

**IMPACT OF ORGANIC MANURE TO COMBAT  
DROUGHT STRESS OF WHEAT**

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**IMPACT OF ORGANIC MANURE TO COMBAT  
DROUGHT STRESS OF WHEAT**

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**CERTIFICATE**

This is to certify that the thesis entitled “**IMPACT OF ORGANIC MANURE TO COMBAT DROUGHT STRESS OF WHEAT**” submitted to the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in AGRONOMY**, embodies the results of a piece of bona fide research work carried out by **MEHEDI HASSAN**, Registration No. **17-08273**, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

I further certify that any help or sources of information received during the course of this investigation have duly been acknowledged.

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## *Dedication*

*Every challenging work needs self-efforts as well as guidance of elders especially those who were very close to our heart.*

*My humble effort I dedicate to my sweet and loving*

*Father*

*Md. Delower Hossain*

*&*

*Mother*

*Rehana Parvin.*

*Whose affection, love, encouragement and prays of day and night make me able to get such success and honor.*

*Along with all hard working and respected*

*Teachers.*

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***The Author***

# IMPACT OF ORGANIC MANURE TO COMBAT DROUGHT STRESS OF WHEAT

## ABSTRACT

A pot experiment was conducted at the net house of Sher-e-Bangla Agricultural University, Dhaka-1207 during the rabi season of the year 2017-18 to evaluate the impact of organic manure to combat drought stress of wheat. The 3×4 factorial experiment was laid out in a Completely Randomized Design (CRD) with three replications. Factor A: Different organic manure [ $F_0$  = Control,  $F_1$  = Cowdung 10 t ha<sup>-1</sup>,  $F_2$  = Vermicompost 7 t ha<sup>-1</sup>] and Factor B: Drought in different growth stages [ $D_0$  = Control,  $D_1$  = Drought in crown root initiation stage (20-29 DAS),  $D_2$  = Drought in booting stage (45-54 DAS),  $D_3$  = Drought in anthesis stage (55-64 DAS)]. BARI Gom-28 was used as test crop. Significant variation was observed on growth, yield and yield contributing parameters. In the case of organic manure, the tallest plant (24.84, 35.77, 56.60 and 78.42 cm, respectively) at 20, 40, 60 DAS and at harvest; highest number of effective tillers plant<sup>-1</sup> (8.33), spike length (14.61 cm), number of spikelet spike<sup>-1</sup> (16.33), number of grains spikelet<sup>-1</sup> (7.67), number of grains spike<sup>-1</sup> (37.00), weight of 1000 seed grain (44.93 g), grain yield (4.39 g plant<sup>-1</sup>), straw yield (4.69 g plant<sup>-1</sup>), biological yield (9.08 g plant<sup>-1</sup>) and harvest index (48.35%) were recorded from  $F_1$ . In the case of drought stress, the tallest plant (23.31, 34.97, 53.72 and 75.07 cm, respectively) at 20, 40, 60 DAS and at harvest; highest number of effective tillers plant<sup>-1</sup> (9.67), spike length (15.22 cm), number of spikelet spike<sup>-1</sup> (17.67), number of grains spikelet<sup>-1</sup> (8.33), number of grains spike<sup>-1</sup> (39.00), weight of 1000 seed grain (45.14 g), grain yield (4.72 g plant<sup>-1</sup>), straw yield (5.05 g plant<sup>-1</sup>), biological yield (9.77 g plant<sup>-1</sup>) and harvest index (48.31%) were recorded from  $D_0$  which was followed by  $D_2$ . In the case of interaction, the maximum plant height (27.66, 48.10, 63.15 and 78.56 cm, respectively) at 20, 40, 60 DAS and at harvest; highest number of effective tillers plant<sup>-1</sup> (10.33), spike length (16.12 cm), number of spikelet spike<sup>-1</sup> (18.00), number of grains spikelet<sup>-1</sup> (9.67), number of grains spike<sup>-1</sup> (40.00), weight of 1000 seed grain (48.37 g), grain yield (4.89 g plant<sup>-1</sup>), straw yield (5.18 g plant<sup>-1</sup>), biological yield (10.07 g plant<sup>-1</sup>) and harvest index (48.56%) were recorded from  $F_1D_0$ . It can be concluded that cowdung may be suggested to apply in drought condition.

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## LIST OF ABBREVIATIONS

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%	Percent
@	At the rate of
<sup>o</sup> C	Degree Celsius
AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
CRD	Completely Randomized Design
CV (%)	Percentage of Coefficient of Variation
e.g.	As for example
<i>et al.</i>	and others
i.e.	that is
kg ha <sup>-1</sup>	kg per hectare
LSD	Least Significant Difference
g	Gram
cm	Centimeter
SAU	Sher-e-Bangla Agricultural University
SAURES	Sher-e-Bangla Agricultural University Research System

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## CHAPTER 1 INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the important cereal crop in the world under the Poaceae family and the main sources of carbohydrate contains a considerable amount of protein, minerals and vitamins. It occupies global rank one in aspect of worldwide production and consumption. It supplies nearly 55% of the carbohydrates and 20% of the food calories consumed as human diet globally and the staple food of more than 36% of world population (Hasanuzzaman *et al.*, 2017).

On a worldwide scale, wheat contributes approximately 30% of total cereal production (Lobell and Gourdjji, 2012). Food and Agriculture Organization (FAO) of the United Nations has estimated 739.9 million tons of wheat production in 2017; again, the total wheat production was 749 million tons worldwide in 2016, which made it the second most produced cereal after maize (1.03 billion tons) (FAOStat, 2016).

In Bangladesh it is the second most significant grain crop after the staple grain rice. The national wheat production during the year 2016-2017 was 1.422 million metric tons from 0.429 million hectares of cultivated land with an average 3.32 metric t/ha while in 2015-2016 it was 1.348 million metric tons from 0.445 million hectares of cultivated land with an average 3.03 metric t/ha (DAE, 2018). However, the wheat yield of Bangladesh is much lower comparing to other wheat producing countries in the world due to the fact of growing wheat under rain fed condition (Bazzaz, 2013).

The main reason for the decline in wheat area is weather, which in recent years has been blamed for low yields. If low temperatures are prolonged in the winter season, the yield of wheat is increased. If winter is short the yield declines due to the temperature sensitivity of this crop. The food productivity is seriously hampered due to the effect of various abiotic and biotic stresses. Among various abiotic stresses, drought stress encompass a significant position due to its nature of destruction and losses to crops. Wheat crop is sensitive to heat and drought stresses mainly at the flowering and grain development stages, which negatively impact the yield and grain quality. Annual production variability estimated at ~40% was mainly due to heat waves and drought situations in major wheat producing belts throughout the world (Zampieri *et al.*, 2017). Drastic climate changes and increased water scarcity is a challenge global food security, which is further exacerbated due to the need to feed a growing global population (Lesk *et al.*, 2016). A reviewed estimate states that global agricultural production might need to increase by 60-110% to meet the increasing demands (Tilman *et al.*, 2011) as well

as to provide food security to the predicted 870 million people who will be chronically undernourished by 2050 (McGuire, 2012). Crop yield is affected by agronomic factors and various environmental variables such as water availability and temperature (Hatfield and Prueger, 2015). There is extensive crop yield variability in many semi-arid regions, which are owed to water limitation and year-to-year fluctuations in meteorological conditions. Although an increase in temperature is beneficial for crop productivity in some cooler regions of the world, drought still significantly reduces national cereal production by 9-10% on a global scale via negative effects on plant growth, physiology, and grain development (Farooq *et al.*, 2014). Caused by reduced precipitation and increased temperature, drought has been the most important limiting factor for crop productivity and, ultimately, for food security worldwide (Daryanto *et al.*, 2017).

Drought stress is one of the major abiotic stresses, which adversely affects crop growth and yield. Drought is the most common environmental stress affecting about 32% of the 99 million hectares under wheat cultivation in developing countries and at least 60 million hectares under wheat cultivation in developed countries (Rajaram, 2000). Drought stress reduces plant growth by affecting various physiological and biochemical processes, such as photosynthesis, transpiration, translocation, and ion uptake, carbohydrate nutrient metabolism and growth promoters. It affects both elongation and expansion growth which ultimately affects the yield of plants (Farooq *et al.*, 2009). Understanding of plant responses to drought stress is of great importance and a fundamental part for making the crops tolerant to stress conditions (Zhao *et al.*, 2008). Drought stress affect crops at all growth stages induced reducing grain yield and yield components. Drought stress at stages of stem elongation, flowering and grain filling stages induced 32%, 32% and 35% reduce in grain yield, respectively (Mirzaei *et al.*, 2011).

Incorporation of soil amendments (cowdung, vermicompost, compost, biochar, poultry litter etc.) enhanced soil water holding capacity, soil water permeability, saturated hydraulic conductivity (SHC), reduced soil strength, modification in soil bulk density and modified aggregate stability (Peng *et al.*, 2011). Soil amendments increases adsorption properties allowing a greater retention of water and nutrients in the soil solution. The ability to retain a relatively large quantity of water aids plant growth when under water stress. The grain yield and yield components of wheat significantly increased with the application of different organic materials resulting in the compost to be the most superior one (Sarwar *et al.*, 2007).



Irrigating the crop at 60% water holding capacity and applying mineral nitrogen 60 kg/fed, with presence of the chicken manure as an organic fertilizer produced the highest wheat yield through two growth seasons (Yassen *et al.*, 2006). Organic soil amendments (cowdung, compost, vermicompost etc.) could be an important tool to increase food security and cropland diversity in areas with severely depleted soils, scarce organic resources, and drought prone areas.

Considering the above facts the present study was undertaken with the following objectives:

- To investigate the effect of organic manures on the growth, yield and yield contributing characters of wheat under drought stress condition,
- To examine the effect of organic manures to mitigate the drought stress in wheat, and
- To identify the superior organic manure to mitigate the drought stress in wheat.

## CHAPTER II

### REVIEW OF LITERATURE

The growth and yield of wheat is very closely related to the availability of water at different growth stages. Time of water supply or irrigation frequencies at different growth stages is a crucial factor for successful wheat production. Water scarcity or drought hamper wheat production in many ways. A number of mitigation approaches have been tried to control drought in wheat. Limited research works are available on mitigation of drought in wheat in Bangladesh. Some of the relevant findings of the research with effect of organic manures on reduction of drought in wheat are reviewed in this chapter.

#### **2.1 Effect of drought**

Kumar *et al.* (2014) stated that under drought condition, contribution of dry matter partitioning from stem and leaf increased significantly under drought condition compared to well watered condition, thereby affecting crop yield.

Comas *et al.* (2013) stated that drought is an edaphic stress which is considered as the most pernicious form of abiotic stress and may limit more than 50% of world agricultural productivity by considerable reduction of plant growth and shoot production. Drought cumulatively effects on all plant tissues through impairing the agronomic, morphological, physiological, biochemical and metabolic traits and eventually decreases the yield attributes.

Hasanuzzaman *et al.* (2013) reported that under drought condition cell division reduces thus the growth of plant also reduces.

Abdoli *et al.* (2013) reported that drought stress decreases root length, relative water content, total chlorophyll content and photosynthesis rate.

Schneekloth *et al.* (2012) reported that drought condition at tillering stage of wheat decreased yield loss up to 46%. Drought stress during booting stage of wheat reduces up to 21% yield loss.

Kamoshita *et al.* (2004) reported that drought stress during vegetative growth, flowering and terminal period of rice cultivation, can interrupt floret initiation (which

cause spikelet sterility) and grain filling, respectively. On the other hand, it has been proposed that grain filling is closely linked to the whole-plant senescence process.

Sokoto and Muhammad (2014) conducted a dry season pot experiment indicated that drought stress had no significant effect on plant height at 3 weeks after planting (WAP). But at tillering resulted to significant reduction in plant height at 6, 9, 12 and 15 WAP. Control (unstressed) was statistically similar with drought stress at flowering and grain filling. The reduction in plant height was as a result of drought stress imposed at tillering stage. This was because imposing drought stress resulted in low leaf water potentials and reductions in photosynthesis; photosynthetic activity declines because of decreased stomatal opening and the inhibition of chloroplast activity; this reduced the length of the internodes at jointing stage which follows tillering stage. At the time when drought stress was imposed at flowering and grain filling, the jointing stage had taken place and plants had reached their maximum height, thus the effect of drought stress was ineffective.

Shahbaz *et al.* (2011) stated that drought hampers critical physiological as well as biochemical mechanisms in plant, which ultimately reduces crop yield.

Pirdashti *et al.* (2009) reported that decreases in chlorophyll content and the maximum quantum yield of PSII ( $F_v/F_m$ ) on drought stressed rice. This reduction in chlorophyll content may occur due to stress-induced impairment in pigment biosynthetic pathways or in pigment degradation, loss of the chloroplast membrane, and increased lipid per oxidation.

Kato and Okami (2011) stated that the reduction in leaf water potential adversely affects the reproductive growth and canopy expansion, leading to significant yield loss.

Anjum *et al.* (2011) reported that drought adversely affects plant physiological performance through reduction in gas exchange in particular stomatal conductance, photosynthetic pigments and overall crop water relations. Regardless of varieties, chlorophyll content, photochemical efficiency ( $F_v/F_m$ ) and leaf relative water content are also affected when drought occurs at the vegetative, flowering or grain-filling stages.

Sikuku *et al.* (2010) reported that panicle length was affected by water deficit as NERICA 4 had the most pronounced reduction in panicle length at the highest water deficit compared to control. They also reported that protein content decreased under

drought stress conditions in rice genotypes due to the disturbed protein synthesis system. They also found that drought stress affects the days to maturity and grain yield by decreasing tiller number, panicle length and field grain percentage of rice varieties.

Zhao *et al.* (2010) observed reduced grain yield by 60%, harvest index by 50%, plant height by 12 cm and delayed flowering by 3 days under drought stress in rice.

Majeed *et al.* (2011) reported that drought stress induced significant decrease in endogenous level of sugar in leaves at soft dough stage; whereas in grains, drought stress induced decreases in sugar in both cultivars.

Kamoshita *et al.* (2004) stated that rice genotypes with greater plant height are often larger in overall plant size, intercept more light and use water faster by transpiration, leading to lower plant water status.

Das and kalita (2010) conducted an experiment with five rice cultivars. They found that seedling length and vigor index decreased with increasing drought stress.

Lafitte *et al.* (2003) observed that delay usually occurs in flowering date, when rice experiences a drought deficit before flowering.

Pirdasthi *et al.* (2003) revealed that plant height increased at vegetative stage under aerobic as compared to flooded but at flowering stage the plant height decreased under water deficit condition as compared to flooded condition. They also observed that seedling growth decreased in rice genotypes with increasing drought stress.

Guan *et al.* (2010) documented that biomass production (plant height and number of tillers per plant) is more affected under vegetative stage stress whereas severe effects on sink size (spikelet fertility, 1000-grain weight and seed yield) under reproductive stage stress would be resulted.

Reynolds and Tuberosa (2008) reported that most of the high yielding popular rice varieties endowed with high yield potential and good grain quality suffers from poor adaptability to drought stress, causing substantial yield losses during years of drought. Water uptake (WU), water-use efficiency (WUE), and harvest index (HI) were considered as drivers of grain yield.

Centritto *et al.* (2009) reported that drought deficit affects rice physiology in countless ways like it affects plant net photosynthesis, transpiration rate, stomatal conductance, water use efficiency, intercellular CO<sub>2</sub>, photosystem II (PSII) activity, relative water

content and membrane stability index. All these parameters reduce under drought in rice.

Haq *et al.* (2010) stated that germination and seedling growth phase is of prime importance in the growth cycle of plants as it determines the successful establishment and final yield of the crop.

Saragih *et al.* (2013) reported that drought stress at the early reproductive stage greatly affects the grain yield of rice. The variation in rice yield component is associated with variability in water availability at different growth stages.

Demirevska *et al.* (2010) reported that drought drastically reduces the leaf respiration and stomatal conductance, photosynthetic efficiency, carboxylation and water-use efficiency (WUE), carbon dioxide (CO<sub>2</sub>) diffusion and transpiration rate, enzymatic activities etc.

Shi *et al.* (2010) reported that generally the growing period of wheat is divided under: vegetative and reproductive stages which are affected by drought stress. Germination is the first step of plant establishment but drought reduces the germination percentage and results poor seedling establishment.

Watanabe *et al.* (2000) observed that drought stress generally accelerates senescence and reduces photosynthesis in susceptible varieties while water balance was maintained under tolerant varieties and keeps pace with photosynthetic activity and carbohydrate metabolism. The increases in the concentration of soluble carbohydrates in three rice cultivars leaves were founded to be remarkable during drought stress.

Kumar and Kujur (2003) reported that the period of delay is partly related to extent of stress, the rice genotypes experienced and those with longer delay will tend to produce less grain.

Keyvan (2010) stated that a reduction of wheat grain yield up to 25% and 46% respectively, if water deficit occur after anthesis period and stem elongation stage.

Taiz and Zeiger (2010) reported that early season drought severely reduces germination and stand establishment principally due to reduced water uptake during the imbibition phase of germination, reduced energy supply, and impaired enzyme activities.

Busso and Fernandez (1998) reported that the radical growth of rice was decreased under drought condition.

Mostajeran and Eichi (2009) observed a decline of total, reducing and non-reducing sugar in rice seedling under drought stress. The decrease was relatively more in susceptible varieties compared to the tolerant.

Cheng and Kato (2010) found a decrease in protein content and yield of rice under drought stress condition and PEG (6000) treatment also resulted in chlorophyll loss and protein degradation in detached rice leaves. Drought induced significant decrease in endogenous level of protein contents in leaves at soft dough stage.

