ALLEVIATION OF DROUGHT STRESS IN WHEAT BY DIFFERENT ORGANIC AMENDMENTS

MD. NUR NABI ISLAM

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

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ALLEVIATION OF DROUGHT STRESS IN WHEAT BY DIFFERENT ORGANIC AMENDMENTS

BY

MD. NUR NABI ISLAM

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Approved by:

....	....
Dr. Mirza Hasanuzzaman	**Shimul Chandra Sarker**
Professor	**Assistant Professor**
Supervisor	**Co-Supervisor**

....

Prof. Dr. Shahidul Islam

Chairman

Examination Committee

Department of Agronomy

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

*This is to certify that thesis entitled, "**ALLEVIATION OF DROUGHT STRESS IN WHEAT BY DIFFERENT ORGANIC AMENDMENTS**"submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN AGRONOMY,** embodies the result of a piece of bona-fide research work carried out by **MD. NUR NABI ISLAM ,** Registration no. 18-09287 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Date:
Dhaka, Bangladesh

Dr. Mirza Hasanuzzaman
Professor
Department of Agronomy
Sher-e-Bangla Agricultural University,
Dhaka-1207

DEDICATED

TO MY

BELOVED PARENTS

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ALLEVIATION OF DROUGHT STRESS IN WHEAT BY DIFFERENT ORGANIC AMENDMENTS

ABSTRACT

Drought stress is one of the major threat of agricultural production. A pot experiment with organic amendments was conveyed at the experimental net house of the Department of Agronomy, Sher-e Bangla Agricultural University, Dhaka from November-February, 2018 to investigate the effect of drought stress on the growth, physiology and yield and the mollification capacity of drought in wheat using organic amendments. The experiment was carried out by BARI gom-26 and treatments were well-watered, water deficit and organic amendments viz. control (C), compost (CO) @10 t ha^{-1}, vermicompost (VC) @ 10 t ha^{-1}, poultry manure (PM) @10 t ha^{-1}, biochar (B) @ 2.5% w/w soil and chitosan (CH) @ 1% w/w soil. Drought stress reduced germination 7.48%, plant height 15.02%, SPAD value 15.91%, relative water content 13.44%, number of spikelet $spike^{-1}$ 16.92%, number of grains $spike^{-1}$ 11.73%, and hundred grains weight 17.83%. Application of organic amendments acts as a protectant and reduces drought stress condition and in most cases it enhanced above these growth, physiological, yield and yield attributes. Germination enhanced 11.82 % by compost application, SPAD value enhanced 17.52% by vermicompost, Plant height increased 16.01% by poultry manure, number of spikelets $spike^{-1}$ enhanced 19.92% by vermicompost, number of grains $spike^{-1}$ increased 16.62% by vermicompost application than control under drought condition. Organic amendments prevents the production of reactive oxygen species and consequently prevents from oxidative stress. So, the present study concluded that organic amendments played significant role to alleviate drought and among these vermicompost performed better.

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LIST OF ACRONYMS AND ABBREVIATIONS

μM	Micromolar
AGR	Absolute growth rate
ANOVA	Analysis of variance
APX	Ascorbate peroxidase
AsA	Ascorbic acid/Ascorbate
B	Biochar
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
C	Control
CO	Compost
CH	Chitosan
CAT	Catalase
Chl	Chlorophyll
DAS	Days after sowing
DHAR	Dehydroascorbate reductase
DNA	Deoxyribo nucleic acid
et al	and others
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
GPX	Glutathione peroxidase
GR	Glutathione reductase
GSH	Reduced glutathione
GSSG	Glutathione disulphide
GST	Glutathione -*S*- transferase
IPCC	Intergovernmental panel on climate change
LSD	Least significant difference
MDA	Malondealdehyde

LIST OF ACRONYMS AND ABBREVIATIONS (Cont'd)

MDHA	Monodehydroascorbate
MDHAR	Monodehydroascorbate reductase
MG	Methylglyoxal
O_2^-	Superoxide radical
$^1O_2$	Singlet oxygen
OH^-	Hydroxyl radical
PM	Poultry manure
PAR	Photosynthetically active radiation
PEG	Poly ethylene glycol
POD	Peroxidase
POX	Peroxidases
Pro	Proline
PS I	Photosystem I
PS II	Photosystem II
RCBD	Randomized completely block design
ROS	Reactive oxygen species
RuBisCo	Ribulose-1,5-bisphosphate carboxylase/oxygenase
RWC	Relative water content
SOD	Superoxide dismutase
SPAD	Soil plant analysis development
SRDI	Soil Resource Development Institute
USDA	United States Department of Agriculture
VC	Vermicompost

Chapter I

INTRODUCTION

Wheat (*Triticum aestivum* L.) belongs to Poaceae (Gramineae) family is one of the most important cultivated cereal crop throughout the world and supplies vital nourishment to the major part of world population. Wheat had been cultivated since 8000 years ago and in Europe, West Asia and North Africa it has been used as a major cereal crop (Curtis, 2002). Wheat alone provides more than about 36% world population as their staple food and contains about 55% of carbohydrates and 20% of food calories taken as human diet worldwide (Lobell and Gourdji, 2012; Hasanuzzaman *et al*., 2017).

In globally ranking produced grain crop, wheat takes first position in area (213.6 million hectares) and third in production (576.4 million metric tons) (FAO, 2000). Annual wheat production of Bangladesh is about 1.2 million tons that covers about 0.64 million ha of land and takes second position of important cereal crop after rice (BBS, 2007). In Bangladesh, daily wheat consumption rate is about 28-30 g per day per person that indicates annual demand is about 4 million tons. Moreover, the necessary of daily consumption is gradually increase day by day due to rapid use of bakery products, livestock and poultry feed. As a result, a greater amount of wheat is need to import to fulfill this increased demand every year (Karim *et al*., 2010).

However, wheat yield production in our country is much lower comparing with other producing countries in the world because of under rain fed condition (Bazzaz, 2013). In current decades, rapid changes in global climate creating a potential intimidation for the world agricultural productivity. Different biotic and abiotic stresses like virus, bacteria, insect-pest infestation, high and low temperature, drought, salinity etc. affected the growing plants throughout the whole growing season.

The consequence of deleterious payoff of global climate alteration in terms of different biotic and abiotic stresses which ultimately come to decline of yield attributes (Hasanuzzaman *et al*., 2012a). About 50% of world agricultural productivity including wheat is drastically declined as a consequence of abiotic stress (Vandenbroucke and Metzlaff, 2013). Drought is liable for water deficiency in plant body and the elementary outcome to reduce water content in plant tissue (Hasanuzzaman *et al.*, 2014).

The primary effect of drought is the creation of oxidative stress that overproduces reactive oxygen species (ROS) that convey different physiological disorders of plant (Gill and Tuteja, 2010; Hasanuzzaman *et al.*, 2012a). Irrigation scarcity greatly waned 1000-grain weight (Emam *et al*., 2007), growth of the plant and grain yield of wheat (Moghaddam *et al.,* 2012), height of plant and grain yield of wheat plant (Akbar *et al.*, 2010 and Aiad, 2019), while the utmost wheat yield was attatined by 84% of full evapotranspiration (Zhang *et al*., 2008). The practice with organic wastage such as like crop residues, animal manures, sewages sludge and by products of plant parts with high organic matter content play two major role on soil characteristics (Dutta *et al.,* 2014). The application of soil amendments in the plants minimizes the stresses of water scarcity (Ahmad *et al*., 2013), through improving soil physical, chemical and biological characteristics (Hueso-Gonzalez *et al.*, 2014 and Mann, 2011).

Drought stress has the negative impact on wheat plant and hence soil amendments may be used to surpass that harmful effects. Agricultural wastages from different sources produces compost that helped to improve tolerance capacity of crops and enhanced growth of the plant by ensuring better soil structure, nutrient supplementation and making up antagonistic microorganisms (Glaser *et al.,* 2002).

Application of biochar at 2% resulted in improved wheat growth and increased height of the plant about 11% (Kanwal *et al.*, 2018) ,whereas at 5 % of biochar application under saline condition improved soil fertility and enhanced sorghum biomass yield production by 25% (Edmunds, 2012). 20 tons/ha of biochar application could promotes fertility of the soil and crop productivity in temperate soils but had limited effects on sandy, salt-stressed soils probably due to differences in soil properties (Diatta, 2016).

Poultry manure is considered as an organic farming for health of human owing to reduce the phyto-toxic components under abiotic stress condition (Gil *et al.*, 2007). Nitrogen uptake of the plant can be stimulated by the application of organic manure (Jones *et al.*, 2007) among the various kinds of organic manure like poultry manure effectively increased the growth and development of the maize plants under drought stress (Hirzel *et al.*, 2007).

Chitosan is second most abundant naturally that produced from chitin occurring polysaccharides after cellulose found inside the earth (Rinaudo, 2006). Chitosan helps to prevent the plant from various defense responses regarding biotic and abiotic stresses. Due to the modification of climate and multiplied food demand that lead to changable use of artificial chemicals helps the plant for prevention from abiotic and biotic stresses.

It has been founded that vermicompost application helps to raises crop yield (Correa *et al.*, 2005; Cordovil *et al.*, 2007) and be evident to give better grain and biological yields than traditional organic fertilizers (Valdez-Perez, 2007). Vermicompost is resulted from compost through the amalgamation with earthworms that hold on different essential nutrient elements and plant growth regulating hormones (Allardice, 2015). It promotes soil attributes (Kheir *et al.*, 2017 and Mahmud *et al.*, 2018). Joshi *et al.* (2014) reported use of 20 tons ha^{-1} vermincompost as an ideal for better growth, higher plant height and total yield production of wheat.

However, further investigations identified to the effects of organic amendments and their effects on growth and stress tolerance are required to gain an understanding of the mechanisms of drought tolerance in wheat plant.

i. To investigate the effect of drought stress induced wheat plant on growth and development and physiological disorders
ii. To measure the oxidative stress under drought stress environment and
iii. To measure the protective role of organic amendments in alleviating drought stress.

Chapter II

REVIEW OF LITERATURE

In this part a short survey of different explores that were led about drought stress in wheat and the mollification of drought stress by applying different organic amendments.

2.1 Wheat

Wheat is one type of grass generally developed for its seed and throughout the world it has been used as a cereal grain food. *Triticum* family is consist with the togetherness of numerous types of wheat and the mostly developed from bread wheat or common wheat (*T. aestivum*). Wheat generally grows from 100-125 days however because of different variety and climatic conditions it may varied. Wheat has a capacity to grow both temperate and tropical climatic conditions it prefers clay type loamy soil, dry climate and bright daylight and it requires 40-110 cm precipitation (Banglapedia, 2014).

Wheat is cultivated in Bangladesh as a robi season crop. Since 1930-1931 it was begun cultivate here and since 1942-1943 it viewed as a food crop (Banglapedia, 2014). Wheat alone covered about 11% of total cropping area during robi season .After rice, wheat is the next position that provides a major part of food supply in Bangladesh.

Wheat cultivation brought about 17% of total arable land area whereas 35% of total populace consumes wheat alongside rice (FAOSTAT, 2013). 65% of total production of wheat is used for food purposes, 17% for feed animal and about 12% is used as industrial applications (FAOSTAT, 2018). Major part of wheat production is grown in cold region because of its temperate origin. Now a days various cultivars which are adaptable to various stressful condition grown in a potential yield in a large extent through traditional and modern breeding techniques.

2.2 Abiotic stress

In entire developing period plants need to confront a great deal of troublesome conditions because of the unstable environmental factors named biotic and abiotic stress. Of them biotic stress includes virus, bacteria, fungus, different kinds of insect-pest attack and other kinds of pathogenic attack on the other hand abiotic stress thrust into adverse effects of low and high temperature, drought, water stagnation, salinity, metal toxicity etc.

Abiotic stresses are directly connected with the changes of environmental conditions, it causes to diminish productivity of plants which eventually makes dangers to food security. The essential abiotic stresses incorporates saltiness, intense temperature, flooding, poisonous metal and metalloids, ultra-violate radiation etc. Some ecological components, along with air temperature, can emerge as annoying in only a few minutes others along with soil water content may also take days to week and elements along with mineral inadequacies can take a long time to emerge as annoying (Taiz and Zeiger, 2006).

