EVALUATION OF ONION (*Allium cepa* L.) GENOTYPES BASED ON MORPHO-PHYSIOGENIC TRAITS

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DECEMBER, 2016

EVALUATION OF ONION (*Allium cepa* L.) GENOTYPES BASED ON MORPHO-PHYSIOGENIC TRAITS

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REGISTRATION NO. 15-06925

A Thesis
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

SEMESTER: July-December, 2016

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CERTIFICATE

This is to certify that thesis entitled, **"EVALUATION OF ONION (*Allium cepa* L.) GENOTYPES BASED ON MORPHO-PHYSIOGENIC TRAITS"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN GENETICS AND PLANT BREEDING**, embodies the result of a piece of bona fide research work carried out by **SABINA YESMIN**, Registration No. **15-06925** 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: December 2016
Place: Dhaka, Bangladesh

(Prof. Dr. Mohammad Saiful Islam)
Supervisor

DEDICATED

TO

MY BELOVED PARENTS,

HUSBAND & CHILDREN

ACKNOWLEDGEMENTS

All the praise are due to the almighty Allah, who blessed the researcher to complete this work successfully. With sincere gratitude and appreciation to her revered supervisor ***Professor Dr. Mohammad Saiful Islam****, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, for his scholastic supervision, helpful commentary and unvarying inspiration throughout the field research and preparation of this thesis.*

The earnest indebtedness to her Co-supervisor ***Prof. Dr. Firoz Mahmud****, Department of Genetics and Plant Breeding, SAU for his continuous support, constructive criticism and valuable suggestions.*

The author expresses her sincere respect to the Chairman of the Department, ***Prof. Dr. Jamilur Rahman****, and his excellent guidance.*

The author expresses her grateful to the teachers of the Department Prof. Dr. Md. Shahidur Rashid Bhuiyan, Prof. Dr. Md. Sarowar Hossain, Prof. Dr. Naheed Zeba, Associate Prof. Dr. Md. Ashaduzzaman Siddikee and all other teachers of her department for their excellent guidance.The author expresses her sincere respect to the honourable Vice Chancellor of Sher-e-Bangla Agricultural University for his supreme support to the research work.

The author thanks all the staffs of her Department, the staffs of the SAU library and the farm workers for their nice cooperation.

The author have received endless encouragement from her beloved friend Sajjad, Noman, Urmee, Jenci throughout her honors and masters life. And also thankful to other friends for their support.

The author, indeed, proud and delighted for her father and mother for their unparallel affections and for numerous sacrifices they have made for her research.

Sincere love and thanks are extended to her beloved husband and child who always blessed, support and continuous encouragement, inspired and sacrificed a lot in the long process of building my academic career which can never be repaid.

December 2016 ***The Author***
SAU, Dhaka

EVALUATION OF ONION (*Allium cepa* L.) GENOTYPES BASED ON MORPHO-PHYSIOGENIC TRAITS

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ABSTRACT

Twelve genotypes of Onion (*Allium cepa* L.) were evaluated to study the evaluation of genotypes based on morpho-physiogenic traits at Sher-e-Bangla Agricultural University, Dhaka during December 2016 to April 2017. In this experiment twelve onion genotypes were used as experimental materials. The experiment was laid out in Randomized Complete Block Design (RBCD) with three replications. Mean performance, variability, genotypic and phenotypic correlation coefficient and path analysis on different yield contributing characters and yield of onion genotypes were estimated. The highest bulb yield/plant (48.93) was recorded in the genotype of Laltir King, whereas the lowest bulb yield/plant (8.6) from the genotype of BARI Piaj 3. Phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the yield contributing traits. In correlation study, yield per bulb positively and significantly correlated with plant height (0.703 and 0.648), root length (0.370 and 0.344), no. of leaves (0.906 and 0.823), leaf length (0.674 and 0.618), leaf breadth (0.738 and 0.519), bulb length (0.869 and 0.728), bulb diameter (0.931 and 0.807) and dry weight per bulb (0.929 and 0.897) at both genotypic and phenotypic levels respectively. Path coefficient analysis revealed to that plant height had direct positive effect (5.058), root length had direct positive effect (0.263), no. of leaves had direct positive effect (1.129) and dry weight per bulb had direct positive effect (0.44) on yield per bulb, indicating these are the main contributors to yield per bulb.

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SOME COMMONLY USED ABREVIATIONS

Full word	Abbreviation
Percent	%
Degree celsius	^{0}C
At the rate	@
Phenotypic variance	$\sigma^2{}_p$
Genotypic variance	$\sigma^2{}_g$
Environmental variance	$\sigma^2{}_e$
Heritability in broad sense	$h^2{}_b$
Agro Ecological Zone	AEZ
Agriculture	Agric.
Agricultural	Agril.
Agronomy	Agron.
Analysis of variance	Anova
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Bangladesh	BD
Centimeter	CN
Percentage of coefficient of variation	CV%
Cultivars	cv.
Degrees of freedom	Df
And others	*et al.*
Etcetera	etc.
The third generation of a cross between two dissimilar homozygous parents	F_3
Food and Agricultural Organization	FAO
Gram	G

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

Full word	Abbreviation
Genotype	G
Genetic advance	GA
Genotypic coefficient of variation	GCV
Harvest Index	HI
Indian Agricultural Research Institute	IARI
International Center for Agricultural Research in Dry Areas	ICARDA
Journal	J.
Kilogram	Kg
Meter	M
Mean sum of square	MS
Murate of potash	MP
Ministry of Agriculture	MOA
Square meter	m^2
Phenotypic coefficient of variation	PCV
Randomized complete block design	RCBD
Sher-e-Bnagla Agicultural University	SAU
Triple super phosphate	TSP

CHAPTER I
INTRODUCTION

Onion (*Allium cepa* L.) belongs to the family Liliaceae, an important group of crops grown worldwide (Best, 2000). It is divided into three groups: *Allium cepa*, *Allium cepa* var. aggregatum, *Allium proliferum*, which are all diploids (2n=2x=16) (Boukary *et al.*, 2012). Onion occupies 4th position in the world level after tomato, cabbage and watermelon with a global annual production of 25 million tonnes (Boukary *et al.*, 2012).

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 disulphide. Onion bulbs and leaves are rich in minerals like Ca, K and P (Ullah *et al.*, 2005). A single bulb provide 2.0 g protein, 72 mg calcium and 54 mg phosphorus (Ado, 2001). It also contain 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.

Onion *(Allium cepa* L.) is one of the important major spice crops in Bangladesh. It is cultivated throughout the country during winter season. In Bangladesh, onion is used not only as spice but also as a vegetable. Its cultivation in commercial scale is concentrated in the greater districts of Faridpur, Jessore, Dhaka, Mymensingh, Commila, Rajshahi, Rangpur and

Pabna. The national average yield of this crop is poor as compared to that of other developed countries. Among the bulb spices onion ranks second in terms of area (34.413 ha) and first in production (138000 m t) covering 24%of the total area under spices and condiments. The average yield being about 4.5 t/ha (BBS, 2004). However, onion production of our country does not meet up the domestic demand. The availability of onion for the domestic consumption is 170 thousand metric tons (BBS, 2004). Thus, according to BBS, 2004, 39 thousand metric tons have to be imported investing hard earned foreign currency. Onion is semi-perishable crop and subject to deterioration during storage, transportation and marketing. Due to the storage loss, it cannot be guaranteed that whole amount of the total production is consumed by the people.

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. The availability of seeds and the cost of seeds affect the adoption of the varieties by the farmers. If the seeds are expensive and difficult to obtain, the farmers find other available cheaper varieties in the local market which usually are low productive. 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). Ijoyah *et al.*, (2008) evaluate the yield performance of onion varieties and found that some other varieties performed better than the commonly grown onion varieties by the farmers. Tesfay *et al.*, (2011) conducted an evaluation trial of onion cultivars and concluded that onion cultivar performed differently and Parachinar local variety resulted in higher yield.

In the bulb forming species like onion the situation is quiet complex because bulb development ultimately leads to cessation of foliage leaf production. Furthermore the longer the duration over which a leaf canopy is transferring photosynthates to harvestable material (bulb) the higher the yield. Cultivar performance plays an important role in the selection of genotypes for yield improvement and adaptation to particular environmental conditions. Onion is highly sensitive to temperature and photoperiod. Successful onion production depends on the selection of varieties that are adapted to different conditions imposed by different environments. Thus, evaluations of local onion genotypes have been carried out all over the world. Most of these characterizations are based either on morphological, agronomical or physical and chemical measurements. Successful bulb production in any district 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.