Borrell (1991) compared different irrigation regimes in dry seeded rice production in Australia. Flooding irrigation from sowing to maturity gave the highest grain yield, and intermittent irrigation had lowest grain yield.

Jha and Singh (1997) studied in eight rice genotypes of their response towards simulated drought stress. It was observed that seedling growth decreased with increasing drought stress. They also observed that total sugar, reducing and non-reducing sugar decreased whereas starch and phenol contents increased in eight rice genotypes with increasing drought stress.

Serraj *et al.* (2009) stated that drought is the major environmental constraints to what productivity in rain fed areas. At all stages of growth and development, drought is the major stress, but it has the greatest impact during flowering, where grain formation is suppressed. This results in considerable yield losses for rain fed ecosystems. Wheat sensitivity to drought stress is more pronounced during reproductive stage; even moderate stress can result in drastic reduction in grain yield.

Farooq *et al.* (2009) stated that a common adverse effect is the reduction in biomass production. Many studies indicate significant decrease in fresh and dry weights of shoots and roots under drought stress. Reduced fresh shoot and root weights as well as their lengths ultimately reduce the photosynthetic rate of physiology and biochemical processes of plants.

Farooq *et al.* (2009) reported that both cell division and cell enlargement are affected under drought owing to impaired enzyme activities, loss of turgor, and decreased energy supply.

Biswas and Choudhuri (1984) reported that the decrease in plant height might be due to sensitivity of reproductive phase to water status.

Renmin and Yuanshu (1989) reported that when the soil drought content lowers, the milled rice recovery and the brown rice protein content are both significantly raised, but the percentage of unripened grain is decreased, meanwhile the amylose content in milled rice is decreased.

Jaleel *et al.* (2009) reported that drought causes many changes related to altered metabolic functions, and one of those is either loss of or reduced the synthesis of photosynthetic pigments. This results in declined light harvesting and generation of reducing powers, which are a source of energy for dark reactions of photosynthesis. These changes in the amounts of photosynthetic pigments are closely associated to plant biomass and yield.

Rawgamannar *et al.* (1978) reported that continuous irrigation in 5 cm depth gave higher grain yield than continuously saturated irrigation.

Hsiao (1982) reported that rice is particularly sensitive to drought stress during reproductive growth, even under moderate drought stress. In rice, moderate stress can be broadly characterized by a 31 to 64% loss in grain yield as compared with non-stress conditions.

Kakade and Soner (1983) observed that continuous submergence and submergence up to flowering significantly increased the rice grain yield over alternate submergence and drying, and upland conditions. Submergence up to flowering significantly increased rice straw yields over alternate submergence and drying, and upland condition treatment.

Hussain *et al.* (2009) stated that drought decreases growth and productivity owing to reductions in leaf water potential, rate of cell division, and enlargement primarily due to loss of turgor.

Jaleel *et al.* (2008a) stated that severe drought may result in the arrest of photosynthesis, disturbance in metabolism and finally the death of plant. It reduces plant growth by affecting various physiological and biochemical processes, such as photosynthesis, respiration, translocation, ion uptake, carbohydrates and nutrient metabolism and growth promoters.

Alvarez (1973) compared 4, 6, and 8 mm seven-day rotational irrigation treatment with 12.5 mm/day continuous flooding irrigation. The continuous flooding irrigation had higher yield than rotational irrigation treatments.

NeSmith and Ritchie (1973) reported that rice root porosity, number of roots, and root dry weight are low under severe stress. Transpiration of root plants began to decrease when 25% of the total extractable water was left in the root zone.

Raju (1980) observed that the flooded irrigation in reproductive stage and saturated at vegetative stage treatment had higher harvest index than flooded at vegetative stage and saturated at reproductive stage. On the other hand, continuous irrigation in 5-cm depth gave the highest grain yield, however it had the lowest harvest index.

Jaleel *et al.* (2008b) reported that drought is a limiting factor in agriculture production by preventing a crop from reaching the genetically determined theoretical maximum yield. In plants, a better understanding of the morphological and physiological basis of changes in water stress resistance could be used to select or create new varieties of crops to obtain a better productivity under drought conditions.

Clark *et al.* (2008) stated that drought hinders root branching. Under limited water supply, reduction in leaf size and leaf pubescence as well as a change in shape and leaf yellowing is observed. Furthermore, the development of new leaves and new tillers and stem expansion is slow during drought. Severe drought ends in leaf drying and finally plant death. Moreover, drought is accompanied by reduction in biomass production. All these modifications in normal status of the different tissues and organs impair with photosynthetic rate and other biochemical processes. The reduction in photosynthetic rate is due to stomatal closure that limits the diffusion of CO<sub>2</sub>, which leads to reduction of photosynthetic enzyme activity, and loss or diminution of photosynthetic pigments such as chlorophyll a and b and carotenoids resulting from the impairment in their synthesis or their post synthesis degradation. Reduction of photosynthetic rate might also be caused by the loss of the chloroplast membrane.

Shao *et al.* (2008) stated that drought affects both elongation as well as expansion growth, and inhibits cell enlargement more than cell division. It impairs the germination of seedlings and reduces number of tillers and plant height.

Beltrano and Marta (2008) stated that drought is a polygenic stress and is considered as one of the most important factors limiting crop yields around the world. As climate



change leads to increasingly hotter and drier summers, the importance of drought constraints on yield and yield components has increased.

Sarvestani *et al.* (2008) reported that drought at flowering stage had a greater grain yield reduction than drought at other times. The reduction of grain yield largely resulted from the reduction in fertile panicle and filled grain percentage. Water deficit during vegetative, flowering and grain filling stages reduced mean grain yield by 21, 50 and 21% on average in comparison to control respectively. The yield advantage of two semi-dwarf varieties; Fajr and Nemat, were not maintained under drought stress.

Wang *et al.* (2007) stated that global climatic changes such as dry spell, heat waves and uneven precipitation patterns limit water availability for farming. However, factors such as timing, intensity and duration of stress have detrimental effect on plant growth. Water is needed at every phase of plant growth from seed germination to plant maturation and any degree of imbalance in the uptake would pose a serious threat to agriculture by adversely affecting the growth and grain yield.

Jaleel *et al.* (2007) reported that drought is characterized by reduction of water content diminished leaf water potential, turgor pressure, stomata activity and decrease in cell enlargement and growth.

Zubaer *et al.* (2007) evaluated effect of drought at different growth stages of different three rice genotypes at three water levels (100%, 70% and 40% Field Capacity). Plant height, numbers of tillers/hill, no. of filled grains /panicle, total dry matter/hill, 1000 grain weight, grain yield and harvest index decreased with increasing drought levels. They also conducted a pot experiment and found that at booting (106.8), flowering (85) and maturity (58.11) stage, the highest number of leaves was found in 100% FC. The number decreased gradually with increasing soil drought stress and 40% FC produced the lowest number of leaves per hill in all growing stages. They carried out a pot experiment to evaluate the performance of the genotypes under varying drought stress. Results showed that the 1000 grain weight was reduced with reduced soil drought levels. It was anticipated that the lower soil drought might had decreased translocation of assimilates to the grain which lowered grain size. But the degree of reduction in 1000 grain size weight was different in different genotypes. Percent reduction was lower in BINA Dhan 4 (4.14 to 6.37%) than in Basmati (6.75 to 12.5%) and RD 2585 (4.57 to 14.64%).

Sarvestani and Pirdashti (2008) evaluated the effect of drought stress on the yield and yield component of four rice cultivars. The different drought stress conditions were drought stress during vegetative, flowering and grain filling stages. Drought stress at vegetative stage significantly reduced plant height of all cultivars. Drought stress at flowering stage had a greater grain yield reduction than drought stress at other times. The reduction of grain yield largely resulted by the reduction in fertile panicle and filled grain percentage. Total biomass, harvest index, plant height, filled grains unfilled grains and 1000 grain weight were reduced under drought stress in all the cultivars. Drought stress at vegetative stage effectively reduced total biomass due to decrease of photosynthesis rate and dry matter accumulation.

Kulkarni and Deshpande (2007) stated that drought stress inhibits root and shoot growth, increases transpiration rate and reduces CO<sub>2</sub> uptake during photosynthesis. Water shortage at crown root initiation stage of wheat causes 27% yield loss. Crop yield is reduced by 70-80% due to a drought spell during the reproductive stage. Spikelet of wheat became sterile due to water deficit at reproductive stage.

Tahi *et al.* (2007) reported that plants experienced drought usually show decreased growth and development, low leaf water and turgor potentials and transpiration rates.

Sharma and Dubey (2005) observed a concomitant decrease in the content of total soluble protein with an increasing level of water deficit in root as well as shoots of growing rice seedling.

Singh (2006) reported that the productivity in rain fed uplands is poor (0.8 to 1.2 t/ha) mainly because of erratic rainfall and drought stress at flowering stage.

Hansen and Jones (2006) reported that drought increases the formation of reactive oxygen species (ROS) resulting in lipid per oxidation, protein denaturation and nucleic acid damage with severe consequences on overall metabolism.

Liu *et al.* (2006) stated that mild drought during grain filling in rice resulted in yield decreases of 11.6% to 14.7% while severe drought at panicle initiation, flowering and grain filling resulted in losses of up to 70%, 88% and 52% respectively. Reductions of 22% for the number of spikelet per panicle and 15% for 1000-grain weight were observed when moisture stress was applied at 7 days before heading and 10 days after heading. They also stated that decreasing water supply affects physiological, morphological and biochemical processes in plants and if that water stress occurs in

critical phase of plant growth, it can decrease yield and even cause crop failure. They also reported that drought could occur at any time of growing seasons. However, severity of stress on productivity depends on distribution of rainfall. Different developmental stages responds differently to drought stress. Reproductive stage during flowering is more vulnerable to stress and may cause spikelet sterility to different degrees.

Blum (2005) reported that some morphological characters such as root length, tillering, spike number per m<sup>2</sup>, grain number per spike, number of fertile tillers per plant, 1000 grain weight, peduncle length, spike weight, stem weight, awn length, and grain weight per spike and affect wheat tolerance to the moisture shortage in the soil.

Tuong *et al.* (2005) reported that drought resulted to decrease in plant height, number of tillers per plant, total biomass and grain yield.

Plaut *et al.* (2004) stated that drought at grain filling process induces early senescence and shortens the grain filling period but increases remobilization of assimilates from the straw to the grains.

Bota *et al.* (2004) reported that severe drought conditions limit photosynthesis due to a decline in Rubisco activity, which is an enzyme of the Calvin cycle. However, the amount of Rubisco activase, which rescues Rubisco sites from dead end inhibition by promoting ATP-dependent conformational changes, enhances under the drought stress as a protective mechanism. The up-regulation of this enzyme might alleviate the damage on Rubisco by drought.

Turk *et al.* (2004) stated that drought may results in delayed and reduced seed germination or many prevent germination completely.

Saneoka *et al.* (2004) stated that many cellular functions of plants, such as protein synthesis, nitrogen metabolism and cell membrane function can also be impaired under prolonged drought.

Chaves *et al.* (2002) reported least effects of moisture stress on height, number of panicles per plant, panicle length and 1000-grain weight in mid-season varieties and on number of grains per panicle and harvest index in early varieties of rice.

Pantuwan *et al.* (2002) reported that the delay in heading under stress was negatively associated with plant water status indicators and stress yields. The delay in heading is

an expression of growth retardation during the drying cycle as well as upon recovery and this delay is a strong indication of susceptibility to stress.

Rahman *et al.* (2002) reported that plant height, tiller number, panicle number, panicle length, number of filled grains per panicle, 1000-grain weight, harvest index (HI), total dry matter (TDM) and yield were decreased in rice with moisture stress.

Tezara *et al.* (2002) stated that the spikelet sterility increases under moisture stress condition which might be due to the reduction of many key metabolic functions and physiological processes in rice plant.

Hossain (2001) reported that water stress might inhibit photosynthesis and produce less amount of assimilates which resulted in lower number of leaves.

Samonte *et al.* (2001) reported that the occurrence of soil moisture stress affects many of the physiological processes such as photosynthesis and transpiration resulting in reduced growth and poor grain filling.

## **2.2 Effect of organic fertilizer to combat drought**

Seghatoleslami (2013) reported that the effect of fertilizer treatment and its interaction with irrigation on seed yield in cumin was significant. In water stress conditions, higher seed yield was related to 5 t ha<sup>-1</sup> manure + nitrogen treatment. He found that the highest harvest index (40.66) was produced for *Lallemantia berica* under the treatment of 150 mm evaporation from class a pan and the application of compost. He showed that manure could be used effectively to modify the impact of water shortage and to stimulate an increase in cumin seed and essential oil yields probably through improving the water holding capacity of the soil.

Kalvanagh and Heris (2013) stated that animal manure produced the highest seed number per plant, 1000-seed weight and seed yield of dragon's head (*Lallemantia iberica*) 5.67 g and 5.65 g respectively.

Adams *et al.* (2013) found in a greenhouse study that the water holding capacity nearly doubled when 15% poultry litter biochar by weight was added to 9 kg of sandy loam soil. The ability to retain a relatively large quantity of water aids plant growth when under water stress.

Liu *et al.* (2013) reported that organic fertilizer increased the soil water holding capacity by increasing the percentage of macro-aggregates (>0.25 mm) and soil nutrients, which ultimately improved yield and water use efficiency.

Artiola *et al.* (2012) conducted a greenhouse study and found that soil amended with 2% and 4% biochar by weight (15 kg of loamy sand used) had higher yields than control plants after undergoing water stress.

Abass and Mohamed (2011) reported that the proline content significantly increased in leaf of soybean plants when the soil was treated with the different doses of biochar as compared with drought stressed plants and control plants. In well watered condition proline content increased by 14.81 and 25.92% when biochar was applied as 25 and 50 t ha<sup>-1</sup>, respectively compared to no biochar application. On the other hands it was 22.58 and 38.70% compared to no biochar application when biochar was applied at the same doses under drought condition. They also reported that photosynthetic pigments contents in leaves of common bean plants were highly significantly decreased with increasing the level of drought stress. The reduction in chlorophyll content under drought stress has been considered a typical symptom of oxidative stress and may be the result of pigment photo-oxidation and chlorophyll degradation. The decrease in the photosynthetic activity under drought stress may be due to stomatal or non-stomatal mechanisms. Stomata closure is one of the first responses to drought stress which result in declined rate of photosynthesis. The drought induced reduction in the chlorophyll content could be attributed to loss of chloroplast membranes, excessive swelling, and distortion of the lamellae vesiculation and the appearance of lipid droplets. Addition of biochar in soil increased chlorophyll content under well water and stress conditions although it was not significant in case of chlorophyll a and total chlorophylls. In well water condition total chlorophyll content increased by 3.31, 3.12, 1.56% and water stress condition it was 7.25, 29, 17% when biochar application rate was 25, 50 and 100 t ha<sup>-1</sup>, respectively. Highest increased of chlorophyll content was found under water stress condition when soil was treated with biochar @ 50 t ha<sup>-1</sup>.

Vaccari *et al.* (2011) stated that biochar can increase the cation exchange capacity of soils, soil pH and water holding capacity, which would improve nutrient and water availability in the soils and thereby improve growing conditions for plants. Some other studies have found increased above and below ground biomass with biochar addition as well as increased plant height and leaf area which ultimately helps to increase grain yield of crops.

Karhu *et al.* (2011) reported that incorporation of biochar to soil enhanced soil water-holding capacity, improved soil water permeability, improved saturated hydraulic conductivity (SHC), reduced soil strength, modification in soil bulk density ( $\rho_b$ ) and

modified aggregate stability. Due to its physical properties, biochar help to increase water holding capacity and reduces nutrient leaching.

Ahmadian *et al.* (2011) stated that organic compost is a rich and a slow release fertilizer which using leads to a clean product of plants, continuous supply of nutrients, which improve some physical properties of soil, increase water retention than that for chemical fertilizers and improves the soil texture. The structural improvement can encourage the plant to have a good root development by improving the aeration in the soil, which leads to a higher plant vegetative growth. They also reported that with essential elements, increases growth, number of umbrella per plant and manure application improves the soil structure and soil moisture content, provides plant biological yield and finally led to increase seed yield of field pea.

Gaskin *et al.* (2010) reported that biochar addition increased the overall accumulation of osmotic active substances such as  $K^+$  in the plant tissues, likely due to its large cation content, leading to an improved plant water uptake which ultimately increased water content in leaf.

Lakhdar *et al.* (2009) reported that composts are used to improve soil fertility and quality because they can increase organic matter content, especially in sandy soils which have low water and nutrient holding capacity.

Tejada *et al.* (2009) stated that by increasing soil organic matter content, composts improve soil physical properties such as structural stability, total porosity, hydraulic conductivity, aggregate formation and water holding capacity.

Johnson *et al.* (2009) showed that poultry and food waste compost increased the water retention capacity of a sandy soil two years after application. Compost produced from organic dairy cattle manure can result in higher soil water content under Kentucky bluegrass (*Poa pratensis* L.) after 8 days without addition of water. They also reported that despite the strong effect on gas exchange during drought, plants with incorporated compost were able to recover rapidly after re-watering which is most likely due to the greater root system and thus ability to take up the added water.

Dehnavy *et al.* (2009) reported that maximum leaf chlorophyll index was obtained by applying animal manure and minimum index was obtained at no animal manure.

Courtney and Mullen (2008) reported that incorporated and mulched compost enhanced soil water content at field capacity (FC) and permanent wilting point (PWP) but only incorporated compost increased total available water (TAW). The increased TAW with

incorporated compost is likely due to greater organic C content as organic C can increase soil water holding capacity (WHC).