As indicated by Araus *et al.* (2002), abiotic stresses together with restricting harvest efficiency also can influence the distribution of plant species in various sorts of climate. Abiotic stress is responsible for change in soil-plant-climate continuum and as a result for diminished yield in a few of the significant harvests in different sides of the world (Ahmad and Prasad, 2012). Bray *et al.* (2000) reported that due to abiotic stresses up to half of overall potential yield loss may be viable. The current total population of the earth is 7.3 billion and it is extended to come at 8.5 billion by 2030, 9.7 billion out of 2050 (Hasanuzzaman *et al.*, 2017). Despite the fact that populace is expanding, the harvest efficiency isn't resemble to the measure of food request it making. To meet up food requirement for additional 2.4 billion people, 70% of more food supply is needed to World agriculture though it has a great challenge fighting with poverty, efficient of natural resources and adjusting to global climate change. Abiotic stress is the aggregate term of all the negative effect applied by climate on living creatures (Hasanuzzaman *et al.,* 2012a).

In Bangladesh, during the period of robi season frequent rainfall occurred as a result plant has often faces shortage of water. Due to severe stage of deficit irrigation condition ultimately result in yield reduction, though wheat has a capacity to tolerate drought condition moderately (Ali *et al.,* 2013).

2.3 Drought stress

Drought is one of the most important phenomena that limit crops' production and yield. A region is said to be in drought condition when it is characterized by water deficiency issue for an extend period of time because of environmental phenomenon or human action. Drought is viewed as the absolute most decimating environmental stress, which diminishes crop efficiency more than some other environmental stress (Lambers *et al.,* 2008). Drought impedes typical development, disturbs water relations, and decreases water use efficiency in plants.

The primary outcomes of drought in crop plants are decreased rate of cell division and development, stem extension and root expansion and disturbed stomatal motions, plant water and supplement relations with reduced harvest profitability, and water use efficiency (Li *et al.,* 2009; Farooq *et al.,* 2009a). Zhao *et al.* (2006) stated that drought stress causes detrimental effect on whole plan life. It caused to reduce plant growth, responsible for poor germination and also decreased fresh and dry weight of plants.

Due to water deficit condition biosynthesis of abscisic acid accelerates and as a result stomatal conductance decreases that lead to minimize transpirational losses (Yamaguchi-Shinozaki and Shinozaki, 2006). IPCC (2007) announced that the consequences of continuous global climate changes results in increased severity and recurrence of drought and delivered a clear report indicates that from any other abiotic stress ,drought effect is more detrimental and as per them, more than 11 million have passed on and 2 billion individuals have been experienced from drought at worldwide since 1900.

2.4 Plant responses to drought stress

2.4.1 Germination and emergence

Germination is an important critical stage that affects seedling vigor and plant population in the unit area. The first effect of water deficit on plant starts with the germination process. Germination begins in the wheat plant by Increasing RNA and protein (Zhang *et al.,* 2009). These processes are introduced by absorbing water directly from surroundings.

The indicator of germination beginning is to increasing RNA and protein content in wheat grain (Zhang *et al.,* 2009). When grain seeds are absorbs water, germination processes are established and due to water scarcity condition these processes are hampered. When plant faces water stress it results declined in shhot elongation of seedlings (Esfandiari *et al.,* 2008). When plants are experienced with an early drought stage causes germination hampers and then causes major low grain yield. During water deficit stage, amount of water uptake is low amount as per needed for the plant and as a result supply of energy hampered and empeded enzyme activities (Taiz and Zeiger, 2010). Germination stage of sesamum is decreased extremely though it is a drought tolerant crop (Bahrami *et al.,* 2012). Seedling establishment of sesame is also impede as a result of drought stress of sesame.

2.4.2 Growth

Development is a constant increment in volume, size, or weight, which incorporates the periods of cell division, cell extension, and separation**.** Under water deficit condition in plant both cell division and cell development are affected because of loss of turgor pressure, diminished energy gracefully and impaired enzyme activities (Farooq *et al.*, 2009). Different crops respond to drought differently. Late flowering of maize is found due to the exposure to deficit irrigation experimented by **(**Abrecht and Carberry, 1993), quinoa (Geerts *et al.*, 2008), and rice (Fukai, 1999), whereas in soyabean, barley and wheat flowering and physiological maturity hastened under drought (McMaster and Wilhelm, 2003).

Leaf area index (LAI) is the ratio of leaf area to ground area, which signifies the degree of assimilatory intensity of yields under field conditions. The consequence of drought reduces LAI. At the time of flowering and budding stage of sunflower under drought condition collapsed LAI. Drought stress inhibits leaf expansion and tillering capacity and decline leaf area due to early senescence (Nooden, 1988). These parameters contribute to minimized dry matter accumulation and grain yield of the crop under drought.

Drought strongly firmly influences crop phenology by shortening the crop growth cycle with a couple of special cases. Restricted water supply triggers a signal to cause an early exchanging of plant improvement from the vegetative to reproductive stage. For example, complete development duration of both bread wheat and barley diminished under deficit water (McMaster and Wilhelm, 2003), which generally results in substantial yield decreases.

2.4.3 Water relations of the plant

Leaf relative water content, leaf area potential, osmotic pressure, and membrane integrity and transpiration rate are important indicators that affected plant-water relations. Due to acute water stress condition growing in wheat plants with mild water deficit state generate the greatest important values of osmotic pressure and membrane integrity of cell linked with good water condition.

Soil water content has a characteristic feature of relative water content which is the vital indicator of deficit water condition (Waraich and Ahmad, 2010). Water use efficiency refers to the proportion between total production of dry matter of plants and amount of consumed water. Plant use little amount of water efficiently during stressful condition as it gets very low amount of water at drought stage and plants endeavor to greatest production of dry matter.

Drought stressed plant shows greater water use efficiency comparing with normal watered plant (Abbate *et al.*, 2004). Closure of stomata leads to decrease transpiration rate is responsible for it. Water drift at the soil to root system of plant or reducing hydraulic conductivity of soil at lower soil humidity is identified by relative water content. Nevertheless, result of progressive water scarcity condition, constant diminish in relative water content that attain approximately 15.15% below excess water deficit condition (Hammad and Ali, 2014) contrast to well water supply in plants (50% of obtained water depletion). Detrimental effect of wheat plant during scarcity of water can diminish by enhancing osmotic adjustment by the procurement of solutes into the plant.

Profound and potential root system of plants needs during water stress condition of plants and increment the depth of roots helps to improve total amount of attainable water needed for growing period (Evans and Sadler, 2008). During stressful condition in plant use of water efficiency is increased because of little amount of water minimizes loss of water. Number of leaves and area of the leaves is also decreased transpiration rate (Lazaridou and Koutroubas, 2004). During drought condition, cell membranes are subject to alternates mostly related to the improvement of permeability (Iqbal, 2009). Wheat drought resistant variety reduces water loss in the plant by mostly use of water use efficiency. Water use efficiency is obtained by advanced crop management and plant breeding processes. When 15% poultry liter biochar added to the soil, water holding capacity increased double and relatively large quantity of water retained that aids plant growth under stressful condition (Adams *et al.,* 2013).

2.4.4 Biomass production and partitioning

The growth and development of the plant was declined by the effect of drought stress which ultimately reduced the crop production (Rabbani *et al.,* 2003). When the plant faced water stress resulting the genotypic variation occurred in the plant in case of different yield parameters (Dencic *et al.,* 2000). The genotypic stability of the yield attributes is desired in case of source parents including cultivar for water stress tolerance breeding purposes.

Drought stress caused the plant showed mass difference for various yield attributes such as grain production, biological yield and harvest index (Chowdhary, 1990). Harvest index and biological yield is an important characters which correlated with drought stress (Satish and Thakur, 2004). Cruz and O'Toole (1984) said that crop yield was significantly reduced when the drought stress affected the initiation of panicle to anthesis. This stress caused the spikelet number was decreased. When the drought stress occurred during the division of meiotic cell or anthesis resulting the florets sterility was increased with concomitantly the filled grain percentage was decreased.

The allocation of biomass production showed the yield estimation and water stress tolerance of crops. Biomass production was allocated through genotypes between the plants shoots and roots (Weiner, 2004). The distribution of biomass and length of roots was decreased the effects of drought (Paustian *et al.*, 2016; Griffiths and Paul, 2017). Edwards *et al.* (2016) concluded that the ratio of root and shoot act as an indicator of biomass distribution to above and below the ground biomass. It was needed to evaluate the genetic heritability and diversification for the distribution of biomass including agronomic characteristics as a prerequisite for the developing of cultivars with water stress tolerance in wheat plant.

2.4.5 Photosynthesis

Photosynthesis is a very important part of the plant which is directly correlated with the crop production. Due to drought stress the crop production is drastically reduced. The photosynthetic activity of plants responses to water stress were very complex and including the various structural level in relation to plant growth and development (Chaves *et al.*, 2009).

The closing of stomata had to be a factor that decrease the plant photosynthesis. In closing of stomata at the time of drought stress decreased the taken of CO_2. Severe drought stress causes the photosynthetic rate was decreased significantly (Le *et al.*, 2017). The statistical analysis showed that the increasing of drought stress resulting the carotenoids and chlorophylls was decreased as contrast to the application of normal water. The reduction of photochemical activity of chloroplast happened through the affecting of drought stress which related with the mitigation of chlorophyll accumulation. Marcinska *et al.* (2013) stated that the total photosynthetic process was hampered due to water stress associated with the non stomatal nature of biochemical process and also occurred the lipids of chloroplast oxidation and altered the proteins and pigments structure.

Cell dehydration is other factor for the reduction of photosynthesis. Its causes the shrinkage of cell, reduces the aggregation of cell volume of protein (Hoekstra *et al.*, 2001). The components of cell concentration was increased owing to drought stress which causes for the enhancement of cytoplasmic viscosity, leading to inactivate the enzyme and finally affected the photosynthesis process.

2.4.6 Nutrient uptake under drought stress

Different kinds of abiotic factors, water stress or drought is the most significant limiting factors that concern the crop production and yield in the whole world (Valliyodan and Nguyen, 2006). When the plant faced drought stress resulting greatly hampered the plant carbohydrate and protein contents which ultimately affected the wheat grains. If the water depletion up 50 to 65 % and had a great effect on the contents of protein and carbohydrate (Kilic and Yagbasanlar, 2010; Hammad and Ali, 2014). This incidence occurred owing to uptake of more amount of nitrogen, phosphorus and potassium from the soil contrast to the acute water stress conditions (Dromantiene *et al.,* 2009; Bakry *et al*., 2012).

2.4.7 Yield and yield attributes

Among different environmental abiotic stress is the maximum common stress accountable for sufficient modifications in increase and improvement of all agricultural crops together with wheat. Germination of seeds and established order of seedlings are greatly minimizes on early season of water deficit condition because of lower water uptake, supplement of energy and activities of impaired energy (Okcu *et al.,* 2005). Activity of germinating enzymes such as α- amylase, protease, and lipase are regulated by shortage of water supply in plants and cause to decline ability of seedling to good germination (Bose *et al.,* 2018). Because of reduced photosynthetic rate in plants, provocation of leaf senescence and barriers of sink mobility, grain filling rate is decline under this state (Madani *et al.,* 2010).

The outcome of water stress differ from crop to crop because of their period of water deficit sustain, When severe water scarcity prevailed in mungbean, cowpea, soyabean and peanut that results in 63, 46, 52 and 53%, respectively reduced the number of pods compared with well watered plants (Pandey *et al.,* 1984a). Leaf area of plants of *Capsicum annum* L. is greatly diminished under stressful condition (Rao *et al.,* 1988). Nicolodi *et al. (*1988) experimented that gaseous exchange affects plant characteristics under water stressed condition.

Taheri *et al.* (2011) experimented with 17 wheat lines under stressful condition and found that the severity of water scarcity differ from crop to crop and even in variety to variety. He also showed that diminished grain yield, biomass production, awn and spike length under stressful condition. Chandler and Singh, (2008) experimented that grain per spike reduced under water deficit. Ramezanpoor and Dastfal (2004) conducted an experiment on wheat and found that decrease in 25% and 50% of water supply causes reduction of wheat by 21.8% and 40.7%, respectively.

Wheat yield production is increase by watering the plant at crown root initiation stage, tillering and flowering degree. Keyvan (2010) proposed that water stressful condition at the period of just after anthesis and stem elongation degree caused for greatly decline of 25% and 46% grain yield, respectively. 46% yield reduction at tillering stage and 21% yield decline at booting period in wheat was experimented by Schneekloth *et al.,* (2012).