Despite the importance of crop, so far very limited breeding work has been done. As a first step of systemic breeding program, collection and evaluation of germplasm is required. 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. So far in Bangladesh few cultivars of onion are grown. Hence, to boost the economy of onion growing farmers in Bangladesh, there is urgent need to select/develop superior varieties for growing in different agro climatic zone.

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

- To assess the variability for bulb yield and yield traits in 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

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

2.3. Correlation analysis

2.4 Path coefficient analysis

2.1 Performance of genotypes

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. 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).

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.

El-Kafoury *et al.* (1996); noticed 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.

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.

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.

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.

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 Arka Niketan (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.

2.2. Genetic variability

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

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

A knowledge of heritability for different component traits seems to be essential for any crop improvement programme, because the heritable component is the consequence of genotype and is inherited from generation to generation. Wright (1921) reported that heritability components comprised of additive andnon additive portion and it was the former which responds to selection.

Estimation of expected genetic advance is important to have an idea of effectiveness of selection. Burton and Devane (1953) suggested that genetic coefficient of variation together heritability estimates would give reliable indication of the amount of improvement to be expected from selection and further remarked that expected genetic gain under particular system supplies to a true practical information, which is needed by a breeder. Johnson *et al.* (1955) also found more useful to estimate the heritability values together with genetic advance in predicting the expected progress to be achieved through selection.

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).

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.

El-Shafie and Ahmed (1977), studied the F_2 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.

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.

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.

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.

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.
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 coefficient of variation (GCV) for weight of 50 cloves, plant height and bulb weight. High heritability along with high genetic advance was observed for plant height and weight of 50 cloves.

Vidyasagar and Monika (1993), estimated genetic parameters of variability on 22 cultivars of onion and reported high phenotypic and genotypic coefficient of variation (PCV and GCV) for sprouting losses, bolting rotting and total losses. High heritability along with high genetic advance (GA) for bolting, sprouting, rotting and total losses. Plant height, bulbs maturity, polar diameter, shape index, bulb size and TSS had high heritability.

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*).

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.

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.

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 observed high heritability with moderate to high genotypic coefficient of variation and genetic gain were recorded for weight of bulb, neck thickness, bulb yield and number of leaves per plant which could be improved by simple selection.

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.

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.

Mohanty (2004), evaluate 12 varieties of onion over four years revealed moderate to high estimates of heritability and genotypic coefficient of variation with moderate genetic gain for neck thickness, weight of bulb and number of leaves/plant which could be improved by simple selection.

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.

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.

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.

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.

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

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

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

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

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

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.

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.

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.

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. Likewise, Schiavi *et al.* (1985) reported that number of leaves and plant height were correlated with bulb weight and as such both could be used as selection criteria for higher yield in onion.

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.

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.

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.

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.

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.

Rahman *et al*. (2002); observed that total bulb yield (kg/ha) had significant positive correlation with plant height, number of leaf per plant, bulb diameter and bulb yield per plant but had significant negative association with plant spacing in onion.

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.

Aliyu *et al.* (2007); studied correlation coefficient analysis in onion and showed that bulb yield had significant positive correlation with plant height but had negative association with percentage of culled bulbs.
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:

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.

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.

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.

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 (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.

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.

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).

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 METHODS

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

3.1 Experimental site

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka-1207 during December 2016 to April 2017. The location of the experimental site was situated at $23^{0}74'$ N latitude and $90^{0}35'$ E longitude with an elevation of 8.6 meter from the sea level. Photograph showing the experimental site (Appendix II).

3.2 Soil and climate

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

3.3 Experimental materials

The healthy seeds of twelve 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.

3.4 Methods

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

3.4.1 Land preparation

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

3.4.2 Application of manure and fertilizer

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

Table 1. Materials used for the experiment

Genotypes	Variety Name	Source
G1	BARI Piaj 1	BARI
G2	BARI Piaj 3	BARI
G3	BARI Piaj 4	BARI
G4	BARI Piaj 5	BARI
G5	BARI Piaj 2	BARI
G6	Taherpuri	Local
G7	Foridpuri	Local
G8	Bombay	Bijoyshital Company Ltd
G9	Green long	Bijoyshital Company Ltd
G10	N-53	Bijoyshital Company Ltd
G11	Upsi	Bijoyshital Company Ltd
G12	Laltir king	Laltir Seed Company Ltd.

3.4.3 Experimental design and layout

Field lay out was done after final land preparation. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Total experimental area was 108 m^2. The spacing between row to row was 15 cm and plant to plant 10 cm. Seeds were sown in line in the experimental plots on 2 December 2016. The seeds were placed at about 1.5 cm depth in the soil. After sowing the seeds were covered with soil carefully so that no clods were on the seeds (Plate 1). A pictorial view of experimental field is presented in plate 2.

3.4.4 Intercultural operations

Intercultural operations, such as weeding, thinning and irrigation etc. were done uniformly in all the plots. Irrigation was given after sowing of seeds to bring proper moisture condition of the soil to ensure uniform germination of the seeds. The irrigation was done frequently on December 30; Jan 7, 11, 17, 22 and 30; February 7, 13, 22 and 28; March 8 and March 15, 2017. A good drainage system was maintained for immediate release of rainwater from the experimental plot during the growing period. A photograph of irrigation and drainage channel was presented in Plate 3. Gap filling was done properly on 13 February 2017. The first weeding was done on 22 February 2017. At the same time, thinning was done for maintaining a distance of 10 cm from plant to plant in rows of 15 cm apart. Second weeding was done on March 14, 2017.

Plate 3. Irrigation and drainage channel preparation in the experimental field of Onion

Plate 1. Experimental field of Onion (*Allium cepa* L)

Plate 2. Experimental field showing different genotypes at seedling stage

3.4.5 Crop harvesting

The crop was harvested on April 20, 2017 depending upon the maturity. 10 plants were selected at randomly from each replication. The plants were harvested by uprooting and then they were tagged properly. Data were recorded on different parameters from these plants.

3.4.6 Data collection

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

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.

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.

Total no. of leaves: Number of leaves per plant was recorded by counting total number of leaves from each of the sampled plant at the time of maximum foliage stage at 90 days after sowing and mean value was obtained. It was denoted in number.

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

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

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.

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.

Dry weight per bulb (g): Ten randomly selected bulbs were dried in an oven at 65^0C temperature until a constant weight was reached. Then weight all the dried bulb and the average were calculated as gram.

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.

3.4.7 Statistical analysis

Mean data of the characters were used to statistical analyze like analysis of variaancce (ANOVA), mean, range were calculated by using MSTAT C software program. Genotypic and phenotypic variance was estimated by the formula used by Johnson *et al*. (1955). Heritability and genetic advance were measured using the formula given by Singh and Chaudhary (1985). Genotypic and phenotypic coefficient of variation was calculated by the formula of Burton (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).

3.4.7.1 Estimation of genotypic and phenotypic variances

Genotypic and phenotypic variances were estimated according to the formula given by Johnson *et al.* (1955).

Genotypic variance (σ^2_g) = $\frac{GMS - EMS}{r}$

Where,

GMS = Genotypic mean sum of square

EMS = Error mean sum of square

r = number of replications

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

Where,

σ^2_g = Genotypic variance

EMS = Error mean sum of square

σ^2_e = Error variance

3.4.7.2 Estimation of genotypic and phenotypic co-efficient of variation

Genotypic and phenotypic co-efficient of variation were calculated by the formula suggested by Burton (1952).

Genotypic co-efficient of variation (GCV %) = $\sqrt{\frac{\sigma_g^2}{\bar{x}}} \times 100$

Where,

σ^2_g = Genotypic variance

$\bar{x}$ = Population mean

Similarly, the phenotypic co-efficient of variation was calculated from the following formula.

Phenotypic co-efficient variation (PCV) = $\sqrt{\frac{\sigma^2_{ph}}{\bar{x}}} \times 100$

Where,
σ^2_p = Phenotypic variance
$\bar{x}$ = Population mean

3.4.7.3 Estimation of heritability

Broad sense heritability was estimated (Lush, 1943) by the following formula, suggested by Johnson *et al.* (1955).

