21 | 7.65 | 6.77 | 18.01 | 28.39 |
| **Faridpuri** | 48.77 | 11.15 | 6.67 | 38.37 | 3.66 | 7.61 | 5.42 | 10.22 | 15.09 |
| **Nath Royal** | 22.90 | 3.19 | 6.33 | 16.50 | 1.41 | 5.89 | 6.07 | 8.53 | 14.11 |
| **Laltir King** | 50.51 | 10.49 | 10.33 | 40.46 | 4.22 | 7.86 | 12.65 | 28.29 | 44.22 |
| **Annex N-53** | 43.59 | 8.48 | 8.67 | 38.64 | 2.92 | 7.47 | 12.95 | 20.24 | 32.04 |

#### 4.1.2.2 Root length (cm)

Root length was exhibited the variation with the ranged from 2.32 cm to 17.33 cm with an average of 6.11 cm. The genotype Faridpuri represented the longest root which was significantly different than other all genotypes. While the shortest root was observed by the genotype BARI Piaj 3 which was statistically similar with BARI Piaj1 (2.9 cm).

#### 4.1.2.3 No. of leaves

Total no. of leaves were performed with the ranged from 6 to 10.33. The average total no. of leaves was 7.37. Genotype Laltir King was showed highest number of leaves which was statistically similar with Taherpuri (10.67). While genotype BARI Piaj 1 represented the lowest value of this trait which was statistically similar with BARI Piaj 3 (6.33). Azoom *et al.* (2014) reported that the variety 'Morada de Amposta' recorded the highest number of leaves (8.71).

#### 4.1.2.4 Leaf length (cm)

Leaf length was exhibited the variation with the ranged from 15.64 cm to 41.93 cm with an average of 30.47 cm. The genotype Laltir King represented the longest leaf which was statistically similar with Annex N-53 (40.96 cm). While the shortest leaf length was observed by the genotype Nath Royal which was unique. Azoom *et al.* (2014) reported that the variety 'Morada de Amposta' recorded the highest leaf length (68.06 cm)

#### 4.1.2.5 Leaf breadth (cm)

Leaf breath was exhibited the variation with the ranged from 1.01 cm to 3.37 cm with an average of 2.49 cm. The genotype Laltir King represented the longest leaf breadth which was significantly different than other all genotypes. While the shortest leaf breadth was observed by the genotype Taherpuri which was statistically similar with BARI Piaj 1 (1.32 cm).

#### 4.1.2.6 Bulb length (cm)

Bulb length was exhibited the variation with the ranged from 4.16 cm to 8.43 cm with an average of 6.46 cm. The genotype Laltir King showed the highest bulb length which was statistically similar with Faridpuri (8.27 cm) and. While the shortest bulb length was observed by the genotype BARI 1 which was followed by BARI 2 (4.55 cm).

#### 4.1.2.7 Bulb diameter (cm)

Bulb diameter was exhibited the variation with the ranged from 4.09 cm to 14.60 cm with an average of 9.10 cm. The genotype Laltir King represented the highest bulb diameter which was statistically similar with Annex N-53 (14.5 cm).While the significant lowest bulb diameter was observed by the genotype BARI Piaj 3. Diameter of bulb was ranged from 4.3 cm to 6.7cm reported by Sindhu *et al*. (1986).

#### 4.1.2.8 Dry weight per bulb (g)

The important yield contributing trait dry weight per bulb was ranged from 3.22 g to 30.36 g with a mean value of 13.91 g. The highest and lowest dry weight per bulb was exhibited by the genotypes Laltir King and BARI Piaj 2 respectively. Since, greater dry weight per bulb is one of the major criteria which contribute to higher bulb yield and it could be utilized in further program.

#### 4.1.2.9 Yield per bulb (g)

The most important trait yield per bulb was ranged from 6.44 g to 47.93 g. The average value of yield per bulb was estimated 21.89 g. The highest yield per bulb was observed by the genotype Laltir King while genotype BARI Piaj 2 showed the lowest yield per bulb. Pandey and Singh (1989) recorded maximum yield in genotype HG-1.Figure (1) showing the yield per bulb of ten onion genotypes.