3. Oxidative stress in plants under drought stress

The production of ROS in plants is known as oxidative stress and it is one of the main biochemical responses that occurred in the plant under water stress condition. Oxygen performs a crucial position in ordinary metabolism but under water deficit state reactive oxygen species are generate which is harmful for for plants. Enhancement of lipid peroxidation, protein degradation, fragmentation of DNA happen under stressed condition which is harmful for plants (Hasanuzzaman *et al.,* 2013a). Closure of stomata and decreased production of

CO_2 found under stressful condition and as a consequence carbon fixation break up and more energy is generate in chloroplast.

Malondialdehyde, hydrogen peroxide, methyl glyoxal etc. are used as oxidative stress indicators. During water stress condition production chemicals such as lipid peroxidation, reactive oxygen species like H_2O_2 content and O_2^- are enhanced (Nahar *et al.,* 2015). Similar outcome was found in stressful condition experimented by Alam *et al.* (2014). Apel and Hirt (2004) also reported that ROS stages growth extensively ensuing in oxidative harm to proteins, DNA and lipids.

In acute stress condition, stimulated pigments in thylakoid membranes may interact with O_2 and form O_2^- (Reddy *et al.,* 2004) and more downstream response create other reactive oxygen species such as H_2O_2 and OH^-. In severe stress condition, excited pigments in thylakoid membranes may interact with O_2 and form O_2^- (Reddy *et al.,* 2004) and more downstream reactions produce other reactive oxygen species such as H_2O_2 and OH^-. 22% and 75% of net photosynthetic rate is declined in severe water stressed compared to the control treatment, respectively. Due to drought stress at 50% field capacity, barley yield production has been lessen. Production of yield in switir and tallit cvultivar declined about 40% and 34% in comparison with normal condition (100% field capacity). Above 36% and 55% yield diminished during vegetative and reproductive stage individually under water deficit.

4. Antioxidant enzyme activities under drought stress

Antioxidant defense system is one of the drought response mechanisms to plant. When plants are exposed to water deficit conditions, various enzymatic and non-enzymatic protection structures that are characteristic collectively to govern the float of out of control oxidation under numerous stressful situations and defend plant cells from oxidative harm through scavenging ROS.

The well-organized antioxidant enzymes in plants are monodehydroascorbate reductase (MDHAR), glutathione reductase (GR), ascorbate peroxidase (APX), dehydroascorbate reductase (DHAR), catalase (CAT), superoxide dismutase (SOD), guaicol peroxidase (GOPX), glutathione-*S*-transferase (GST) and glutathione peroxidase (GPX) etc.

To make resistance and adaptive functions in opposition to water stress condition, the improvement of antioxidant protection is effective. Antioxidant stress protection performs well by the action of ROS scavenging enzymes. The creation of ROS and improved mobility of numerous antioxidant enzymes in the course of abiotic stress were suggested in various plant research reviews introducing that the mobility of antioxidant enzymes of tolerant genotypes accelerated in regard to abiotic stress while the sensorial species didn’t do so (Hasanuzzaman *et al.,* 2012a).

Intracellular creation and dismal of ROS is potentially equilibrium under stress less condition but this equilibrium state broken with the exposure of stressful condition and the obsessive procurement of ROS damages plant cell, and the oxidative decay may finally lead to demise. Proline is an osmo-protectants and facilitates the plant to live by decreasing the ROS. Water uplift is disturbed because of decrement of soil humidity regularly. In this respect, proline is regarded in cell to uplift of water (Ghobadi *et al.,* 2011).

Ahmadizadeh *et al.* (2011a) reported from an experiment on wheat varieties to accomplishment of 37 varieties under water deficit condition. He experimented that enormity of mean performance for SOD and CAT progressed and index of damage declined in water deficit condition. 35.6% of SOD is enhanced whereas CAT density enhanced by 3.1% under stressful condition. SOD, CAT and another antioxidant enzyme activities enhanced in stressful condition and this may found higher in resistant than susceptible variety (Ahmadizadeh *et al.,* 2011a).

The outcome of water scarcity on physiological and biochemical indexes of wheat guided by a research by Dong *et al.* (2018) and set out the action of POD, GSH and proline change into improved in wheat. Different types of management, usage of protectant such as boron (Abdel-Motagally and El-Zohri, 2016), ascorbic acid, and zinc (Yavas and Unay, 2016), potassium (Wei *et al.*, 2013) facilitates to soothe the stringent impact of water deficit stress (Hasanuzzaman *et al.*, 2018).

5. Role of biochar under normal and drought stress

Rapid decomposition is occurred in soil and as a result various types of soil organic amendments need to apply every year (Gupta and Monika, 2016). Shoot and root biomass and grain yield is greatly enhanced by the application of biochar under normal condition. This may achieved by the interchange in physiological change in leaf. Photosynthesis rate of leaf and stomatal conductance is raised to a great extent thus result in high productivity through the application of biochar in soyabean (Xu *et al.*, 2015).

Establishment of biochar in soil under normal condition adds organic carbon thus effect on soil fertility improvement (Glaser *et al.*, 2002; Lehmann, 2006), increased WHC (Asai *et al.*, 2009; Laird *et al.*, 2010 and Karhu *et al.*, 2011), raised saturated hydraulic conductivity (Asai *et al.*, 2009), declined soil strength (Chan *et al.*, 2007; Busscher *et al.*, 2010), altered soil bulk density (Laird *et al.*, 2010), changed the stability of aggregates (Busscher *et al.*, 2010).

Biochar is a used possibly for its greater stability under drought condition (Glaser *et al.*, 2002). Growth development of wheat is obtained by the application of biochar at 2% on soil and height of wheat plant is enhanced 11% through the application of it (Kanwal *et al.*, 2018). Edmunds (2012) reported that fertility of soil is raised by application of 5% biochar under soil drought condition and biomass production of sorghum yield is enhanced by 25% by exercise with biochar in soil. In acidic and neutral p^H soils, crop productivity enhanced through the application of biochar in soil but in alkaline soil few experimented found under drought stress (Jeffery *et al.,* 2011; Raboin *et al.,* 2016).

Drought triggered through water insufficiency is a primary quandary to the sustainability of worldwide crop production (Lobell *et al.,* 2014; Parvin *et al.,* 2019). Water deficit ought to modify physiological traits plant leaves, consisting of reducing leaf photosynthetic and transpiration fee and stomatal electrical phemonenon, as a preventing productivity of crops (Jaleel *et al.,* 2009; Mathobo *et al*., 2017 and Hussain *et al.,* 2018). Moreover, water deficit can also have an effect on plant phenology such as enhance or postpone the flowering time after which impact on crop productivity (Farooq *et al.,* 2017).

Biochar contains high amount of organic matter that it can be used in drought stress condition as a necessary tool for security of food and used in areas where soil is depleted severely, lack of organic matter and the area where severe water scarcity is prevailed. Basically, yield of crops is raised through the application of biochar that achieved by the adjustment of soil pH (Sun *et al.,* 2017), enhance soil carbon storage (Obia *et al.,* 2016), keep nutrient and water of soil (Fischer *et al.,* 2017).

6. Role of chitosan under normal and drought stress

Chitosan application in soil under normal condition makes the plant resistance against as a fungal, bacterial and virus activities (Wang *et al.,* 2006), promoting the growth and development of plants and germination of seeds (Chandrkrachang, 2002), developing fertility and productivity of soil and promoting nutrient uptake of plants (Dzung, 2007), sequential increasing of nitrogen fixing nodes of leguminous plants (Dzung and Thang, 2004) and declining the effects of abiotic stress on plants (Song *et al.,* 2006). In the past of flowering stage exogenous apply of chitosan in three times helps to flowering and full blown, decreased the harmful effect of water stress condition oil yield (Bistgani *et al.*, 2017).

Both biotic and abiotic stress can be managed by the application of chitosan because it is biocompatible and environmentally harmless. When chitosan is applied on leaf it acts as an antitranspirant compound which is responsible for raising jasmonic acid synthesis and as a consequence stomatal conductance and rate of transpiration is decreased, water use efficiency is enhanced (Iriti *et al.,* 2009; Bittelli *et al.,* 2001).

During drought stress plants faces scarcity of water supply that causes reduction of leaf water potential, losses of turgor pressure, termination of stomata, decline in cell growth and development and reactive oxygen species and lipid peroxidation activeness etc. Chitosan is a cationic polysaccharide natural polymer that is attained from waste materials of seafood processing (Ye and Lou, 2009).

When plant faces water scarcity, a promoted root system helps to absorb the plant so that additional water plant can uptake (Zhang *et al.*, 2002). Coating of chitosan in plant can minimize probation the growth of stem and roots under water deficit condition. Thus, application of chitosan improved the exploitation ability of water and developed drought tolerance wheat seedlings (Zeng and Luo, 2012).

7. Role of compost under normal and drought stress

Compost is one type of organic amendments that is produced from the various kinds of agricultural wastage and helps to the plant by changing structure of soil, providing soil nutrients and developing up antagonistic microorganisms under normal condition (Raviv *et al.,* 2004; Tejada *et al.,* 2009). During stressful condition several physiological and metabolic alternation is occurred in plants by the addition of compost in soil (Tartoura, 2009). Formation and structure of different bacterial activities is greatly influenced by accession of compost in soil (Paranychianakis *et al.*, 2013. and Lavecchia *et al.,* 2015). Carbon conversation (Bowles *et al.,* 2014. and Ng *et al.,* 2014) and Nitrogen cycling (Paranychianakis *et al.,* 2013; Sanchez-Garcia *et al.,* 2016) may also altered with the application of compost in soil.

When plant faces lack of sufficient water supply as required that influence growth and development and productivity of plants. During water scarcity state plants tends to close their stomata because of decline gaseous exchange (Ache *et al.,* 2010). Reactive oxygen species is produced when plants are in stressful condition (Apel *et al.,* 2004; Papadakis and Roubelaskis-Angelakis, 2005) which is harmful for the plant and injure cellular macromolecules for example DNA, lipid and enzymes (Foyer and Nocton, 2005). By antioxidant defense systems plant can restrain from these harmful situations.

Application of compost is an important of sustain agriculture that is responsible for changing physiological and agronomical attributes under drought conditions (Antolin *et al.,* 2010). Under water deficit condition, soil water holding capacity is enhanced by the addition of compost (Hudson, 1994). Establishment of organic amendments such as compost has a positive impact on growth and development and productivity of plants (Parr *et al.*, 1989; Gopinath *et al.*, 2008 and Ibrahim *et al.,* 2008).

8. Role of vermicompost under normal and drought stress

Vermicompost is originated from the decomposition of organic matter exercising nonfervent interaction within earthworms and microorganisms (Sallaku *et al.,* 2009). Vermicompost has a characteristics feature of high porosity that facilitate good drainage capacity and high water storage capacity (Atiyeh *et al.*, 2002). Soil microbial activity is greatly enhanced resulting positive biological activity for growth and development of plants (Marinari *et al.*, 2000). Vermicompost is a profound source of humic substances that play a great role for the development of drought stress (Atik, 2013).

Under normal condition when vermicompost is applied in soil, protein and other necessary oil contents of plants are greatly influenced. Necessary oil content of Pogostemon cablin (Singh *et al.*, 2013) and protein content was effectively improved by vermicompost apply (Joshi and Singh, 2013). Vermicompost apply in the soil has a role in improving leaf chlorophyll contents (Berova and Karanatsidis, 2009).

Vermicompost has a positive on uplifting of magnesium and calcium in plants (Mahmoud and Ibrahim, 2012). Gutierrez-Miceli *et al.* (2007) reported that vermicompost practice in the soil could be changed the nutrient contents in opposite way and the developing strength of plants may also be exchanged negatively (Lazcano and Dominguez, 2010). Paul and Metzger (2005) reported that with the application of vermicompost in soil root and shoot ratio of plants is greatly increased or not greatly changed (Sallaku *et al.*, 2009). Soil properties such as mineral nutrient content biological attributes are ameliorate by the application of vermicompost in soil (Pant *et al.*, 2011) and reduced the negative impact of water scarcity in *Cicer arietinum* L. (Gholipoor *et al.* (2014), and Gholami, 2014).