Heritability, $h^2{}_b\% = \frac{\sigma^2{}_g}{\sigma^2{}_p} \times 100$

Where,

h^2_b = Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

3.4.7.4 Estimation of genetic advance

The expected genetic advance for different characters under selection was estimated using the formula suggested by Lush (1943) and Johnson *et al.* (1955).

Genetic advance, GA = K. h^2. σ_p

Or Genetic advance, GA = K. $\frac{\sigma^2{}_g}{\sigma^2{}_p} . \sigma_p$

Where,

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

σ_p = Phenotypic standard deviation

h^2_b= Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

3.4.7.5 Estimation of genetic advance mean's percentage

Genetic advance as percentage of mean was calculated from the following formula as proposed by Comstock and Robinson (1952):

$$\text{Genetic advance (\% of mean)} = \frac{\text{Genetic Advance}}{\text{Population mean}} \times 100$$

3.4.7.6 Estimation of genotypic and phenotypic correlation co-efficient

The calculation of genotypic and phenotypic correlation co-efficient for all possible combinations through the formula suggested by Miller *et al.* (1958), Johnson *et al.* (1955) and Hanson *et al.* (1956) were adopted. The genotypic co-variance component between two traits and have the phenotypic co-variance component were derived in the same way as for the corresponding variance components. The co-variance components were used to compute genotypic and phenotypic correlation between the pairs of characters as follows:

$$\text{Genotypic correlation, } r_{gxy} = \frac{GCOVxy}{\sqrt{GVx \cdot GVy}} = \frac{\sigma_{gxy}}{\sqrt{(\sigma^2_{gx} \cdot \sigma^2_{gy})}}$$

Where,

σ_{gxy} = Genotypic co-variance between the traits x and y

σ^2_{gx} = Genotypic variance of the trait x

σ^2_{gy} = Genotypic variance of the trait y

$$\text{Phenotypic correlation } (r_{pxy}) = \frac{PCOVxy}{\sqrt{PVx \cdot PVy}} = \frac{\sigma_{pxy}}{\sqrt{(\sigma^2_{px} \cdot \sigma^2_{py})}}$$

Where,

σ_{pxy} = Phenotypic covariance between the trait x and y

σ^2_{px} = Phenotypic variance of the trait x

σ^2_{py} = Phenotypic variance of the trait y

3.4.7.7 Estimation of path co-efficient

It was done according to the procedure employed by Dewey and Lu (1959) also quoted in Singh and Chaudhary (1985), using phenotypic correlation coefficient values. In path analysis, correlation coefficients between yield and yield contributing characters were partitioned into direct and indirect effects on yield per plant.

After calculating the direct and indirect effect of the characters, residual effect (R) was calculated by using the formula (Singh and Chaudhary, 1985) given below:

$P^2_{RY} = 1- (r_{1.y}P_{1.y} + r_{2.y}P_{2.y} + \ldots\ldots\ldots\ldots\ldots.. + r_{8.y}P_{8.y})$

Where,

$P^2_{RY} = R^2$

and hence residual effect, $R = (P^2_{RY})^{1/2}$

$P_{1.y}$ = Direct effect of the ith character on yield y.

$r_{1.y}$ = Correlation of the ith character with yield 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 2016-17 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 morpho-physiogenic traits are shown in Table 2. 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 twelve Onion genotypes for their traits are shown in Table 3&4.

4.1.2.1 Plant height (cm)

Plant height among the genotypes ranged from 18.20 cm to 53.47 cm with a mean value of 39.76 cm. highest plant height was observed in genotype Laltir King and it was statistically similar with the genotype Green long (51.53 cm) while lowest in genotype BARI Piaj 2. Azoom *et al.* (2014) reported that the variety ‘Morada de Amposta’

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

Characters/Variety	Mean sum of square		
	Replication (r-1) = 2	Genotype (g-1) = 11	Error (r-1)(g-1) = 22
Plant height (cm)	45.47	369.15**	5.87
Root length (cm)	2.08	52.40**	1.05
No. of leaves	1.54	19.14**	1.71
Leaf length (cm)	33.00	267.84**	8.01
Leaf breath (cm)	0.04	0.93**	0.07
Bulb length (cm)	0.42	5.41**	0.59
Bulb diameter (cm)	3.46	26.34**	2.08
Dry weight per bulb (g)	94.02	537.24**	35.34
Yield per bulb (g)	80.40	582.30**	30.96

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

Table 3. Range, mean, CV (%) and standard deviation of 12 Onion (*Allium cepa* L.) genotypes

Parameters	Range		Mean	CV (%)	SD	SE
	Min	Max				
Plant height (cm)	18.20	53.47	39.76	6.10	2.42	0.92
Root length (cm)	2.61	17.33	6.90	14.91	1.03	0.39
No. of leaf	3.93	10.93	7.24	18.08	1.31	0.49
Leaf length (cm)	15.73	43.93	34.10	8.30	2.83	1.07
Leaf breath (cm)	1.07	3.24	1.84	14.90	0.27	0.10
Bulb length (cm)	4.93	8.43	6.80	11.37	0.77	0.29
Bulb diameter (cm)	5.30	14.60	10.67	13.52	1.44	0.55
Dry weight per bulb (g)	5.19	29.62	14.47	22.75	3.29	1.24
Yield per bulb (g)	8.60	48.93	24.02	23.17	5.56	2.10

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

Table 4. Mean performance of different characters of 12 Onion (*Allium cepa* L.) genotypes

Genotypes	Plant height (cm)	Root length (cm)	No. of leaf	Leaf length (cm)	Leaf breath (cm)	Bulb length (cm)	Bulb diameter (cm)	Dry weight per bulb (g)	Yield per bulb (g)
BARI Piaj 1	29.33ef	3.667de	3.933e	28.20c	1.360cd	5.167b	8.667d	6.16de	10.27f
BARI Piaj 3	42.00d	4.107de	6.400d	36.87b	1.907b	5.307b	7.947d	5.16e	8.600f
BARI Piaj 4	31.27e	2.700e	4.000e	26.63c	1.067d	5.900b	8.173d	7.40de	12.33f
BARI Piaj 5	42.67cd	5.267d	7.467cd	36.73b	1.667bc	5.933b	11.49bc	14.00cd	23.33de
BARI Piaj 2	18.20g	4.467de	3.933e	15.73d	1.147d	4.933b	8.367d	6.24de	10.40f
Taherpuri	44.07bcd	8.400c	7.667bcd	36.80b	2.000b	7.733a	13.08ab	22.96b	38.27bc
Foridpuri	44.73bcd	7.600c	9.667abc	40.60ab	1.947b	7.800a	13.03ab	20.20c	33.67bc
Bombay	46.93bc	10.67b	10.00ab	41.80ab	1.813bc	7.967a	12.85abc	17.68bc	29.47cd
Green long	51.73a	17.33a	7.267cd	42.27a	3.240a	8.267a	5.300e	9.88de	16.47ef
N-53	47.40b	7.267c	9.933ab	40.53ab	1.947b	8.000a	14.19a	24.84ab	41.40ab
Upsi	25.27f	2.613e	5.667de	19.07d	2.027b	6.167b	10.30cd	9.04de	15.07ef
Laltir king	53.47a	8.733c	10.93a	43.93a	1.987b	8.433a	14.60a	29.36a	48.93a
LSD	4.10	1.74	2.21	4.79	0.46	1.30	2.44	10.07	9.42

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

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).

4.1.2.2 Root length (cm)

Root length was exhibited the variation with the ranged from 2.61 cm to 17.33 cm with an average of 6.90 cm. The genotype Green long represented the longest root which was significantly different than other all genotypes. While the shortest root were observed by the genotype Upsi which was statistically similar with BARI Piaj 4 (2.7 cm), BARI Piaj 1 (3.67 cm) and BARI Piaj 3 (4.1 cm).

4.1.2.3 No. of leaves

Total no. of leaves were performed with the ranged from 3.93 to 10.93. The average total no. of leaves were 7.24. Genotype Laltir King was showed highest number of leaves which was statistically similar with Bombay (10.00), N-53 (9.93) and Foridpuri (9.67). While both the genotypes BARI Piaj 1 and BARI Piaj 2 represented the lowest value of this trait which was statistically similar with BARI Piaj 4 (4.00) and upsi (5.67). 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 15.73 cm to 43.93 cm with an average of 34.10 cm. The genotype Laltir King represented the longest leaf which was statistically similar with Green long (42.27 cm) and N-53 (40.53 cm). While the shortest leaf length was observed by the genotype BARI Piaj 2 which was similar in statistically with Upsi (19.07 cm). Azoom *et al.* (2014) reported that the variety 'Morada de Amposta' recorded the highest leaf length (68.06 cm)

4.1.2.5 Leaf breathe (cm)

Leaf breath was exhibited the variation with the ranged from 1.07 cm to 3.24 cm with an average of 1.84 cm. The genotype Green long represented the longest leaf breadth which was significantly different than other all genotypes. While the shortest leaf breadth was observed by the genotype BARI Piaj 4 which was statistically similar with BARI Piaj 2 (1.15 cm) and BARI Piaj 1 (1.36 cm).