### 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 7.

#### 4.2.1 Variability parameters

A wide range of variation was observed among ten Onion genotypes for eight yield contributing traits and yield as well. The perusal of data revealed that variance for all

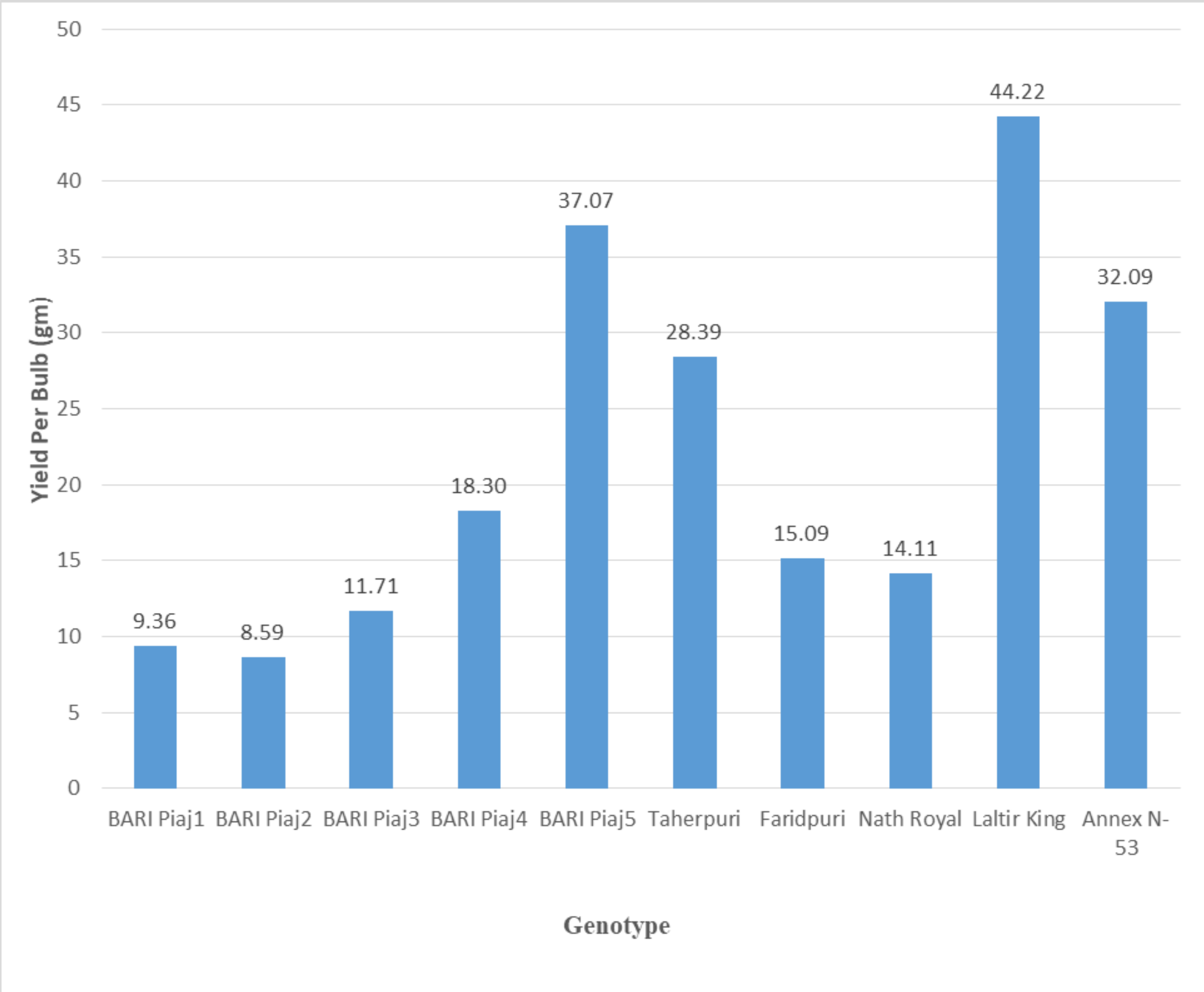



**Figure 1.** Showing the yield per bulb of ten onion genotypes

**Table 7: Estimation of genotypic, phenotypic and environmental variance and coefficient of variation in nine traits of onion**

| Parameters | $\sigma^2 p$ | $\sigma^2 g$ | $\sigma^2 e$ | PCV | GCV | GCV:PCV |
|---|---|---|---|---|---|---|
| **Plant height (cm)** | 106.44 | 102.28 | 4.15 | 28.17 | 27.51 | 0.98 |
| **Root length (cm)** | 10.86 | 9.56 | 1.30 | 51.77 | 50.58 | 0.98 |
| **No. of leaf** | 2.72 | 2.29 | 0.42 | 22.91 | 20.57 | 0.90 |
| **Leaf length (cm)** | 72.08 | 68.53 | 3.55 | 27.71 | 27.17 | 0.98 |
| **Leaf breadth (cm)** | 0.99 | 0.91 | 0.07 | 39.67 | 38.29 | 0.97 |
| **Bulb length (cm)** | 1.69 | 1.43 | 0.27 | 20.28 | 18.49 | 0.91 |
| **Bulb diameter (cm)** | 8.83 | 8.29 | 0.54 | 33.49 | 31.63 | 0.95 |
| **Dry weight per bulb (g)** | 67.99 | 64.09 | 3.89 | 59.23 | 57.59 | 0.97 |
| **Yield per bulb (g)** | 163.19 | 156.83 | 6.37 | 58.43 | 57.22 | 0.98 |