Bhattacharyya *et al.* (2007) studied change in soil physical properties due to organic matter addition under dry tropical conditions in India. In both cases, farmyard manure addition to soils with loamy sand and silty clay loam texture and low initial organic carbon of 2 and 7 g kg<sup>-1</sup> total organic carbon (TOC) respectively, enhanced aggregation, resulting in higher saturated hydraulic conductivity.

Lehmann *et al.* (2006) reported that application of biochar in *Triticum aestivum* L. not only improve the availability of nutrients but also promote vegetative growth by improving the photosynthetic pigments chlorophyll (a, b and total) under stressed condition.

Dang *et al.* (2006) suggested that fertilization increases the availability of limited nutrients, and then could alter system properties, which might be a potentially practical way to stimulate plant growth, enhance stress tolerance, and improve the efficiency of using finite resources in infertile and dry environments.

Silva *et al.* (2006) reported increasing in maize 1000-seed weight by animal manure under drought stress.

Curtis and Claassen (2005) stated that the effect of compost on plant growth is most likely to increased nutrient availability, which resulted in increased shoot N and K concentrations. The higher K concentration may have contributed to conservation of water during drought and the more rapid recovery of plants with incorporated compost after re-watering because it is well known that K is important for plant water status, turgor pressure of cells and stomata regulation.

Osborne *et al.* (2002) reported that biological yield of corn increased by consumption of animal and chemical fertilizers.

Shirani *et al.* (2002) showed a strong increase in soil organic matter on an arid silty clay loam with 5 g kg<sup>-1</sup> total organic carbon (TOC) in Iran by addition of farmyard manure, resulting in improved aggregation, lower bulk density, higher saturated hydraulic conductivity and nearly double dry matter yield of irrigated corn.

Siddique *et al.* (2001) reported that relative water content increased by addition of biochar both in well water and water stress conditions. In well water condition relative water content increased 3.83, 5.25 and 3.51% and in water stress condition it was 4.35, 6.81 and 4.92% by addition of biochar @ 25, 50 and 100 t ha<sup>-1</sup>, respectively.

## **CHAPTER III MATERIALS AND METHODS**

The pot experiment was conducted at the net house of Sher-e-Bangla Agricultural University Farm, Dhaka during the period from November 2017 to April 2018. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and their analyses.

### **3.1 Experimental site**

The experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka - 1207, under the Agro-Ecological Zone of Madhupur Tract (AEZ-28). The land area is situated at 23°41'N latitude and 90°22'E longitude at an altitude of 8.6 meter above the sea level. The experimental site is shown in the AEZ Map of Bangladesh in Appendix I.

### **3.2 Climate**

The experimental area is under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the rabi season (October-March). The details are presented in Appendix II.

### **3.3 Soil**

The experimental area's soil belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. The experimental area was flat having available irrigation and drainage system. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental pot. The analyses were done by Soil Resources and Development Institute (SRDI), Farmgate, Dhaka. The physicochemical properties of the soil are presented in Appendix III.



### 3.4 Planting material

Seeds of BARI Gom-28 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh. This is a high yielding, short stature and early maturing variety. Plant height becomes 95-100 cm. It takes 60-65 days for heading. It is highly tolerant to terminal heat stress due to its earliness and grain yield 15-20% higher under late seeding. Grains per spike 45-50. Grains are white, amber in color and medium in size. Its 1000-grain weight is 35-40 g. The variety is resistant to leaf rust and moderately tolerant to *Bipolaris* leaf blight. Grain yield potentially is about 3.5-5.4 t ha<sup>-1</sup>. Duration of the crop is about 105-110 days.

### 3.5 Treatments

The following treatments were included in this experiment:

Factor A: Organic manure - 3 levels

- i. F<sub>0</sub> = Control
- ii. F<sub>1</sub> = Cowdung 10 t ha<sup>-1</sup>
- iii. F<sub>2</sub> = Vermicompost 7 t ha<sup>-1</sup>

Factor B: Drought stress - 4 levels

- i. D<sub>0</sub> = Control
- ii. D<sub>1</sub> = Drought in crown root initiation stage (20-29 DAS)
- iii. D<sub>2</sub> = Drought in booting stage (45-54 DAS)
- iv. D<sub>3</sub> = Drought in anthesis stage (55-64 DAS)

### 3.6 Conduction of the experiment

#### 3.6.1 Seed collection

The seeds were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, Dhaka.

### **3.6.2 Preparation of pot**

The collected soil was sun dried, crushed and sieved properly. The soil and fertilizers were mixed well before placing the soils into the pots (having 24 cm top, 18 cm bottom diameter and 22 cm depth). Then each pot was filled up with 18 kg soil.

### **3.6.3 Moisture measurement (%)**

Moisture meter (Model - DSMM 500) was set up in 3 different location of a pot and 3 individual data was recorded. Then its average data was recorded to have moisture percentage by gravimetric method. The moisture percentage of the soil are presented in Appendix IV.

### **3.6.4 Fertilizer dose and method of application**

Urea, TSP, MOP, gypsum and boric acid were applied @ 160 kg N, 92 kg P, 144 kg K, 20 kg S and 1.5 kg B per hectare, respectively. Cowdung and vermicompost were applied according to the treatment. Two-third of urea and all other fertilizers were applied at the final pot preparation as basal and the rest one-third urea was top dressed at 1<sup>st</sup> irrigation (18 days after sowing) (FRG, 2012).

### **3.6.5 Design of the experiment**

The experiment was laid out in Completely Randomized Design (CRD) with three replications. There were 36 pots all together replication with the given factors.

### **3.6.6 Seed sowing**

Before placing the seeds into pots, germination test were done. Eight healthy seeds were placed into each pot. After germination, three healthy seedlings were allowed to grow in each pot.

## **3.7 Intercultural operation**

### **3.7.1 Thinning**

Continuous observation was done after seed sowing. Keen observation was made for thinning to maintain three seedlings. Thinning was done to maintain spacing in the pots. Three healthy seedlings were allowed to grow in each pot.

### **3.7.2 Weeding**

During plant growth period two hand weeding's were done. First weeding was done at 20 days after sowing followed by second weeding at 15 days after first weeding.

### **3.7.3 Irrigation**

Irrigations were given according to treatments of the experiment.

### **3.7.4 Plant protection measure**

The crop was infested by aphid (*Aphis spp.*). Therefore, Thiamethoxam (Actara) was used @ 52 gm/ha to control aphid.

### **3.7.5 General observation of the experimental pots**

Observations were made regularly and the plants looked green. No lodging was observed at any stage. The maximum tillering, panicle initiation, and flowering stages were not uniform.

### **3.7.6 Harvesting and threshing**

The crop was harvested at full maturity. Plants of each pot was bundled separately with tag mark indicating the respective treatment combinations and brought to the threshing floor for threshing and recording data on yield and yield contributing parameters.

## **3.8 Data collection**

Data collections from the experiment on different growth stages were done under the following heads as per experimental requirements.

### **Phenological and yield attributed data:**

- i. Plant height (cm)
- ii. Number of effective tillers plant<sup>-1</sup>
- iii. Spike length (cm)
- iv. Number of spikelet spike<sup>-1</sup>
- v. Number of grains spikelet<sup>-1</sup>
- vi. Number of grains spike<sup>-1</sup>

- vii. Weight of 1000 grain (g)

**Yield and harvest index data:**

- viii. Grain yield (g plant<sup>-1</sup>)
- ix. Straw yield (g plant<sup>-1</sup>)
- x. Biological yield (g plant<sup>-1</sup>)
- xi. Harvest index (%)

**3.9 Procedures of recording data**

A brief outline of the data recording procedure is given below:

**3.9.1 Plant height (cm)**

Plant height was measured at 20 days interval starting from 20 days after sowing (DAS) and continued up to harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading, and to the tip of spike after heading. The collected data were finally averaged.

**3.9.2 Number of effective tillers plant<sup>-1</sup>**

Number of effective tillers plant<sup>-1</sup> were counted from the pots after harvesting and finally averaged.

**3.9.3 Spike length (cm)**

The spike length (cm) was measured with a meter scale from the plants of each pot and the average value was recorded as per plant.

**3.9.4 Number of spikelet spike<sup>-1</sup>**

The number of spikelet were counted in each spike and average value of 10 spike was used to determine the number of spikelet spike<sup>-1</sup>.

**3.9.5 Number of grains spikelet<sup>-1</sup>**

The number of grains were counted in each spike and averaged and then expressed as number of grains spikelet<sup>-1</sup>.

### **3.9.6 Number of grains spike<sup>-1</sup>**

The number of grains were counted in each spikelet and averaged and then expressed as number of grains spike<sup>-1</sup>.

### **3.9.7 Weight of 1000 grain (g)**

One hundred (100) grains from each pot were randomly selected and weighed by an electric balance after sun dried and then the weight was multiplied with 10 to have weight of 1000 grain.

### **3.9.8 Grain yield (g plant<sup>-1</sup>)**

Grain harvested from each pot was sun dried and weighed carefully. The dry weight of the grains of the plant was recorded, and then divided by 3 for per plant grain yield.

### **3.9.9 Straw yield (g plant<sup>-1</sup>)**

Straw obtained from each pot was sun dried and weighed carefully. The dry weight of straw of the plant was recorded, and then divided by 3 for per plant straw yield.

### **3.9.10 Biological yield (g plant<sup>-1</sup>)**

Grain yield and straw yield were all together regarded as biological yield and calculated with the following formula:

$$\text{Biological yield (g plant}^{-1}\text{)} = \text{Grain yield (g plant}^{-1}\text{)} + \text{Straw yield (g plant}^{-1}\text{)}$$

### **3.9.11 Harvest index (%)**

Harvest index was calculated by dividing the economic (grain) yield from the net pot by the total biological yield (grain + straw) from the same area and multiplying by 100.

$$\text{Harvest index (\%)} = (\text{Grain yield/Biological yield}) \times 100$$

## **3.10 Statistical analysis**

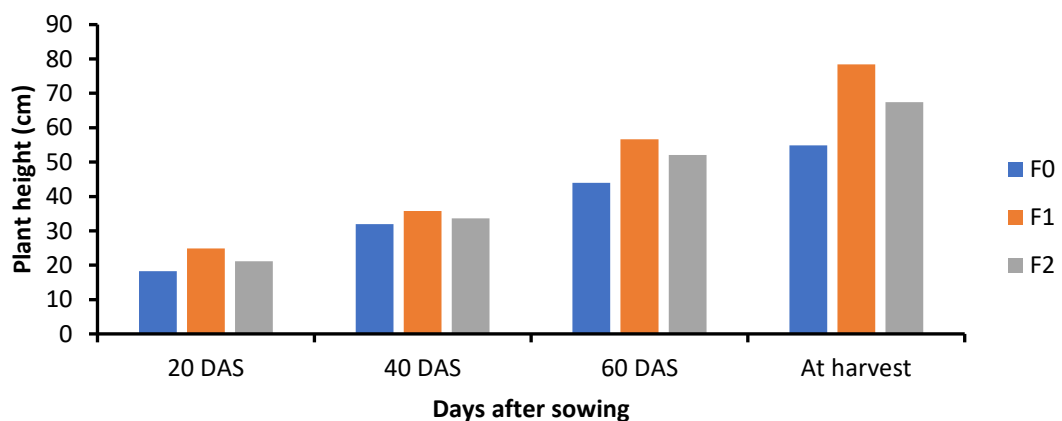
The data were compiled and tabulated in proper form and were subjected to statistical analysis. Analysis of variance was done following the computer package MSTAT-C program developed by Russel (1986). The mean differences among the treatments were adjusted by Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

## CHAPTER IV RESULTS AND DISCUSSION

The results obtained from the study have been presented, discussed and compared in this chapter through figure, table and appendices. The results are interpreting under the following headings.

### 4.1 Plant height

The plant height of BARI Gom-28 were significantly influenced by different organic manures at 20, 40, 60 DAS and at harvest (Figure 1 and Appendix IV). At 20, 40, 60 DAS and at harvest, the treatment F<sub>1</sub> produced the tallest plant (24.84, 35.77, 56.60 and 78.42 cm, respectively) followed by F<sub>2</sub> (21.16, 33.64, 52.09 and 67.46 cm, respectively) and the treatment F<sub>0</sub> produced the shortest plant (18.26, 31.90, 43.95 and 54.87 cm, respectively). This results confirms the findings of Kobayashi *et al.* (1989) who reported that organic manure had positive effect on plant height.

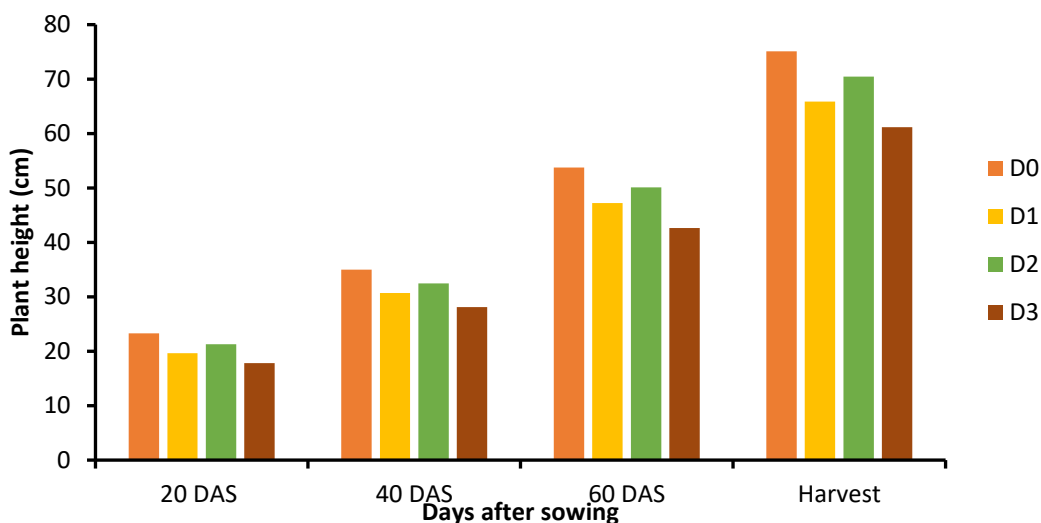


**Figure 1: Effect of different organic manures on plant height at different days after sowing of BARI Gom-28 (LSD<sub>0.05</sub> = 0.29, 0.21, 0.22, 0.23 at 20, 40, 60 DAS and at harvest, respectively)**

F<sub>0</sub> = Control, F<sub>1</sub> = Cowdung 10 t ha<sup>-1</sup>, F<sub>2</sub> = Vermicompost 7 t ha<sup>-1</sup>

Significant variation was observed on plant height of BARI Gom-28 at 20, 40, 60 DAS and at harvest due to differences in drought stress conditions (Figure 2 and Appendix IV). At 20, 40, 60 DAS and at harvest, the treatment D<sub>0</sub> produced the tallest plant (23.31, 34.97, 53.72 and 75.07 cm, respectively) followed by D<sub>2</sub> (21.27, 32.45, 50.09 and 70.44 cm, respectively) and the treatment D<sub>3</sub> produced the shortest plant (17.83, 28.11, 42.62 and 61.17 cm, respectively). This results corroborates the findings of Shao *et al.* (2008) who stated that drought affects both elongation as well as expansion

growth, and inhibits cell enlargement more than cell division. It impairs the germination of seedlings and reduces number of tillers and plant height.



**Figure 2: Effect of different level of drought stress on plant height at different days after sowing of BARI Gom-28 (LSD<sub>0.05</sub> = 0.32, 0.24, 0.25, 0.25 at 20, 40, 60 DAS and at harvest, respectively)**

D<sub>0</sub> = Control, D<sub>1</sub> = Drought in crown root initiation stage (20-29 DAS), D<sub>2</sub> = Drought in booting stage (45-54 DAS), D<sub>3</sub> = Drought in anthesis stage (55-64 DAS)

Interaction effect of different organic manures and drought stress showed significant variation on plant height at 20, 40, 60 DAS and at harvest (Table 1 and Appendix IV). At 20 DAS, the tallest plant (27.66 cm) was observed from the F<sub>1</sub>D<sub>0</sub> which was statistically similar with F<sub>1</sub>D<sub>2</sub> (26.88 cm) and the shortest (18.95 cm) from F<sub>0</sub>D<sub>3</sub>. At 40 DAS, the tallest plant (48.10 cm) was observed from the F<sub>1</sub>D<sub>0</sub> which was statistically similar with F<sub>1</sub>D<sub>2</sub> (47.69 cm) and the shortest (38.92 cm) from F<sub>0</sub>D<sub>3</sub>. At 60 DAS, the tallest plant (63.15 cm) was observed from the F<sub>1</sub>D<sub>0</sub> which was statistically similar with F<sub>1</sub>D<sub>2</sub> (62.61 cm) and the shortest (53.32 cm) from F<sub>0</sub>D<sub>3</sub>. At harvest, the tallest plant (78.56 cm) was observed from the F<sub>1</sub>D<sub>0</sub> which was statistically similar with F<sub>1</sub>D<sub>2</sub> (77.95 cm) and the shortest (68.53 cm) from F<sub>0</sub>D<sub>3</sub> which was statistically similar with F<sub>0</sub>D<sub>1</sub> (69.13 cm).