4.1.2.6 Bulb length (cm)

Bulb length was exhibited the variation with the ranged from 4.93 cm to 8.43 cm with an average of 6.80 cm. The genotypeLaltir King showed the highest bulb length which was statistically similar with Green long (8.27 cm), N-53 (8.00 cm), Bombay (7.97 cm) and Foridpuri (7.80 cm). While the shortest bulb length was observed by the genotype BARI 2 which was followed by BARI 1 (5.17 cm) and BARI 3 (5.31 cm). Photographs showing of all genotypes of Onion plant with bulb studied in this experiment in Plate 5.

4.1.2.7 Bulb diameter (cm)

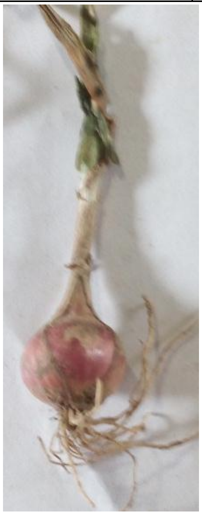
Bulb diameter was exhibited the variation with the ranged from 5.30 cm to 14.60 cm with an average of 10.67 cm. The genotype Laltir king represented the highest bulb diameter which was statistically similar with N-53 (14.19 cm) and Taherpuri (13.08 cm). While the significant lowest bulb diameter was observed by the genotype Green long. Diameter of bulb was ranged from 4.3 cm to 6.7cm reported by Sindhu *et al.* (1986).

G1=BARI Piaj 1

G2=BARI Piaj 3

G3=BARI Piaj 4

G4=BARI Piaj 5



G5=BARI Piaj 2

G6=Taherpuri

G7=Foridpuri

G8=Bombay

G9=Green long

G10=N-53

G11=Upsi

G12=Laltir king

Plate 5. Photographs showing of 12 Onion genotypes

4.1.2.8 Dry weight per bulb (g)

The important yield contributing trait dry weight per bulb was ranged from 5.19 g to 29.62 g with a mean value of 14.47 g. The highest and lowest dry weight per bulb was exhibited by the genotypes Laltir king and BARI Piaj 3 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 8.60 g to 48.93 g. The average value of yield per bulb was estimated 24.02 g. The highest yield per bulb was observed by the genotype Laltir king which was statistically similar with N-53 (41.40 g) while genotype BARI Piaj 3 showed the lowest yield per bulb which was similar in statistically with BARI Piaj 1 (10.27 g) and BARI Piaj 2 (10.40 g). Pandey and Singh (1989) recorded maximum yield in genotype HG-1.

4.2 Estimation of genetic parameters of Onion genotypes

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

4.2.1 Variability parameters

A wide range of variation was observed among 12 Onion genotypes for eight yield contributing traits and yield as well. The perusal of data revealed that variance for all traits was highly significant (Table 5). 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 for 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 5) indicating that they all interacted with the environment to some extent. Among the all traits, high PCV and GCV were found for root length (61.77 and 59.94, respectively) followed by yield per bulb (61.02 and 56.45%), dry weight per bulb (60.88 and 56.47%), no. of leaves (37.89 and 33.29%), leaf breadth (32.58 and 28.97%), bulb diameter (29.89 and 26.66%) and leaf length (28.53 and 27.29). 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.

Table 5. Estimation of genetic, phenotypic and environmental variance and coefficient of variation in nine traits

Parameters	$\sigma^2 p$	$\sigma^2 g$	$\sigma^2 e$	PCV	GCV	ECV	GCV:PCV
Plant height (cm)	126.97	121.09	5.88	28.34	27.68	6.10	0.98
Root length (cm)	18.17	17.11	1.06	61.77	59.94	14.91	0.97
No. of leaf	7.52	5.81	1.71	37.89	33.29	18.08	0.88
Leaf length (cm)	94.62	86.61	8.01	28.53	27.29	8.30	0.96
Leaf breadth (cm)	0.36	0.28	0.08	32.58	28.97	14.90	0.89
Bulb length (cm)	2.20	1.60	0.60	21.82	18.62	11.37	0.85
Bulb diameter (cm)	10.17	8.09	2.08	29.89	26.66	13.52	0.89
Dry weight per bulb (g)	77.31	66.16	11.15	60.88	56.47	22.75	0.92
Yield per bulb (g)	214.74	183.78	30.96	61.02	56.45	23.17	0.93

$\sigma^2 p$ = 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

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-5)

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 72.85 to 95.37 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 plant height (95.37%) followed by root length (94.17%), leaf length (91.53 %), dry weight per bulb (86.03%) and yield per bulb (85.58%) (Table 6). A graphical presentation of heritability for all the traits was shown in Figure 7. 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 dry weight per bulb (107.90) followed by yield per bulb (107.57), root length (119.83), no. of leaves (60.27), plant height (55.68), leaf length (53.79), leaf breadth (53.07) and bulb diameter (48.98) and lowest for bulb length (32.75) among yield and yield contributing traits (Table 6). 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. 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).

Table 6. Estimation of heritability and genetic advance in nine characters of twelve genotypes

Parameters	Heritability	Genetic advance (5%)	Genetic advance (% mean)
Plant height (cm)	95.37	22.14	55.68
Root length (cm)	94.17	8.27	119.83
No. of leaf	77.22	4.36	60.27
Leaf length (cm)	91.53	18.34	53.79
Leaf breadth (cm)	79.08	0.98	53.07
Bulb length (cm)	72.85	2.23	32.75
Bulb diameter (cm)	79.54	5.22	48.98
Dry weight per bulb (g)	86.03	15.61	107.90
Yield per bulb (g)	85.58	25.83	107.57

Mohanty (2001a) found that high values of heritability coupled with high genetic gain were observed for the number of leaves per plant, neck thickness, 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 co-efficient

Relationships among yield and yield contributing traits were studied through analysis of correlation among them. Phenotypic and genotypic correlation co-efficient among nine traits of 12 Onion genotypes are presented in Table 7.

In the present study out of 36 associations of genotypic and phenotypic origin, 34 associations were significant at both genotypic and phenotypic level. Among the 34 associations at genotypic level, all associations were positively significant. Similarly, in phenotypic correlation, among the 34 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, two associations were positive and non-significant at both genotypic and phenotypic level. The positive and non-significant association referred information of inherent relation among the pairs of combination. On the other hand two relationships were found negative and non-significant both at genotypic and phenotypic level. The negative and non-significant association referred a complex linked of relation among the pair of combinations.

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.

Yield per bulb positively and significantly correlate with plant height (0.703 and 0.648), root length (0.370 and 0.344), no. of leaves (0.906 and 0.823), leaf length (0.674 and 0.618), leaf breath (0.738 and 0.519), bulb length (0.869 and 0.728), bulb diameter (0.931 and 0.807) and dry weight per bulb (0.929 and 0.897) at both genotypic and phenotypic levels respectively Table-7.

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 genetic association with plant height, number of leaves per plant, bulb weight, equatorial and polar bulb diameter.

Table 7. 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	No. of leaf	Leaf length (cm)	Leaf breadth (cm)	Bulb length (cm)	Bulb diameter (cm)	Dry weight per bulb (g)
Plant height	G	0.725**							
	P	0.685**							
Root length	G	0.880**	0.567**						
	P	0.786**	0.476**						
No. of leaf	G	0.991**	0.685**	0.876**					
	P	0.968**	0.640**	0.759**					
Leaf length (cm)	G	0.679**	0.865**	0.494**	0.605**				
	P	0.598**	0.736**	0.408*	0.500**				
Leaf breadth (cm)	G	0.874**	0.824**	0.901**	0.825**	0.738**			
	P	0.740**	0.667**	0.786**	0.684**	0.519**			
Bulb length (cm)	G	0.410*	-0.041	0.786**	0.424*	-0.107	0.566**		
	P	0.406*	-0.002	0.702**	0.411*	-0.100	0.482**		
Bulb diameter (cm)	G	0.765**	0.387*	0.954**	0.655**	0.287	0.887**	0.954**	
	P	0.645**	0.354*	0.834**	0.645**	0.232	0.765**	0.823**	
Dry weight per bulb(g)	G	0.703**	0.370*	0.906**	0.674**	0.261	0.869**	0.931**	0.929**
	P	0.648**	0.344*	0.823**	0.618**	0.210	0.728**	0.807**	0.897**

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

Highly significant positive correlations at both the levels were recorded for plant height with root length (0.725 and 0.685), no. of leaves (0.880 and 0.786), leaf length (0.991 and 0.968), bulb length (0.874 and 0.740) and dry weight per bulb (0.765 and 0.645).

