SELECTION OF ONION (*Allium cepa* L.) GENOTYPES FOR DROUGHT TOLERENCE USING MORPHO-PHYSIOLOGICAL AND YIELD CONTRASTING INDICES

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JUNE, 2022

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REGISTRATION NO. 20-11114

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: January-June, 2022

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CERTIFICATE

This is to certify that thesis entitled, " SELECTION OF ONION (*Allium cepa* L.) GENOTYPES FOR DROUGHT TOLERENCE USING MORPHO-PHYSIOLOGICAL AND YIELD CONTRASTING INDICES" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN GENETICS AND PLANT BREEDING**, embodies the result of a piece of bona fide research work carried out by MD. MAHMUDUL HASAN, Registration No. 20-11114 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: June, 2022
Place: Dhaka, Bangladesh

(Prof. Dr. Mohammad Saiful Islam)

Supervisor

DEDICATED

TO

MY BELOVED FAMILY & FRIENDS

ACKNOWLEDGEMENTS

All the praise are due to the almighty Allah, who blessed the author to complete this work successfully. With sincere gratitude and appreciation to his 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 his Co-supervisor Prof. Dr. Naheed Zeba, Department of Genetics and Plant Breeding, SAU for her continuous support, constructive criticism and valuable suggestions.

The author expresses his sincere respect to the Chairman of the Department, Dr. Shahanaz Parveen, and her excellent guidance.

The author expresses his gratefulness to the all teachers of his department for their co-operative guidance. The author expresses his sincere respect to the honorable Vice Chancellor of Sher-e-Bangla Agricultural University for his supreme support to the research work.

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

The author has received endless encouragement from his beloved friend Abu Hanjala, respective senior Md. Ariful Islam, adorable junior Daraz Prodhan throughout his masters' life. And also thankful to other friends for their support.

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

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

June 2022 *The Author*
SAU, Dhaka

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ABSTRACT

Eight genotypes of Onion (*Allium cepa* L.) were evaluated to find out the genotypes for drought tolerance using morpho-physiological and yield contrasting indices at Sher-e-Bangla Agricultural University, Dhaka during July, 2021 to June, 2022. The experiment was laid out in Complete Randomized Design (CRD) with three replications. Mean performance, genetic parameters, Pearson's correlation coefficient, and principal component biplot analysis on different yield contributing characters and yield of onion genotypes were estimated. The longest plant (49.43 cm) was recorded in the genotype Lal Teer King, while the shortest plant (20.287 cm) was found in onion genotype BARI Piaj 3. The highest bulb yield/plant (34.50 g) was recorded in the genotype of Lal Teer King, whereas the lowest bulb yield/plant (21.38 g) 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 indicating drought stress influenced the genotypes. In Pearson's correlation study, yield per bulb positively and significantly correlated with plant height (0.818), root length (0.511), no. of leaves (0.744), leaf length (0.720), leaf breadth (0.756), bulb length (0.469), bulb diameter (0.716), leaf area (0.893), chlorophyll content (0.886) and dry weight per bulb (0.854). The positive and significant correlation observed between grain yield and traits under-drought stress conditions provided evidence that studied traits might ultimately be considered as a tool for effective selection of drought tolerant genotypes. 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 were the main contributors to yield per bulb. The study selected 8 genotypes with high grain yields under drought stressed conditions and favorable adaptive traits useful for breeding. In consideration of yield contributing characters and yield Lal Teer King performed better under drought condition followed by BARI Piaj 1, BARI Piaj 2, BARI Piaj 3, Taherpuri, Faridpuri, Bombay and Annex N-53.

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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	cm
Percentage of coefficient of variation	CV%
Cultivars	cv.
Degrees of freedom	df
And others	*et al.*
Etcetera	etc.
Food and Agriculture Organization	FAO
Gram	g
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

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

Full word	Abbreviation
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.) is the most important, widely grown bulbous vegetable crop belongs to the family Liliaceae and divided into three groups: *Allium cepa*, *Allium cepa* var. aggregatum, *Allium proliferum*, which are all diploids (2n=2x=16) (Boukary *et al.*, 2012). It is an economically important vegetable crop, with nearly 98 million tons produced globally (FAOSTAT, 2019) and which is cultivated worldwide in a diverse range of climatic conditions and it varies from temperate to semi-arid areas.

Onion contains a volatile compound known as allyl-propyl disulphide which is responsible for pungency. Onion is known for a momentous source of vitamin C and contains about 60 calories in a medium-sized bulb and has very low sodium content. A single bulb provides 2.0 g protein, 72 mg calcium and 54 mg phosphorus (Ado, 2001). It also contains vitamins viz., thiamine, riboflavin, niacin, antioxidants and compounds that fight inflammation, decrease triglycerides and reduce cholesterol levels all of which may lower heart disease risk. Their potent anti-inflammatory properties may also help reduce high blood pressure and protect against blood clots.

Onion *(Allium cepa* L.) is one of the most 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 average yield of onion in Bangladesh is only 3.45 t/ha (FAO 2002). This is a very poor yield compared to other leading onion growing countries of the world. As a result, Bangladesh has to import onion from other countries to meet its demand (Hossain and Islam,1994). One of the major problems to onion production is improper agronomic practice used by farmers. The optimum level of any agronomic practice such as plant population, planting date, harvesting date, and fertilizer of the crop varies with environment, purpose of the crop and cultivar.

Drought stress affects plant growth by altering various morphological, physiological, and metabolic processes (Diaz *et al.*, 2010). It causes major damages to plants by disturbing water relations, inducing cellular membrane damage and forming of reactive oxygen species in plant tissues (Sairam and Saxena, 2000). Prolonged dry spell leads to poor plant growth and photosynthesis, which ultimately results in heavy yield losses. Phenotyping is a significant approach for screening germplasm based on morpho-physiological, biochemical, and yield performance (Passioura, 2012). Phenotypic attribute is the best criterion used for identifying tolerant genotypes among different crops based on their promising adaptive traits under drought stress (Vaezi *et al.*, 2010; Mwadzingeni *et al.*, 2016). In cereals, traits namely the plant height, number of productive tillers, spikelet per spike, and days to maturity are some of the important yield traits used for screening genotypes under limited water supply (Blum, 2010). Thus largely diverse phenotypic responses have been reported among different crop genotypes due to alteration in various physiological, biochemical, and molecular responses (Fenta *et al.*, 2014; Ramakrishnan *et al.*, 2016; Aghaie *et al.*, 2018). This indicates variation in genotypic difference among the genotypes in terms of their drought tolerance level.

Onion is a shallow rooted crop; a fairly high concentration of nutrient should normally be maintained at the surface of the soil for its optimum growth and yield. Bulb yield in the onion crop has been reported to be directly associated with the amount of water supply. Information regarding genetic diversity among genotypes and the correlation among different traits under different water regimes is limited. Bulb yield is the primary trait that needs to be considered while evaluating drought tolerance along with secondary indicators, namely plant water status, physiological, and biochemical parameters. The extent of damage to bulb yield depends on the genotype and phonological stage at which drought stress occurs (Ghodke *et al.*, 2018). Typically, genotypes with better drought-adaptive traits and relatively higher yield under water stress conditions need to be identified. Screening of genotypes based on few phenotypic traits and identifying the best criterion or trait among them is the major challenge while a screening large germplasm pool. Thus numerous genotypes can be more precisely evaluated at the same time by using appropriate statistical tools and employing multiple phenotypic, physiological, biochemical, and yield traits.