**Table 1: Interaction effect of organic manures and drought stress on plant height at different days after sowing of wheat**

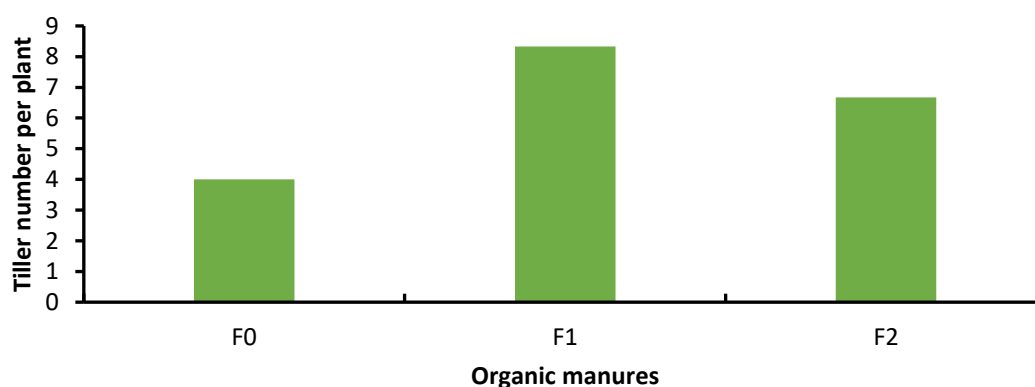
Treatments	Plant height (cm)			
	20 DAS	40 DAS	60 DAS	At harvest
F <sub>0</sub> D <sub>0</sub>	21.29 f	40.15 g	55.21 f	70.35 fg
F <sub>0</sub> D <sub>1</sub>	19.73 g	39.33 h	54.13 g	69.13 gh
F <sub>0</sub> D <sub>2</sub>	20.51 fg	39.74 gh	54.67 g	69.74 g
F <sub>0</sub> D <sub>3</sub>	18.95 h	38.92 hi	53.59 gh	68.53 h
F <sub>1</sub> D <sub>0</sub>	27.66 a	48.10 a	63.15 a	78.56 a
F <sub>1</sub> D <sub>1</sub>	26.12 b	47.28 b	62.07 b	77.34 b
F <sub>1</sub> D <sub>2</sub>	26.88 ab	47.69 ab	62.61 ab	77.95 ab
F <sub>1</sub> D <sub>3</sub>	25.34 c	46.87 bc	61.53 c	76.73 bc
F <sub>2</sub> D <sub>0</sub>	24.49 cd	44.11 d	59.28 d	74.34 d
F <sub>2</sub> D <sub>1</sub>	22.93 de	43.29 ef	58.20 e	73.12 ef
F <sub>2</sub> D <sub>2</sub>	23.71 d	43.70 de	58.74 de	73.75 de
F <sub>2</sub> D <sub>3</sub>	22.16 e	42.88 f	57.66 ef	72.51 f
<b>LSD (0.05)</b>	<b>0.78</b>	<b>0.41</b>	<b>0.54</b>	<b>0.61</b>
<b>CV (%)</b>	<b>5.68</b>	<b>4.32</b>	<b>5.06</b>	<b>6.11</b>

F<sub>0</sub> = Control, F<sub>1</sub> = Cowdung 10 t ha<sup>-1</sup>, F<sub>2</sub> = Vermicompost 7 t ha<sup>-1</sup>

D<sub>0</sub> = Control, D<sub>1</sub> = Drought in crown root initiation stage (20-29 DAS), D<sub>2</sub> = Drought in booting stage (45-54 DAS), D<sub>3</sub> = Drought in anthesis stage (55-64 DAS)

#### 4.2 Number of effective tillers plant<sup>-1</sup>

Significant variation was observed on the number of effective tillers plant<sup>-1</sup> of BARI Gom-28 due to different organic manures (Figure 3 and Appendix IV). The treatment F<sub>1</sub> produced the highest number of effective tillers plant<sup>-1</sup> (8.33) followed by F<sub>2</sub> (6.67) and F<sub>0</sub> produced the lowest value (4.00).

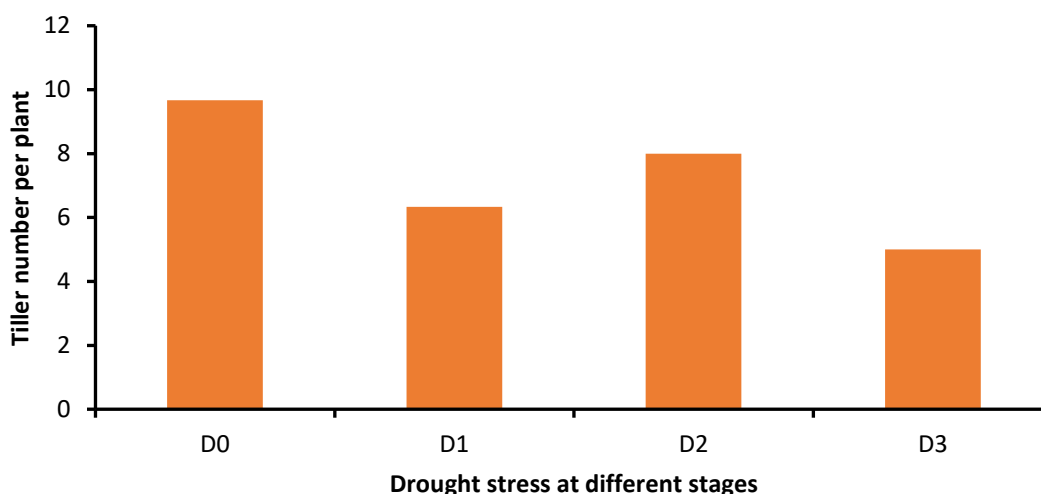




**Figure 3: Effect of different organic manures on number of effective tillers plant<sup>-1</sup> of BARI Gom-28 (LSD<sub>0.05</sub> = 1.06)**

F<sub>0</sub> = Control, F<sub>1</sub> = Cowdung 10 t ha<sup>-1</sup>, F<sub>2</sub> = Vermicompost 7 t ha<sup>-1</sup>

Significant variation was observed on the number of effective tillers plant<sup>-1</sup> due to drought stress imposition at different stages of BARI Gom-28 (Figure 4 and Appendix IV). The treatment D<sub>0</sub> produced the highest number of effective tillers plant<sup>-1</sup> (9.67) followed by D<sub>2</sub> (8.00) and the D<sub>3</sub> produced the lowest (5.00) followed by D<sub>1</sub> (6.33). This results support the findings of Shao *et al.* (2008) who stated that drought affects both elongation as well as expansion of growth, and inhibits cell enlargement. It impairs the germination of seedlings and reduces number of tillers and plant height.



**Figure 4: Effect of drought stress imposition at different stages on number of effective tillers plant<sup>-1</sup> of BARI Gom-28 (LSD<sub>0.05</sub> = 1.81)**

D<sub>0</sub> = Control, D<sub>1</sub> = Drought in crown root initiation stage (20-29 DAS), D<sub>2</sub> = Drought in booting stage (45-54 DAS), D<sub>3</sub> = Drought in anthesis stage (55-64 DAS)

Interaction effect of different organic manures and drought stress at different stages showed significant variation on number of effective tillers plant<sup>-1</sup> of BARI Gom-28 (Table 2 and Appendix IV). The interaction F<sub>1</sub>D<sub>0</sub> produced the highest number of effective tillers plant<sup>-1</sup> (10.33) followed by F<sub>1</sub>D<sub>2</sub> (9.00), F<sub>1</sub>D<sub>1</sub> (8.33) and F<sub>1</sub>D<sub>3</sub> (8.00) while, F<sub>0</sub>D<sub>3</sub> produced the lowest (3.00) followed by F<sub>0</sub>D<sub>2</sub> (4.33) and F<sub>0</sub>D<sub>1</sub> (4.00).

**Table 2: Interaction effect of organic manures and drought stress imposition at different growth stages on yield attributes of wheat**

Treatments	Number of effective tillers plant <sup>-1</sup>	Spike length (cm)	Number of spikelet spike <sup>-1</sup>	Number of grains spikelet <sup>-1</sup>

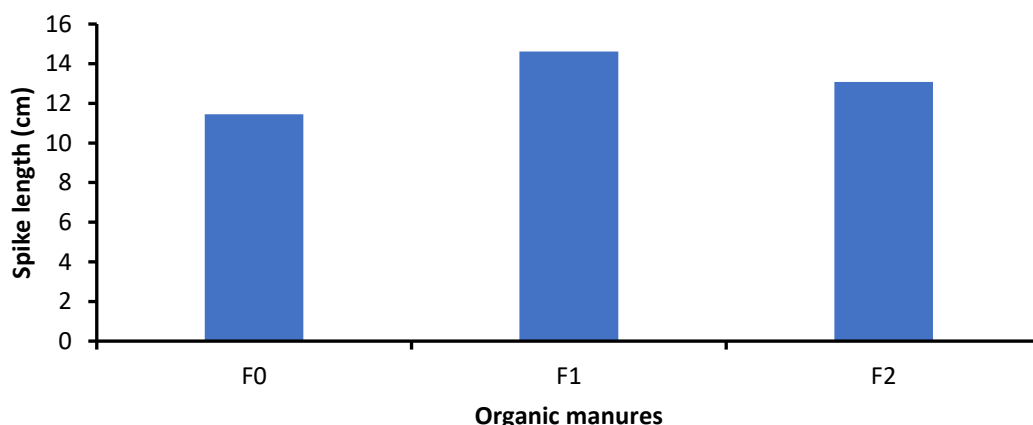
F <sub>0</sub> D <sub>0</sub>	5.00 e	11.76 g	10.00 h	6.67 e
F <sub>0</sub> D <sub>1</sub>	4.00 e	10.73 h	9.00 i	6.00 f
F <sub>0</sub> D <sub>2</sub>	4.33 e	11.34 g	9.67 h	6.33 f
F <sub>0</sub> D <sub>3</sub>	3.00 f	10.13 i	7.33 j	5.00 g
F <sub>1</sub> D <sub>0</sub>	10.33 a	16.12 a	18.00 a	9.67 a
F <sub>1</sub> D <sub>1</sub>	8.33 b	15.06 b	16.00 c	8.67 c
F <sub>1</sub> D <sub>2</sub>	9.00 b	15.52 b	17.33 ab	9.33 b
F <sub>1</sub> D <sub>3</sub>	8.00 b	14.44 c	15.33 d	8.33 c
F <sub>2</sub> D <sub>0</sub>	7.67 bc	13.75 d	14.33 e	7.67 d
F <sub>2</sub> D <sub>1</sub>	6.67 d	12.79 e	12.00 f	7.00 e
F <sub>2</sub> D <sub>2</sub>	7.00 c	13.27 d	13.00 e	7.33 d
F <sub>2</sub> D <sub>3</sub>	6.00 d	12.33 ef	11.00 g	6.67 e
<b>LSD (0.05)</b>	<b>1.22</b>	<b>0.51</b>	<b>0.97</b>	<b>0.46</b>
<b>CV (%)</b>	<b>5.49</b>	<b>6.06</b>	<b>4.69</b>	<b>2.49</b>

F<sub>0</sub> = Control, F<sub>1</sub> = Cowdung 10 t ha<sup>-1</sup>, F<sub>2</sub> = Vermicompost 7 t ha<sup>-1</sup>

D<sub>0</sub> = Control, D<sub>1</sub> = Drought in crown root initiation stage (20-29 DAS), D<sub>2</sub> = Drought in booting stage (45-54 DAS), D<sub>3</sub> = Drought in anthesis stage (55-64 DAS)

### 4.3 Spike length

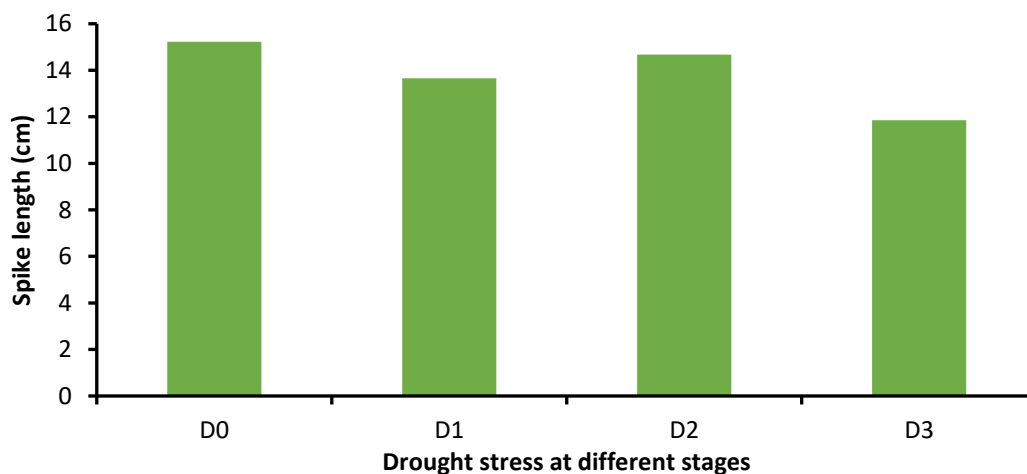
Significant variation was observed on spike length of BARI Gom-28 due to different organic manures (Figure 5 and Appendix V). The treatment F<sub>1</sub> produced the highest spike length (14.61 cm) and the F<sub>0</sub> produced the lowest spike length (11.44 cm) while F<sub>2</sub> showed the intermediate level of spike length (13.08 cm).



**Figure 5: Effect of different organic manures on spike length of BARI Gom-28 (LSD<sub>0.05</sub> = 0.72)**

F<sub>0</sub> = Control, F<sub>1</sub> = Cowdung 10 t ha<sup>-1</sup>, F<sub>2</sub> = Vermicompost 7 t ha<sup>-1</sup>

Significant variation was observed on spike length of BARI Gom-28 due to drought stress imposition at different stages (Figure 6 and Appendix V). The treatment D<sub>0</sub> produced the highest spike length (15.22 cm) which was statistically similar with D<sub>2</sub> (14.68 cm) and D<sub>3</sub> produced the lowest spike length (11.86 cm). This results support the results of Akram *et al.* (2002) who reported that spike length was significantly affected by increasing moisture stress.



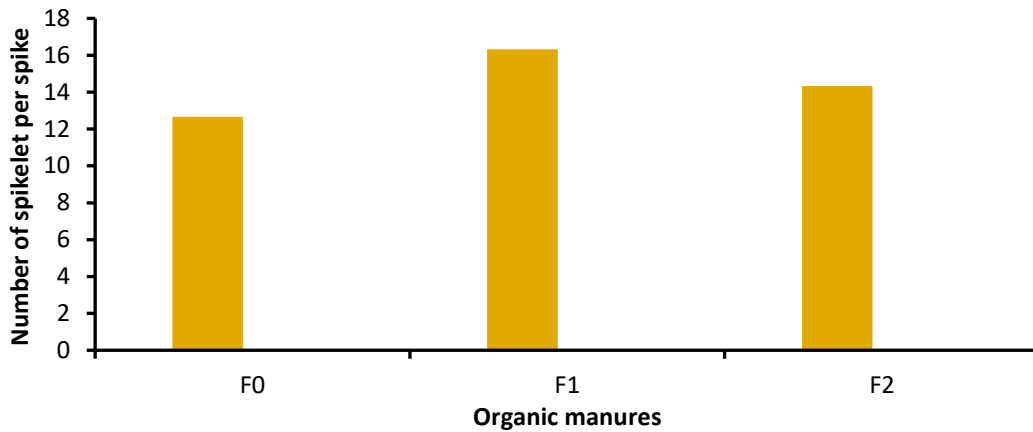
**Figure 6: Effect of drought stress imposition at different stages on spike length of BARI Gom-28 (LSD<sub>0.05</sub> = 0.61)**

D<sub>0</sub> = Control, D<sub>1</sub> = Drought in crown root initiation stage (20-29 DAS), D<sub>2</sub> = Drought in booting stage (45-54 DAS), D<sub>3</sub> = Drought in anthesis stage (55-64 DAS)

Interaction effect of different organic manures and drought stress showed significant variation on spike length of BARI Gom-28 (Table 2 and Appendix V). The result shows that the interaction F<sub>1</sub>D<sub>0</sub> produced the highest spike length (16.12 cm) followed by F<sub>1</sub>D<sub>2</sub> (15.52 cm) and F<sub>1</sub>D<sub>1</sub> (15.06 cm) while, F<sub>0</sub>D<sub>3</sub> produced the lowest spike length (10.13 cm) followed by F<sub>0</sub>D<sub>1</sub> (10.73 cm).

#### 4.4 Number of spikelet spike<sup>-1</sup>

Significant variation was observed on number of spikelet spike<sup>-1</sup> of BARI Gom-28 among different organic manures (Figure 7 and Appendix V). The treatment F<sub>1</sub> produced the highest number of spikelet spike<sup>-1</sup> (16.33) followed by F<sub>2</sub> (14.33) and the F<sub>0</sub> produced the lowest (12.67) number of spikelet spike<sup>-1</sup>.