$\sigma^2 p$ = Phenotypic variance, $\sigma^2 g$ = Genotypic variance and $\sigma^2 e$ = Environmental variance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, ECV = Environmental coefficient of variation traits was highly significant (Table 7). This suggested that there were inherent genetic differences among the genotypes. Significant genetic variation in various component traits exhibited by the genotypes indicated these traits might be effective further improvement in Onion. Phenotypic variance was higher than the genotypic variances for all the traits that was 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 (Table 7) indicating that they all interacted with the environment to some extent. Among the all traits, high PCV and GCV were found for dry weight per bulb (59.23 and 57.59) followed by yield per bulb (58.43 and 57.22), Root length (51.77 and 50.58), leaf breadth (39.67 and 38.29) bulb diameter (33.49 and 31.63) leaf length (27.78 and 27.17), no. of leaves (22.91 And 20.57) and Randhawa *et al.* (1974) found that the phenotypic and genotypic coefficient of variation was maximum for bulb yield. Patil *et al.* (1986) reported the GCV and PCV were moderate to high (15-30%) 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. Santra *et al.* (2017) reported high GCV was recorded for plant height, number of leaves, polar diameter, equatorial diameter, average marketable bulb weight and marketable yield. The high values of GCV and PCV for these traits suggested the possibility of yield improvement through selection of these traits (Table-7).

### 4.2.2 Heritability

The estimates of heritability act as predictive instrument in expressing the reliability of phenotypic value. Therefore, high heritability helps in effective selection for a particular trait. Heritability was classified as low (below 30%), medium (30-60%) and high (above 60%) as suggested by Johnson *et al.* (1955). The traits studied in the present investigation expressed high heritability estimates for all studied traits ranging from 80.61 to 95.89 percent. Patil *et al.* (1986) reported that heritability was high for bulb yield and number of leaves per plant. Among the traits, highest heritability was recorded by yield per bulb (95.896%) followed by leaf length (95.675 %), root length (95.464%), plant height (95.335 %), dry weight per bulb (94.514%), bulb diameter (89.197%), no. of leaf (80.624), root length (91.86), bulb length (83.138%) leaf breadth (93.168 %). High heritability values indicate that the traits under study are less influenced by environment in their expression. The plant breeder, therefore, may make his selection safely on the basis of phenotypic expression of these traits in the individual plant by adopting simple selection methods. Study by Singh *et al.* (1995) reported bulb weight, bulb yield/ha and leaves per plant had high heritability (97.88, 96.95 and 95.92 per cent, respectively). Rajalingam and Haripriya (1998) reported that very high values of heritability were observed for the bulb volume (96.50%) and bulb yield (91.62%). Haydar *et al.* (2007) recorded high broad sense heritability for plant height bulb yield and bulb length. Yaso (2007) reported that high values of heritability were observed for total and marketable yield and bulb weight.

**4.2.3 Genetic advance**

The genetic advance is a useful indicator of the progress that can be expected as result of exercising selection on the pertinent population. Heritability in conjunction with genetic advance would give a more reliable index of selection value (Johnson *et al.* 1955). In the present study genetic advance in percent of mean was highest for Yield per bulb (115.42) followed by dry weight per bulb (115.33), root length (101.81), leaf breadth (76.13), bulb diameter (61.54), plant height (55.33), no. of leaves (38.05), and and lowest for bulb length (34.73) among yield and yield contributing traits (Table 8). Patil *et al.* (1986) reported that expected genetic advance was high for bulb weight. Singh *et al.* (1995) found high genetic advance (44.80, 42.85 and 40.96 per cent, respectively) for bulb weight, bulb yield/ha and leaves per plant. The information on genetic variation, heritability and genetic advance helps to predict the genetic gain that could be obtained in later generations, if selection is made for improving the particular trait under study. In general, the traits that show high heritability with high genetic advance are controlled by additive gene action (Panse and Sukhatme, 1957) and can be improved through simple or progeny selection methods. Selection for the traits having high heritability coupled with high genetic advance is likely to accumulate more additive genes leading to further improvement of their performance through selection. In the present study, high heritability along with high genetic advance was noticed for the traits, plant height, root length, leaf length, dry weight per bulb, yield per bulb, no. of leaves, leaf breadth and bulb diameter (Table 8). High heritability along with high genetic advance was observed for plant height by Shaha *et al.* (1990). Weight of plant, bulb length, bulb diameter, volume of bulb and bulb yield per plant recorded very high heritability estimates coupled with high genetic advance reported by Rajalingam and Haripriya(1998).