Therefore, from the breeding perspective, effective screening techniques should be used to identify tolerant genotypes that can perform better under limited water supply than the other genotypes. To date, why is the relationship among physiological markers and bulb yield in drought conditions still now unknown. To expand onion cultivation and to sustain bulb yield under drought prone areas of Bangladesh, our present investigation will be carried out to evaluate the sensitivity of some physiological markers and to observe the relationship among physiological markers and grain yield under drought stress. The present investigation was, therefore, planned with the following objectives:

Detailed research objectives:

i). The relationship among morpho-physiological and bulb yield were observed and which can perform well under drought stress conditions, and

ii). The various morpho-physiological parameters were evaluated related to drought stress tolerance.

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). Successful bulb production 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 researchers. Such as:

Neslihan *et al.* (2022) observed that the abiotic stresses deteriorate plant growth resulting in devastating yield losses. Salt stress solely cause ionic toxicity and disturbed homeostasis, whereas combined salt and drought stress has more pronounced effects on plants. This study aimed to screen 32 Turkish onion breeding lines and commercial cultivars based on their morpho-physiological and biochemical responses after exposure to drought, salt, and salt + drought stresses at the bulbification stage under greenhouse conditions. All genotypes responded differentially to the applied single and combined stresses. Overall results revealed that in the breeding lines K25, U6, U17 and commercial cultivar K58, the bulb weight (41.71–47.93 g) was significantly ($p \leq 0.05$) lower, therefore they were grouped as sensitive across all stresses; whereas in the breeding lines K41, U47, U49 and commercial cultivar K52, the bulb weight (96.75–106.31 g) was significantly ($p \leq 0.05$) higher among all the tested breeding lines and commercial cultivars and therefore found to be the most stable upon stress. These resilient genotypes can be used as breeding material for future abiotic stress studies.

Pranjali *et al.* (2021) found that drought is a leading abiotic constraints for onion production globally. Breeding by using unique genetic resources for drought tolerance is a vital mitigation strategy. With a total of 100 onion genotypes were screened for drought tolerance using multivariate analysis. The experiment was conducted in a controlled rainout shelter for 2 years 2017–2018 and 2018–2019 in a randomized block design with three replications and two treatments (control and drought stress). The plant was exposed to drought stress during the bulb development stage (i.e., 50–75 days after transplanting). Under drought conditions, clusters II and IV contained highly tolerant and highly sensitive genotypes, respectively.

Semida *et al.* (2016) observed that the field-applied salicylic acid (SA) could provide a potential protection against drought stress in onion large-scale production. Two-season field experiments were consecutively conducted in 2013/2014 and 2014/2015 to study the effect of 1 and 2 mM SA on growth, yield, plant water relations, chlorophyll a fluorescence, osmoprotectants, and water-use efficiency (WUE) in onion plants under four levels of irrigation (I120 = 120%, I100 = 100%, I80 = 80%, and I60 = 60% of crop evapotranspiration). Foliar application of SA enhanced drought stress tolerance in onion plants by improving photosynthetic efficiency and plant water status as evaluated by membrane stability index and relative water content. These results were positively reflected by improving plant growth, productivity, and WUE under drought stress conditions. Therefore, SA application may, in future, find application as a potential growth regulator for improving plant growth and yield under deficit irrigation by 20–40%.

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.

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.

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.

Gamie *et al.*,(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.

Leilah *et al.* (2003); decleared that local onion strains markedly differed in most of growth and yield characteristics.

Mohanty *et al.*,(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.

Mohamed *et al.*,(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.

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.

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.

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

2.2. Genetic variability

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

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

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 metro glyph 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.

Gupta *et al*. (2023) studied the genetic diversity of 36 genotypes of multiplier onion and it was examined using 17 ILP markers in thier study. PIC values ranged from 0.03 to 0.44 with a mean of 0.24, and amplification of ILP markers revealed a total of 41 loci, one of which was monomorphic. A total of 1008 bands were obtained. Principal component analysis (PCA) detected one PC contributing 54.54% of the genetic diversity of genotypes. A total of 17 primers were amplified and they produced 41 alleles in these genotypes. The genotypes 1539-Agg and 1523-Agg have the highest degree of similarity (0.97) in cluster A whereas, the least degree of similarity was revealed in cluster E between genotypes 1549-Agg and 1533-Agg. The genetic diversity among multiplier onion genotypes was estimated based on similarity coefficient of molecular markers facilitates the selection of diverse parents that can generate desirable segregants in future breeding program.

A study was undertaken by Manjunath *et al.* (2022) to evaluate the variability present among the rabi genotypes and predict the results for hybridization programme. Thirty-seven genotypes of onion were used for the experiment. On the basis of mean performance RVC-21-40 was found best performing genotype with highest bulb yield (35.20 t/ha). Higher estimates of heritability were found for pyruvic acid followed by bulb weight, yield, TSS, polar diameter and equatorial diameter characters, indicating the presence of high variability, which suggests that these traits can aid in simple selection which could be helpful for further crop improvement.

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.

An investigation was carried out by Singh *et al.*(2011) to study the genetic variability in late kharif germplasm of onion. The mean data indicated that the highest gross yield (41.17 t/ha) and marketable yield (39.13 t/ha) was recorded in line 744 and was at par with line 682 (39.07 t/ha) and (34.39 t/ha). A wide range of variability was observed for gross yield (19.65 to 41.17 t/ha), marketable yield (10.05 to 39.13 t/ha), bulb size index (20.40 to 35.90 cm2), bolters (0.00 to 40.83%), doubles (0.00 to 47.50 %), thrips/plant (8.75 to 25.80) and plant height (54.95 to 71.80 cm).

Dhotre *et al.* (2010) were studied genetic variability, character association and path coefficients in red onion involving 14 genotypes. High heritability with moderate to high GCV and genetic advance were recorded for double/split bulb per cent, fresh bulb weight and bulb yield as well as storage losses due to rotting, sprouting and total loss denoting their possibility of improvement with simple selection. Number of rings per bulb, TSS and dry matter content exhibited high heritability coupled with high expected genetic advance.

Hosamani *et al.* (2010) observed variability, heritability, genetic advance and inter association between traits in twenty one diverse onion genotypes was carried out for bulb yield, yield attributing traits and quality parameters. The range of variation was maximum for yield/ha (8.52 to 32.42 t) followed by average bulb weight (26.67 to 84.00 g), dry matter content (15.93 to 24.80 %) and bulb neck thickness (0.47 to 1.37 cm). The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high for yield t/ha and average bulb weight. Whereas, moderate variation for all the characters except TSS and number of leaves per plant. The heritability in broad sense ranged from 37.33 (number of leaves per plat) to 80.30 per cent (dry matter content). Higher heritability estimates were obtained for the dry matter content (80.30 %), yield/ha (79.63%), TSS (74.24 %) and average bulb weight (64.64 %) and it was moderate for other traits. The genetic advance as percentage of mean varied from 10.36 to 47.88 per cent for plant height and average bulb weight, respectively.

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.

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 *et al.*, (2007), evaluated range, phenotypic and genotypic coefficient of variance, heritability and genetic advance for thirteen characters of 62 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.

Gurjar *et al.*,(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.

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.

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 (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.

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 *et al.*,(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.

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.

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.

Pandey *et al.*, (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.

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 *et al.*, (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.

Mehta *et al.*, (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.

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.

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

El-Shafie *et al.*, (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.

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.

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).

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).

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).

Reddy *et.al* (2022) carried out an investigation on correlation analysis in onion genotypes under North-Eastern dry zone of Karnataka with thirty-two onion genotypes in three replications. Correlation co-efficient analysis revealed that total yield per plot had positive and significant correlation with Plant height (cm), number of leaves per plant, leaf length (cm), leaf area (cm^2), average bulb weight (g), longitudinal diameter of bulb (cm), equatorial diameter of bulb (cm), number of rings per bulb, days to maturity, bulb neck thickness (cm), dry matter of onion (%), total yield per plot (kg/plot) at genotypic and phenotypic level.