The results of correlation coefficients implied that highly significant positive correlations at both the levels were recorded for root length with no. of leaves (0.567 and 0.476), leaf length (0.685 and 0.640), leaf breadth (0.865 and 0.736) and bulb length (0.824 and 0.667). Highly significant positive correlation of no. of leaves with leaf length (0.876 and 0.759), bulb length (0.901 and 0.786), bulb diameter (0.786 and 0.702) and dry weight per bulb (0.954 and 0.834) at both genotypic and phenotypic level respectively.

Leaf length was correlated as positively highly significant with leaf breadth (0.605 and 0.500), bulb length (0.825 and 0.684) and dry weight per bulb (0.655 and 0.645) at both levels. Leaf breadth was highly significant positive correlated with bulb length (0.738 and 0.519).

Highly significant and positive correlation of bulb length at genotypic and phenotypic level with bulb diameter (0.566 and 0.482) and dry weight per bulb (0.887 and 0.765). Hossain *et al.* (2008) recorded positive and significant phenotypic correlation coefficient of bulb length with weight of bulb. Haydar *et al.* (2007) reported that Bulb length had positive significant association with bulb diameter.

Positive and highly significant correlation was observed of bulb diameter with dry weight per bulb (0.954 and 0.823) at both genotypic and phenotypic level. Hossain *et al.* (2008) recorded positive and significant correlation of bulb diameter with weight of bulb.

4.3.2 Estimation of path co-efficient

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

In path coefficient analysis revealed that plant height (5.058), root length (0.263), number of leaves (1.129) and dry weight per bulb (0.44) had direct positive effect on yield per bulb, indicating these are the main contributors to yield per bulb. Plant height had high positive direct effect on bulb yield reported by Yaso (2007). Aliyu *et al.* (2007) studied in onion and indicated that bulb diameter, plant height and number of leaves per plant were the principal component of yield. Plant height, bulb length and bulb diameter is the major components of bulb yield in onion (Haydar *et al.,* 2007). Gurjar and Singhania (2006) reported that plant height, number of leaves per plant, bulb weight, equatorial and polar bulb diameter had high positive direct effect on yield.

The highest positive indirect effects on yield per bulb were obtained by root length (3.667), number of leaves (4.351), leaf length (5.012), leaf breadth (3.434), bulb length (4.421) and bulb diameter (2.074) via plant height which was followed by root length (0.640), leaf length (0.989), leaf breadth (0.558), bulb length (1.017), bulb diameter (0.887) and dry weight per bulb (1.02) 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 (2007).

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

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)	**5.058**	0.191	0.994	-4.907	-0.674	-0.065	-0.167	0.28	0.703**
Root length (cm)	3.667	**0.263**	0.640	-3.392	-0.859	-0.061	0.017	0.10	0.370*
No. of leaf	4.451	0.149	**1.129**	-4.338	-0.491	-0.067	-0.321	0.40	0.906**
Leaf length (cm)	5.012	0.180	0.989	**-4.952**	-0.601	-0.061	-0.173	0.28	0.674**
Leaf breadth (cm)	3.434	0.227	0.558	-2.996	**-0.993**	-0.055	0.044	0.04	0.261
Bulb length (cm)	4.421	0.217	1.017	-4.085	-0.733	**-0.074**	-0.231	0.34	0.869**
Bulb diameter (cm)	2.074	-0.011	0.887	-2.100	0.106	-0.042	**-0.408**	0.42	0.931**
Dry weight per bulb (g)	3.20	0.06	1.02	-3.15	-0.09	-0.06	-0.39	**0.44**	0.929**

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

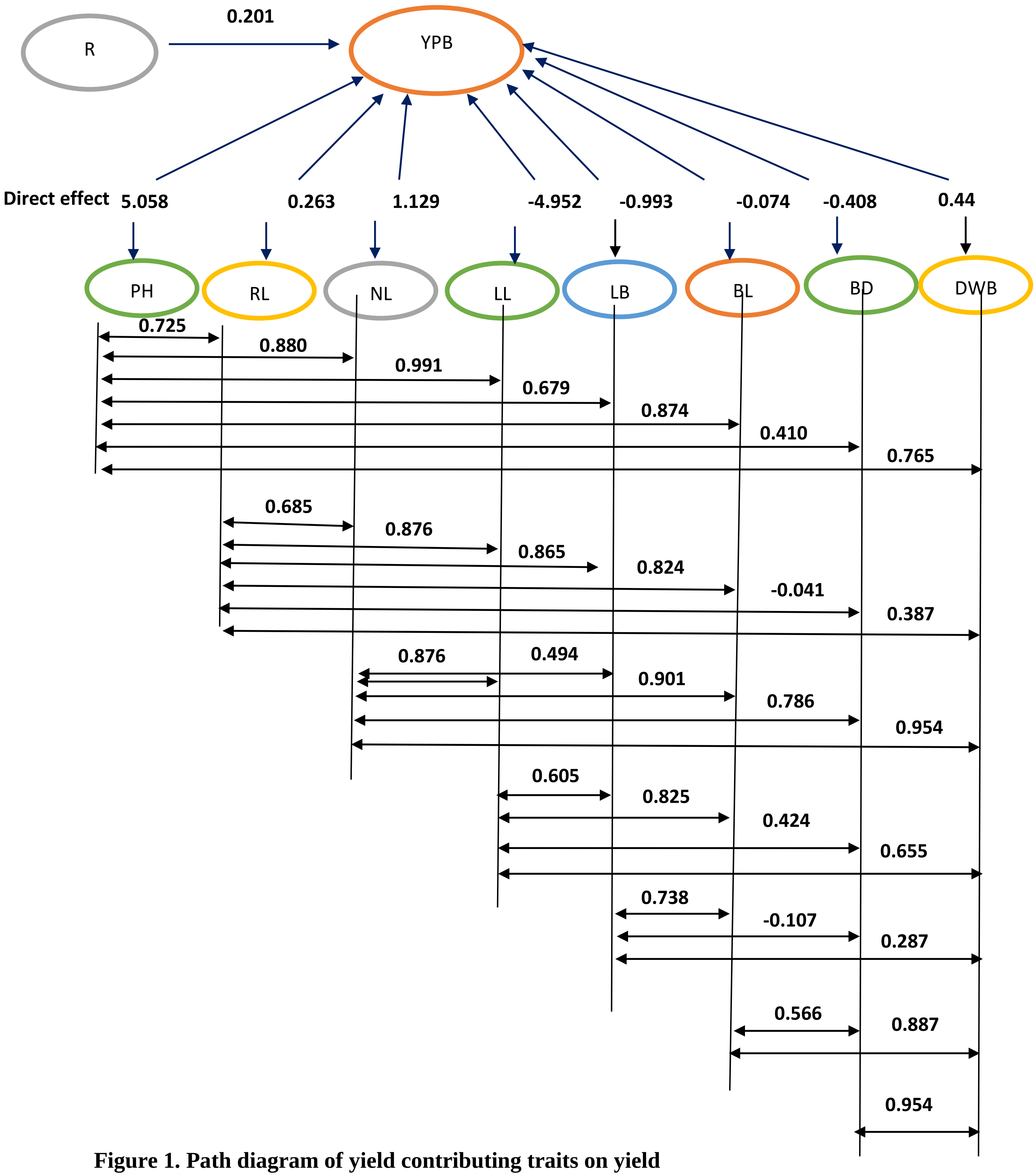


Figure 1. Path diagram of yield contributing traits on yield

CHAPTER V
SUMMARY AND CONCLUSION

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). The maximum plant height was produced by the genotype Laltir King (53.47 cm) and minimum in the genotype BARI 2 (18.20 cm). The genotype Green long represented the longest root (17.33 cm) and the shortest root was observed by the genotype Upsi (2.61 cm). The maximum number of leaves per plant was produced by the genotype Laltir King (10.93) and the minimum was by both the genotypes BARI 1 and BARI Piaj 2 (3.93). The highest leaf length was produced by the genotype Laltir King (43.93 cm) and the lowest leaf length was produced by the genotype BARI Piaj 2 (15.73 cm). The genotype Green long (3.24 cm) represented the longest leaf breadth and the shortest leaf breadth was observed by the genotype BARI Piaj 4 (1.07 cm). The highest bulb length was found in genotype Laltir King (8.43 cm) and the lowest bulb length was observed in the genotype BARI Piaj 2 (4.93 cm). The genotype Laltir king (14.60 cm) represented the highest bulb diameter and the lowest bulb diameter was observed by the genotype Green long (5.30 cm). The maximum dry weight per bulb was produced by the genotype Laltir king (29.62 g) and the minimum in the genotype BARI Piaj 3 (5.19 g). Genotype produced the highest yield per (48.93 g) and genotype produced the lowest yield per bulb (8.60 g).