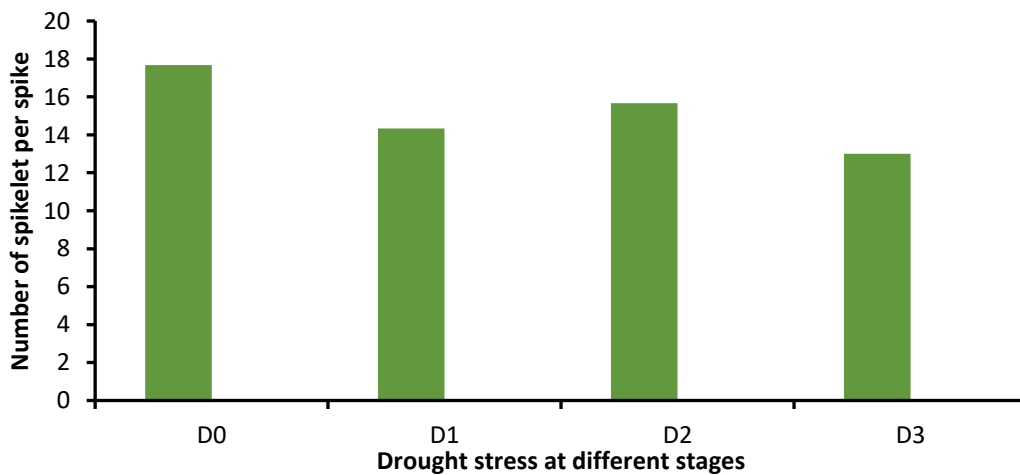


**Figure 7: Effect of different organic manures on number of spikelet spike<sup>-1</sup> of BARI Gom-28 (LSD<sub>0.05</sub> = 1.04)**

F<sub>0</sub> = Control, F<sub>1</sub> = Cowdung 10 t ha<sup>-1</sup>, F<sub>2</sub> = Vermicompost 7 t ha<sup>-1</sup>

Significant variation was observed on number of spikelet spike<sup>-1</sup> of BARI Gom-28 due to drought stress imposition at different stages (Figure 8 and Appendix V). The treatment D<sub>0</sub> produced the highest number of spikelet spike<sup>-1</sup> (17.67) followed by D<sub>2</sub> (15.67) and the D<sub>3</sub> produced the lowest (13.00) number of spikelet spike<sup>-1</sup>.

Interaction effect of different organic manures and drought stress showed significant variation on number of spikelet spike<sup>-1</sup> of BARI Gom-28 (Table 2 and Appendix V). The interaction F<sub>1</sub>D<sub>0</sub> produced the highest number of spikelet spike<sup>-1</sup> (18.00) which was statistically similar with F<sub>1</sub>D<sub>2</sub> (17.33) while, F<sub>0</sub>D<sub>3</sub> produced the lowest number of spikelet spike<sup>-1</sup> (7.33) followed by F<sub>0</sub>D<sub>2</sub> (9.67) and F<sub>0</sub>D<sub>1</sub> (9.00).

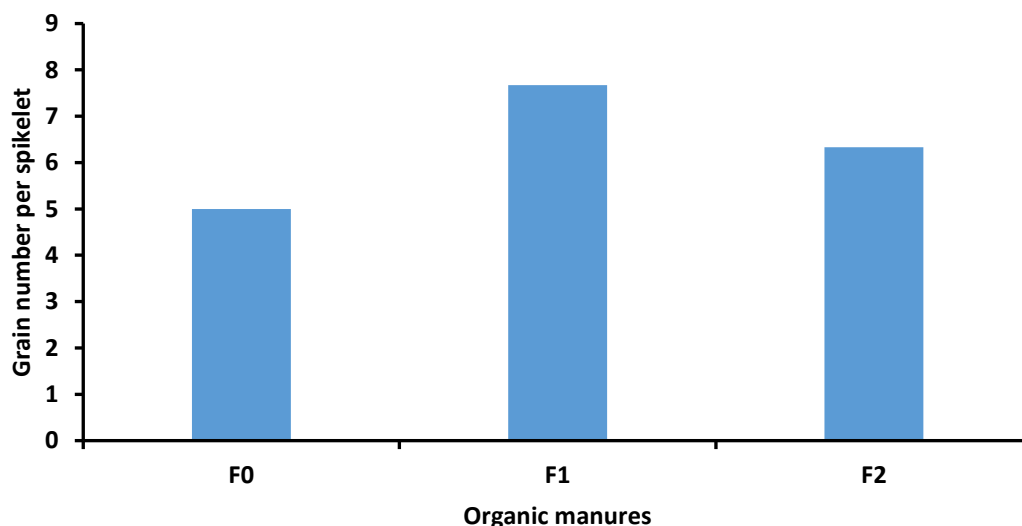


**Figure 8: Effect of drought stress imposition at different stages on number of spikelet spike<sup>-1</sup> of BARI Gom-28 (LSD<sub>0.05</sub> = 0.68)**

D<sub>0</sub> = Control, D<sub>1</sub> = Drought in crown root initiation stage (20-29 DAS), D<sub>2</sub> = Drought in booting stage (45-54 DAS), D<sub>3</sub> = Drought in anthesis stage (55-64 DAS)

#### 4.5 Number of grains spikelet<sup>-1</sup>

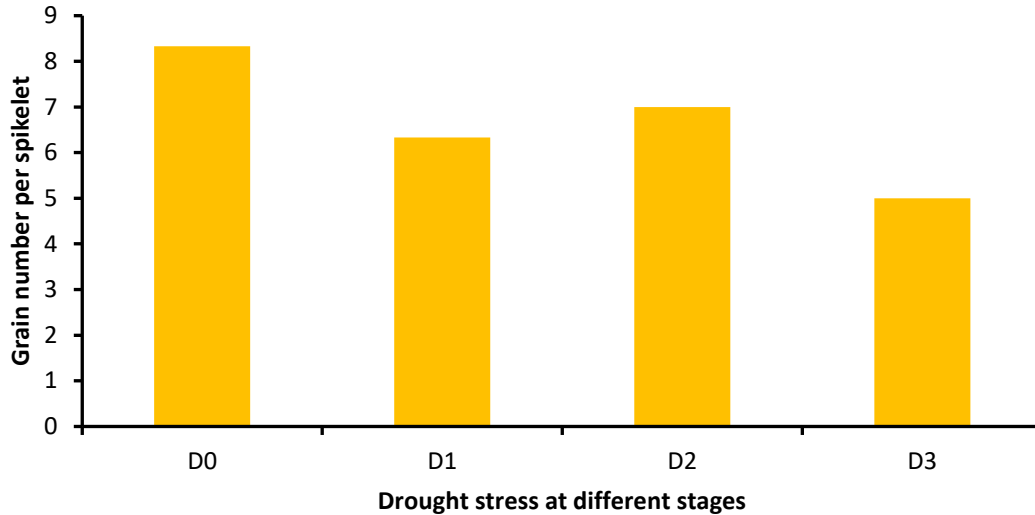
Significant variation was observed on number of grains spikelet<sup>-1</sup> of BARI Gom-28 due to different organic manures (Figure 9 and Appendix V). The treatment F<sub>1</sub> produced the highest number of grains spikelet<sup>-1</sup> (7.67) followed by F<sub>2</sub> (6.33) and the F<sub>0</sub> produced the lowest (5.00) value.



**Figure 9: Effect of different organic manures on number of grains spikelet<sup>-1</sup> of BARI Gom-28 (LSD<sub>0.05</sub> = 0.51)**

F<sub>0</sub> = Control, F<sub>1</sub> = Cowdung 10 t ha<sup>-1</sup>, F<sub>2</sub> = Vermicompost 7 t ha<sup>-1</sup>

Significant variation was observed on number of grains spikelet<sup>-1</sup> of BARI Gom-28 due to drought stress imposition at different stages (Figure 10 and Appendix V). The treatment D<sub>0</sub> produced the highest number of grains spikelet<sup>-1</sup> (8.33) followed by D<sub>2</sub> (7.67) and D<sub>1</sub> (7.00) while, the D<sub>3</sub> produced the lowest (6.00). This results support the results of Chaves *et al.* (2002) who reported that moisture stress decrease plant height, number of tillers, number of grains and 1000-grain weight.



**Figure 10: Effect of drought stress imposition at different stages on number of grains spikelet<sup>-1</sup> of BARI Gom-28 (LSD<sub>0.05</sub> = 0.80)**

D<sub>0</sub> = Control, D<sub>1</sub> = Drought in crown root initiation stage (20-29 DAS), D<sub>2</sub> = Drought in booting stage (45-54 DAS), D<sub>3</sub> = Drought in anthesis stage (55-64 DAS)

Interaction effect of different organic manures and drought stress showed significant variation on number of grains spikelet<sup>-1</sup> of BARI Gom-28 (Table 2 and Appendix V). The interaction F<sub>1</sub>D<sub>0</sub> produced the highest number of grains spikelet<sup>-1</sup> (9.67) and F<sub>0</sub>D<sub>3</sub> produced the lowest (5.00) grains spikelet<sup>-1</sup>.

#### **4.6 Number of grains spike<sup>-1</sup>**

Significant variation was observed on number of grains spike<sup>-1</sup> of BARI Gom-28 due to different organic manures (Table 3 and Appendix V). The data revealed that, treatment F<sub>1</sub> produced the highest number of grains spike<sup>-1</sup> (37.00) followed by F<sub>2</sub> (35.67) and the F<sub>0</sub> produced the lowest (31.33). This results support the result of Rahman *et al.* (2009) who reported that the application of organic manure increased grain yield of wheat.

Significant variation was observed on number of grains spike<sup>-1</sup> of BARI Gom-28 due to drought stress imposition at different stages (Table 3 and Appendix V). The treatment D<sub>0</sub> produced the highest number of grains spike<sup>-1</sup> (39.00) followed by D<sub>2</sub> (37.67) and D<sub>1</sub> (36.33) while, the D<sub>3</sub> produced the lowest (34.67). This results support the findings of Chaves *et al.* (2002) who reported that moisture stress decrease plant height, number of tillers, number of grains and 1000-grain weight.

Interaction effect of different organic manures and drought stress showed significant variation on number of grains spike<sup>-1</sup> of BARI Gom-28 (Table 4 and Appendix V). The

interaction F<sub>1</sub>D<sub>0</sub> produced the highest number of grains spike<sup>-1</sup> (40.00) followed by F<sub>1</sub>D<sub>2</sub> (38.67) and F<sub>0</sub>D<sub>3</sub> produced the lowest (28.33) followed by F<sub>0</sub>D<sub>2</sub> (30.67) and F<sub>0</sub>D<sub>1</sub> (30.00).

**Table 3: Effect of different organic manures and drought stress on yield attributes of wheat**

Treatments	Number of grains spike <sup>-1</sup>	Weight of 1000 grain (g)
Organic manures		
F <sub>0</sub>	31.33 c	40.59 c
F <sub>1</sub>	37.00 a	44.93 a
F <sub>2</sub>	35.67 b	42.24 b
<b>LSD<sub>0.05</sub></b>	<b>0.69</b>	<b>0.79</b>
<b>CV (%)</b>	<b>4.78</b>	<b>6.43</b>
Drought stress		
D <sub>0</sub>	39.00 a	45.14 a
D <sub>1</sub>	36.33 c	41.53 c
D <sub>2</sub>	37.67 b	43.67 b
D <sub>3</sub>	34.67 d	39.82 d
<b>LSD<sub>0.05</sub></b>	<b>0.91</b>	<b>1.11</b>
<b>CV (%)</b>	<b>4.78</b>	<b>6.43</b>

F<sub>0</sub> = Control, F<sub>1</sub> = Cowdung 10 t ha<sup>-1</sup>, F<sub>2</sub> = Vermicompost 7 t ha<sup>-1</sup>

D<sub>0</sub> = Control, D<sub>1</sub> = Drought in crown root initiation stage (20-29 DAS), D<sub>2</sub> = Drought in booting stage (45-54 DAS), D<sub>3</sub> = Drought in anthesis stage (55-64 DAS)

**Table 4: Interaction effect of organic manures and drought stress on yield attributes of wheat**

Treatments	Number of grains spike <sup>-1</sup>	Weight of 1000 grain (g)
F <sub>0</sub> D <sub>0</sub>	32.00 f	40.05 ef
F <sub>0</sub> D <sub>1</sub>	30.00 g	39.29 f
F <sub>0</sub> D <sub>2</sub>	30.67 g	39.88 f
F <sub>0</sub> D <sub>3</sub>	28.33 h	37.47 g
F <sub>1</sub> D <sub>0</sub>	40.00 a	48.37 a
F <sub>1</sub> D <sub>1</sub>	37.33 c	44.91 c

F <sub>1</sub> D <sub>2</sub>	38.67 b	46.58 b
F <sub>1</sub> D <sub>3</sub>	35.33 d	43.77 c
F <sub>2</sub> D <sub>0</sub>	34.67 d	42.11 d
F <sub>2</sub> D <sub>1</sub>	32.33 f	40.62 de
F <sub>2</sub> D <sub>2</sub>	33.67 e	41.88 d
F <sub>2</sub> D <sub>3</sub>	32.00 f	40.39 e
<b>LSD<sub>0.05</sub></b>	<b>0.79</b>	<b>1.62</b>
<b>CV (%)</b>	<b>4.78</b>	<b>6.43</b>

F<sub>0</sub> = Control, F<sub>1</sub> = Cowdung 10 t ha<sup>-1</sup>, F<sub>2</sub> = Vermicompost 7 t ha<sup>-1</sup>

D<sub>0</sub> = Control, D<sub>1</sub> = Drought in crown root initiation stage (20-29 DAS), D<sub>2</sub> = Drought in booting stage (45-54 DAS), D<sub>3</sub> = Drought in anthesis stage (55-64 DAS)

#### 4.7 Weight of 1000 grain

Significant variation was observed on weight of 1000 grain of BARI Gom-28 due to different organic manures (Table 3 and Appendix VI). The treatment F<sub>1</sub> produced the highest weight of 1000 grain (44.93 g) followed by F<sub>2</sub> (42.24 g) and the F<sub>0</sub> produced the lowest (40.59 g). This findings support the results of Yang *et al.* (2004) who reported that 1000 grain weight was increased by the application of organic manure.

Significant variation was observed on weight of 1000 grain of BARI Gom-28 due to drought stress imposition at different stages (Table 3 and Appendix VI). The treatment D<sub>0</sub> produced the highest weight of 1000 grain (45.14 g) followed by D<sub>2</sub> (43.67 g) and the D<sub>3</sub> produced the lowest (39.82 g). This results corroborates with the findings of Chaves *et al.* (2002) who reported that moisture stress decrease plant height, number of tillers, number of grains and 1000-grain weight.

Interaction effect of different organic manures and drought stress showed significant variation on weight of 1000 grain of BARI Gom-28 (Table 4 and Appendix VI). The interaction F<sub>1</sub>D<sub>0</sub> produced the highest weight of 1000 grain (48.37 g) followed by F<sub>1</sub>D<sub>2</sub> (46.58 g) and F<sub>0</sub>D<sub>3</sub> produced the lowest (37.47 g).

#### 4.8 Grain yield

Significant variation was observed on grain yield of BARI Gom-28 due to different organic manures (Table 5 and Appendix VI). The result revealed that the treatment F<sub>1</sub> produced the highest grain yield (4.39 g plant<sup>-1</sup>) followed by F<sub>2</sub> (3.45 g plant<sup>-1</sup>) and the F<sub>0</sub> produced the lowest (2.77 g plant<sup>-1</sup>). This results confirms the findings of Rahman *et*



*al.* (2009) who reported that the application of organic manure increased grain yield of wheat. Tuong *et al.* (2005) also reported that drought resulted to decrease in grain yield.

**Table 5: Effect of different organic manures and drought stress on yield and harvest index data of wheat**

Treatments	Grain yield (g plant <sup>-1</sup> )	Straw yield (g plant <sup>-1</sup> )	Biological yield (g plant <sup>-1</sup> )	Harvest index (%)
Organic manures				
F <sub>0</sub>	2.77 c	3.68 c	6.45 c	42.95 c
F <sub>1</sub>	4.39 a	4.69 a	9.08 a	48.35 a
F <sub>2</sub>	3.45 b	4.12 b	7.57 b	45.57 b
<b>LSD<sub>0.05</sub></b>	<b>0.64</b>	<b>0.38</b>	<b>0.82</b>	<b>0.64</b>
<b>CV (%)</b>	<b>2.61</b>	<b>3.34</b>	<b>5.43</b>	<b>6.51</b>
Drought stress				
D <sub>0</sub>	4.72 a	5.05 a	9.77 a	48.31 a
D <sub>1</sub>	3.21 c	3.70 c	6.91 c	46.45 c
D <sub>2</sub>	3.93 b	4.39 b	8.32 b	47.23 b
D <sub>3</sub>	2.25 d	2.71 d	4.96 d	45.36 d
<b>LSD<sub>0.05</sub></b>	<b>0.57</b>	<b>0.61</b>	<b>1.07</b>	<b>0.69</b>
<b>CV (%)</b>	<b>2.61</b>	<b>3.34</b>	<b>5.43</b>	<b>6.51</b>

F<sub>0</sub> = Control, F<sub>1</sub> = Cowdung 10 t ha<sup>-1</sup>, F<sub>2</sub> = Vermicompost 7 t ha<sup>-1</sup>

D<sub>0</sub> = Control, D<sub>1</sub> = Drought in crown root initiation stage (20-29 DAS), D<sub>2</sub> = Drought in booting stage (45-54 DAS), D<sub>3</sub> = Drought in anthesis stage (55-64 DAS)

Significant variation was observed on grain yield of BARI Gom-28 due to drought stress imposition at different stages (Table 5 and Appendix VI). The treatment D<sub>0</sub> produced the highest grain yield (4.72 g plant<sup>-1</sup>) followed by D<sub>2</sub> (3.93 g plant<sup>-1</sup>) and the D<sub>3</sub> produced the lowest (2.25 g plant<sup>-1</sup>). Similar findings were also reported by Tuong *et al.* (2005) who reported that drought resulted to decrease in plant height, number of tillers per plant, total biomass and grain yield.