Singh *et. al* (2022) observed that the plant height, leaf length, polar diameter and equatorial diameter exhibited significant positive correlation with total bulb yield.

Pranjali *et.al* (2021) observed that the analysis of variance indicated significant differences among the tested genotypes and treatments for all the parameters studied, viz. phenotypic, physiological, biochemical, and yield attributes. Bulb yield was strongly positively correlated with membrane stability index (MSI), relative water content (RWC), total chlorophyll content, antioxidant enzyme activity, and leaf area under drought stress.

Twenty landraces were planted by Mousavizadeh (2019) and the result was the genotypic correlation coefficients were higher than the phenotypic correlation coefficients which indicated the inherent association among various characters independent of environmental influence. Bulb-yield/plant showed significant positive correlation with leaf length, leaf number, bulb diameter and bulb length at phenotypic and genotypic levels. So, improvement of leaf length, leaf number, and bulb diameter and bulb length traits could improve the capacity of the plants to synthesize and translocate photosynthates to the bulb.

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).

Lakshmi (2015) found the genotypic correlation coefficients were higher than the corresponding phenotypic ones for most of the characters, reflecting a predominant role of the heritable factors. Yield showed positive association with plant height, neck thickness, weight, length, equatorial diameter of the bulb, both at the phenotypic and genotypic levels.

Chatto *et al.* (2015) conducted an experiment using forty eight genotypes/hybrid of onion for bulb yield and yield related traits and recorded total bulb yield was found to be positively correlated with average bulb weight, days to harvest, % splitted bulb, equatorial diameter, dry matter, polar diameter, total soluble solids, plant height, collar thickness and % double genotypes.

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.

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.

Gurjar *et al.*, (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

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.

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 (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.

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

In an experiment Baiday *et al.*, (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.

Vidyasagar *et al.*, (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.

Netrapal *et al.* (1988) observed positive correlation of bulb yield with bulb weight, diameter of bulb and plant height 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.

Rahman *et al.*, (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.

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 *et al.*, (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.

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

Buso *et al.*, (1979), reported negative phenotypic as well as genotypic correlations amongst bulb weight, bulb diameter and TSS in onion.

Korla *et. al.*, (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.

Tripple *et al.*, (1976), observed the significant positive correlation between bulb yield and bulb size of garlic.

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.

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

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:

Reddy *et.al* (2022) carried out an investigation on path analysis in onion genotypes under North-Eastern dry zone of Karnataka with thirty-two onion genotypes in three replications. Path co-efficient analysis revealed that Plant height (cm), average bulb weight (g), equatorial diameter of bulb (cm), total soluble solids (0B), bulb shape index and dry matter of onion percent exhibited positive and direct effect on total yield per plot, and could be utilized as selection criteria in onion improvement program.

Singh *et. al* (2022) observed that the genotypic path analysis showed that leaf length (cm) had maximum positive direct effect on total bulb yield followed by equatorial diameter, total sugar and total pyruvic acid of bulb.

Twenty landraces were planted by Mousavizadeh (2019) and the path analysis showed that bulb diameter has the largest positive direct effect on bulb-yield/plant. The indirect effect of length of leaves on onion yield through bulb diameter was considerable. Accordingly, selection of plants with larger leaf length and bulb diameter could be suitable for breeding onion for higher yield. The presence of negligible residual effect (0.06) indicated that most of the important traits contributing to yield were included in the path analysis.

Lakshmi (2015) found the path coefficient analysis which revealed a positive direct effect with regard to plant height, neck thickness, weight, length and diameter of the bulb. Hence, these are the main characters contributing to yield potential of the onion plant. Therefore, it is suggested to lay emphasis on these traits while imposing selection for bulb yield in the onion crop.

Chatto *et al.* (2015) conducted an experiment using forty-eight genotypes/hybrid of onion for bulb yield and yield related traits and the path coefficient analysis revealed that average bulb weight had maximum positive direct effect on total bulb yield followed by days to harvest, % splitted bulb, equatorial diameter, dry matter, polar diameter, TSS, plant height, collar thickness and % double genotypes indicating true and perfect relationship.

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.

Ananthan *et al.*, (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.

Haydar *et al.*, (2007) studied the path analysis in 10 genotypes of onion and revealed that plant height, bulb length and bulb diameter is the major components of bulb yield in onion.

Gurjar *et al.*, (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.

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.

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.

Rajalingam *et al.*, (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.

Suthanthira *et al.*, (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.

CHAPTER III

MATERIALS AND METHODS

The present research work was conducted to find out the genotypes for drought tolerance using morpho-physiological and yield contrasting indices. Materials used and methodology followed for conducting the research along with data recording and analyzing procedure were described briefly as follows:

3.1 Description of the experimental site

3.1.1 Experimental period:

The experiment was conducted during the period from July, 2021 to June, 2022 in rabi season.

3.1.2 Site description:

The present piece of research work was conducted in the net house upon the Dept. of Genetics and Plant Breeding of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka.

3.2 Climatic condition

The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by three distinct seasons, namely winter season from the month of November to February and the pre-monsoon period or hot season from the month of March to April and monsoon period from the month of May to October (Edris *et al.*, 1979). The records of air temperature, humidity and rainfall during the period of experiment were noted from the Bangladesh Meteorological Department, Agargaon, Dhaka (Appendix I).

3.3 Geographical location and soil characteristics:

Geographical location of the experimental site was described as 23°74’ N latitude and 90° 35’ E longitude at an altitude of 8.6 meter above the sea level. The soil belonged to “The Modhupur Tract”, AEZ-28 (FAO, 1988).

3.4 Planting materials:

The planting materials were collected from BARI, Bijoyshital Company Ltd, Laltir Seed Company Ltd and other local markets. The materials used in this study is listed in Table 1.

3.5 Methods

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

3.5.1 Design of experiment:

The experiment was conducted with complete randomized design (CRD) with three replications.

3.5.2 Pot preparation and fertilization:

The pot was prepared by soil mixed. All the stubbles and weeds were removed from the soil. In the following day, cowdung was added. According to recommended fertilizer doses TSP, MP and Gypsum was applied 3 kg, ½ kg and 1 kg respectively. Required amount of Urea was also applied during final pot preparation and rest amount was split applied at sowing time. Plate 1 and 2 showing the fertilization and pot preparation process respectively.

3.5.3 Plant growth and application of drought treatment:

The seeds of each genotype were sown in plastic pots of 10 liter (L) volume filled with sand and other necessary inputs during Rabi seasons, 2021-22 in completely randomized design (CRD) in net house under drought stress conditions. Regular water supply was maintained in the pots until 75 DAS. Then, water supply was stopped in the pots for continuous 25 days during the bulb enlargement stage

Table 1: Materials used for the experiment

Genotypes	Variety Name	Source
G1	BARI Piaj 1	BARI
G2	BARI Piaj 3	BARI
G3	BARI Piaj 2	BARI
G4	Taherpuri	Local Market
G5	Foridpuri	Local Market
G6	Bombay	Bijoyshital Company Ltd.
G7	Annex N-53	Bijoyshital Company Ltd.
G8	Laltir king	Lalteer Seed Ltd.

BARI= Bangladesh Agricultural Research Institute

Plate 1. Showing the fertilizer mixing process as per requirement for pot preparation

Plate 2. Filling up the pot with prepared soil.