9. Role of poultry manure under normal and drought stress

Climate change is a very important issue in agriculture which ultimately influence the crop cultivation. In agriculture activities the shortness of water is increasing in the whole world due to the rapid growth of population and the greater incidence of water stress causes for the changing of climate and also various activities of mankind (World Bank, 2006).

Organic manure such as poultry manure is considered as the important source of soil nutrients which contain more amount of nitrogen ,phosphorus and potassium including some more essential plant nutrients where the grains economic value vary with the inorganic products (Delate and Camberdella, 2004). The soil health and nutrient status was developed by the foliar application of organic compost in the agricultural land (Pandey & Shukla, 2006).

Manure compost is considered as an organic farming for health of human owing to reduce the phytotoxic components under abiotic stress condition (Gil *et al.,* 2007). Nitrogen uptake of the plant can be stimulated by the application of poultry manure (Jones *et al.,* 2007) among the various kinds of organic manure like poultry manure effectively increased the growth and development of the maize plants under drought stress (Hirzel *et al.,* 2007), because it hold vast amounts of N compounds (Nahm, 2003).

The ecosystem is conserved by the proper uses of poultry manure in the crop husbandry (Farhad *et al*., 2009) and the substantial effect on the crop production cannot easily over emphasized (Reddy *et al.,* 2004). The soil fertility was enhanced by the used of organic type fertilizer which was a best strategic management of low clay soil activity. Poultry manure was an organic type fertilizer when optimum amount used in the soil which increased the chemical and physical properties of soil (Farhad *et al.,* 2009).

Chapter III

MATERIALS AND METHODS

This section contains the materials and methodology that were precisely used throughout the experimental duration. It takes on experimental design and layout, growing conditions, experimental site and experimental duration, nutrient and treatment doses, materials that are used for the experiment, different intercultural operations, recording of data and their analyses presented under the following headings:

3.1 Experimental site and growing conditions

This experiment was performed at the net house of Agronomy department at Sher-e-Bangla Agricultural University, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28. The land area is located at 23°41′N latitude and 90°22′E longitude at an altitude of 8.6 meter above sea level. The experiment was conducted at the net house of Agronomy department at Sher-e-Bangla Agricultural University. The experiments was carried out in pots. Pots were placed in polyethylene covered shade to allow sufficient light and aeration. Healthy seeds were used and proper spacing (6-8cm) was maintained. The pots of the plants were fertilized with proper nutrients.

3.2 Experimental period

The experiment was conducted during the growing period of wheat from November 2018-March, 2019. The plants were grow without disturbance at 20 days after that stressed was applied.

3.3 Climate

Climatic conditions of the area of the experiment was sub-tropical and the salient features characteristics of this zone is high temperature, heavy rainfall and high relative humidity with extemporaneous inclement winds in kharif season (April-September) and very little rainfall associated with moderately low temperature during the period of rabi season (October to March). The weather data of the experimental site was recorded by the meteorology center, Dhaka.

3.4 Soil

The soil of this experimental site 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. Soils from the field was made prepared for experiment and placed into pots. The pots were placed above the flood level and adequate sunshine was available during the experimental period.

3.5 Materials

Wheat (*Triticum aestivum*) cv. BARI Gom-26 seed was used as plant material in conducting the entire experiment. It was released in 2010. It was previously the characteristics of fairly good resistance capacity and impressive agronomic performance.

3.6 Characteristics of BARI Gom 26

- ❖ BARI Gom-26 commonly known as Hashi which yielded 10% higher than the most popular variety.
- ❖ This variety is relatively shorter height about 92-96cm and 5-6 tillers plant^{-1}.
- ❖ It takes 60-63 days for panical initiation and 1000 grain weight is about 48-52 gm.

- Yield 3500-4500kg ha^{-1}, at late planting yield about 10-12% greater than satabdi.
- It is tolerant to leaf rust and leaf spot disease(blight)
- It is also capacity to salt and temperate tolerant.

3.7 Treatment

Factor A: Drought

1. Well-watered
2. Water deficit

Factor B: Organic amendments

1. Control
2. 10 t compost ha^{-1}
3. 10 t vermicompost ha^{-1}
4. 10 t poultry manure ha^{-1}
5. Biochar @ 2.5% w/w soil
6. Chitosan @ 1% w/w soil

3.8 Experimental design

Experimental design	: RCBD
No. of replications	: 3
Total no. of pots	: 36

3.9 Seed source

Seeds for this experiment of BARI Gom- 26 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh.

3.10 Irrigation source

Irrigation water for this experiment was supplied from the ground water by pump near the experimental field. The treatments that were grown without any disturbance supplied water in 3 times throughout the growing period but in stressed treatment supply of water was stopped 20 DAS.

3.11 Preparation of experimental pot

Soil for the experiment was collected for field and it was sun dried and crushed to prepare a well pulverised soil for the experiment. The soil was first crushed on 4 November, 2018 and weeds and stubbles were removed from the soil. The soil was then bought into good tilth condition to fill up the pots. The pots were covered half part with the soil on 7 November, 2018. During this time rest part of the soil are mixed with recommended amount of manures. Fertilizer was added to the soil on 14 November, 2018.The experiment was laid out on 15 November, 2018 according to the experimental design.

3.12 Fertilizer dose and methods of application

Fertilizer	**Doses (kg ha^{-1})**
Urea	220
TSP	150
MOP	60
Gypsum	110
Zinc sulfate	8
Boric acid	2
Cowdung	10 (t ha^{-1})

All the fertilizers were mixed with soil properly and applied in basal dose.

3.13 Sowing of seeds

Wheat seeds were sown on 15 November, 2018 by hand. After preparing soil in proper “Joe” condition, wheat seeds were sown in pot. Wheat seeds were then covered properly with soil by hand. 4-5 cm plant to plant was maintained when seeded.

3.14 Intercultural operations

Wheat seeds start to germinate 3-4 days after sowing. Various kinds of intercultural operations like thinning (18 plants remaining in pots), weeding and plant protection measures are done when needed.

3.15 Harvesting and postharvest operation

At the time of maturity period, the plants become golden yellowish in color and ready to harvest. In every pot, five plants are selected at earlier randomly and data are collected on different growth and yield attributes were collected from these. Five plants from different part of each pot was harvested separately and bundled, properly tagged and then brought to the threshing floor for recording grain yield. After threshing, grains of wheat seeds were cleaned properly. After that seeds were sun dried at 12% moisture level.

3.16 Data collection

Experimental data were recorded from 40 DAS and continued until harvest. The following data were recorded during the experimentation.

3.16.1 Crop growth character parameters

1. Germination percentage
2. Root length

3. Shoot length

4. Plant height

5. Leaf relative water content

6. SPAD value

3.16.2 Yield and others crop character parameters

1. Spikelet length
2. Number of spikelet spike^{-1}
3. Number of grains spike^{-1}
4. 100 seed weight

3.16.3 Oxidative stress parameters

2. Determination MDA content
3. Determination Proline content

3.17 The procedures of data recording of crop growth character parameters

A brief outline of the data recording procedure during the crop growth period.

3.17.1 Germination percentage

For the measurement of germination percentage, 40 wheat seeds were placed in petri dishes with equal basis of treatments applied as grown in pots.
Germination percentage of wheat plants were measured at 9 DAS (Appendix III).
Germination percentage (%) = (Total number of seeds germinated /Total number of seeds sown) x 100.

3.17.2 Root length

When germination of wheat was completed, root length (cm) was measured. Randomly selected 5 plants from eighteen plants and used for the measurement of root length and finally it calculated into average.

3.17.3 Shoot length

After the measurement of root length of uprooted selected five plants, shoot length (cm) was also measured from the same plants and then made into average.

3.17.4 Plant height

Plant height (cm) was recorded 50 days after sowing of wheat seeds. Plant height of wheat plants were measured by using a measuring scale from ground level to highest tip of the leaf of plants. On each pot five plants were selected randomly for the measurement of plant height. Then collected data made into average.

3.17.5 Relative water content

Five uprooted sample plants from each pot randomly collected at 40DAS through scissors and washed them in fresh water. Using a balance randomly selected plants were weighted and averaged fresh weight (FW) taken. After that the weighted sample were taken and immediately sank into distilled water in petri dish at a period of 24 hours. Tissue paper was used for measurement of turgid weight (TW) so that excess water were removed from leaves. After drying of the samples two days RWC was calculated (Appendix IV) using formula in the following:

RWC (%) = $(FW - DW) / (TW - DW) \times 100$

3.18 Procedure of data recording of yield and others crop character parameters

3.18.1 Spikelet length per plant

For each replication 5 plants on each pot was selected randomly and spikelet length (cm) were measured carefully and finally average data was recoded.

3.18.2 Number of spikelet per plant

After collected spikelet length on each pot, the numbers of spikelet was calculated and finally recorded the average data.

3.18.3 Number of grains per spike

When wheat plants were ready to harvest before that five plants on each pot were selected randomly and on each spike, total number of grains were recorded.

3.18.4 Weight of 100 seeds

Using an electronic balance, counted fresh and sundried of hundred seeds were weighted (g) accurately and recorded the calculated data expressed in grams.

3.19 The procedure of data recording of oxidative stress parameters

3.19.2 Determination of proline content

The following the protocol of Bates *et al.* (1973) was used for determination of free proline. With the help of pre-cooled mortar and pestle fresh leaf (0.5 g) on each sample was homogenized well in 5 ml of 3% sulfo-salicylic acid on ice. 1 ml of the supernatant was than mixed with 1 ml of acid ninhydrin (1.25 g ninhydrin in 30 ml glacial acetic acid and 20 ml 6 M phosphoric acid) and 1 ml of glacial acetic acid after the homogenate was centrifuged at 11,500 × g for 15 min. After that the mixture was settled at 100 °C in water bath for 1 h, then immediately shifted in to test tube and kept in ice to be cooled, 2 ml of toluene was added when it was cooled and compounded thoroughly by vortex mixture. Then, transferring the upper aqueous layer to a new test tube. At last, the optical density of the chromophore containing toluene was read spectrophotometrically at 520 nm using toluene as a blank solution. The amount of proline was then calculated with the help of a standard curve (Appendix V).

3.19.3 Determination of MDA content

Lipid peroxidation (MDA content) was weighted consequent upon Heath and Packer (1968) with slight modification by Hasanuzzaman *et al.*, (2012b). To measure this, leaf sample of (0.5 g) homogenized in 3 mL 5% (w/v) trichloroacetic acid (TCA), and the homogenate was centrifuged at 11,500 × g for 15 min. The supernatant (1 mL) was diluted with 4 mL of thiobarbituric acid reagent (0.5% of TBA in 20% TCA). Then the mixture was warmed at 95 °C for 30 min in a water bath and then rapidly consoled in an ice bath and centrifuged again at 11,500 × g for 10 min. Then it was measured at 532 nm and was rectified for non-specific absorbance at 600 nm. MDA content was calculated by using extinction coefficient 155 mM^{-1} cm^{-1} and expressed as nmol g^{-1} FW (Appendix V).

3.20 Statistical analysis

The collected data were subjected to analysis statistically by the following of computer based Costat v.6.400 (Costat, 2008) and two-way analysis of variance (ANOVA). To determine the replications mean differences. Fisher's least significant difference test at the 5% level of significance was applied.

Chapter IV

RESULTS AND DISCUSSION

4.1 Germination

Germination is an insight growth parameter that describes if any effects on crop growth by applying treatments. In my experiment wheat seedlings are grown on petridishes and the data on germination are collected at 9 DAS.

4.1.1 Effect of drought stress

Notable reduction of germination% was noticed under water deficit condition 7.48% compared to well-water control of wheat figure 1(A). Germination of seed in well-water condition was found at 72% where in water deficit condition it was reduced up to 50% of germination (Timmusk *et al.*, 2014).

4.1.2 Effect of organic amendments

Organic amendments has positive effect in improving germination%. In this study noticeable increment of germination% was found in vermicompost (14.79%), poultry manure (12.24%) and chitosan (11.22%) compared to control and lowest result obtained from biochar treatment showed in figure 1(B).