Mohanty (2001a) found that high values of heritability coupled with high genetic gain were observed for the number of leaves per plant, neck thickness, and plant height and bulb weight. Mohanty and Prusti (2001) studied and found high values of heritability associated with moderate to high genetic gain were manifested by bulb yield, bulb weight, plant height, number of leaves per plant and neck thickness, which might be attributed to additive gene action regulating their inheritance and phenotypic selection. Haydar *et al.* (2007) recorded that bulb yield per hectare and number of green leaves per plant had high broad sense heritability estimates with high genetic gain. Hossain *et al.* (2008) recorded high heritability along with high genetic advance as percentage of mean plant height, fresh weight of bulb and bulb length.

### 4.3 Relationship among yield and yield contributing traits

#### 4.3.1 Estimation of correlation coefficient

Relationships among yield and yield contributing traits were studied through analysis of correlation among them. In the present study out of 36 associations of genotypic and phenotypic origin, 32 associations were significant at genotypic level and 31 association were at phenotypic level. Among the 32 associations at genotypic level, all associations were positively significant. Similarly, in phenotypic correlation, among the 31 associations, also all associations were positively significant. The significant and positive association between the traits suggested additive genetic model thereby less affected by the environmental fluctuation. Besides, four associations were positive and non-significant at genotypic level and five associations at phenotypic level. The positive and non-significant association referred information of inherent relation among the pairs of combination.

**Table 8. Estimation of heritability and genetic advance in nine characters of ten genotypes of onion**

| Parameters | Heritability | Genetic advance | Genetic Advance (% mean) |
|---|---|---|---|
| **Plant height (cm)** | 95.34 | 20.34 | 55.33 |
| **Root length (cm)** | 95.46 | 6.22 | 101.81 |
| **No. of leaf** | 80.62 | 2.80 | 38.05 |
| **Leaf length (cm)** | 95.68 | 16.68 | 54.74 |
| **Leaf breadth (cm)** | 93.17 | 1.89 | 76.13 |
| **Bulb length (cm)** | 83.14 | 2.24 | 34.73 |
| **Bulb diameter (cm)** | 89.19 | 5.60 | 61.54 |
| **Dry weight per bulb (g)** | 94.51 | 16.03 | 115.33 |
| **Yield per bulb (g)** | 95.89 | 25.26 | 115.42 |

Phenotypic and genotypic correlation co-efficient among nine traits of ten Onion genotypes are presented in Table 9.

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 of environment (Singh 1980). Very close values of genotypic and phenotypic correlations were also observed between some character combinations, such as 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 to minor proportions as reported by Dewey and Lu (1959). Thus selection for higher yield on the basis of above traits would be reliable.

Dry weight per bulb positively and significantly correlate with plant height (0.43 and 0.45), root length (0.59 and 0.60), no. of leaves (0.82 and 0.72), leaf length (0.44 and 0.45), leaf breadth (0.47 and 0.48), bulb length (.84 and 0.78), bulb diameter (.65 and 0.65) and dry weight per bulb (0.98 and 0.89) at both genotypic and phenotypic levels respectively (Table-9)

Santra *et al.* (2017) were revealed that bulb yield was positively and significantly correlated with plant height (0.802), number of leaves (0.630), polar diameter (0.572), equatorial diameter (0.919) and average bulb weight (0.974). Aliyu *et al.* (2007) studied and revealed that bulb yield had significant positive correlation with plant height. Haydar *et al.* (2007) found that bulb yield had highly positive significant correlation with bulb length and bulb diameter. Gurjar and Singhania (2006) and Mohanty (2004) evaluated on Onion varieties and revealed that bulb yield expressed positive and significant phenotypic and genetypic association with plant height, number of leaves per plant, bulb weight, equatorial and polar bulb diameter.

The results of correlation coefficients implied that highly significant positive correlations at both the levels were recorded for root length leaf length (0.89and 0.88), leaf breadth (0.87 and 0.74) and bulb length (0.82 and 0.67).