(75- 100 DAS). The automated rain-out shelter were protected the experiment from any possible seasonal rainfall. Data on all phenotypic and physiological traits were collected from the pots.

3.5.4 Sowing of seeds and growth of seedling in the pot:

Pots were made for sowing the onion seeds when the pot was in proper joe condition and seeds were sown at October, 2021. After sowing, seeds were covered with soil & coco pit and slightly pressed by hand. Plate 3 and Plate 4 showing the sowing process and seedling stages respectively.

3.5.5 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 pot preparation. The remaining urea and MoP were as top dressing in two installments. Rest of Urea was top dressed after first irrigation (BARI, 2011).

3.5.6 After care:

After the germination of seeds, various intercultural operations such as weeding, top dressing of fertilizer and plant protection measures were accomplished for better growth and development of the onion seedlings as per the recommendation of BARI. Plate 5 showing field inspection at different stages in the net house.

3.5.7 Intercultural operations:

Intercultural operations, such as weeding, thinning and irrigation etc. were done uniformly in all the pots. 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 as per required. A good drainage system was maintained for immediate release of rainwater from the experimental pot during

Plate 3. Sowing the seeds in the pot for seedling preparation.

Plate 4. Growing seedling for transplanting in the main pot

Plate 5. Demonstration of field inspection at different stages in the net house.

the growing period. A photograph of irrigation and drainage channel was presented in Plate 6. Gap filling was done properly.

3.5.8 Crop harvesting

The crop was harvested on April 20, 2021 depending upon the maturity. Three plants were selected at randomly from each replication. The plants were harvested by uprooting and then they were tagged properly. Data were recorded on different parameters from these plants (Plate 7).

3.5.9 Data recording

Data were recorded from each pot based on different morphological and physiological traits. Eleven characters were taken into consideration for studying different genetic parameters, association and correlation study. Data were recorded on three selected plants for each genotype for each replication on following parameters. The details of data recording are given below on individual plant basis.

3.5.9.1 Morphological Traits

Plant height (cm):

Data of plant height were recorded from three plants selected randomly from each unit pot 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 three plants selected randomly from each unit pot. The length was measured in centimeter (cm) from the base of the bulb root to the tip of the largest root.

Plate 6. Showing Irrigation and gap filling process.

Plate 7. Demonstrating matured crops for harvesting.

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 means value was obtained. It was denoted in number.

Leaf length (cm):

Length of leaves was recorded from three randomly selected plants at maximum vegetative stage from each unit pot. Length of each leaf of individual plant was measured by a centimeter scale. Then the mean length of leaf was calculated as cm (Plate 8).

G8=Lal Teer king

Plate 8: Showing genotypes with best performance

Leaf breadth (cm):

Breadth of leaves was recorded from three randomly selected plants at maximum vegetative stage from each unit pot. 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 five 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):

Five randomly selected bulbs were dried in sun 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 five 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.

3.5.9.2 Physiological Traits

Determination of SPAD Value

Relative chlorophyll content was expressed by SPAD value. SPAD value were received from the middle portion of the flag leaf of five main shoots at a thesis using SPAD meter (Plate 9) and these data were averaged as SPAD value of each leaf for both the water regimes after relieving stress.

Plate 9: Showing measurement of chlorophyll in the fully expanded leaf.

3.5.10 Statistical Analysis

Physiological, morphological and yield data were analyzed using SAS software. Analysis of variance (ANOVA) and the least significance test were be performed using SAS software to test the genotypic difference, drought stress effect and to compare the phenotypic value of the genotype for specific traits. The mean data (pooled) for the recorded traits were used for calculating Pearson's correlation coefficient and the association among different traits under drought stress conditions by using SPSS software (Version 16.0). Biplot PCA were performed for genotypes and traits under drought stress by using SPSS and XLSTAT software to show the relationships among the tested genotypes based on different trait.

3.5.10.1. Estimation of genotypic and phenotypic variances

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

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

Where,

GMS = Genotypic mean sum of square

EMS = Error mean sum of square

r = number of replications

$$\text{Phenotypic variance } (\sigma^2_p) = \sigma^2_g + \sigma^2_e$$

Where,

σ^2_g = Genotypic variance

EMS = Error mean sum of square

σ^2_e = Error variance

3.5.10.2 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) = $\sqrt{\frac{\sigma_{ph}^2}{\bar{x}}} \times 100$

Where,
σ^2_p = Phenotypic variance

$\bar{x}$ = Population mean

3.5.10.3 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

3.5.10.4 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

$\sigma^2{}_g$ = Genotypic variance

$\sigma^2{}_p$ = Phenotypic variance

3.5.10.5 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):

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

3.5.10.6 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:

Genotypic correlation, $r_{gxy} = \dfrac{GCOVxy}{\sqrt{GVx.GVy}} = \dfrac{\sigma_{gxy}}{\sqrt{\sigma^2{}_{gx}.\sigma^2{}_{gy}}}$

Where,

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

$\sigma^2{}_{gx}$ = Genotypic variance of the trait x

$\sigma^2{}_{gy}$ = Genotypic variance of the trait y

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

Where,

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

$\sigma^2{}_{px}$ = Phenotypic variance of the trait x

$\sigma^2{}_{py}$ = Phenotypic variance of the trait y

3.5.10.7 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 study was conducted to find out the effect of morpho-physiological parameters of onion genotypes under drought stress. The anova and mean performance of the plant height, root length, no. of leaves, leaf length, leaf breath (cm), bulb length (cm), bulb diameter (cm), leaf area (cm^2), chlorophyll content, dry weight per bulb (g) and yield per bulb (g) are shown in the Table 2 and Table 3.

4.1 Evaluation of performance of onion genotypes

4.1.1 Analysis of variance

The analysis of variance of eight onion genotypes for morphological traits are shown in Table 2. Analysis of variance indicated that the highly significant difference among genotypes for eleven traits under study viz., plant height, root length, no. of leaves, leaf length, leaf breath (cm), bulb length (cm), bulb diameter (cm), leaf area (cm^2), chlorophyll content, dry weight per bulb (g) and yield per bulb (g). This results suggested that the presence of variation among the genotypes for all these traits. Previous studies in onion also found significant variation for these traits (Santra *et al.*, 2017).

4.1.2 Mean 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 eight onion genotypes for their traits are shown in Table 3 under drought tress.

4.1.2.1 Plant height (cm)

Plant height was exhibited the variation with the ranged from 20.29 cm to 49.43 cm with an average of 37.42 cm. The genotype Lal Teer King exhibited the

Table 2. Combined analysis of variance for eleven characters in eight Onion (*Allium cepa* L.) genotypes under drought stress

Source of variances	DF	PH	RL	NL	LL	LB	BL	BD	LA	CC	DWB	YPB
Replication	2	1.28	1.45	0.63	0.55	0.55	3.56	2.52	0.51	0.45	0.48	1.50
Genotypes	7	500.94**	39.86**	32.69**	252.44**	0.60**	9.86**	48.47**	115.75**	345.17**	120.18**	135.71**
Treatment	1	155.70**	1.52*	15.21**	67.26**	0.09*	10.43**	24.83**	152.40**	1469.10**	121.19**	170.71**
Genotype x Treatment	7	4.49*	0.27	1.98**	1.72*	0.04	1.08	0.65	1.48	12.90**	0.71	0.99
Error	30	1.66	0.26	0.21	0.57	0.02	0.19	0.39	0.76	0.48	0.38	0.80

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

PH= Plant height, RL= Root length, NL= No. of leaves, LL= Leaf length, LB = leaf breath (cm), BL= Bulb length (cm), BL= Bulb diameter (cm), LA= Leaf area (cm^2), CL= Chlorophyll content, DWB= Dry weight per bulb (g) and YL= Yield per bulb (g)