Phenotypic variance was higher than the genotypic variances for all the traits. Phenotypic coefficient of variation (PCV) was higher than the corresponding genotypic coefficient of variation (GCV) for all the traits. High PCV and GCV were found for root length (61.77 and 59.94), yield per bulb (61.02 and 56.45%), dry weight per bulb (60.88 and 56.47%), no. of leaves (37.89 and 33.29%), leaf breadth (32.58 and 28.97%), bulb diameter (29.89 and 26.66%) and leaf length (28.53 and 27.29). High heritability was recorded by plant height (95.37%), root length (94.17%), leaf length (91.53 %), dry weight per bulb (86.03%) and yield per bulb (85.58%). Genetic advance in percent of mean was high for dry weight per bulb (107.90), yield per bulb (107.57), root length (119.38), no. of leaves (60.27), plant height (55.68), leaf length (53.79), leaf breadth (53.07) and bulb diameter (48.98) and lowest for bulb length (32.75). 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 provided opportunity for selection of high yielding genotypes.

Genotypic correlation coefficients were of higher in magnitude than the corresponding phenotypic correlation coefficients in most of the associations which might be due to masking or modifying effect. Very close genotypic and phenotypic correlations were observed the traits, plant height with bulb diameter, leaf length with bulb diameter and leaf length with dry weight per bulb, which might be due to reduction in error (environmental) variance, thus selection for higher yield on the basis of above traits would be reliable. Yield per bulb positively and significantly correlate with plant height (0.703 and 0.648), root length (0.370 and 0.344), no. of leaves (0.906 and 0.823), leaf length (0.674 and 0.618), bulb length (0.869 and 0.728), bulb diameter (0.931 and 0.807) and dry weight per bulb (0.929 and 0.897) at both genotypic and phenotypic levels. Plant height was correlated positively and significantly in levels with root length (0.725 and 0.685), no. of leaves (0.880 and 0.786), leaf length (0.991 and 0.968), bulb length (0.874 and 0.740) and dry weight per bulb (0.765 and 0.645). Highly significant positive correlations were recorded for root length with no. of leaves, leaf length, leaf breadth and bulb length. Highly significant positive correlation of no. of leaves with leaf length, bulb length, bulb diameter and dry weight per bulb at both genotypic and phenotypic levels. Highly significant and positive correlation of bulb length at genotypic and phenotypic level with bulb diameter and dry weight per bulb. Positive and highly significant correlation was observed of bulb diameter with dry weight per bulb at both genotypic and phenotypic levels.

Path analysis revealed plant height (5.058), root length (0.263), number of leaves (1.129) and dry weight per bulb (0.44) 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 (3.667), number of leaves (4.351), leaf length (5.012), leaf breadth (3.434), bulb length (4.421) and bulb diameter (2.074) via plant height. 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.

Conclusion

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. So, yield per bulb in Onion would be achieved through selection of these traits.

The traits plant height, root length, no. of leaves, leaf length, bulb length, bulb diameter and dry weight per bulb showed positive and significant correlation with yield per bulb. So, yield per bulb of onion can be increased by improving these traits. 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 N-53 may be selected for high yield, more dry weight of bulb, maximum bulb length, bulb diameter, no. of leaves, leaf length and plant height. These varieties produced and marketed by company. That`s why need to buy every year by the farmers. Another two varieties named Taherpuri and Foridpuri have been producing for many years by the farmers of Bangladesh in many districts. So, these are suggested to produce by the farmers. Even these varieties seed is produced by farmers and no need to buy seeds from the seed store or from a company. These two varieties yield and other traits already tested and satisfied Bangladeshi consumer.

REFERRENCE

Ado, P.O. (2001). Onion cultivation. *Onion News letter*, **20**: 30-34

Aliyu, U., Mangaji, M.D., Yakubu, A.I. and Dikko, A.U. (2007). Correlation and path coefficient analysis for some yield related traits in onion (*Allium cepa* L.). *J. Plant Sci.* **2**(3): 366-369.

Ananthan, M. and Balakrishnamoorthy, G. (2007). Genetic variability and path analysis in bellary onion (*Allium cepa* var. *cepa* L.) for storage losses. *Madras Agric. J.* **94**(7/12): 147-150.

Azoom, A.A.K.A., Zhani, K. Hannachi, C. (2014). Performance of Eight Varieties of Onion (*Allium cepa* L.) Cultivated under Open Field in Tunisia. *J. Tropical Agric.* **34**: 17-20.

Baiday, A.C. and Tiwari, R.S. (1995). Character association and evaluation of garlic germplasm. *Recent Hort*. **2**(2): 117-123.

BBS. (2004). Statistical Year Book of Bangladesh. Statistical Division. Ministry of Planning. Govt. of the Peoples Republic of Bangladesh, pp: 160.

Best, K. (2000). Red Onion Cultivars Trial. Horticultural Nova Scotia, Kentville Agricultural Centre, Nova Scotia (Canada):10-13.

Boukary H, Haougui, A., Barage, M., Adam, T., Roumba, A. and Saadou, M., (2012). Evaluation agro-morphology of onion varieties under ecotypes of Nigeria. *Intl. J. Bio. Chem. Sci.* **6**(6): 3098-3106.

Bremner, J.M. and Mulvaney, C.S.1982. Total nitrogen, In: Methods of Soil Analysis, Part 2, 2nd Ed., Page, A.L., Miller, R.H., Keeney, D.R., Am. Soc. Agron. Madison, USA. pp. 599-622.

Burton, G.M. and Devane, E.H. (1953). Estimating heritability in tall Fescue (*Festuca arundinaceae*) from replicated clonal material. *J. Agron.*, **45**: 478-481.

Burton, G.W. (1952). Quantitative inheritance in grasses. pp. 277-283. Proceeding 6th International Grassland Congress, Pennsylvania.17-23 August.Pennsylvania State College, State College, Pennsylvania, USA.

Busa, J.A. and Costa, C.P. (1979). Heritability and correlations of onion bulb traits (*Allium cepa* L.). *I Revista Brasiteira Genetica*. **2**: 49-55.

Cheema, A.A., Awan, M.A. and Iqbal, J. (1987). Improvement of plant height architecture in basmati rice. *Pakistan J. Agric. Res.* **8**:371-4.

Comstoc, R.E. and Robinson, H.F. (1952). Genetic parameters. Their estimation and significance. P.2844-291.

Day, P.R. (1915). Particle fractionation and particle-size analysis. In C.A. Black, D.D. Evans, J.L. White, L.E. Ensminger, and F.E. Clark (eds.), Methods of soil analysis. Part 1. Physical and mineralogical properties, including statistics of measurement and sampling. *1st ed. Agron*. **9**:545-567.

Dehdari, A., Mobli, M. and Rezao, A. (2002). Relationship between traits and path coefficient analysis for bulb and seed yield in Iranian landraces of onion (*Allium cepa* L.). *J. Sci. Tech. Agric. Natural Resour*. **5**(4): 53-69.

Dewey, O.R. and Lu, K.H. (1959). Correlation and path coefficient analysis of components of crested wheat grass seed production. *J. Agron.* **51**: 515-518.