Interaction effect of different organic manures and drought stress showed significant variation on grain yield of BARI Gom-28 (Table 6 and Appendix VI). The interaction F<sub>1</sub>D<sub>0</sub> produced the highest grain yield (4.89 g plant<sup>-1</sup>) followed by F<sub>1</sub>D<sub>2</sub> (4.40 g plant<sup>-1</sup>)

and F<sub>1</sub>D<sub>1</sub> (4.26 g plant<sup>-1</sup>) while, that of the lowest (2.41 g plant<sup>-1</sup>) was observed with F<sub>0</sub>D<sub>3</sub> followed by F<sub>0</sub>D<sub>2</sub> (2.94 g plant<sup>-1</sup>) and F<sub>0</sub>D<sub>1</sub> (2.86 g plant<sup>-1</sup>).

**Table 6: Interaction effect of organic manures and drought stress on yield and harvest index data of wheat**

Treatments	Grain yield (g plant <sup>-1</sup> )	Straw yield (g plant <sup>-1</sup> )	Biological yield (g plant <sup>-1</sup> )	Harvest index (%)
F <sub>0</sub> D <sub>0</sub>	3.12 d	3.42 d	6.54 e	47.70 b
F <sub>0</sub> D <sub>1</sub>	2.86 e	3.25 e	6.11 e	46.81 d
F <sub>0</sub> D <sub>2</sub>	2.94 e	3.34 d	6.28 e	46.82 c
F <sub>0</sub> D <sub>3</sub>	2.41 f	3.17 e	5.58 f	43.19 e
F <sub>1</sub> D <sub>0</sub>	4.89 a	5.18 a	10.07 a	48.56 a
F <sub>1</sub> D <sub>1</sub>	4.26 b	4.66 b	8.92 b	47.75 b
F <sub>1</sub> D <sub>2</sub>	4.40 b	4.78 ab	9.18 b	47.93 b
F <sub>1</sub> D <sub>3</sub>	3.86 c	4.31 c	8.17 c	47.24 c
F <sub>2</sub> D <sub>0</sub>	3.74 c	4.05 c	7.79 c	48.01 a
F <sub>2</sub> D <sub>1</sub>	3.39 d	3.77 d	7.16 d	47.34 b
F <sub>2</sub> D <sub>2</sub>	3.62 cd	3.94 c	7.56 d	47.88 b
F <sub>2</sub> D <sub>3</sub>	3.31 d	3.72 d	7.03 d	47.08 c
<b>LSD<sub>0.05</sub></b>	<b>0.39</b>	<b>0.46</b>	<b>0.57</b>	<b>0.62</b>
<b>CV (%)</b>	<b>2.61</b>	<b>3.34</b>	<b>5.43</b>	<b>6.51</b>

F<sub>0</sub> = Control, F<sub>1</sub> = Cowdung 10 t ha<sup>-1</sup>, F<sub>2</sub> = Vermicompost 7 t ha<sup>-1</sup>

D<sub>0</sub> = Control, D<sub>1</sub> = Drought in crown root initiation stage (20-29 DAS), D<sub>2</sub> = Drought in booting stage (45-54 DAS), D<sub>3</sub> = Drought in anthesis stage (55-64 DAS)

#### 4.9 Straw yield

Significant variation was observed on straw yield of BARI Gom-28 due to different organic manures (Table 5 and Appendix VI). The treatment F<sub>1</sub> produced the highest straw yield (4.69 g plant<sup>-1</sup>) followed by F<sub>2</sub> (4.12 g plant<sup>-1</sup>) and the F<sub>0</sub> produced the lowest (3.68 g plant<sup>-1</sup>) straw yield.

Significant variation was observed on straw yield of BARI Gom-28 due to drought stress imposition at different stages (Table 5 and Appendix VI). The treatment D<sub>0</sub> produced the highest straw yield (5.05 g plant<sup>-1</sup>) followed by D<sub>2</sub> (4.39 g plant<sup>-1</sup>) and D<sub>3</sub> produced the lowest (2.71 g plant<sup>-1</sup>).

Interaction effect of different organic manures and drought stress showed significant variation on straw yield of BARI Gom-28 (Table 6 and Appendix VI). The interaction  $F_1D_0$  produced the highest straw yield ( $5.18 \text{ g plant}^{-1}$ ) which was statistically similar with  $F_1D_2$  ( $4.78 \text{ g plant}^{-1}$ ) and  $F_0D_3$  produced the lowest ( $3.17 \text{ g plant}^{-1}$ ) straw yield which was statistically similar with  $F_0D_1$  ( $3.25 \text{ g plant}^{-1}$ ).

#### **4.10 Biological yield**

Significant variation was observed on biological yield of BARI Gom-28 due to different organic manures (Table 5 and Appendix VII). The treatment  $F_1$  produced the highest biological yield ( $9.08 \text{ g plant}^{-1}$ ) followed by  $F_2$  ( $7.57 \text{ g plant}^{-1}$ ) and the  $F_0$  produced the lowest ( $6.45 \text{ g plant}^{-1}$ ) biological yield. This results are in conformity with Ahmadian *et al.* (2011) who reported that manure application improves the soil structure and soil moisture content, provides plant with essential elements, increases growth, number of umbrella per plant and biological yield and finally lead to increase seed yield.

Significant variation was observed on biological yield of BARI Gom-28 due to drought stress imposition at different stages (Table 5 and Appendix VII). The result showed that the treatment  $D_0$  produced the highest biological yield ( $9.77 \text{ g plant}^{-1}$ ) followed by  $D_2$  ( $8.32 \text{ g plant}^{-1}$ ) and that of the lowest ( $4.96 \text{ g plant}^{-1}$ ) was recorded from  $D_3$ . This confirms the findings of Tuong *et al.* (2005) who reported that drought resulted to decrease in plant height, number of tillers per plant, total biomass and grain yield.

Interaction effect of different organic manures and drought stress showed significant variation on biological yield of BARI Gom-28 (Table 6 and Appendix VII). It can be inferred from the result that the interaction  $F_1D_0$  produced the highest biological yield ( $10.07 \text{ g plant}^{-1}$ ) followed by  $F_1D_2$  ( $9.18 \text{ g plant}^{-1}$ ) and  $F_1D_1$  ( $8.92 \text{ g plant}^{-1}$ ) while,  $F_0D_3$  produced the lowest biological yield ( $5.58 \text{ g plant}^{-1}$ ).

#### **4.11 Harvest index**

Significant variation was observed on harvest index of BARI Gom-28 due to different organic manures (Table 5 and Appendix VII). The treatment  $F_1$  produced the highest harvest index (48.35%) followed by  $F_2$  (45.57%) and that of the lowest (42.95%) was found at  $F_0$ .

Significant variation was observed on harvest index of BARI Gom-28 due to drought stress imposition at different stages (Table 5 and Appendix VII). It was observed from

the data that the treatment  $D_0$  produced the highest harvest index (48.31%) followed by  $D_2$  (47.23%) and that of the lowest (45.36%) was found at  $D_3$  condition.

Interaction effect of different organic manures and drought stress showed significant variation on harvest index of BARI Gom-28 (Table 6 and Appendix VII). The result revealed that the interaction  $F_1D_0$  produced the highest harvest index (48.56%) which was statistically similar with  $F_2D_0$  (48.01%) and  $F_0D_3$  interaction produced the lowest (43.19%) value of harvest index.

## CHAPTER V

### SUMMARY AND CONCLUSION

The pot experiment was conducted at the net house of the Department of Agronomy, Sher-e-Bangla Agricultural University, November 2017 to April 2018 to study the impact of organic manure to combat drought stress of wheat. The experiment comprised of two factors viz. Factor A: Organic manure - 3 levels [ $F_0$  = Control,  $F_1$  = Cowdung 10 t ha<sup>-1</sup>,  $F_2$  = Vermicompost 7 t ha<sup>-1</sup>] and Factor B: Drought stress - 4 levels [ $D_0$  = Control,  $D_1$  = Drought in crown root initiation stage (20-29 DAS),  $D_2$  = Drought in booting stage (45-54 DAS),  $D_3$  = Drought in anthesis stage (55-64 DAS)]. The experiment was laid out in Completely Randomized Design (CRD) with three replications.

Different growth and yield parameters varied significantly due to difference in organic manure dose. At 20, 40, 60 DAS and at harvest, the treatment  $F_1$  produced the tallest plant (24.84, 35.77, 56.60 and 78.42 cm, respectively) and the  $F_0$  produced the shortest (18.26, 31.90, 43.95 and 54.87 cm, respectively). The treatment  $F_1$  produced the highest number of effective tillers plant<sup>-1</sup> (8.33) and  $F_0$  produced the lowest (4.00). The treatment  $F_1$  produced the highest spike length (14.61 cm) and the  $F_0$  produced the lowest (11.44 cm). The treatment  $F_1$  produced the highest number of spikelet spike<sup>-1</sup> (16.33) and the  $F_0$  produced the lowest (12.67). The treatment  $F_1$  produced the highest number of grains spikelet<sup>-1</sup> (7.67) and the  $F_0$  produced the lowest (5.00). The treatment  $F_1$  produced the highest number of grains spike<sup>-1</sup> (37.00) and the  $F_0$  produced the lowest (31.33). The treatment  $F_1$  produced the highest weight of 1000 grain (44.93 g) and the  $F_0$  produced the lowest (40.59 g). The treatment  $F_1$  produced the highest grain yield (4.39 g plant<sup>-1</sup>) and the  $F_0$  produced the lowest (2.77 g plant<sup>-1</sup>). The treatment  $F_1$  produced the highest straw yield (4.69 g plant<sup>-1</sup>) and the  $F_0$  produced the lowest (3.68 g plant<sup>-1</sup>). The treatment  $F_1$  produced the highest biological yield (9.08 g plant<sup>-1</sup>) and the  $F_0$  produced the lowest (6.45 g plant<sup>-1</sup>). The treatment  $F_1$  produced the highest harvest index (48.35%) and the  $F_0$  produced the lowest (42.95%).

Different growth and yield parameters varied significantly due to difference in drought stress level. At 20, 40, 60 DAS and at harvest, the treatment  $D_0$  produced the tallest plant (23.31, 34.97, 53.72 and 75.07 cm, respectively) and the  $D_3$  produced the shortest (17.83,

28.11, 42.62 and 61.17 cm, respectively). The treatment D<sub>0</sub> produced the highest number of effective tillers plant<sup>-1</sup> (9.67) and the D<sub>3</sub> produced the lowest (5.00). The treatment D<sub>0</sub> produced the highest spike length (15.22 cm) and the D<sub>3</sub> produced the lowest (11.86 cm). The treatment D<sub>0</sub> produced the highest number of spikelet spike<sup>-1</sup> (17.67) and the D<sub>3</sub> produced the lowest (13.00). The treatment D<sub>0</sub> produced the highest number of grains spikelet<sup>-1</sup> (8.33) and the D<sub>3</sub> produced the lowest (5.00). The treatment D<sub>0</sub> produced the highest number of grains spike<sup>-1</sup> (39.00) and the D<sub>3</sub> produced the lowest (34.67). The treatment D<sub>0</sub> produced the highest weight of 1000 grain (45.14 g) and the D<sub>3</sub> produced the lowest (39.82 g). The treatment D<sub>0</sub> produced the highest grain yield (4.72 g plant<sup>-1</sup>) and the D<sub>3</sub> produced the lowest (2.25 g plant<sup>-1</sup>). The treatment D<sub>0</sub> produced the highest straw yield (5.05 g plant<sup>-1</sup>) and the D<sub>3</sub> produced the lowest (2.71 g plant<sup>-1</sup>). The treatment D<sub>0</sub> produced the highest biological yield (9.77 g plant<sup>-1</sup>) and the D<sub>3</sub> produced the lowest (4.96 g plant<sup>-1</sup>). The treatment D<sub>0</sub> produced the highest harvest index (48.31%) and the D<sub>3</sub> produced the lowest (45.36%).

At 20 DAS, the tallest plant (27.66 cm) was observed from the F<sub>1</sub>D<sub>0</sub> interaction and the shortest (18.06 cm) from F<sub>0</sub>D<sub>3</sub>. At 40 DAS, the tallest plant (48.10 cm) was observed from the F<sub>1</sub>D<sub>0</sub> interaction and the shortest (38.44 cm) from F<sub>0</sub>D<sub>3</sub>. At 60 DAS, the tallest plant (63.15 cm) was observed from the F<sub>1</sub>D<sub>0</sub> interaction and the shortest (53.32 cm) from F<sub>0</sub>D<sub>3</sub>. At harvest, the tallest plant (78.56 cm) was observed from the F<sub>1</sub>D<sub>0</sub> interaction and the shortest (68.03 cm) from F<sub>0</sub>D<sub>3</sub>. The interaction F<sub>1</sub>D<sub>0</sub> produced the highest number of effective tillers plant<sup>-1</sup> (10.33) and F<sub>0</sub>D<sub>3</sub> produced the lowest (3.00). The interaction F<sub>1</sub>D<sub>0</sub> produced the highest spike length (16.12 cm) and F<sub>0</sub>D<sub>3</sub> produced the lowest (10.13 cm). The interaction F<sub>1</sub>D<sub>0</sub> produced the highest number of spikelet spike<sup>-1</sup> (18.00) and F<sub>0</sub>D<sub>3</sub> produced the lowest (7.00). The interaction F<sub>1</sub>D<sub>0</sub> produced the highest number of grains spikelet<sup>-1</sup> (9.67) and F<sub>0</sub>D<sub>3</sub> produced the lowest (5.00). The interaction F<sub>1</sub>D<sub>0</sub> produced the highest number of grains spike<sup>-1</sup> (40.00) and F<sub>0</sub>D<sub>3</sub> produced the lowest (28.33). The interaction F<sub>1</sub>D<sub>0</sub> produced the highest weight of 1000 grain (48.37 g) and F<sub>0</sub>D<sub>3</sub> produced the lowest (37.47 g). The interaction F<sub>1</sub>D<sub>0</sub> produced the highest grain yield (4.89 g plant<sup>-1</sup>) and F<sub>0</sub>D<sub>3</sub> produced the lowest (2.41 g plant<sup>-1</sup>). The interaction F<sub>1</sub>D<sub>0</sub> produced the highest straw yield (5.18 g plant<sup>-1</sup>) and F<sub>0</sub>D<sub>3</sub> produced the lowest (3.17 g plant<sup>-1</sup>). The interaction F<sub>1</sub>D<sub>0</sub> produced the highest biological yield (10.07 g plant<sup>-1</sup>) and F<sub>0</sub>D<sub>3</sub> produced the lowest (5.58 g plant<sup>-1</sup>). The

interaction F<sub>1</sub>D<sub>0</sub> produced the highest harvest index (48.56%) and F<sub>0</sub>D<sub>3</sub> produced the lowest (43.19%).

From the above results it can be concluded that,

- Drought stress adversely affects all the growth and yield related attributes.
- D<sub>0</sub> (control) produced better yield and yield contributing attributes than other drought stress level, and
- F<sub>1</sub> (cowdung) showed better result in all aspects under drought stress than vermicompost and control treatment.

### **Recommendation**

Bearing in mind the above observation of the present study further investigation in the following areas may be recommended:

- Further study may be required in different Agro-Ecological Zones (AEZ) of Bangladesh for rational adaptability.
- This study may be laid out in main field and more number of wheat varieties may be chosen to study the effect of drought on those varieties.

## CHAPTER VI REFERENCES

- Abass, S. M. and Mohamed, H. I. (2011). Alleviation of adverse effects of drought stress on common bean (*Phaseolus vulgaris* L.) by exogenous application of hydrogen peroxide. *Bangladesh J. Bot.* **41**: 75-83.
- Abdoli, A., Saeidi, M., Jalali-Honarmand, S., Mansourifar, S. and Ghobad, M. (2013). Effect of post-anthesis water deficiency on storage capacity and contribution of stem reserves to the growing grains of wheat cultivars. *Plant Knowl. J.* **2**(1): 99-107.
- Adams, M. M., Benjamin, T. J., Emery, N. C., Brouder, S. J. and Gibson, K. D. (2013). The effect of biochar on native and invasive prairie plant species. *Invas. Plant Sci. Mana.* **6**: 197-207.
- Ahmadian, A., Ghanbari, A., Siahisar, B., Haydari, M., Ramroodi, M. and Mousavinik, S. M. (2011). Study of Chamomile's yield and its components under drought stress and organic and inorganic fertilizer using and their residue. *J. Microbiol. Antimicrob.* **3**(2): 23-28.
- Akram, M., Hussain, M., Akhtar, S. and Rasul, E. (2002). Impact of NaCl salinity on yield components of some wheat accessions/varieties. *Intl. J. Agric. Biol.* **4**(1): 156-158.
- Alvarez, L. A. (1973). Irrigation policy and management in south Asia. International Rice Research Institute. Los Banos, Philippines. p. 130.
- Anjum, S. A., Xie, X. Y., Wang, L. C., Saleem, M. F., Man, C. and Lei, W. (2011). Morphological, physiological and biochemical responses of plants to drought stress. *African J. Agric. Res.* **6**(9): 2026-2032.
- Artiola, J. F., Rasmussen, C. and Freitas, R. (2012). Effects of a biochar amended alkaline soil on the growth of romaine lettuce and bermuda grass. *Soil Sci.* **177**: 561-570.