Table 3. Mean, standard error and LSD performance of eleven characters in eight Onion genotypes under drought stress

Genotypes	PH	RL	NL	LL	LB	BL	BD	LA	CC	DWB	YPB
G1	26.73d	3.96 f	4.57d	25.54f	1.43 d	4.34d	7.23 d	23.07de	24.24 d	15.68 d	23.66 e
G2	20.28 e	4.84 e	3.65 e	23.65 g	1.07 e	5.65c	6.13 e	19.34 g	15.66 h	13.90 e	21.38 f
G3	39.08 c	4.66 ef	5.23 c	34.78 e	1.67 c	4.43d	6.76 de	22.45 ef	17.34 g	12.49 f	25.08 d
G4	42.67b	8.54 c	7.45 b	35.12 e	2.12 a	6.56b	11.37 c	26.23 c	34.84 a	19.89 b	32.45 b
G5	41.23bc	7.45 d	8.34 a	38.30 c	1.54 cd	5.78c	12.59ab	27.75 b	31.23 c	17.46 c	29.49 c
G6	40.73bc	11.39 a	8.25 a	37.21 d	1.67 c	7.62a	11.39 c	21.57 f	19.45 f	14.86 de	24.06 de
G7	39.21 c	7.12 d	7.23 b	39.68 b	1.96 b	6.24bc	13.45 a	24.24 d	23.17 e	20.80 b	28.20 c
G8	49.43 a	9.81 b	8.63 a	41.23 a	1.90 b	7.32 a	12.27bc	33.09 a	32.81 b	25.09 a	34.50 a
Min	20.29	3.96	3.65	23.65	1.07	4.34	6.13	19.34	15.67	12.49	21.38
Max	49.43	11.39	8.63	41.23	2.12	7.62	13.45	33.09	34.84	25.09	34.50
Mean	37.42	7.22	6.67	34.44	1.67	5.99	10.15	24.72	24.84	17.52	27.35
SE	1.19	0.39	0.26	0.36	0.07	0.33	0.49	0.63	0.46	0.47	0.63
LSD	2.56	0.85	0.56	0.77	0.14	0.70	1.06	1.35	0.99	1.02	1.35

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

PH= Plant height, RL= Root length, NL= No. of leaves, LL= Leaf length, LB = leaf breath (cm), BL= Bulb length (cm), BL= Bulb diameter (cm), LA= Leaf area (cm^2), CL= Chlorophyll content, DWB= Dry weight per bulb (g) and YL= Yield per bulb (g)

highest plant height (49.43 cm) while the shortest plant height was observed by the genotype BARI Piaj 3 (20.29 cm) (Table 3). Azoom *et al.* (2014) reported that the variety 'Morada de Amposta'recorded the highest plant height (76.95 cm). Plant height in onion is a complex character and has several genetically controlled factors (Cheema *et al*., 1987).

4.1.2.2 Root length (cm)

Root length among the genotypes ranged from 3.96 cm to11.39 cm with a mean value of 7.22 cm. Highest root length was observed in genotype Bombay while the lowest in genotype BARI Piaj 1 (Table 3). Azoom *et al.* (2014) reported that the variety 'Morada de Amposta' recorded the highest root length (10.91 cm).

4.1.2.3 No. of leaves

Total no. of leaves were performed with the ranged from 3.85 to 10.933. The average total no. of leaves was 7.715. 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 3 showed lowest number of leaves (Table 3). 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 25.73 cm to 43.93 cm with an average of 36.41 cm. The genotype Laltir King represented the longest leaf. While the shortest leaf length was observed by the genotype BARI Piaj 3 (Table 3). Azoom *et al.* (2014) reported that the variety 'Morada de Amposta' recorded the highest leaf length (68.06 cm)

4.1.2.5 Leaf breadth (cm)

Leaf breath was showed the variation with the ranged from 1.14 cm to 2 cm with an average of 1.72 cm. The genotype Taherpuri 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 3 which was statistically similar with BARI Piaj 1 (1.36 cm) (Table 3).

4.1.2.6 Bulb length (cm)

Bulb length was found the variation with the ranged from 4.93 cm to 8.43 cm with an average of 6.80 cm. The genotype Laltir King showed the highest bulb length which was statistically similar with Faridpuri (7.800 cm), Annex N-53 (8.00 cm), and Bombay (7.96 cm). While the shortest bulb length was observed by the genotype BARI 3 which was followed by BARI 1 (5.16 cm) and BARI 2 (5.37 cm). Photographs showing of all genotypes of Onion plant with bulb studied in this experiment in Plate 10.

4.1.2.7 Bulb diameter (cm)

Bulb diameter was performed the variation with the ranged from 7.937 cm to 14.597 cm with an average of 11.524 cm. The genotype Laltir king represented the highest bulb diameter which was statistically similar with Annex N-53 (14.19 cm), Taherpuri (13.08 cm) and Faridpuri (13.033). While the significant lowest bulb diameter was observed by the genotype BARI piaj-2 (Table 3). Diameter of bulb was ranged from 4.3 cm to 6.7cm reported by Sindhu *et al.* (1986).

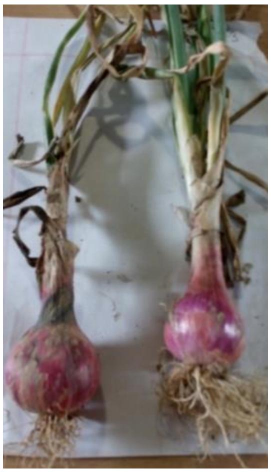
4.1.2.8 Leaf area (cm^2)

Different onion genotypes showed statistically significant differences in terms of leaf area (Table-3). The average leaf area was 24.72 cm^2 with a range from 19.34 cm^2 to 33.09 cm^2. The highest leaf area (33.09 cm^2) was recorded in Lalti king while the lowest leaf area (19.34 cm^2) was observed in the onion genotype BARI piaj 3 (Table 3).

G1=BARI Piaj 1

G3=BARI Piaj 3

G2=BARI Piaj 2



G4=Taherpuri

G5=Foridpuri

G6=Bombay

G7= Annex N-53

G8=Laltir king

Plate 10: Mature onion plant with bulb after drought stress, respectively

4.1.2.9 Chlorophyll content (µmol m^{-2})

Statistically significant variation was recorded for different onion genotypes in terms of chlorophyll content (Table 3). Data revealed that the average chlorophyll content was around 24.34 µmol m^{-2} with a range from 15.67 µmol m^{-2} to 34.84 µmol m^{-2} . The highest chlorophyll content (34.84 µmol m^{-2}) was attained in Taherpuri whereas the lowest chlorophyll content (15.67 µmol m^{-2}) was found in the onion genotype BARI Piaj 3.

4.1.2.10 Dry weight per bulb (g)

The important yield contributing trait dry weight per bulb was ranged from 15.16 g to 29.36 g with a mean value of 21.012 g. The highest and lowest dry weight per bulb was exhibited by the genotypes Laltir king and BARI Piaj 2 respectively (Table 3). 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.

4.1.2.11 Yield per bulb (g)

The most important trait yield per bulb was ranged from 24.40 g to 38.93 g. The average value of yield per bulb was estimated 31.234 g (Table 3). The highest yield per bulb was observed by the genotype Laltir king while genotype BARI Piaj 3 showed the lowest yield per bulb. 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 4.