El- Kafoury, A.K., Mostafa, A.K., Ibrahim, M.Y. and Hegazy, A.M. (1996). Performance of some onion cultivars concerning yield, quality, chemical constituents and storability of bulbs. *J. Agric. Sci. Mansoura Univ.* **21** (4): 1275 - 1285.

El-Shafie, M.W. and Ahmed, A.A. (1977). Inheritance of earliness and bulb weight in the common onion. *Libyan J. Agric.* **6**: 253-266.

Fisher, R.A. (1918). The correlation among relatives on the supposition of mendelion inheritance. *Royal Soci Edinburgh.* **52**: 399-433.

Galton, C.F. (1989). Statistical methods for research workers by Fisher, R.A. (1945). *Oliver Boyer Ltd., London* : 209.

Gamie, A.A. and Yaso, I.A.A. (2007). Evaluation of some Egyptian onion genotypes in Sohag Governorate. *J. Adv. Agric. Res.* **12** (1): 77-85.

Gowda, R.V., Singh, T.H. and Somkuwar, R.G. (1998). Genetic variability in onion (*Allium cepa* L.). *PKV Res. J.* **22**: 146-148.

Gurjar, R.S.S. and Singhania, D.L. (2006). Genetic variability, correlation and path analysis of yield and yield components in Onion. *Indian J. Hor.* **63**(1): 53-58.

Hanson, C.H., Robinson, H.P. and Comstock, RE. (1956). Biometrical studies of yield in segregating populations of Korean Lespedeza. *Agron. J*. **48**: 268-272.

Haydar, A., Sharker, N., Ahmed, M.B., Hannan, M.M., Razvy, M.A., Hossain, M., Hoque, A. and Karim, R. (2007). Genetic variability and inter-relationship in onion (*Allium cepa* L.). *Middle-East J. Sci. Res.* **2** (3-4): 132-134.

Hossain, M.S., Khalkuzzaman, M., Rashid, M.H. and Rahman, M.S. (2008). Variability and interrelationship among yield and yield contributing characters in onion (*Allium cepa* L.). *J. Bio. Sci.* **16**: 85-88.

Ijoyah, M.O, Rakotomavo, H., Naiken, M.V. (2008). Yield performance of four onions (*Allium cepa* L.) varieties compared with the local variety under open field conditions at Anse Boileau, Seychelles. *J. Sci. Techno.* **28** (3): 28-33.

Jilani, M.S. and Ghafoor, A. (2003). Screening of Local Onion Varieties for Bulb Formation. *Intl. J. Agric. Bio.* **5** (2): 129-133.

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

Jones, H. A. and L. K. Mann (1963). Onion and their allies. Inter science publishers, Inc., New York.

Kadams, A.M. and Nwasike, C.C. (1986). Heritability and correlation studies of some vegetative traits in Nigerian local white onion (*Allium cepa* L.). *Plant Breed.* **97**: 232-236.

Kalloo, G., Pandey, U.C., Lal, S. and Pandita, M.L. (1982). Correlation and path coefficient analysis studies in garlic. *Haryana J. Hor. Sci.* **11**: 97-102.

Kimani, P.M., Kariuki, J.W., Peters, R. and Rabinowitch, H.D. (1993). Influence of the Environment on the Performance of Some Onion Cultivars in Kenya. *African Crop Sci. j.* **1**(1): 15-23.

Korla, B.N. and Rastogi, K.B. (1979a). Correlation and path analysis between some economic characters in garlic. *Punjab Hort. J.* **19**: 89-92.

Korla, B.N. and Rastogi, K.B. (1979b). Performance studies of some garlic clones. *Haryana J. Hort. Sci.* **8**: 69-72.

Korla, B.N., Singh, A.K. and Kalia, P. (1981). Genetic variability in garlic. *Haryana J. Hort. Sci*. **10**: 77-80.

Leilah, A.A., El-Kalla, S.A., Mostafa, A.K. and Afifi, H.M.A. (2003). Performance of some local Egyptian onion strains under different planting dates. *Scientific J. King Faisal Univ*. **4** (1): 119 - 136.

Lush, J.L. (1943). Inter size correlation, regression of offspring on dams as a method of estimating heritability of characters. Proc. Amer. Soc. Anim. Prod. **33**: 293-301.

Madalageri, B.B., Bojappa, K.M., Sulladmath, U.V. and Patil, N.M. (1986). Onion breeding for higher solids: Genetic variation, heritability and stability. *Indian J. Hort*. **43**: 248-251.

McCollum, G.D. (1968). Heritability and genetic correlation of soluble solids, bulb size and shape in white Spanish onion. *Canadian J. Genet. Cytol*. **10**: 508-514.

Mehta, K.C. and Patel, P.H. (1985). Genetic variability and path analysis in garlic. *Madras Agric. J.* **72**: 691-695.

Mettananda, K.A. and Fordham, R. (2001). The Effects of Plant Size and Leaf Number on the Bulbing of Tropical Short-day Onion Cultivars (*Allium cepa* L.) Under Controlled Environments. *J. Hort. Sci.* **14**(5): 22-31.

Miller, P. A., Willams, C., Robiwson, H. F. and Comstock, R. E. (1958). Estimates of genotypic and environmental variance and covariance and their implication in section. *Agron. J.* **50**: 126-131.

Mohamed, E.I. and Gamie (1999). Evaluation of some organic fertilizers as substitutions of chemical fertilizers in fertilizing onion. *Egypt. J. Appl. Sci.* **14** (7): 664-678.

Mohanty, B.K. (2001). Genetic variability, inter-relationship and path analysis in onion. *J. Tropical Agric.* **39**: 17-20.

Mohanty, B.K. (2001a). Analysis of genetic divergence in kharif onion. *Indian J. Hort*. **58**: 260-263.

Mohanty, B.K. (2001b). Genetic variability, inter-relationship and path analysis in kharif onion. *Annals of Agric. Res.* **22**(3): 349-353.

Mohanty, B.K. (2002). Genetic variability, character association and path analysis in bulb onion seed crop. *Hort. J.* **15**(2): 61-68.

Mohanty, B.K. (2004). Genetic variability and path analysis in onion. *Indian J. Agric. Res.* **38**(1): 65-68.

Mohanty, B.K. and Prusti, A. M. (2001). Performance of common onion varieties in kharif seasons. *J. Tropical Agric.* **39**: 21-23.

Mohanty, B.K. and Prusti, A.M. (2001). Multivariate analysis for genetic divergence in onion seed crop. *Progres Hort*. **33**: 134-137.

Moravec, J., Kwasmicka, S. and Velicka, O.C. (1974). Correlation between bulb weight and other characters in varieties of the world collection of garlic. *Bullentin Vyzkumy Utsav Zelinarsky*, *Oiomouc*. **18**: 15-23.

Netrapal, Singh, N. and Chaudhury, B. (1988). Correlation and path coefficient studies in onion (*Allium cepa* L.). *Indian J. Hort.* **45** : 295-299.

Padda, D.S., Singh, G. and Saimbhi, M.S. (1973). Genetic variability and correlation studies in onion. *Indian J. Hort.* **31**: 391-393.

Pandey, U.C. and Singh, J. (1989). Performance of new varieties of garlic. *Haryana J. Hort. Sci.* **19**: 69-71.

Panse, V.G. and Sukhatme, P.V. (1957). Genetics and quantitative characters in relation to plant breeding. *Indian J. Genet.* **17**:312-328.

Patil, B.D., Desale, G.Y. and Kale, P.N. (1986). Genetic variability studies in onion (*Allium cepa* L.). *J. Maharashtra Agric. Univ*. **11**: 218-283.

Patil, J.D., Desale, G.Y. and Kale, P.N. (1987). Genetic divergence in onion (*Allium cepa* L.). *South Indian Hort.* **35**: 241-244.

Pavlovic N., Zecevic, B., Zdravkovic, M., Ivanovic, M. and Damjanovic, M. (2003). Variability and heritability of average yield of onion bulb (*Allum cepa* L.). *Genetika*, **35**(3): 149-154.

Rahman, A.K.M.M. and Das, M.K. (1985). Correlation and path analysis in garlic. *Bangladesh J. Agric. Res.* **10**: 50-54.

Rahman, M.A., Saha, S.R., Salam, M.A., Masum, A.S.M.H. and Chowdhury, S.S. (2002). Correlation and path coefficient analysis in onion (*Allium cepa* L.). *J. Bio. Sci.* **2**: 531-532.