4.1.3 Interaction effect of drought stress and organic amendments

In the present study germination% decreased significantly under water deficit condition by 9.71% compared to well-water control. But application of organic amendments improved the germination% in both well-water and water-deficit stressed plants. All the organic amendments except biochar increased germination% remarkably in well-water plants compared to untreated control. Compared to well-watered control alone compost, poultry manure, chitosan and vermicompost showed remarkable increment of germination% by 10.65, 13.67, 3.86 and 11.66%, respectively. However, adverse effect of water stress can be ameliorated through the organic amendments supplementation.

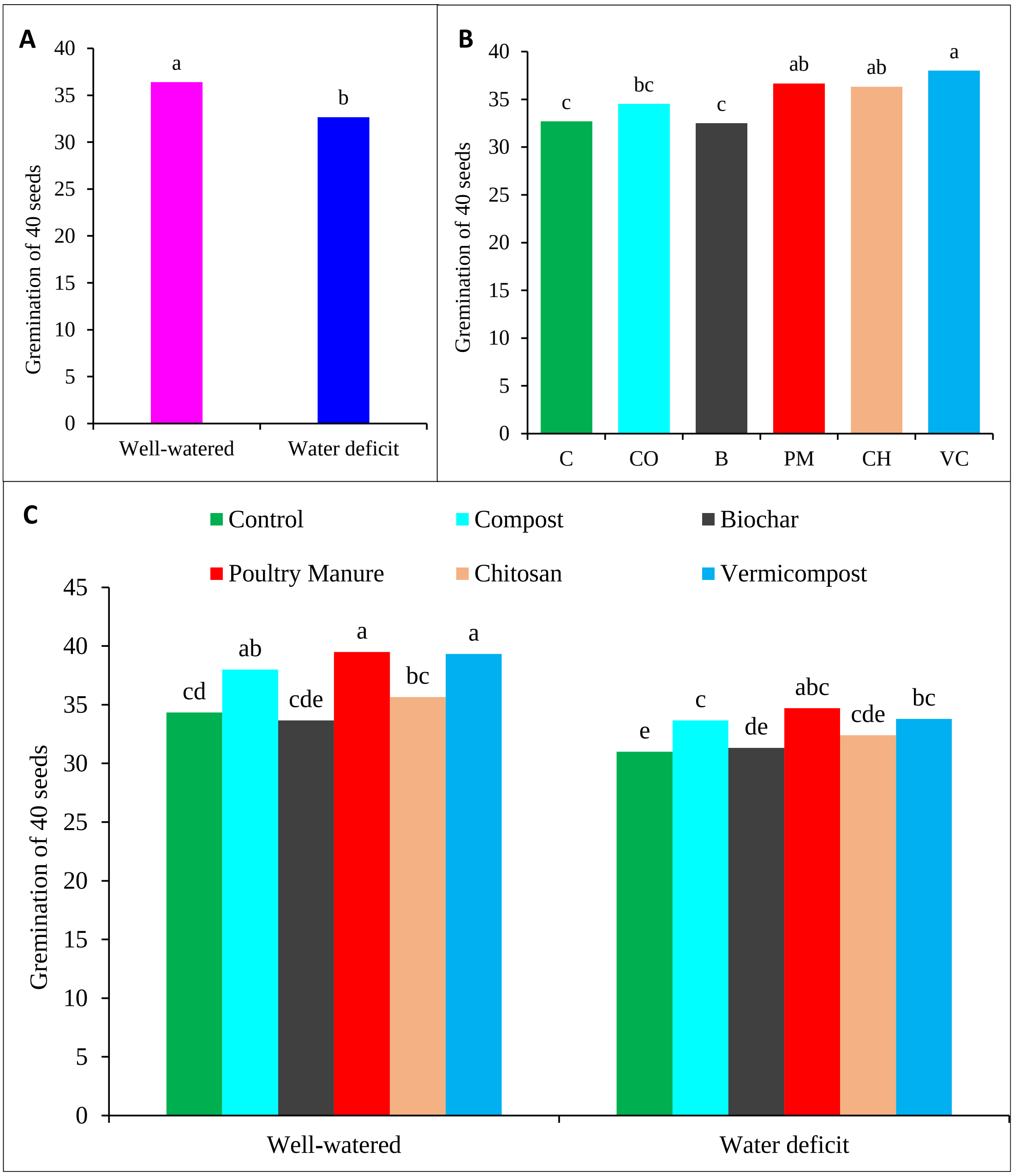

Figure 1. Effect of drought stress (A), effect of organic amendments (B) and interaction effect of organic amendments and drought stress (C) on germination. In a column different letter(s) indicates significance of values at 5% probability following LSD test

Germination% improved markedly in compost, poultry manure and vermicompost treated water deficit plants by 11.82, 9.67 and 6.45%, respectively compared to water deficit plants only showed in figure 1(C).

The application of soil organic amendments causes to interchange soil properties viz. soil pH, soil bulk density etc. that may affect germination capacity of seedlings (Atiyeh, Subler, Edwards, and Metzger, 1999). However, addition of biochar in soil assisted in management for sustainable agriculture. Under drought stress condition, germination and early vegetative growth of glycine max greatly reduced and practiced with biochar has positive impact (Woolf *et al.,* 2010). Germination of maize is also decreased because of drought stress and even at severe stage germination was found at zero (Khayatnezhad *et al.,* 2010).

4.2 Root length of seedlings

Seeds were sown in petri dishes with recommended supply of organic amendments and data were recorded at 9 DAS.

4.2.1 Effect of drought stress

A significance variation was observed in drought stage condition. Root length of BARI gom-26 in drought stress condition was 5.36% more compared with well-watered condition showed in figure 2(A).

4.2.2 Effect of organic amendments

Among all these amendments root length of wheat was highest in vermicompost treatment. As compared with untreated control root length was decreased in chitosan at 10.28% but increased root length was observed in vermicompost and compost treatment at 13.17 and 7.45%, respectively than control.

4.2.3 Interaction effect of drought stress and organic amendments

Interaction of different organic amendments and drought stress showed significance differences on root length showed in figure 2(C). The result showed that highest root length was obtained in vermicompost treatment and compared with control condition vermicompost and poultry manure root length increased at 29.79 and 10.68%, respectively.

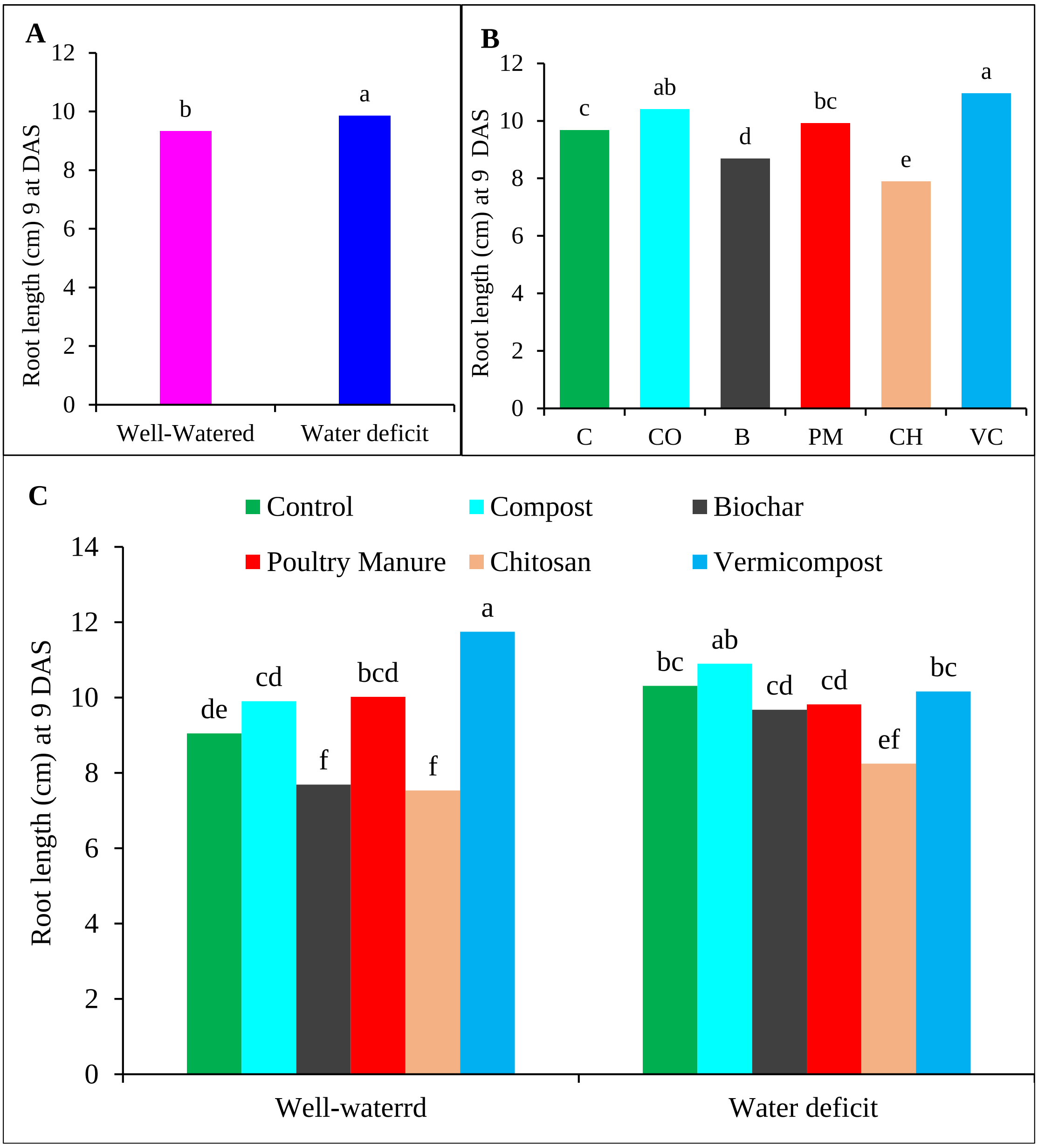

Figure 2. Effect of drought stress (A), effect of organic amendments (B) and interaction effect of organic amendments and drought stress (C) on root length. In a column different letter(s) indicates significance of values at 5% probability following LSD test

Decreased root length was found in biochar treatment and it was 15.03 % than untreated control under well-water. Oppositely under water stress condition, highest root length was found in compost and it was 5.73% more than untreated control whereas declined root length was observed in biochar, poultry manure and chitosan at 6.11, 4.75 and 20.01%, respectively than control.

4.3 Shoot length of seedlings

After measuring root length (cm) of wheat seedlings, shoot length of seedlings data were also recorded at that time.