4.2.1 Variability parameters

A wide range of variation was observed among 8 Onion genotypes for eleven yield contributing traits and yield as well. The perusal of data revealed that variance for all traits was highly significant (Table 2). 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 were supported by Pavlović *et al.* (2003) and Gurjar and Singhania (2006). This was indicated the influences of environmental factor on these traits. Coefficient of variation studied indicated that estimates of phenotypic coefficient of variation (PCV) were higher than the corresponding genotypic coefficient of variation (GCV) for all the traits (Table 4) indicating that they all interacted with the environment to some extent. Among the all traits, high PCV and GCV were found for root length (36.35 and 36.96 respectively) followed by yield per bulb (16.71 and 16.10 %), dry weight per bulb (23.80 and 24.03%), no. of leaves 28.58 and 28.98%), leaf breadth (19.65 and 20.25%), bulb diameter (28.78 and 29.39) and leaf length (18.75 and 18.79) (Table 4). Hossain *et al.* (2008) recorded higher genotypic coefficients of variations in plant height, fresh weight of bulb and bulb length. Santra *et al.* (2017) reported high GCV was recorded for plant height, number of leaves, polar diameter, equatorial diameter, average marketable bulb weight and marketable yield. The high values of GCV and PCV for these traits suggested the possibility of yield improvement through selection of these traits (Table-5).

4.2.2 Heritability

The traits studied in the present investigation expressed high heritability estimates for all studied traits ranging from 89.62 to 99.54 percent (Table 4). 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 leaf length (99.54%) followed by plant height (97.59%), dry weight per bulb (98.09%) and yield per bulb (97.22%) (Table 4). High heritability values indicate

Table 4. Estimation of genotypic and phenotypic coefficient of variation, heritability and genetic advance of eleven characters in eight genotypes of onion under drought stress

Parameters	GCV	PCB	Heritability	Genetic advance	Genetic advance in percentage of mean
PH	24.86	25.17	97.59	18.94	50.60
RL	36.35	36.96	96.73	5.32	73.65
NL	28.58	28.98	97.30	3.87	58.08
LL	18.75	18.79	99.54	13.27	38.53
LB	19.65	20.25	94.21	0.66	39.29
BL	19.69	20.80	89.62	2.30	38.40
BD	28.78	29.39	95.91	5.89	58.06
LA	17.24	17.52	96.81	8.64	34.94
CC	29.51	29.60	99.41	15.06	60.61
DWB	23.80	24.03	98.09	8.51	48.56
YPB	16.71	16.95	97.22	9.28	33.94

PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, ECV = Environmental coefficient of variation 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. Haydar *et al.* (2007) recorded high broad sense heritability for plant height bulb yield and bulb length.

4.2.3 Genetic advance

In the present study genetic advance in percent of mean was highest for plant height (18.94) followed by yield per bulb (9.28), root length (5.32), no. of leaves (3.80), leaf length (13.27), leaf breadth (0.66) and bulb diameter (5.89) and low bulb length (2.30) among yield and yield contributing traits (Table 4). 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.

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).

4.3 Correlation matrix among yield and yield contributing traits

Highly significant positive correlations under drought stress were recorded for plant height with root length (0.695), no. of leaves (0.870), leaf length (0.931), bulb length (0.776), bulb diameter (0.746), leaf area (0.752), chlorophyll content (0.631), dry weight per bulb (0.631) and yield per plant bulb (0.818) (Table 5). The results of correlation coefficients implied that highly significant positive correlations were recorded for root length with no. of leaves (0.859), leaf length (0.701), leaf breadth (0.541), bulb length (0.884), bulb diameter (0.719), leaf area (0.425), chlorophyll content (0.401), dry weight per bulb (0.493) and yield per plant or bulb (0.511) (Table 5). Highly significant positive correlation of no. of leaves with leaf length (.886), bulb length (0.690), bulb diameter (0.903), leaf area (0.674), chlorophyll content (0.643), dry weight per bulb (0.631) and yield per plant or bulb (0.744) (Table 5).

Leaf length was correlated as positively highly significant with leaf breadth (0.727), bulb length (0.565), bulb diameter (0.831), leaf area (0.660), chlorophyll content (0.488), dry weight per bulb (0.613) and yield per plant or bulb (0.7290) (Table 5).was highly significant positive. Highly significant and positive correlation of bulb length with bulb diameter (0.684), dry weight per bulb (0.533) and yield per plant or bulb (0.469) (Table 6). 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 leaf area (0.587), chlorophyll content (0.627), dry weight per bulb (0.701) and yield per plant bulb (0.716) (Table 5). Hossain *et al.* (2008) recorded positive and significant correlation of bulb diameter with weight of bulb. Highly significant and positive correlation of leaf area with chlorophyll content (0.833), dry weight per bulb (0.844) and yield per plant bulb (0.893) (Table 5). Highly significant and positive correlation of chlorophyll content with dry weight per bulb (0.755) and yield per plant bulb (0.886) (Table 5).

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). 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 5. Correlation matrix of different yield contributing characters and yield of onion under drought condition Pearson's correlation coefficients (r) describing association of eleven traits of eight onion genotypes evaluated under drought stress

	PH	RL	NL	LL	LB	BL	BD	LA	CC	DWB
RL	.695**									
NL	.870**	.859**								
LL	.931**	.701**	.886**							
LB	.776**	.541**	.690**	.727**						
BL	.537**	.884**	.723**	.565**	.476*					
BD	.746**	.719**	.903**	.831**	.695**	.684**				
LA	.752**	.425*	.674**	.660**	.508*	0.330	.587**			
CC	.631**	0.404	.643**	.488*	.591**	0.332	.627**	.833**		
DWB	.616**	.493*	.631**	.613**	.603**	.533**	.701**	.844**	.755**	
YPB	.818**	.511*	.744**	.720**	.756**	.469*	.716**	.893**	.886**	.854**

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

PH= Plant height, RL= Root length, NL= No. of leaves, LL= Leaf length, LB = leaf breath (cm), BL= Bulb length (cm), BL= Bulb diameter (cm), LA= Leaf area (cm^2), CL= Chlorophyll content, DWB= Dry weight per bulb (g) and YL= Yield per bulb (g)

4.4 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 6.

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 6. 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								
	PH	**RL**	**NL**	**LL**	**LB**	**BL**	**BD**	**DW**	**Genotypic correlation with yield per bulb**
PH	**5.058**	0.191	0.994	-4.907	-0.674	-0.065	-0.167	0.28	0.703**
RL	3.667	**0.263**	0.640	-3.392	-0.859	-0.061	0.017	0.10	0.370*
NL	4.451	0.149	**1.129**	-4.338	-0.491	-0.067	-0.321	0.40	0.906**
LL	5.012	0.180	0.989	**-4.952**	-0.601	-0.061	-0.173	0.28	0.674**
LB	3.434	0.227	0.558	-2.996	**-0.993**	-0.055	0.044	0.04	0.261
BL	4.421	0.217	1.017	-4.085	-0.733	**-0.074**	-0.231	0.34	0.869**
BD	2.074	-0.011	0.887	-2.100	0.106	-0.042	**-0.408**	0.42	0.931**
DW	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%.

PH= Plant height, RL= Root length, NL= No. of leaves, LL= Leaf length, LB = leaf breath (cm), BL= Bulb length (cm), BL= Bulb diameter (cm), DWB= Dry weight per bulb (g) and YL= Yield per bulb (g)

4.5 Principal Component Analysis (PCA)

The rotated component matrix (Table 7) shows the proportion of total variance explained by different principal components and their correlations with variable traits. From the stress treatment, two principal components were important, contributing 0.7258% of the total variation observed. The two principal components were the most influential with a cumulative contribution to the total variation of 0.6256 %. (Table 7). Variables LA, CC, DWB and YPB had high positive loading into the first principle component while RL, LL, NL, BL and BD had high positive loading into the second principal component. Scree plot showing the contribution of the component and eigen value (Figure 1).