- Bazzaz, M. (2013). Growth, production physiology and yield in wheat under variable water regimes. Ph.D. thesis. Dept. of Agronomy. Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur.
- Beltrano, J. and Marta, G. R. (2008). Improved tolerance of wheat plants (*Triticum aestivum* L.) to drought stress and rewatering by the arbuscular mycorrhizal fungus *Glomus claroideum*: effect on growth and cell membrane stability. *Brazilian J. Plant Physiol.* **20**(1): 335-342.
- Bhattacharyya, R., Chandra, S., Singh, R. D., Kundu, S., Srivastva, A. K. and Gupta, H. S. (2007). Long-term farmyard manure application effects on properties of a silty clay loam soil under irrigated wheat-soybean rotation. *Soil Till. Res.* **94**: 386-396.
- Biswas, A. K. and Choudhuri, M. A. (1984). Effect of water stress at different developmental stages of field-grown rice. *J. Plant Biol.* **26**(4): 263-266.
- Blum, A. (2005). Drought resistance, water-use efficiency, and yield potential-are they compatible, dissonant, or mutually exclusive? *Australian J. Agr. Res.* **56**(11): 1159-1167.
- Borrell, A. K. (1991). Irrigation methods for rice in tropical Australia. In: *Intl. Rice Res. Notes.* **16**(3): 28.
- Bota, J., Medrano, H. and Flexas, J. (2004). Is photosynthesis limited by decreased Rubisco activity and RuBP content under progressive water stress? *New Phytol.* **162**(3): 671-681.
- Busso, C. A. and Fernandez, O. A. (1998). Dry weight production and partitioning in *Medicago minima* and *Erodium cicutarium* under water stress. *Ann. Bot.* **82**: 217-227.
- Centritto, M., Lauteri, M., Monteverdi, M. C. and Serraj, R. (2009). Leaf gas exchange, carbon isotope discrimination, and grain yield in contrasting rice genotypes subjected to water deficits during the reproductive stage. *J. Exp. Bot.* **60**(8): 2325-2339.

- Chaves, M. M., Pereira, J. S., Maroco, J., Rodrigues, M. L., Ricardo, C. P. P., Oserio, M. L., Carvalho, I., Faria, T. and Pinheiro, C. (2002). How do plants cope with water stress in the field? Photosynthesis and growth. *Ann. Bot.* **89**: 907-916.
- Cheng, D. G. and Kato, C. H. (2010). Effects of exogenous spermine on polyethylene glycol-induced responses in rice leaves. *Crop Environ. Bioinformatics.* **7**: 233-242.
- Clark, L. J., Price, A. H., Steele, K. A. and Whalley, W. R. (2008). Evidence from near-isogenic lines that root penetration increases with root diameter and bending stiffness in rice. *Funct. Plant Biol.* **35**: 1163-1171.
- Comas, L. H., Becker, S. R., Cruz, V. M. V., Byrne, P. F. and Dierig, D. A. (2013). Root traits contributing to plant productivity under drought. *Front. Plant Sci.* **4**: 1-16.
- Courtney, R. G. and Mullen, G. J. (2008). Soil quality and barley growth as influenced by the land application of two compost types. *Bioresour. Technol.* **99**: 2913-2918.
- Curtis, M. J. and Claassen, V. P. (2005): Compost incorporation increases plant available water in a drastically disturbed serpentine soil. *Soil Sci.* **170**: 939-953.
- DAE (Department of Agricultural Extension) (2018). <http://dae.portal.gov.bd/>
- Dang, T. H., Cai, G. X., Guo, S. L., Hao, M. D. and Heng, L. K. (2006). Effects of nitrogen management on yield and water use efficiency of rainfed wheat and maize in northwest China. *Pedosphere.* **16**: 495-504.
- Daryanto, S., Wang, L. and Jacinthe, P. A. (2017). Global synthesis of drought effects on cereal, legume, tuber and root crops production: A review. *Agric. Water Manag.* **179**: 18-33.
- Das, R. and Kalita, P. (2010). Characterization of some upland rice cultivars under moisture stress condition. *Indian J. Plant Physiol.* **15**(1): 54-60.

- Dehnavy, M. M., Sanavy, S. A. M. M. and Bidgoli, A. M. (2009). Foliar application of zinc and manganese improves seed yield and quality of safflower (*Carthamus tinctorius* L.) grown under water deficit stress. *Ind. Crop Prod.* **30**(1): 82-92.
- Demirevska, K., Simova-Stoilova, L., Fedina, I., Georgieva, K. and Kunert, K. (2010). Response of oryzacystatin I transformed tobacco plants to drought, heat and light stress. *J. Agron. Crop Sci.* **196**(2): 90-99.
- FAOSTAT. Food and Agriculture Organization of The United Nations. (2016). Food and agricultural commodities production. <http://faostat3.fao.org>.
- Farooq, M., Hussain, M. and Siddique, K. H. M. (2014). Drought stress in wheat during flowering and grain-filling periods. *Crit. Rev. Plant Sci.* **33**: 331-349.
- Farooq, M., Wahid, A., Kobayashi, N., Fujita, D. and Basra, S. M. A. (2009). Plant drought stress: Effects, mechanisms and management. *Agron. Sustain. Dev.* **29**(1): 185-212.
- FRG (Fertilizer Recommendation Guide). (2012). Bangladesh Agricultural Research Council (BARC). Farmgate, Dhaka-1215. p. 88.
- Gaskin, J. W., Speir, R. A., Harris, K., Das, K. C., Morris, R. D., Lee, L. A. and Fisher, D. S. (2010). Effect of peanut hull and pine chip biochar on soil nutrients, corn nutrient status, and yield. *Agron. J.* **102**: 623-633.
- Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedures for Agricultural Research. 2<sup>nd</sup> Edition. An International Rice Research Institute. John Wiley and Sons. New York, Chichester, Brisbane, Toronto, Singapore. pp. 139-240.
- Guan, Y. S., Serraj, R., Liu, S. H., Xu, J. L., Ali, J., Wang, W. S., Venus, E., Zhu, L. H. and Li, Z. K. (2010). Simultaneously improving yield under drought stress and non-stress conditions: A case study of rice (*Oryza sativa* L.). *J. Exp. Bot.* **61**: 4145-4156.
- Hansen, J. M. and Jones, G. D. P. (2006). Nuclear and mitochondrial compartmentation of oxidative stress and redox signaling. *Annu. Rev. Pharmacol. Toxicol.* **46**: 215-234.

- Haq, A. U., Vamil, R. and Agnihotri, R. K. (2010). Effect of osmotic stress on germination and seedling survival of Lentil (*Lens culinaris* Medik). *J. Agric. Sci.* **1**(3): 201-204.
- Hasanuzzaman, M., Nahar, K., Gill, S. S. and Fujita, M. (2013). Drought stress responses in plants, oxidative stress, and antioxidant defense. In: Tuteja, N. and Gill, S. S. (eds) *Climate Change and Plant Abiotic Stress Tolerance*. Weinheim: Wiley-VCH Verlag GmbH & Co. KGaA. pp. 209-250.
- Hasanuzzaman, M., Nahar, K., Hossain, M. S., Mahmud, J. A., Rahman, A., Inafuku, M., Oku, H. and Fujita, M. (2017). Coordinated actions of glyoxalase and antioxidant defense systems in conferring abiotic stress tolerance in plants. *Intl. J. Mol. Sci.* **18**(1): 200.
- Hatfield, J. L. and Prueger, J. H. (2015). Temperature extremes: Effect on plant growth and development. *Weather Clim. Extrem.* **10**: 4-10.
- Hossain, M. A. (2001). Growth and yield performance of some boro rice cultivars under different soil moisture regimes. M.S. Thesis. Department of Crop Botany. Bangladesh Agricultural University, Mymensingh 2202.
- Hsiao, T. C. (1982). The soil-plant-atmosphere continuum in relation to drought and crop production. In: *Drought resistance in crops with emphasis on rice*. IRRI, Los Banos, Philippines. pp. 39-52.
- Hussain, M., Malik, M. A., Farooq, M., Khan, M. B., Akram, M. and Saleem, M. F. (2009). Exogenous glycinebetaine and salicylic acid application improves water relations, allometry and quality of hybrid sunflower under water deficit conditions. *J. Agron. Crop Sci.* **195**: 98-109.
- Jaleel, C. A., Manivannan, P., Sankar, B., Kishorekumar, A., Gopi, R., Somasundaram, R. and Panneerselvam, R. (2007). Water deficit stress mitigation by calcium chloride in *Catharanthus roseus*; effects on oxidative stress, proline metabolism and indole alkaloid accumulation. *Colloids Surf. B Biointerfaces.* **60**: 110-116.
- Jaleel, C. A., Manivannan, P., Lakshmanan, G. M. A., Gomathinayagam, M. and Panneerselvam, R. (2008a). Alterations in morphological parameters and

photosynthetic pigment responses of *Catharanthus roseus* under soil water deficits. *Colloids Surf. B Biointerfaces*. **61**: 298-303.

Jaleel, C. A., Gopi, R., Sankar, B., Gomathinayagam, M. and Panneerselvam, R. (2008b). Differential responses in water use efficiency in two varieties of *Catharanthus roseus* under drought stress. *C. R. Biol.* **331**: 42-47.

Jaleel, C. A., Manivannan, P., Wahid, A., Farooq, M., Al-Juburi, H. J., Somasundaram, R. and Panneerselvam, R. (2009). Drought stress in plants: A review on morphological characteristics and pigments composition. *Intl. J. Agric. Biol.* **11**: 100-105.

Jha, B. N. and Singh, R. A. (1997). Physiological responses of rice varieties to different levels of moisture stress. *Indian J. Plant Physiol.* **2**(1): 81-84.

Johnson, G. A., Qian, Y. L. and Davis, J. G. (2009). Topdressing Kentucky bluegrass with compost increases soil water content and improves turf quality during drought. *Compost Sci. Util.* **17**: 95-102.

Kakade, B. V. and Soner, K. R. (1983). Nutrient uptake and yield of rice as influenced by moisture regimes. In: *Intl. Rice Comm. Newsl.* No: 32.

Kalvanagh, J. S. and Heris, A. N. (2013). The effect of water deficit stress, organic and inorganic fertilizers on yield and yield components of dragon's head (*Lallemantia iberica*). *Intl. J. Agron. Plant Prod.* **4**(7): 1558-1563.

Kamoshita, A., Rodriguez, R., Yamauchi, A. and Wade, L. (2004). Genotypic variation in response of rainfed lowland to prolonged drought and rewatering. *Plant Prod. Sci.* **7**(4): 406-420.

Karhu, K., Mattila, T., Bergström, I. and Regina, K. (2011). Biochar addition to agricultural soil increased CH<sub>4</sub> uptake and water holding capacity-results from a short-term pilot field study. *Agric. Ecosyst. Environ.* **140**: 309-313.

Kato, Y. and Okami, M. (2011). Root morphology, hydraulic conductivity and plant water relations of high yielding rice grown under aerobic conditions. *Ann. Bot.* **108**(3): 575-583.

- Keyvan, S. (2010). The effects of drought stress on yield, relative water content, proline, soluble carbohydrates and chlorophyll of bread wheat cultivars. *J. Anim. Plant Sci.* **8**(3): 1051-1060.
- Kobayashi, Y., Abe, S. and Masking, K. (1989). Growth and yield of paddy under natural cultivation. *Soil Fert.* **54**(12): 19-31.
- Kulkarni, M. and Deshpande, U. (2007). In Vitro screening of tomato genotypes for drought resistance using polyethylene glycol. *African J. Biotechnol.* **6**: 691-696.
- Kumar, R. and Kujur, R. (2003). Role of secondary traits in improving the drought tolerance during flowering stage in rice. *Indian J. Plant Physiol.* **8**(3): 236-240.
- Kumar, S., Dwivedi, S. K., Singh, S. S., Bhatt, B. P., Mehta, P., Elanchezhian, R., Singh, V. P. and Singh, O. N. (2014). Morphophysiological traits associated with reproductive stage drought tolerance of rice (*Oryza sativa* L.) genotypes under rain-fed condition of eastern Indo-Gangetic Plain. *Indian J. Plant Physiol.* **19**(2): 87-93.
- Lafitte, R., Blum, A. and Atlin, G. (2003). Using secondary traits to help identify drought tolerant genotypes In: Breeding rice for drought-prone environments, International Rice Research Institute, Philippines.
- Lakhdar, A., Rabhi, M., Ghnaya, T., Montemurro, F., Jedidi, N. and Abdelly, C. (2009). Effectiveness of compost use in salt-affected soil. *J. Hazard. Mater.* **171**: 29-37.
- Lehmann, J., Gaunt, J. and Rondon, M. (2006). Biochar sequestration in terrestrial ecosystems - A review. *Mitigation and Adaptation Strategies for Global Change.* **11**(2): 403-427.
- Lesk, C., Rowhani, P. and Ramankutty, N. (2016). Influence of extreme weather disasters on global crop production. *Nature.* **529**: 84-87.
- Liu, C. A., Li, F. M., Zhou, L. M., Zhang, R. H., Lin, S. L. and Wang, L. J. (2013). Effect of organic manure and fertilizer on soil water and crop yields in newly

- built terraces with loess soils in a semi-arid environment. *Agric. Water Manag.* **117**: 123-132.
- Liu, J. X., Liao, D. Q., Oane, R., Estenor, L., Yang, X. E., Li, Z. C. and Bennett, J. (2006). Genetic variation in the sensitivity of anther dehiscence to drought stress in rice. *Field Crops Res.* **97**: 87-100.
- Lobell, D. B. and Gourджи, S. M. (2012). The influence of climate change on global crop productivity. *Plant Physiol.* **160**(4): 1686-1697.
- Majeed, A., Salim, M., Bano, A., Asim, M. and Hadees, M. (2011). Physiology and productivity of rice crop influenced by drought stress induced at different developmental stages. *African J. Biotechnol.* **10**(26): 5121-5136.
- McGuire S. (2012). WHO, World Food Programme, and International Fund for Agricultural Development. 2012. The State of Food Insecurity in the World 2012. Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition. Rome, FAO. *Adv. Nutr.* **4**: 126-127.
- Mirzaei, A., Naseri, R. and Soleimani, R. (2011). Response of different growth stages of wheat to moisture tension in a semiarid land. *World Appl. Sci. J.* **12**(1): 83-89.
- Mostajeran, A. and Eichi, V. R. (2009). Effects of drought stress on growth and yield of rice (*Oryza sativa* L.) cultivars and accumulation of proline and soluble sugars in sheath and blades of their different ages leaves. *Am. Eurasian J. Agric. Environ. Sci.* **5**(2): 264-272.
- Nayak, D. R., Babu, X. and Adhay, T. K. (2007). Long-term application of compost influences mineral biomass and enzyme activities in a tropical Aeris Endoaquept planted to rice under flooded condition. *J. Soil. Sci.* **39**(8): 1897-1906.
- NeSmith, D. S. and Ritchie, J. T. (1973). Effects of soil water-deficits during tassel emergence on development and yield component of maize (*Zea mays* L.). *Field Crops Res.* **28**(3): 251-256

- Osborne, S. L., Schepersb, J. S., Francisb, D. D. and Schlemmerb, M. R. (2002). Use of spectral radiance to estimate in season biomass and grain yield in nitrogen and water stress on corn. *Crop Sci.* **42**: 165-171.
- Pantuwan, G., Fukai, S., Cooper, M., Rajatasereekul, S. and O'Toole, J. C. (2002). Yield response of rice (*Oryza sativa* L.) genotypes to drought under rain fed lowland. Plant factors contributing to drought resistance. *Field Crops Res.* **73**: 181-200.
- Peng, X., Ye, L. L., Wang, C. H., Zhou, H. and Sun, B. (2011). Temperature and duration dependent rice straw-derived biochar: Characteristics and its effects on soil properties of an ultisol in southern China. *Soil Tillage Res.* **112**: 159-166.
- Pirdashti, H., Sarvestani, Z. T. and Bahmanyar, M. A. (2009). Comparison of physiological responses among four contrast rice cultivars under drought stress conditions. *World Acad. Sci. Eng. Technol.* **49**: 52-53.
- Pirdashti, H., Sarvestani, Z. T., Nematzadeh, H. and Ismail, A. (2003). Effect of Water stress on seed germination and seedling growth of rice (*Oryza sativa* L.) genotypes. *Pakistan J. Agr. Sci.* **2**(4): 217-222.
- Plaut, Z., Butow, B. J., Blumenthal, C. S. and Wrigley, C. W. (2004). Transport of dry matter into developing wheat kernels and its contribution to grain yield under post-anthesis water deficit and elevated temperature. *Field Crops Res.* **86**: 185-198.
- Rahman, M. I., Islam M. I. and Islam, M. O. (2002). Effect of water stress at different growth stages on yield and yield contributing characters of transplanted aman rice. *Pakistan J. Biol. Sci.* **5**(2): 169-172.
- Rahman, M. S., Islam, M. R., Rahman, M. M. and Hossain, M. I. (2009). Effect of cowdung, poultry manure and urea-N on the yield and nutrient uptake of BRRI dhan29. *Bangladesh Res. Public. J.* **2**: 552-558.
- Rajaram, S. (2000). International wheat breeding: Past and present achievements and future directions. Warren E. Kronstand Honorary Symposium. 18 Feb, 1999. Oregon State University Extension Service. Special Report. p. 1017.