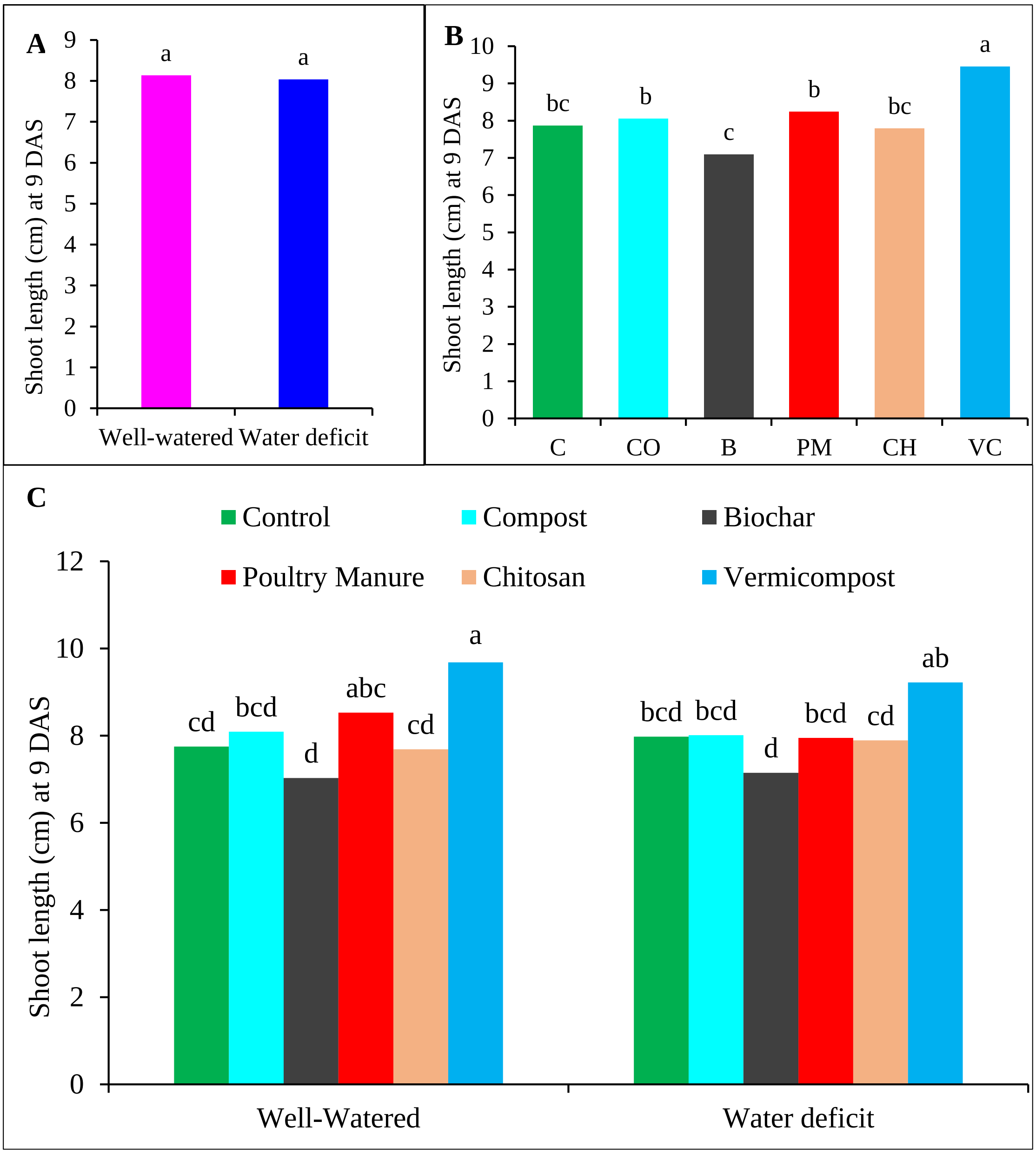

Figure 3. Effect of drought stress (A), effect of organic amendments (B) and interaction effect of organic amendments and drought stress (C) on shoot length. In a column different letter(s) indicates significance of values at 5% probability following LSD test

4.3.1 Effect of drought stress

There was a difference on shoot length of BARI GOM-26. Under water deficit condition 1.16% decreased shoot length was found compared with well-water condition showed in figure 3(A).

4.3.2 Effect of organic amendments

The highest value of shoot length was attained in vermicompost treatment and compared with control vermicompost and poultry manure reached 20.22 and 4.75%, respectively more shoot length. Lowest shoot length was found in biochar treatment and which was 9.83% less as compared to control treatment showed in figure 3(B).

4.3.3 Interaction effect of drought stress and organic amendments

The combined effect of drought and organic amendments on shoot length showed significance difference. Shoot length of seedlings generally decreased due to stressful condition of drought. Experimented on seedlings resulted in lowest shoot length was found in biochar which was 9.29% less compared with control condition but vermicompost and compost increased shoot length at 24.91 and 4.39%, respectively more. On the other hand under water deficit condition highest result was recorded in vermicompost which was 15.54% excess than control condition and lowest recorded data in biochar which was 10.40% less than control condition.

4.4 Plant height

Plant height is a visible growth attribute that ascertained either the treatments have any impact on crop growth or not. In this experiment wheat seedlings were grown on pot culture and required data were collected.

4.4.1 Effect of drought stress

Upon exposure to drought stress, plant height was taken at 50 DAS. The data revealed that there was a statistically significance variation on plant height under drought stress. Compared with well-water condition 15.02% reduced plant height was recorded under drought stress showed in figure 4(A). Plant height and drought has a reverse relationship whereas diminished plant height found at drought stress condition (Taheri *et al.*, 2011).

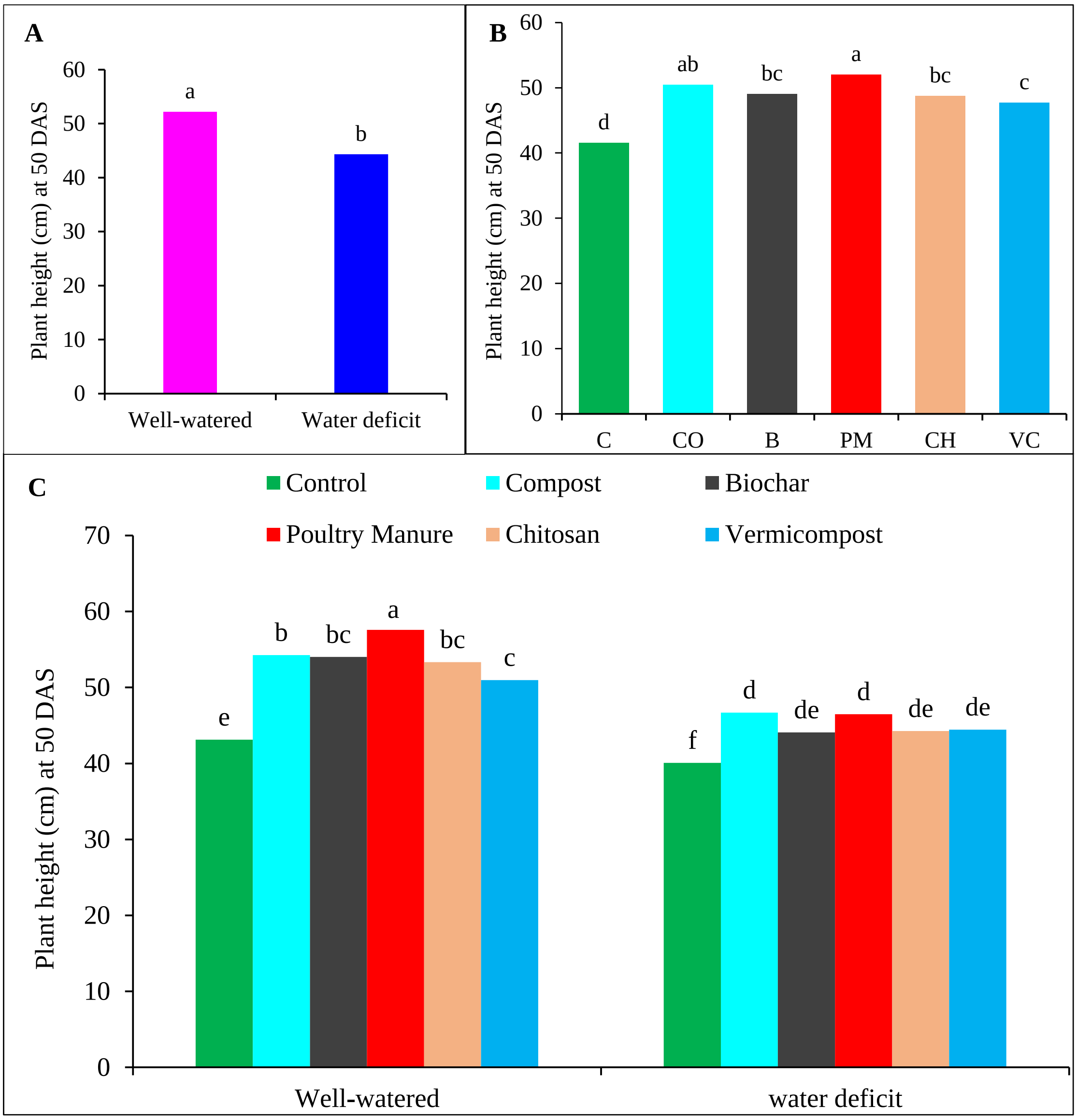

Figure 4. Effect of drought stress (A), effect of organic amendments (B), interaction effect of drought stress and organic amendments (C) on plant height. In a column different letter(s) indicates significance of values at 5% probability following LSD test

4.4.2 Effect of organic amendments

The highest plant height was received from poultry manure treatment and lowest plant height was in control condition. This result indicated that after the application of organic amendments in soil increased plant height was found in poultry manure, vermicompost and compost at 25.08, 14.71 and 21.36%, respectively showed in figure 4(B). Biochar and chitosan gave almost similar result and they were statistically similar.

4.4.3 Interaction effect of drought and organic amendments

The combined effect of drought stress and different organic amendments on plant height was statistically significant. Plant height generally decreased up on the exposure of drought stress. Organic amendments in soil enhanced plant height both in well-water and water stress condition than untreated control and statistically significant.

Under well-water condition, highest plant height was recorded in poultry manure treatment. The recorded data revealed that plant height increased in poultry manure, biochar and vernicompost at 33.51, 25.22 and 18.19%, respectively. On the other hand, increased plant height in water deficit condition was filed and highest data found in poultry manure in 16.01% more than untreated control whereas lowest in biochar treatment and it was 10.03% more than control. Zhai *et al.,* (2003) reported that under water deficit state plant height was greatly reduced and 7.7% of reduced plant height was found as compared with watered to deficit irrigation condition experimented by Kilic and Yagbasanlar, (2010). Gupta *et al.,* (2001) supported that result and also said booting or flowering stage was more critical under stressful condition than stress free condition. Through the alternation of physical and biological properties of soil crop growth and productivity greatly enhanced by compost supplement under water deficit condition (Zheljazkov and Warman, 2004). Application of vermicompost in soil helps to increase wheat plant growth and production (Ibrahim *et al.,* 2015) where amalgamation of vermicompost with biochar tends to support suppression of pathogens to plants and increase crop productivity (Shoaf, 2014).

4.5 SPAD value of leaf

4.5.1 Effect of drought stress

Due to drought stress chlorophyll content of leaf greatly changed. Analysis of variance indicated that the effect of drought stress on wheat on the SPAD value of leaf was differed significantly. The SPAD value was recorded at 57.29 under well watered condition and 48.17 under water deficit condition. This result indicated that SPAD value was 15.91% decreased in water stress than well-water condition. Chlorophyll content of leaf is more critical specially in booting stage under drought stress condition (Zhang *et al.,* 2008).

4.5.1 Effect of organic amendments

In this experiment, among all these organic amendments vermicompost gave the highest SPAD value and lowest value was attained in compost treatment than control condition. Chlorophyll content in vermicompost, biochar and poultry manure was enhanced at 10.14, 6.54 and 2.04%, respectively than untreated control.

4.5.3 Interaction effect of drought stress and organic amendments

The combined effect of drought and organic amendments results in a variation of chlorophyll content in leaf. Under well-water condition except vermicompost diminished chlorophyll content was found and compost and poultry manure gave similar result that were statistically similar. On the other hand, chlorophyll content was increased under stressful condition in vermicompost and biochar at 17.52 and 15.82%, respectively and lowest result attained in control treatment.

Al-Shaheen *et al.,* (2014) reported that drought stress reduced the chlorophyll content. Different types of physiological and biological activities such as photosynthesis, nutrient metabolism, respiration etc. were hampered due to exposure of drought stress and as a consequences injurious impact on crop growth and development (Hussain *et al.*, 2018).