Rajalingam, G.V. and Haripriya, K. (1998). Correlation and path coefficient analysis in Onion (*Allium cepa* L. var. aggregatum Don.). *Madras Agric. J.* **87** (7-9): 405-407.

Rajalingam, G.V. and Haripriya, K. (2000). Correlation and Path coefficient analysis in onion (*Allium cepa* L. Var Aggregatum Don.). *Madras Agric. J.* **87**: 405-407.

Randhawa, K.S., Sadhu, J.S., Thakur, J.C. and Singh, D. (1974). Variability and heritability of some important quantitative characters in onion (*Allium cepa* L.). *Punjab Hort. J.* **14**: 147-153.

Robinson, H.F., Comstock, R.E. and Harvery, P.H. (1951). Genotypic and phenotypic correlation in corn and their implications in selection. *J. Agron.* **43**: 282-287.

Santra, P., Manna, D., Sarkar, H. K. and Maity, T. K. (2017). Genetic variability, heritability and genetic advance in kharif onion (*Allium cepa* L.). *J. Crop Weed*, **13** (1): 103-106.

Shah, S.T., Sajid, M., Alam, R., Rab, A., Mateen, I. J., Ali, A. and Wahid, F. (2012). Comparative study of onion cultivars at Mardan, Khyber Pakhtunkhwa - Pakistan. *Sarhad J. Agric.* **28** (3), 399-402.

Shaha, S.R., Kale, P.N., Dhankhar, B.S. and Shirsath, N.S. (1990). Variability and correlation studies in Garlic. *Haryana J. Hort. Sci.* **19** (3-4): 313-317.

Sindhu, A.S., Singh, S. and Thakur, M.R. (1986). Variability and correlation studies in onion. *Indian J. Hort.* **43**: 260-264.

Singh, R.P. (1980) Association of grain yield and its component in F_1 and F_2 population of rice. *Oryza*, **17**: 200-204.

Singh, D.N., Nandi, A., Tripathy, P. and Sahu, A. (1995). Genetic variability and correlation in onion (*Allium cepa* L.). *Indian J. Agric. Sci*. **65** (11): 793-796.

Singh, R.K. and Chaudary, B.D. (1985). Biometrical methods in quantitative genetic analysis. Kalyani Publishers, New Delhi, India.p.56.

Singh, R.P. (1981). Genetic evaluation and path analysis in garlic. *Madras Agric. J. Univ*. **24**: 92.

Smith, C. (2003). Genetic Analysis of Quercetin in Onion (*Allium cepa* L.) 'Laddy Raider'. *The Texas J. Agric. Natural Resour*. **16**: 24-28.

Suthanthira Pandian, I.R. and Muthukrishnan, C.R. (1982). Correlation and path coefficient analysis in onion (*Allium cepa* L.). *South Indian Hort*. **30**: 22-24.

Tesfay, S.Z., Bertling, I., Odindo, A.O., Greenfield, P.L. and Workneh, T.S.(2011). Growth responses tropical onion cultivars to photoperiod and temperature based on growing degree days. *African J. Biotech*. **10** (71): 15875-15882.

Tripple, V.V. and Chubrikova, L.P. (1976). Referativny Zhurnal. **8**: 55-771.

Ullah, M.H., Huq, S.M.I. Alam, D.U. and Rahman, M.A. (2005). Effects of nitrogen, phosphorus and potassium on nutrient content in onion. *Bangladesh J. Agric. Res.* **30** (1): 41-48.

Vadival, B., Muthukrishanan, C.R. and Iruloppan, I. (1981). Association of characters between yield and yield components in aggregatum onion. *South Indian Hort***.** **29**: 227-228.

Vidyasagar and Monika, (1993). Interrelationship of yield components in Onion (*Allium cepa* L.). *South Indian Hort*. **41**(4): 201-203.

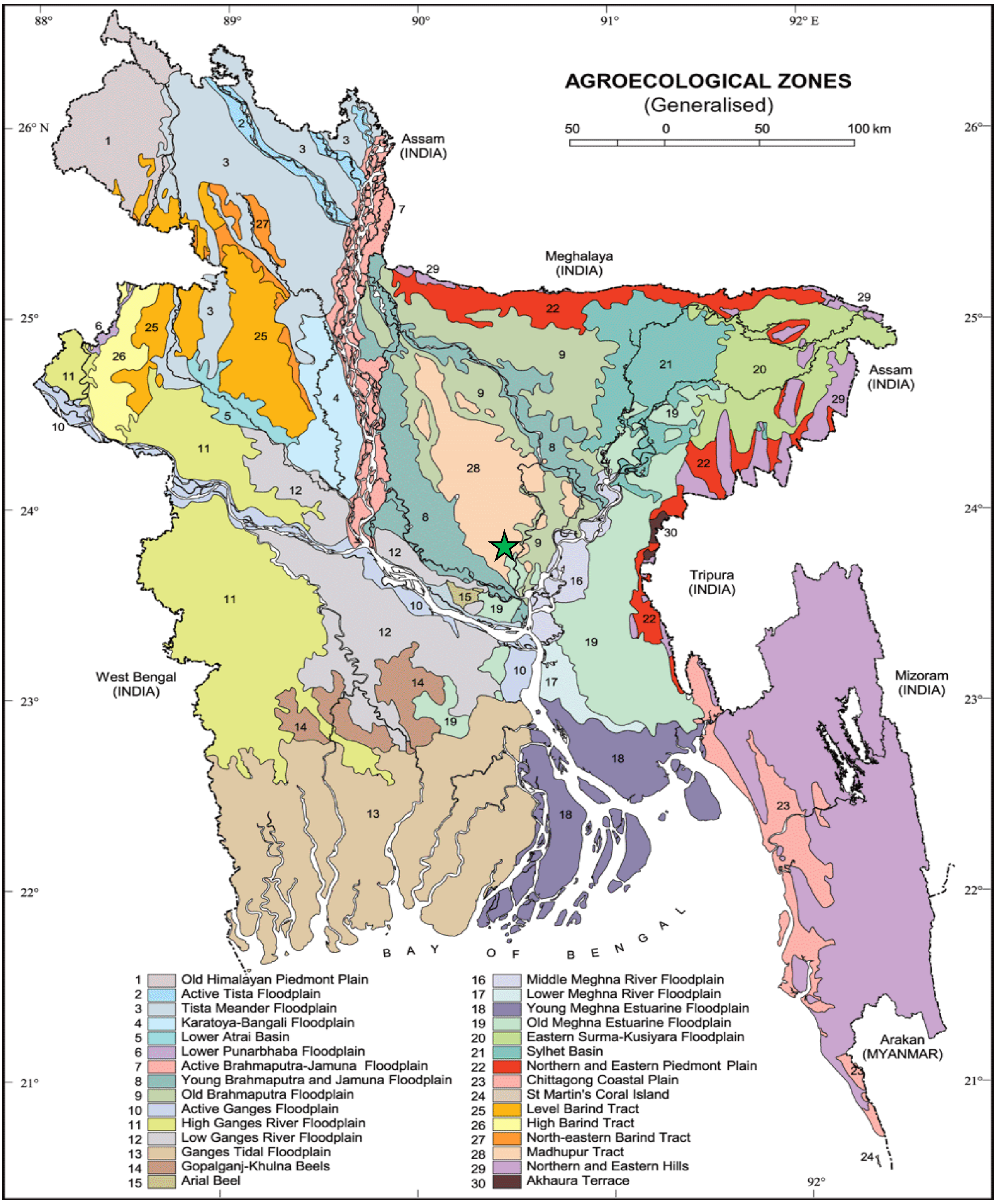
Walkley, A. (1947). A Critical Examination of a Rapid Method for Determination of Organic Carbon in Soils - Effect of Variations in Digestion Conditions and of Inorganic Soil Constituents. *Soil Sci*. **63**:251–257.

Wright, S. (1921). Correlation and causation. *J. Agric. Res.* **20**: 557-585.

Yaso, I.A.A. (2007). Performance and genetic parameters for six onion genotypes in Nubaria area. *Egypt. J. plant Breed.* **11** (3): 307-318

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 rainfall and sunshine of the experimental site during the period from November, 2016 to February, 2017.

Month	Air temperature (ºc)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (hr)
	Maximum	Minimum			
November, 2016	34.7	18.0	77	227	**5.8**
December, 2016	32.4	16.3	69	0	**7.9**
January, 2017	29.1	13.0	79	0	**3.9**
February, 2017	**28.1**	**11.1**	**72**	**1**	**5.7**

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