Table 7: Principle component rotated matrix of nine phenotypic traits and two physiological traits (leaf area, chlorophyll content) content of eight onion genotypes evaluated under drought stressed

Parameters	**PC1**	**PC2**
PH	0.421	0.430
RL	0.036	0.897
NL	0.273	0.668
LL	0.286	0.536
LB	0.430	0.244
BL	0.020	0.811
BD	0.293	0.543
LA	0.826	0.065
CC	0.808	0.034
DWB	0.665	0.126
YPB	0.851	0.121
Eigen Value	7.984	1.401
Variability	72.58	12.737
Cumulative variance %	62.564	55.32

PH= Plant height, RL= Root length, NL= No. of leaves, LL= Leaf length, LB = leaf breath (cm), BL= Bulb length (cm), BL= Bulb diameter (cm), LA= Leaf area (cm^2), CL= Chlorophyll content, DWB= Dry weight per bulb (g) and YL= Yield per bulb (g)

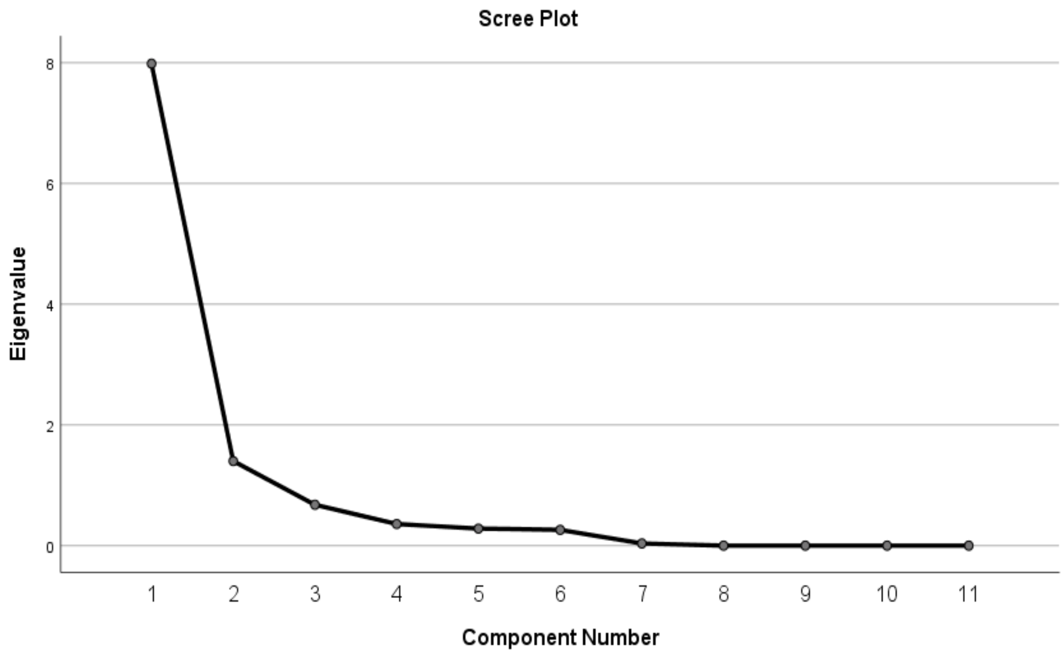


Figure 1: Scree plot showing the contribution of the component and Eigen value. 1. PH= Plant height, 2. RL= Root length, 3. NL= No. of leaves, 4. LL= Leaf length, 5. LB = leaf breath (cm), 6. BL= Bulb length (cm), 7. BL= Bulb diameter (cm), 8. LA= Leaf area (cm^2), 9. CL= Chlorophyll content, 10. DWB= Dry weight per bulb (g) 11. YL= Yield per bulb (g)

4.6 Principal Component Biplot Analysis

The relationships between the different variables and genotypes with respective principal components are further illustrated by the principal component biplots in Figure 2 for the stressed conditions, respectively. Smaller angles between dimension vectors in the same direction indicated high correlation of the variable traits in terms of discriminating genotypes. Genotypes excelling in a particular trait were plotted closer to the vector line and further in the direction of that particular vector, often on the vertices of the convex hull. Under drought stress, most of the genotypes were scattered in the positive side of the first principal component, with genotypes such as BARI Piaj 1, BARI Piaj 2, BARI Piaj 3, Taherpuri, Faridpuri, Bombay, Annex N-53 and laltir king excelling in yield which was contributed most of the characters. In the relationship between PC1 and PC2, the genotypes were also more concentrated on the positive side of the 2nd principal component with other components. Under combination of PC1 and PC2 most of the traits were scattered in the positive side of the principal component, it indicates that all the traits more or less influences the bulb yield (Figure 2).

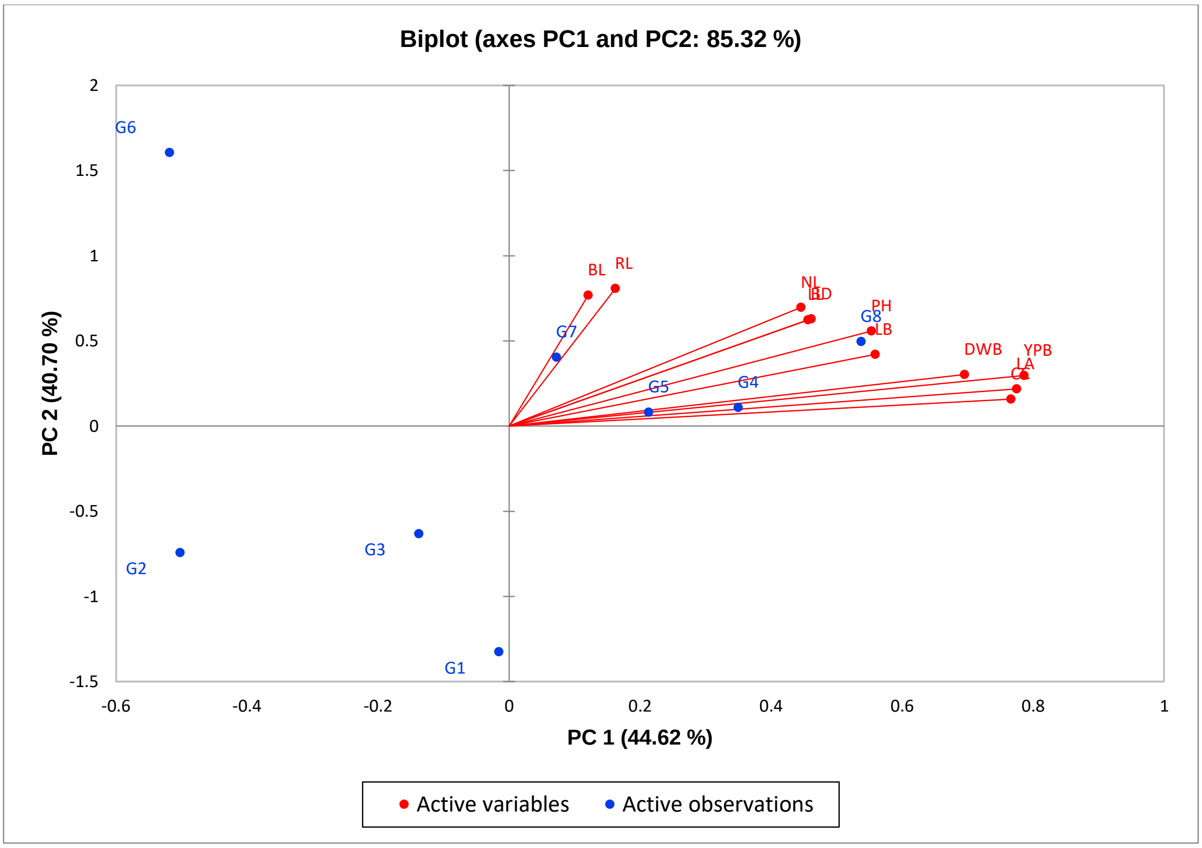


Figure 2. Biplot graph showing PC1 and PC2. PH= Plant height, RL= Root length, NL= No. of leaves, LL= Leaf length, LB = leaf breath (cm), BL= Bulb length (cm), BL= Bulb diameter (cm), LA= Leaf area (cm^2), CL= Chlorophyll content, DWB= Dry weight per bulb (g) and YL= Yield per bulb (g)