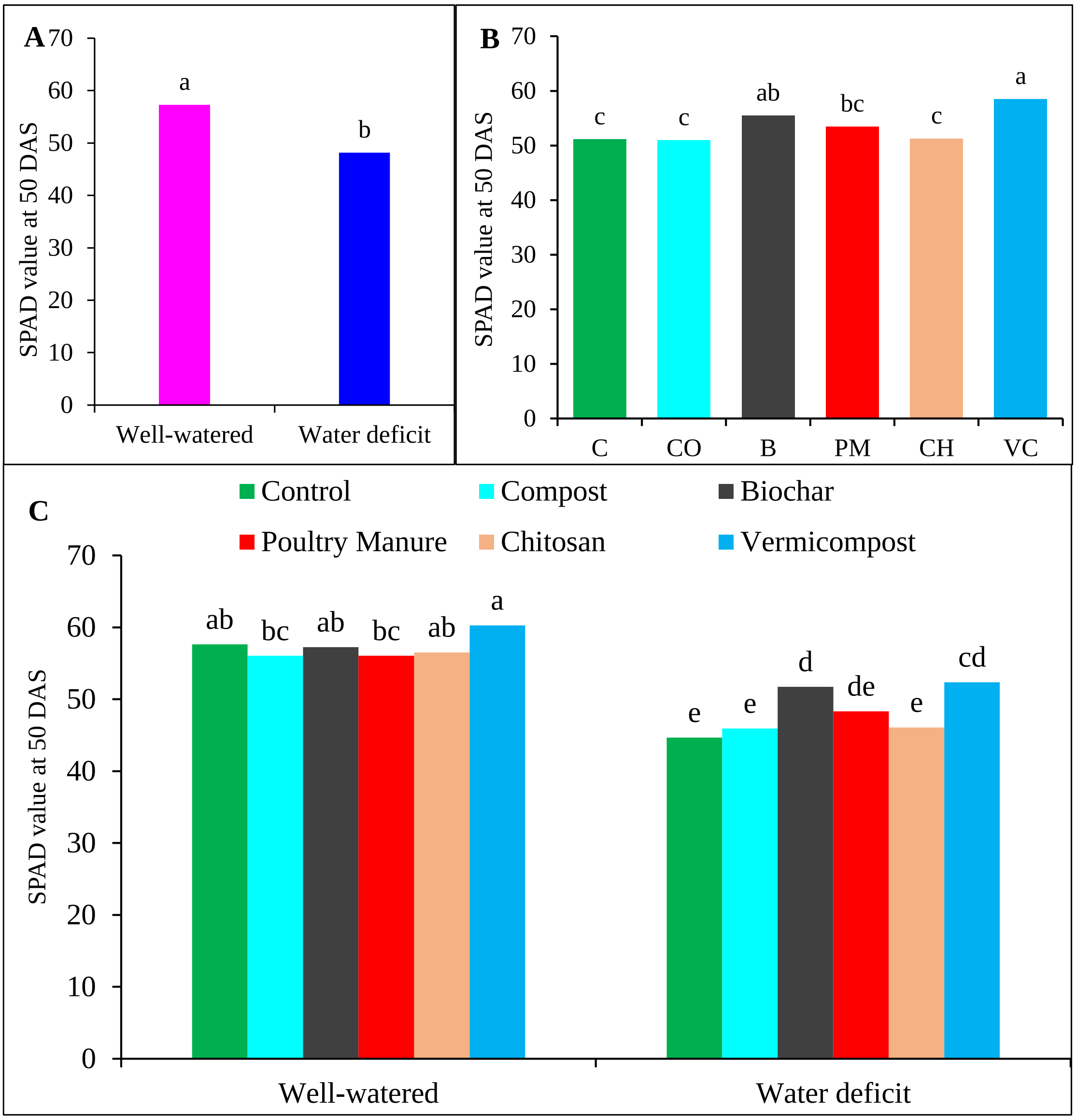

Figure 5. Effect of drought stress (A), effect of organic amendments (B) and interaction effect of drought stress and organic amendments on SPAD value (C). In a column different letter(s) indicates significance of values at 5% probability following LSD test

Chlorophyll content is determined by the photosynthetic capacity of the plants.

A remarkable reduction in leaf chlorophyll was accomplished under water scarcity (Nagswara *et al.,* 2001). Under severe water scarcity, chlorophyll content in leaf was greatly declined (Fotovat *et al.,* 2007).

4.6 Leaf relative water content

4.6.1 Effect of drought stress

As it was well known to all that water scarcity has a serious negative effect on plant lifecycle and during this condition plant water content was greatly decreased. From the recorded data we found that relative water content in leaf reduced to a great extent and here 13.44% reduced water content found in drought state as compared to well water (Figure 6A).

4.6.2 Effect of organic amendments

Compost and vermicompost showed almost similar content of relative water in leaves showed in figure 3(B) and it was 6.82 and 5.96%, respectively more as compared to control condition. Lowest amount of relative water content was obtained from poultry manure treatment and the other treatment showed statistically similar result.

4.6.3 Interaction effect of drought stress and organic amendments

Interaction of different organic amendments and drought showed significant variation on RWC. The highest RWC was obtained from compost treatment and compost and vermicompost attained 4.24 and 2.95%, respectively more RWC than control condition. On the contrary, lowest result attained from poultry manure and it was 3.50% less than control under well water condition. On the other hand, under stressful condition all treatment resulted in better RWC than control and 11.96 and 8.03%, respectively more RWC found in vermicompost and compost treatment. The RWC of main leaf was reduced under different drought stress condition showed in figure 6(C).

During stressful condition, turgor pressure was imbalanced in condition as a result water uplifted from the soil was greatly hampered (Pandey and Shukla, 2015). There was a contradictory relationship between water scarcity and leaf RWC (Hasanuzzaman *et al.*, 2013).

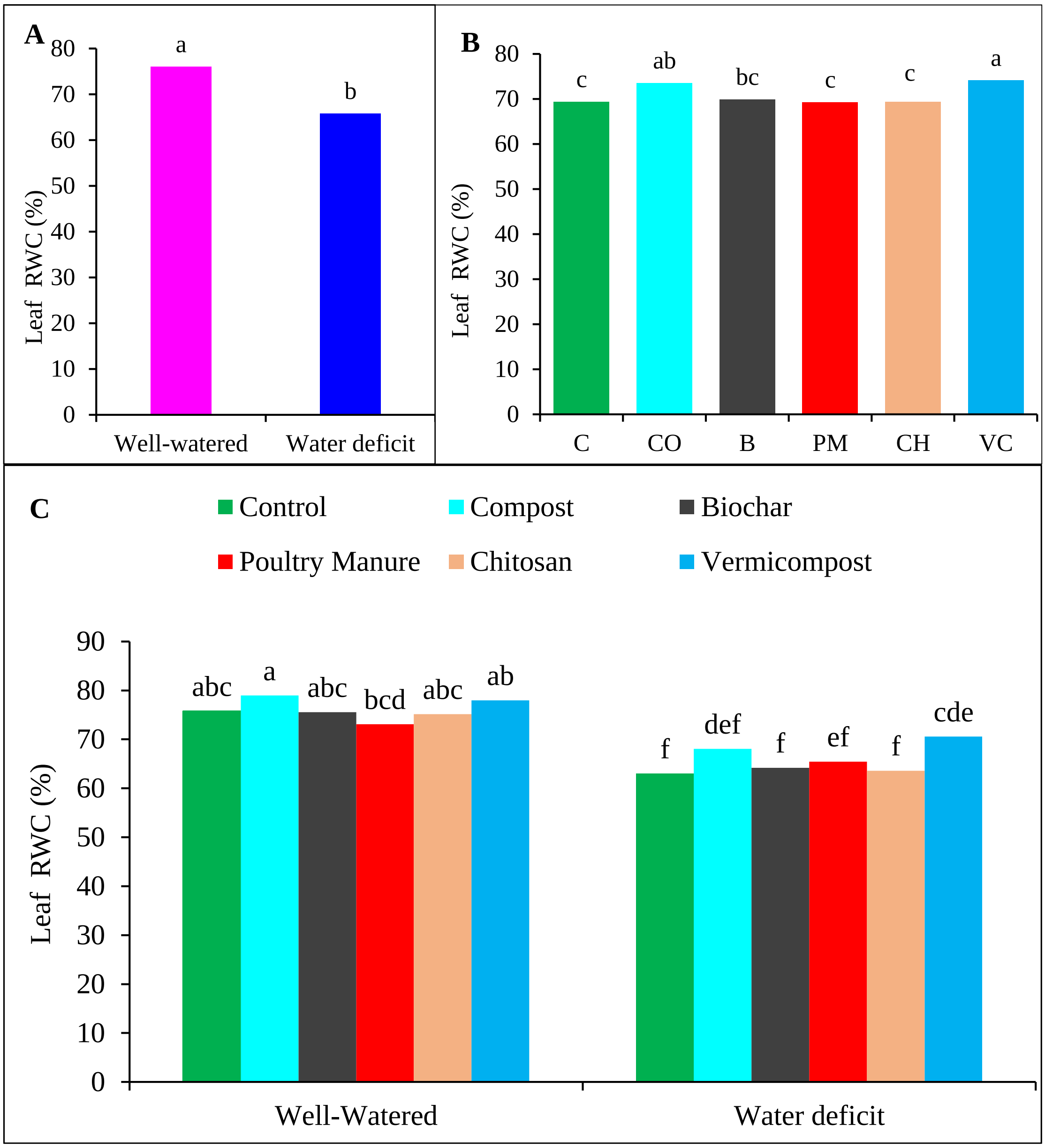

Figure 6. Effect of drought stress (A), effect of organic amendments (B) and interaction effect of drought stress and organic amendments (C) on wheat leaf relative water content. In a column different letter(s) indicates significance of values at 5% probability following LSD test

For this reason, leaf RWC is a significant parameter for amending to drought tolerance. Lima *et al.*, (2015) reported that due to drought stress the RWC was greatly reduced. Drought stress defends the cell division and cell expansions as a consequences disturbs plant water relationships, declines the leaf and water content of the plants (Alam *et al.,* 2013).

As compared to higher transpiration rate than uplifting of water results in diminished turgor pressure that causes to reduced RWC and volume of cell and ultimately abated plant growth (Lawlor and Cornic, 2002). Wheat plants practiced with soil organic amendments have more potential to cope with drought stress and yield production also enhanced (Schonfeld *et al.,* 1988). Drought stress unfortunately negative impact on physiology, morphology and biochemistry of wheat plant and 43% increase in RWC when seeds were treated with compost (Shao *et al.,* 2007).

4.7 Spike length

4.7.1 Effect of drought stress

Spike length is a yield determining parameters in wheat. Drought stress decreased the spike length. From the recorded data, the result revealed that, 11.37% decreased spike length in drought stress showed in figure 7(A).

4.7.2 Effect of organic amendments

Vermicompost and poultry manure gave the highest spike length that was 13.8 and 8.68%, respectively more than control treatment.

4.7.3 Interaction effect of drought stress and organic amendments

The assembled effect of drought and organic amendments creates a reverse interaction on wheat where drought stress reduced the spike length and organic amendments application increased the spike length. From the recorded data, the highest result was found in vermicompost and poultry manure treatment that was 14.45 and 8.85%, respectively more than the control condition under well water. Lowest spike length was found in control condition and similar results was observed in other organic amendments. On the other hand, under water deficit condition highest value was observed in vermicompost treatment which 13.11% more than control condition.

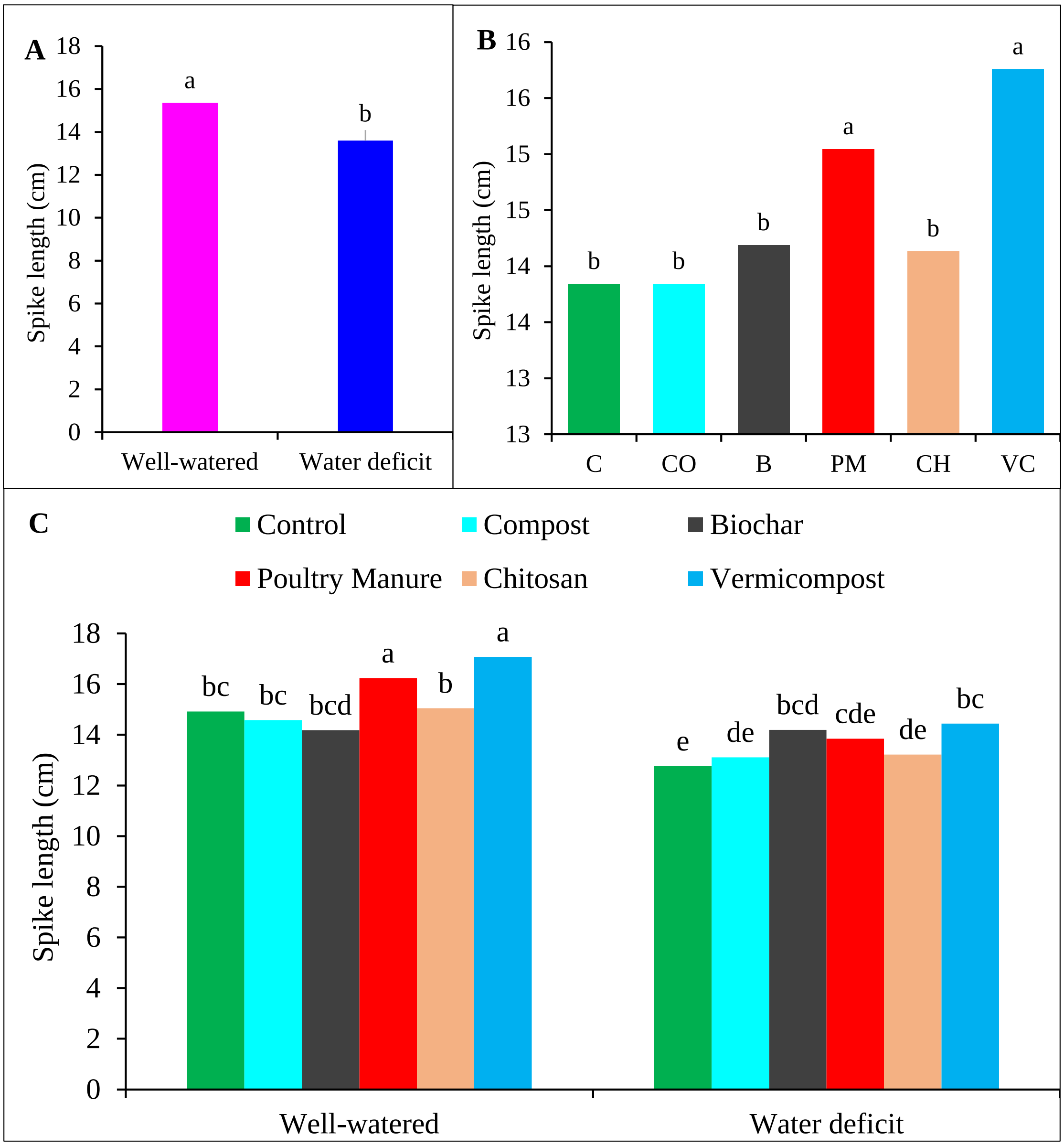

Figure 7. Effect of drought stress (A), effect of organic amendments (B) and interaction effect of drought stress and organic amendments (C) on spike length. In a column different letter(s) indicates significance of values at 5% probability following LSD test