**Table 9. Genotypic and phenotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotypes of onion (*Allium cepa* L.).**

| | | Plant Height(cm) | Root Length(cm) | No of Leaf | Leaf Length(cm) | Leaf Breadth(cm) | Bulb Length(cm) | Bulb Diameter (cm) | Dry Weight per Bulb(g) |
|---|---|---|---|---|---|---|---|---|---|
| **Plant height** | G | $0.89^{**}$ | | | | | | | |
| | P | $0.88^{**}$ | | | | | | | |
| **Root length** | G | $0.23^{NS}$ | $0.41^{*}$ | | | | | | |
| | P | $0.20^{NS}$ | $0.39^{*}$ | | | | | | |
| **No. of leaf** | G | $0.98^{**}$ | $0.85^{**}$ | $0.27^{NS}$ | | | | | |
| | P | $0.97^{**}$ | $0.83^{**}$ | $0.27^{NS}$ | | | | | |
| **Leaf length (cm)** | G | $0.98^{**}$ | $0.89^{**}$ | $0.35^{NS}$ | $0.93^{**}$ | | | | |
| | P | $0.96^{**}$ | $0.88^{**}$ | $0.29^{NS}$ | $0.89^{**}$ | | | | |
| **Leaf breadth (cm)** | G | $0.44^{*}$ | $0.76^{**}$ | $0.78^{**}$ | $0.41^{*}$ | $0.49^{**}$ | | | |
| | P | $0.43^{*}$ | $0.70^{**}$ | $0.67^{**}$ | $0.41^{*}$ | $0.46^{*}$ | | | |
| **Bulb length (cm)** | G | $0.57^{**}$ | $0.41^{*}$ | $0.43^{*}$ | $0.66^{**}$ | $0.49^{**}$ | $0.24^{NS}$ | | |
| | P | $0.58^{**}$ | $0.40^{*}$ | $0.32^{NS}$ | $0.65^{**}$ | $0.48^{**}$ | $0.22^{NS}$ | | |
| **Bulb diameter (cm)** | G | $0.46^{**}$ | $0.63^{**}$ | $0.84^{**}$ | $0.47^{**}$ | $0.51^{**}$ | $0.84^{**}$ | $0.66^{**}$ | |
| | P | $0.47^{**}$ | $0.61^{**}$ | $0.71^{**}$ | $0.47^{**}$ | $0.48^{**}$ | $0.78^{**}$ | $0.65^{**}$ | |
| **Dry weight per bulb(g)** | G | $0.43^{*}$ | $0.59^{**}$ | $0.82^{**}$ | $0.44^{*}$ | $0.47^{**}$ | $0.84^{**}$ | $0.64^{**}$ | $0.98^{**}$ |
| | P | $0.45^{*}$ | $0.60^{**}$ | $0.72^{**}$ | $0.45^{*}$ | $0.48^{**}$ | $0.78^{**}$ | $0.64^{**}$ | $0.89^{**}$ |

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

Highly significant positive correlations at both the levels were recorded for plant height with no. of leaves (0.98 and 0.97), leaf length (0.98 and 0.96), bulb length (0.57 and 0.58), bulb diameter (0.46 and 0.47).

Highly significant positive correlation of no. of leaves with leaf length (0.88 and 0.76), bulb diameter (0.63and 0.61) and dry weight per bulb (0.59 and 0.60) at both genotypic and phenotypic level respectively. Highly significant and positive correlation of no. of leaves with leaf length (0.58 and 0.58), bulb length (0.78 and 0.73), bulb diameter (0.80 and 0.78) and dry weight per bulb (0.91 and 0.88). Leaf length was correlated as positively highly significant with bulb length (0.78 and 0.73) and dry weight per bulb (0.91 and 0.88) at both levels. Highly significant and positive correlation of bulb length at genotypic and phenotypic level with bulb diameter (.80 and 0.78) and dry weight per bulb (0.89 and 0.76). Hossain *et al.* (2008) recorded positive and significant phenotypic correlation coefficient of bulb length with dry weight of bulb.

Haydar *et al.* (2007) reported that and highly significant correlation was observed of bulb diameter with dry weight per bulb (0.907 and 0.878) at both genotypic and phenotypic level.

### 4.3.2 Estimation of path coefficient

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 coefficient 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 10.

In path coefficient analysis disclosed that number of leaves (1.85), no of leaves (0.12), bulb length (0.59), bulb diameter (0.32) and dry weight per bulb (0.21) had direct positive effect on yield per bulb, indicating these are the main contributors to yield per bulb. The highest positive indirect effects on yield per bulb were obtained by root length (1.64), number of leaves (0.43), leaf length (1.82), leaf breadth (1.81), bulb length (0.81) and bulb diameter (8.95) via plant height which was followed by root length (0.64), leaf length (0.99), leaf breadth (0.56), bulb length (1.02), bulb diameter (1.06) and dry weight per bulb (0.86) via number of leaves. Moreover, plant height, number of leaves, leaf length and bulb length and bulb diameter had positive and higher indirect effect on yield per bulb through dry weight per bulb. The number of leaves per plant revealed moderate positive indirect effect on bulb yield reported by Yaso (2000).