- Raju, R. A. (1980). Effect of irrigation regimes on agronomic characters of rice. In: *Intl. Rice Comm. Newsl.* No: 5.
- Rawgamannar, K. T. V., Pande, H. K. and Nitra, B. N. (1978). Studies on water management of rice in relation to contribution from ground water table, pot culture experiments. *Intl. Rice Comm. Newsl.* No: 32.
- Renmin, W. and Yuanshu, D. (1989). Studies on ecological factors on ecological factors of rices from heading to maturity I. Effect of different soil moisture content on fertilization, grain-filling and grain quality of early indica rice. *J. Zhejiang U.* **1**: 114-125.
- Reynolds, M. and Tuberosa, R. (2008). Translational research impacting on crop productivity in drought-prone environments. *Curr. Opin. Plant Biol.* **11**(2): 171-179.
- Russel, D. F. (1986). MSTAT-C Package Programme. Crop and Soil Science Department. Michigan State University, USA.
- Samonte, S., Wilson, L. T., McClung, A. M. and Tarpley, L. (2001). Seasonal dynamics of non-structural carbohydrates in 15 diverse rice genotypes. *Crop Sci.* **41**: 902-909.
- Saneoka, H., Moghaieb, R. E. A., Premachandra, G. S. and Fujita, K. (2004): Nitrogen nutrition and water stress effects on cell membrane stability and leaf water relation in *Agrostis palustris* Huds. *Environ. Exp. Bot.* **52**: 131-138.
- Saragih, A. A., Puteh, A. B., Ismail, M. R. and Mondal, M. M. A. (2013). Pollen quality traits of cultivated (*Oryza sativa* L. ssp. *indica*) and weedy (*Oryza sativa* var. *nivara*) rice to water stress at reproductive stage. *Australian J. Crop Sci.* **7**(8): 1106-1112.
- Sarvestani, Z. T. and Pirdashti, H. (2008). Study of water stress effect in different growth stages on yield and yield components of different rice cultivars. *Pakistan J. Biol. Sci.* **11**(10): 1303-1309.

- Sarvestani, Z. T., Pirdashti, H., Ali, S., Sanavy, M. M. and Balouchi, H. (2008). Study of water stress effects in different growth stages on yield and yield components of different rice (*Oryza sativa* L.) cultivars. *Pakistan J. Biol. Sci.* **11**(10): 1303-1309.
- Sarwar, G., Hussain, N., Schmeisky, H. and Muhammad, S. (2007). Use of compost an environment friendly technology for enhancing rice-wheat production in Pakistan. *Pak. J. Bot.* **39**(5): 1553-1558.
- Schneekloth, J., Bauder, T. and Hansen, N. (2012). Limited Irrigation Management: Principles and Practices. Colorado State University Extension. 4/03. Fact Sheet No. 4.720. <http://www.ext.colostate.edu/pubs/crops/04720.html>.
- Seghatoleslami, M. (2013). Effect of water stress, bio-fertilizer and manure on seed and essential oil yield and some morphological traits of cumin. *Bulg. J. Agric. Sci.* **19**(6): 1268-1274.
- Serraj, R., Kumar, A., McNally, K. L., Slamet-Loedin, I., Bruskiewich, R., Mauleon, R., Cairns, J. and Hijmans, R. J. (2009). Improvement of drought resistance in rice. *Adv. Agron.* **103**: 41-99.
- Shahbaz, M., Ashraf, M., Akram, N. A., Hanif, A., Hameed, S., Joham, S. and Rehman, R. (2011). Salt-induced modulation in growth, photosynthetic capacity, proline content and ion accumulation in sunflower (*Helianthus annuus* L.). *Acta Physiol. Plant.* **33**: 1113-1122.
- Shao, H. B., Chu, L. Y., Shao, M. A., Jaleel, C. A. and Mi, H. M. (2008). Higher plant antioxidants and redox signaling under environmental stresses. *C. R. Biol.* **331**: 433-441.
- Sharma, P. and Dubey, R. S. (2005). Drought induced oxidative stress and enhances the activities of antioxidant enzyme in growing rice seedling. *Plant Growth Regul.* **46**: 209-221.
- Shi, J. F., Mao, X. G., Jing, R. L., Pang, X. B., Wang, Y. G. and Chang, X. P. (2010). Gene expression profiles of response to water stress at the jointing stage in wheat. *Agric. Sci. China.* **9**(3): 325-330.

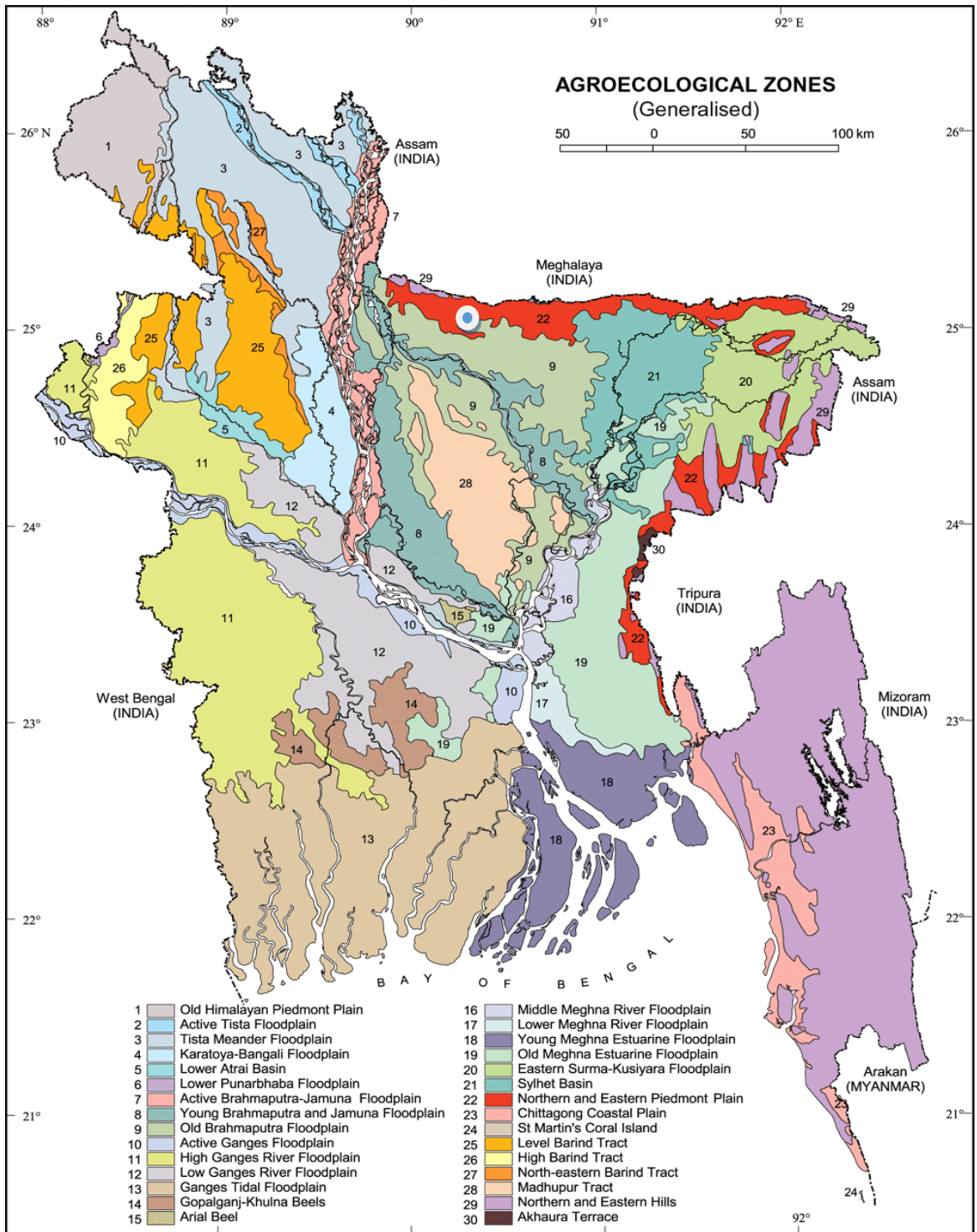
- Shirani, H., Hajabbasi, M. A., Afyuni, M. and Hemmat, A. (2002). Effects of farmyard manure and tillage systems on soil physical properties and corn yield in central Iran. *Soil Till. Res.* **68**: 101-108.
- Siddique, M. R. B., Hamid, A. and Islam, M. S. (2001). Drought stress effects on water relations of wheat. *Bot. Bull. Acad. Sinica.* **41**: 35-39.
- Sikuku, P. A., Netondo, G. W., Onyango, J. C. and Musyimi, D. M. (2010). Chlorophyll fluorescence, protein and chlorophyll content of three nerica rainfed rice varieties under varying irrigation regimes. *J. Agric. Biol. Sci.* **23**: 19-25.
- Silva, P. S. L., Silva, J. D., Henrique, F., Oliveira, T. D., Sousa, A. K. F. and Duda, G. P. (2006). Residual effect of cattle manure application on green ear yield and corn grain yield. *Horticultura. Brasileira.* **24**: 166-169.
- Singh, B. N. (2006). Breeding for drought resistant upland and rainfed lowland rice cultivars. In: Abstracts of 26<sup>th</sup> International Rice Research Conference, held at IARI, New Delhi during October 9-13, 2006. p. 245.
- Sokoto, M. B. and Muhammad, A. (2014). Response of rice varieties to water stress in Sokoto, Sudan Savannah, Nigeria. *J. Biosci. Med.* **2**: 68-74.
- Tahi, H., Wahbi, S., Wakrim, R., Aganchich, B., Serraj, R. and Centritto, M. (2007): Water relations, photosynthesis, growth and water use efficiency in tomato plants subjected to partial root zone drying and regulated deficit irrigation. *Plant Biosystems.* **141**: 265-274.
- Taiz, L. and Zeiger, E. (2010). *Plant Physiology*. 5<sup>th</sup> Edition. Sinauer Associates Inc., Sunderland. pp. 772-782.
- Tejada, M., Hernandez, M. T. and Garcia, C. (2009). Soil restoration using composted plant residues: Effects on soil properties. *Soil Till. Res.* **102**: 109-117.
- Tezera, W., Mitchell, V., Driscoll, S. P. and Lawlor, D. W. (2002). Effects of water deficit and its interaction with CO<sub>2</sub> supply on the biochemistry and physiology of photosynthesis in sunflower. *J. Exp. Bot.* **53**: 1781-1791.

- Tilman, D., Balzer, C., Hill, J. and Befort, B. L. (2011). From the Cover: Global food demand and the sustainable intensification of agriculture. *Proc. Natl. Acad. Sci. USA*. **108**: 20260-20264.
- Tuong, T. P. and Bouman, B. A. M. (2005). Rice production in water-scarce environments. International Rice Research Institute (IRRI), Metro Manila, Philippines.
- Turk, M. A, Tawaha, A. R. and Lee, D. K. (2004). Seedling growth of three lentil cultivars under moisture stress. *Asian J. Plant Sci.* **3**(3): 394-397.
- Vaccari, F. P., Baronti, S. and Lugato, E. (2011). Biochar as a strategy to sequester carbon and increase yield in durum wheat. *European J. Agron.* **34**: 231-238.
- Wang, S. X., Xia, S. T., Peng, K. Q., Kuang, F. C., Yong, C. and Xiao, L. T. (2007). Effects of formulated fertilizer synergist on abscisic acid accumulation, proline content and photosynthetic characteristics of rice under drought. *Rice Sci.* **14**(1): 42-48.
- Watanabe, S., Kojima, K., Ide, Y. and Satohiko, S. (2000). Effects of saline and osmotic stress on proline and sugar accumulation in *Populus euphratica* in vitro. *Plant Cell Tissue Organ Cult.* **63**(3): 199-206.
- Yang, C. M., Yang, L., Yang, Y. and Ouyang, Z. (2004). Rice root growth and nutrient uptake as influenced by organic manure in continuously and alternately flooded paddy soils. *Water Sci. Technol.* **70**(1): 67-81.
- Yassen, A. A., El-Hady, M. A. and Zaghloul, S. M. (2006). Replacement part of mineral N fertilizer by organic ones and its effect on wheat plant under water regime conditions. *World J. Agric. Sci.* **2**: 421-428.
- Zampieri, M., Ceglar, A., Dentener, F. and Toreti, A. (2017). Wheat yield loss attributable to heat waves, drought and water excess at the global, national and subnational scales. *Environ. Res. Lett.* **12**: 64-80.

- Zhao, C. X., Guo, L. Y., Jaleel, C. A., Shao, H. B. and Yang, H. B. (2008). Prospects for dissecting plant-adaptive molecular mechanisms to improve wheat cultivars in drought environments. *Comp. Rend. Biol.* **331**: 579-586.
- Zhao, D. L., Atlinb, G. N., Amantea, M. and Kumara, A. (2010). Developing aerobic rice cultivars for water-short irrigated and drought-prone rainfed areas in the tropics. *J. Environ. Qual.* **28**(50): 2268-2276.
- Zubaer, M. A., Chowdhury, A. K. M. M. B., Islam, M. Z., Ahmed, T. and Hasan, M. A. (2007). Effects of water stress on growth and yield attributes of aman rice genotypes. *Intl. J. Sustain. Crop Prod.* **2**(6): 25-30.

## APPENDICES

### Appendix I. Experimental location on the map of Agro-Ecological Zones of Bangladesh



**Appendix II. Morphological characteristics of the experimental field**

<b>Morphology</b>	<b>Characteristics</b>
Location	SAU Farm, Dhaka
Agro Ecological Zone	Madhupur Tract (AEZ- 28)
General Soil Type	Deep Red Brown Terrace Soil
Parent material	Madhupur Terrace
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

**Source: SAU Farm, Dhaka**

**Appendix III. Initial physical and chemical characteristics of the soil**

<b>Characteristics</b>	<b>Value</b>
Mechanical fractions:	
% Sand (2.0-0.02 mm)	37.00
% Silt (0.02-0.002 mm)	50.00
% Clay (<0.002 mm)	13.00
Textural class	Silt Loam
pH (1: 2.5 soil- water)	6.0
Organic Matter (%)	2.29
Total N (%)	0.115
Available K (ppm)	0.20
Available P (ppm)	32.74
Available S (ppm)	6.52

**Source: SRDI, Farmgate, Dhaka (2017)**

**Appendix IV. Moisture content (%) before and after drought stress impose**

Treatment	Moisture after 1 <sup>st</sup> drought impose	Moisture before 2 <sup>nd</sup> drought impose	Moisture after 2 <sup>nd</sup> and before 3 <sup>rd</sup> drought impose	Moisture after 3 <sup>rd</sup> drought impose
F <sub>0</sub> D <sub>0</sub>	9.79	11.46	7.29	7.04
F <sub>0</sub> D <sub>1</sub>	4.98	12.26	8.11	7.12
F <sub>0</sub> D <sub>2</sub>	9.72	12.17	1.60	7.33
F <sub>0</sub> D <sub>3</sub>	11.02	12.07	8.67	1.87
F <sub>1</sub> D <sub>0</sub>	11.36	13.64	9.69	9.55
F <sub>1</sub> D <sub>1</sub>	7.59	13.36	11.15	9.67
F <sub>1</sub> D <sub>2</sub>	11.09	13.20	2.96	9.48
F <sub>1</sub> D <sub>3</sub>	11.52	13.61	9.79	2.92
F <sub>2</sub> D <sub>0</sub>	9.95	13.01	8.57	7.90
F <sub>2</sub> D <sub>1</sub>	5.84	13.20	9.98	8.23
F <sub>2</sub> D <sub>2</sub>	9.68	12.28	1.72	8.12
F <sub>2</sub> D <sub>3</sub>	9.78	12.83	9.57	2.21

**Appendix V. Analysis of variance of the data on plant height at different days after sowing, and number of effective tillers plant<sup>-1</sup>**

Source of variation	Degrees of freedom	Mean square					Number of effective tillers plant <sup>-1</sup>
		Plant height					
		20 DAS	40 DAS	60 DAS	At harvest		
Factor A	2	341.19*	872.67*	1891.79*	3459.43**	511.56*	
Factor B	3	18.51**	19.58*	15.96*	18.95**	52.64*	
A × B	6	1.12*	1.61**	1.05*	2.53*	17.48*	
Error	24	3.15	2.08	3.59	2.44	11.35	

\*Significant at 5% level

\*\*Significant at 1% level

**Appendix VI. Analysis of variance of the data on spike length, number of spikelet spike<sup>-1</sup>, number of grains spikelet<sup>-1</sup> and number of grains spike<sup>-1</sup>**



Source of variation	Degrees of freedom	Mean square			
		Spike length	Number of spikelet spike <sup>-1</sup>	Number of grains spikelet <sup>-1</sup>	Number of grains spike <sup>-1</sup>
Factor A	2	148.28*	40.54*	47.89*	643.57**
Factor B	3	49.28*	7.79*	21.77**	82.64*
A × B	6	6.98*	4.43*	3.58*	2.48*
Error	24	4.86	1.09	1.58	2.52

\*Significant at 5% level

\*\*Significant at 1% level

**Appendix VII. Analysis of variance of the data on weight of 1000 grain, grain yield and straw yield**

Source of variation	Degrees of freedom	Mean square		
		Weight of 1000 grain	Grain yield	Straw yield
Factor A	2	353.59*	564.83*	1223.42*
Factor B	3	23.52**	66.59**	53.29*
A × B	6	3.82*	1.86**	1.29 *
Error	24	2.85	6.36	5.66

\*Significant at 5% level

\*\*Significant at 1% level

**Appendix VIII. Analysis of variance of the data on biological yield and harvest index**

Source of variation	Degrees of freedom	Mean square	
		Biological yield	Harvest index
Factor A	2	47.54*	46.82*
Factor B	3	17.28**	15.63**
A × B	6	3.44*	2.45*
Error	24	1.98	2.62

\*Significant at 5% level

\*\*Significant at 1% level

# PLATES



Plate 1: Experiment in net house



Plate 2: Plants without organic manure



**Plate 3: Plants treated with cowdung**



**Plate 4: Plants treated with vermicompost**



**Plate 5: Tagging for data collection**



**Plate 6: Data collection**



**Plate 7: Field visit by Member Director (Crop) - BARC and Supervisor**