CHAPTER V
SUMMARY AND CONCLUSION

The present piece of research work was conducted in the net house of Genetics and Plant Breeding of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to find out the effect of morpho-physiological parameters of 8 Onion genotypes under drought stress during the period from July 2021 to June 2022 in rabi season. In this experiment eight onion genotypes were used as experimental materials. The experiment was laid out in complete randomized design (CRD) with three replications. 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), leaf area, Chlorophyll content, dry weight per bulb (g) and yield per bulb (g).

The genotype Lal Teer King (49.43 cm) represented the highest plant height while the shortest plant height was observed by the genotype BARI Piaj 3 (20.29 cm). Highest root length was observed in genotype Bombay (11.39 cm) while the lowest in genotype BARI Piaj 1 (3.96 cm). Genotype Laltir King (10.933) 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 3 showed lowest number of leaves. The genotype Laltir King (43.93 cm) represented the longest leaf. While the shortest leaf length was observed by the genotype BARI Piaj 3 (25.74). The genotype Taherpuri (2) 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 3 (4.93) which was statistically similar with BARI Piaj 1. The highest leaf area (33.09 cm^2) was recorded in Lalti king while the lowest leaf area (19.34 cm^2) was observed in the onion genotype BARI piaj 3. The highest chlorophyll content (34.84 µmol m^{-2}) was attained in Taherpuri whereas the lowest chlorophyll content (15.67 µmol m^{-2}) was found in the onion genotype BARI

Piaj 3. The highest and lowest dry weight per bulb was exhibited by the genotypes Laltir king (29.36 g) and BARI Piaj 2 (15.16 g) respectively. The highest yield per bulb was observed by the genotype Laltir king (38.93 g) while genotype BARI Piaj 3 (15.16) showed the lowest yield per bulb.

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. Phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the yield contributing traits indicating influences of drought stress. In person's correlation study, yield per bulb positively and significantly correlated with plant height (0.818), root length (0.511), no. of leaves (0.744), leaf length (0.720), leaf breadth (0.756), bulb length (0.469), bulb diameter (0.716), leaf area (0.893), chlorophyll content (0886) and dry weight per bulb (0.854).

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.

In consideration of yield contributing characters and yield and other genetic analysis Laltir King performed better under drought condition followed by BARI Piaj 1, BARI Piaj 2, BARI Piaj 3, Taherpuri, Faridpuri, Bombay and Annex N-53. Another two varieties named Taherpuri and Foridpuri had been producing for many years by the farmers of Bangladesh in many districts. So, these were suggested to produce by the farmers. Even these varieties seed was 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.

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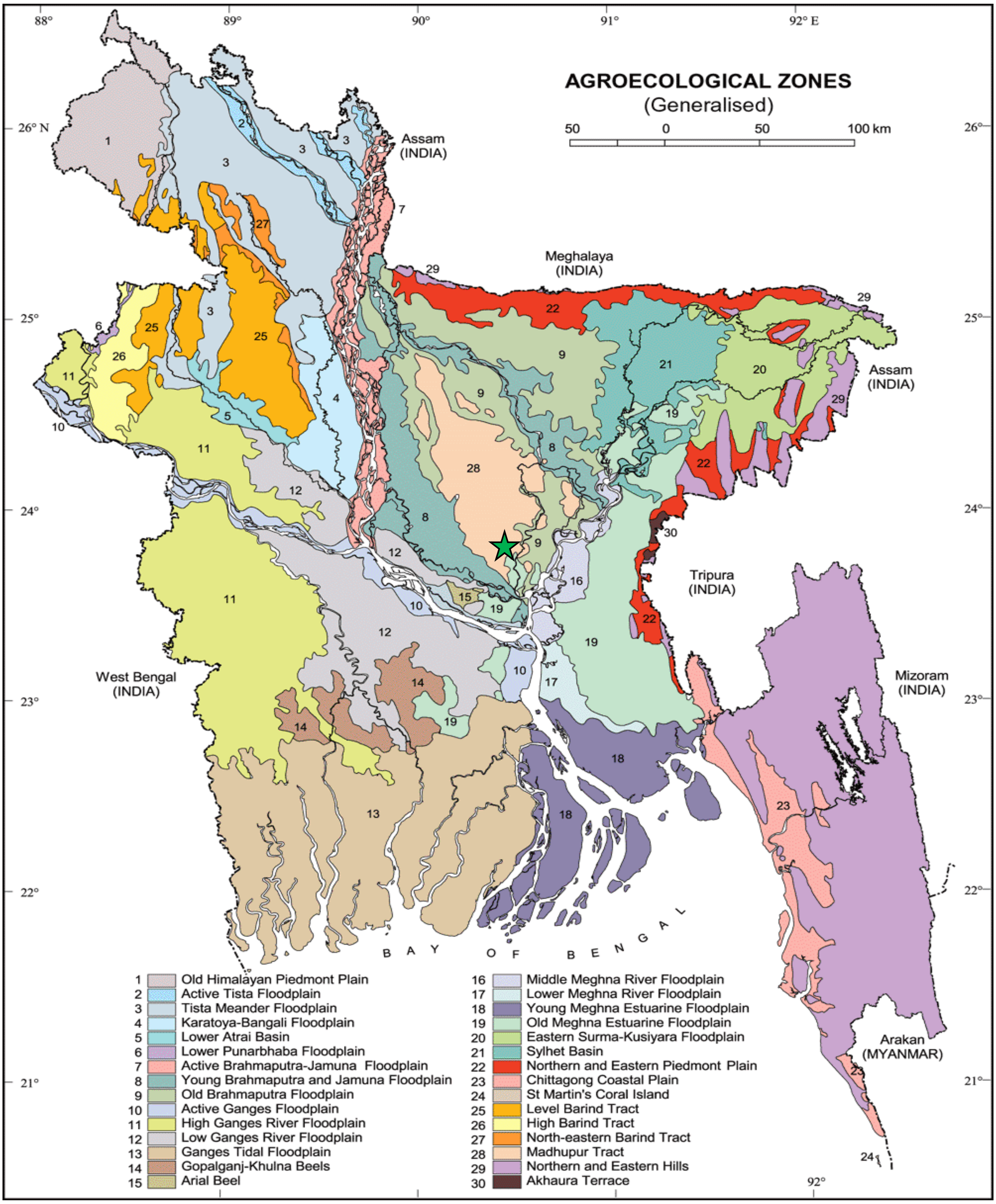
APPENDICES

Appendix I. Map showing the experimental site under the study



The experimental site under the study

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

A. Physical composition of the soil

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

B. Chemical composition of the soil

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

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

Appendix III. Monthly average temperature, relative humidity and total 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