**Table 10. Partitioning of genotypic correlations into direct (bold) and indirect effects of eight important characters by path analysis**

| Parameters | Indirect Effect Via | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Plant height (cm) | Root length (cm) | No. of leaf | Leaf length (cm) | Leaf breadth (cm) | Bulb length (cm) | Bulb diameter (cm) | Dry weight per bulb(g) | Genotypic correlation with yield per bulb |
| **Plant height(cm)** | **1.85** | -0.45 | 0.02 | -1.15 | -0.51 | 0.26 | 0.18 | 0.22 | 0.43* |
| **Root length(cm)** | 1.64 | **-0.51** | 0.04 | -0.99 | -0.47 | 0.45 | 0.13 | 0.29 | 0.59** |
| **No. of leaf** | 0.43 | -0.21 | **0.12** | -0.32 | -0.18 | 0.46 | 0.14 | 0.39 | 0.82** |
| **Leaf length (cm)** | 1.81 | -0.43 | 0.03 | **-1.17** | -0.48 | 0.25 | 0.21 | 0.22 | 0.44* |
| **Leaf breadth (cm)** | 1.81 | -0.45 | 0.04 | -1.09 | **-0.52** | 0.29 | 0.16 | 0.24 | 0.47** |
| **Bulb length (cm** | 0.81 | -0.38 | 0.08 | -0.48 | -0.25 | **0.59** | 0.08 | 0.39 | 0.84** |
| **Bulb diameter (cm)** | 1.06 | -0.21 | 0.05 | -0.78 | -0.25 | 0.14 | **0.32** | 0.32 | 0.65** |
| **Dry weight per bulb(g)** | 0.86 | -0.32 | 0.09 | -0.55 | -0.26 | -0.26 | 0.49 | **0.21** | 1.00** |

Residual effect: 0.201 ** = Significant at 1% * = Significant at 5%.

# CHAPTER V

# SUMMARY AND CONCLUSION

The perusal of data revealed that variance for all traits was highly significant. There were inherent genetic differences among the genotypes. Significant genetic variation in various component traits exhibited by the genotypes indicated these traits might be effective for further improvement in onion. 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), dry weight per bulb (g) and yield per bulb (g). Highest plant height was observed in genotype Laltir King while lowest in genotype Taherpuri (20.19 cm). The genotype Faridpuri represented the longest root (12.33) While the shortest root were observed by the genotype BARI Piaj 3 which was statistically similar with BARI Piaj1 (2.32 cm). Genotype Laltir King was showed highest number of leaves which was statistically similar with Taherpuri (10.33). The genotype Laltir King represented the longest leaf which was statistically similar with Annex N-53 (41.93 cm). While the shortest leaf length was observed by the genotype Nath Royal which was unique. The genotype Laltir King represented the longest leaf breadth which was significantly different than other all genotypes. While the shortest leaf breadth was observed by the genotype Taherpuri which was statistically similar with BARI Piaj 1 (1.01 cm). The genotype Laltir King(8.43) showed the highest bulb length which was statistically similar with Faridpuri (8.267 cm) and. While the shortest bulb length was observed by the genotype BARI 1 which was followed by BARI 2 (4.16 cm). The genotype Laltir King represented the highest bulb diameter which was statistically similar with Annex N-53 (14.60 cm). While the significant lowest bulb diameter was observed by the genotype BARI Piaj 3. The highest and lowest dry weight per bulb was exhibited by the genotypes Laltir King and BARI Piaj 2 respectively. Since, greater dry weight per bulb is one of the major criteria which contribute to higher bulb yield and it could be utilized in further program. The highest yield per bulb was observed by the genotype Laltir King while genotype BARI Piaj 2 showed the lowest yield per bulb. A wide range of variation was observed among 10 onion genotypes for eight yield contributing traits and yield as well. Significant genetic variation in various component traits exhibited by the genotypes indicated these traits might be effective for further improvement in Onion.

**Coefficient of variance**

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 (Table 7) indicating that they all interacted with the environment to some extent. Among the all traits, high PCV and GCV were found for dry weight per bulb (59.23 and 57.59) followed by yield per bulb (58.43 and 57.22), Root length (51.77 and 50.58), leaf breadth (39.67vand 38.29) bulb diameter (33.49 and 31.63) leaf length (27.78 and 27.17), no. of leaves (22.91 And 20.57). The high values of GCV and PCV for these traits suggested the possibility of yield improvement through selection of these traits.

**Heritability**

The traits studied in the present investigation expressed high heritability estimates for all studied traits ranging from 77.17 to 96.39 percent. Among the traits, highest heritability was recorded by yield per bulb (95.89%) followed by leaf length (95.68 %), root length (95.46%), plant height (95.34 %), Dry weight per bulb (g) (94.51%), Bulb diameter (cm) (89.19%), No. of leaf (80.62), , Root length (cm) (91.9), Bulb length (cm) (83.14%),leaf breadth (93.17 %). High heritability values indicate that the traits under study are less influenced by environment in their expression. The plant breeder, therefore, may make his selection safely on the basis of phenotypic expression of these traits in the individual plant by adopting simple selection methods.

**Genetic Advance**

Study revealed that genetic advance in percent of mean was highest for yield per bulb (115.42) followed by dry weight per bulb (115.33), root length (101.81), leaf breadth (76.13), bulb diameter (61.54), plant height (55.33), no. of leaves (38.05), and lowest for bulb length (34.73) among yield and yield contributing traits. In the present study, high heritability along with high genetic advance was noticed for the traits, plant height, root length, leaf length, dry weight per bulb, yield per bulb, no. of leaves, leaf breadth and bulb diameter.

Relationships among yield and yield contributing traits were studied through analysis of correlation among them. In the present study out of 36 associations of genotypic and phenotypic origin, 32 associations were significant at genotypic level and 31 associations were at phenotypic level. Among the 32 associations at genotypic level, all associations were positively significant. Similarly, in phenotypic correlation, among the 31 associations, also all associations were positively significant. The significant and positive association between the traits suggested additive genetic model thereby less affected by the environmental fluctuation. Besides, four associations were positive and non-significant at genotypic level and five associations at phenotypic level. The positive and non-significant association referred information of inherent relation among the pairs of combination.

Yield per bulb positively and significantly correlate with plant height (0.430 and 0.45), root length (0.59 and 0.60), no. of leaves (0.82 and 0.72), leaf length (0.44 and 0.45), leaf breath (0.47 and 0.48), bulb length (.84 and 0.76), bulb diameter (0.65 and 0.65) and dry weight per bulb (0.98 and 0.89) at both genotypic and phenotypic levels respectively.

**Correlation Coefficient**

The results of correlation coefficients implied that highly significant positive correlations at both the levels were recorded for root length leaf length (0.89 and 0.88), leaf breadth (0.87 and 0.74) and bulb length (0.82 and 0.67). Highly significant positive correlations at both the levels were recorded for plant height with no. of leaves (0.98 and 0.97), leaf length (0.98 and 0.96), bulb length (0.57 and 0.58), and bulb diameter (0.46 and 0.47).Highly significant positive correlation of no. of leaves with leaf length (0.88 and 0.76), bulb diameter (0.62and 0.61) and dry weight per bulb (0.59 and 0.60) at both genotypic and phenotypic level respectively. Highly significant and positive correlation of no. of leaves with leaf length (0.584 and 0.58), bulb length (0.78 and 0.73), bulb diameter (0.80 and 0.78) and dry weight per bulb (0.90 and 0.88).Leaf length was correlated as positively highly significant with bulb length (0.78 and 0.73) and dry weight per bulb (0.91 and 0.88) at both levels. 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 9.

**Path Coefficient Analysis**

In disclosed that number of leaves (0.11), Bulb length (0.59), Bulb diameter (0.32) and dry weight per bulb (0.21) had direct positive effect on yield per bulb, indicating these are the main contributors to yield per bulb. The highest positive indirect effects on yield per bulb were obtained by root length (1.64), number of leaves (0.43), leaf length (1.81), leaf breadth (1.81), bulb length (0.81) and bulb diameter (8.95) via plant height which was followed by root length (0.64), leaf length (0.99), leaf breadth (0.56), bulb length (1.02), bulb diameter (1.06) and dry weight per bulb (0.86) via number of leaves.

The research has shown that yield per bulb in Onion would be achieved through selection of these traits, high heritability coupled with high genetic advance in per cent of mean were observed in plant height, root length, leaf length, dry weight per bulb, yield per bulb, no. of leaves, leaf breadth and bulb diameter. Yield per bulb positively and significantly correlate with plant height, root length, no. of leaves, leaf length, leaf breath, bulb length, bulb diameter and dry weight per bulb at both genotypic and phenotypic levels respectively. Path coefficient indicated maximum direct contribution towards yield per bulb through plant height, root length, number of leaves and dry weight per bulb.The genotypes Laltir king and Faridpuri may be selected for high yield, more dry weight of bulb, maximum bulb length, bulb diameter, no. of leaves, leaf length and plant height.

Ministry of agriculture and agricultural aid agencies through conducting extra researches of which outputs are transferred to the farmers through extension agents and backing financially the poor farmers to develop onion yield in the country and motivating Onion produce from the households. Lack of appropriate storage facility was the major problems of onion cultivation in the study areas and needs immediate attention to solve these problems.

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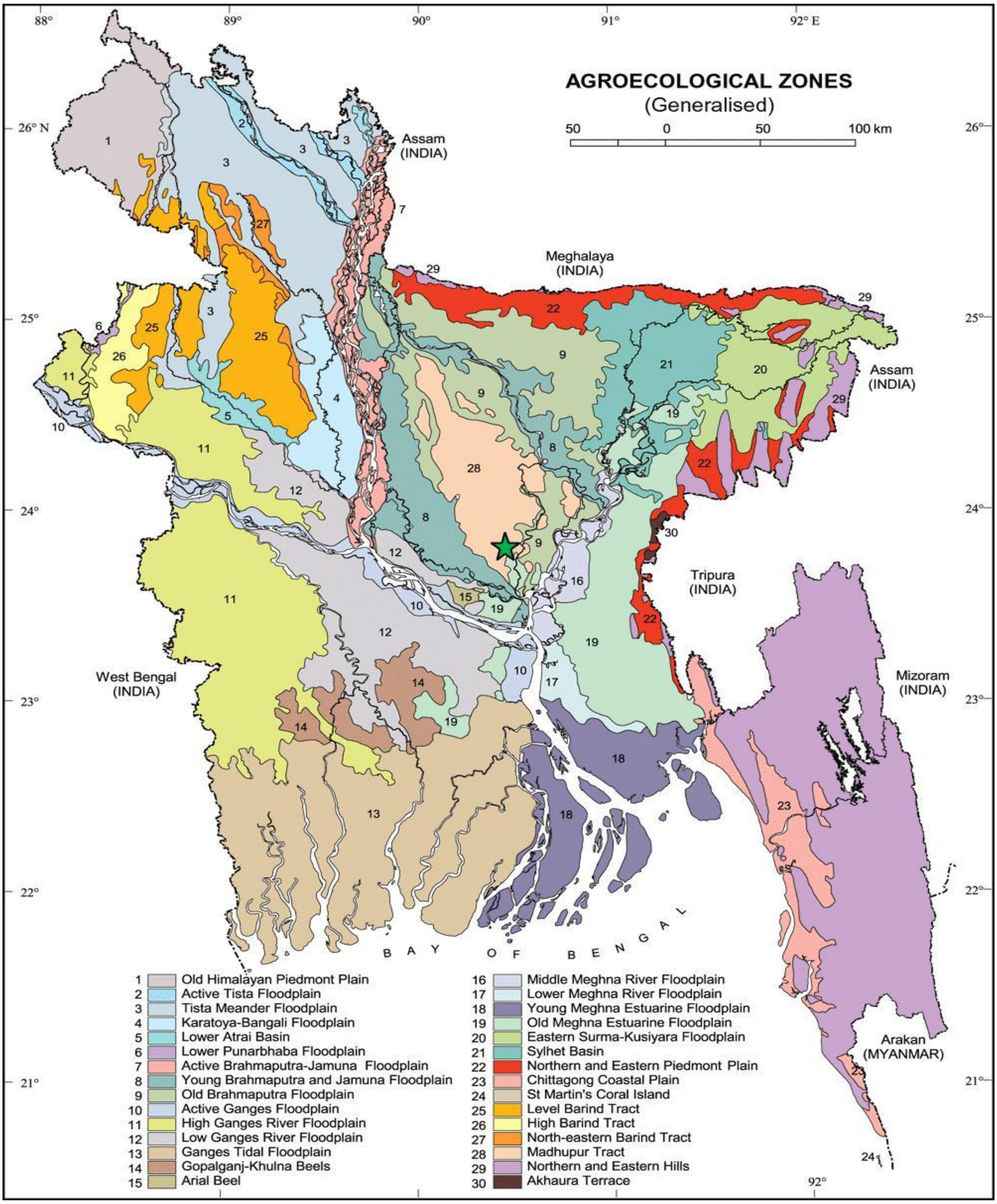
# APPENDICES

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




★ = 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, 1965 |
| **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 of the experimental site during the period from October 2017 to April 2018

| **Month** | **Air temperature (⁰C)** | | **R. H. (%)** | **Total rainfall (mm)** |
|---|---|---|---|---|
| | **Maximum** | **Minimum** | | |
| October, 17 | 29.36 | 18.54 | 74.80 | Trace |
| November, 17 | 21.15 | 13.72 | 56 | 4 |
| December, 17 | 20.13 | 14.47 | 54 | 0 |
| January, 18 | 17.45 | 11.44 | 43 | 0 |
| February, 18 | 27.34 | 16.71 | 67 | 3 |
| March, 18 | 31.43 | 19.63 | 54 | 12 |

**Source**: Bangladesh Metrological Department (Climate and weather division) Agargaon, Dhaka