Number of spikelet spike^{-1}

4.8.1 Effect of drought stress

Yield production of wheat is determined by the number of spikelet produced per spike. Drought stress reduced the number of spikelet spike^{-1}. The result revealed that 16.92% reduced spikelet spike^{-1} was found under water deficit condition figure 8(A).

4.8.2 Effect of organic amendments

In this experiment different types of organic amendments were used. From the recorded data maximum number of spikelet per plant obtained from vermicompost treatment which was 16.54% more than control condition. Biochar and poultry manure gave almost similar result.

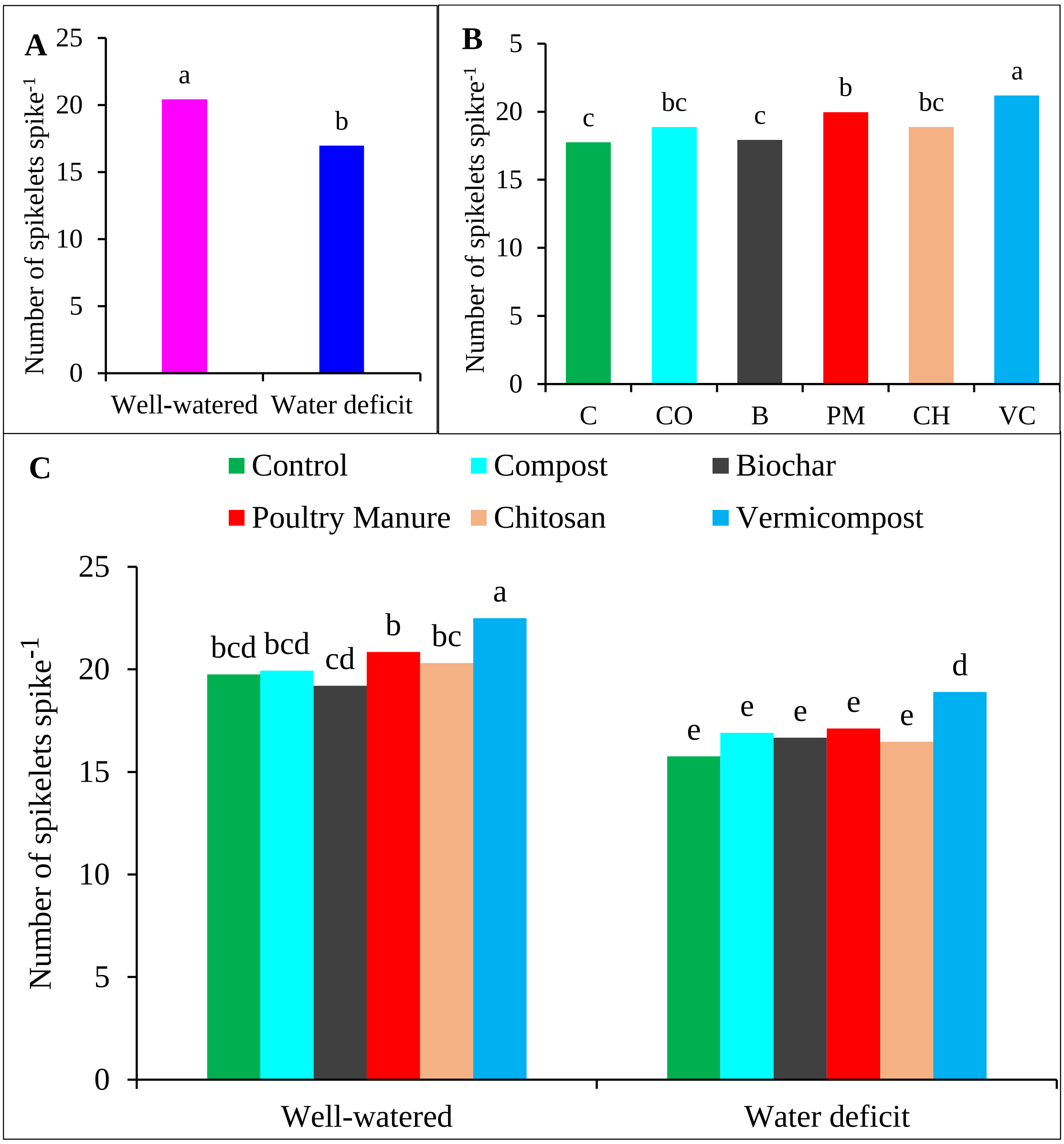

Figure 8. Effect of drought stress (A), effect of organic amendments (B) and interaction effect of drought stress and organic amendments (C) on number

of spikelet spike^{-1}. In a column different letter(s) indicates significance of values at 5% probability following LSD test

4.8.3 Interaction effect of drought stress and organic amendments

Maximum number of Spikelet spike^{-1} was attained from vermicompost treatment. Vermicompost and poultry manure resulted in 13.84 and 5.51%, respectively more spikelet spike^{-1} than control and lowest number of spikelet spike^{-1} was found in biochar treatment under well watered condition which was 2.84% less than compared with control condition.

On the other hand, under water deficit condition greatest value of spikelet spike^{-1} was recorded in vermicompost treatment which was 19.92% spare than control and lowest data recorded in control condition. Wheat production under water deficit condition decreased and practiced with vermicompost dose enhanced number of spikelet spike^{-1} (Joshi et al., 2010).

4.9 Number of grains spike^{-1}

4.9.1 Effect of drought stress

Drought stress has negative impact on the production of wheat cultivation. Number of grains per spike differed significantly with the drought modification. From the recorded data, upon exposure of drought stress number of grains per spike was reduced 11.73% drastically.

4.9.2 Effect of organic amendments

The recorded data showed that highest number of grains per spike was performed by vermicompost and poultry manure treatment that was 11.02 and 6.19%, respectively more than control treatment. Oppositely, the lowest number of grain spike^{-1} was received from biochar treatment.

4.9.3 Interaction effect of drought stress and organic amendments

The assembled effect of drought and organic amendments was significantly varied from different treatments performed in the growing period of wheat.

Vermicompost and poultry manure showed the greater number of grain spike-1 that was 6.43 and 3.45%, respectively more than control under well water. Although the number of grain spike^{-1} of control and biochar were statistically similar under well watered condition.

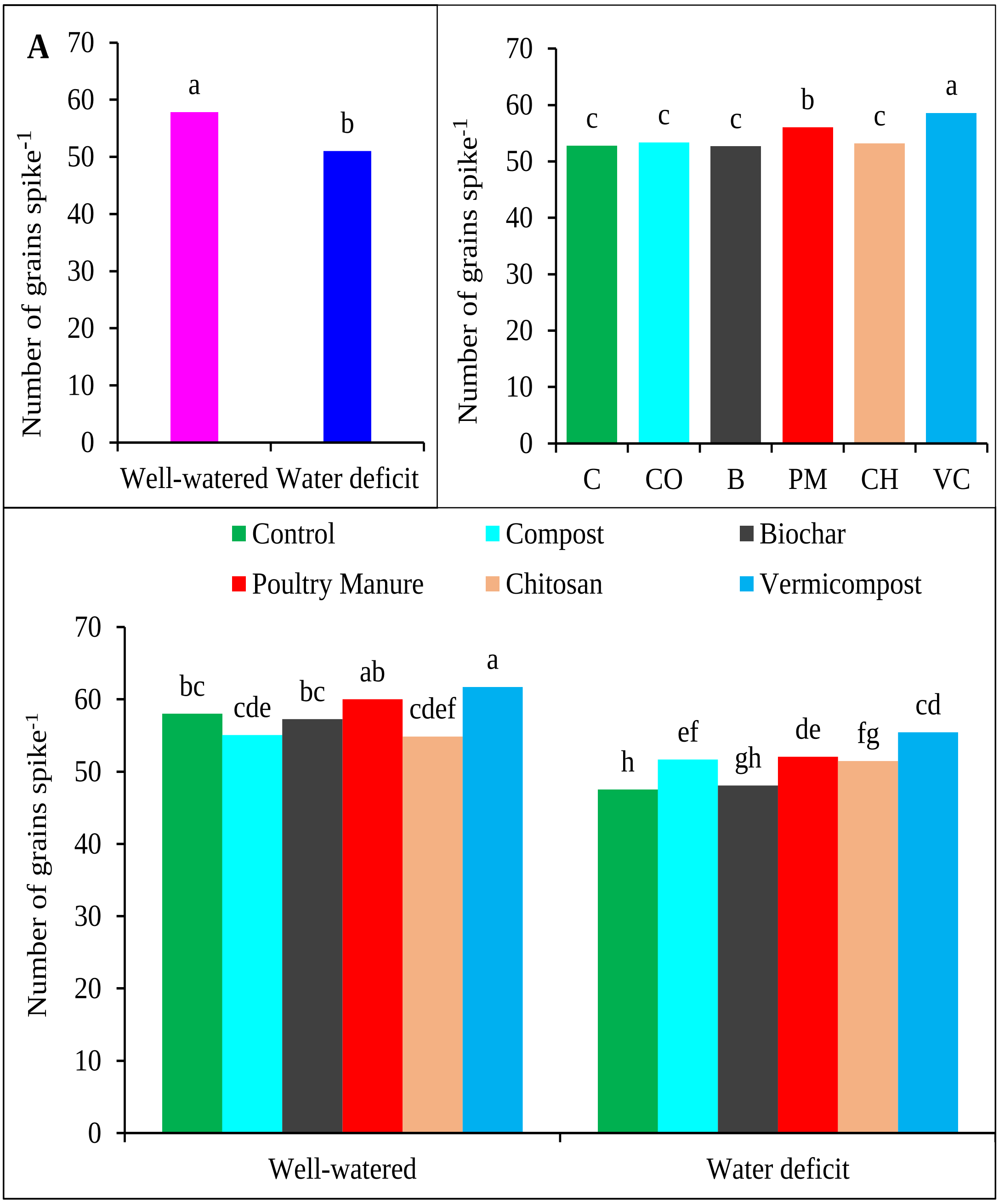

Figure 9. Effect of drought stress (A), effect of organic amendments (B) and interaction effect of drought stress and organic amendments (C) on number grains spike^{-1}. In a column different letter(s) indicates significance of values at 5% probability following LSD test

Application of biochar at 2% and 4% in soil had more yields than normal plants comparing with drought stressed plant (Artiola *et al.*, 2012). During wheat cultivation, flowering and grain development stage was so sensitive to drought stress and consequently decline number of grain per spike. Sprinkler irrigation during grain filling and tillering stage diminished grains spike^{-1} Mushtaq *et al.*, (2011); Nahar, (2013). Singh *et al.*, (2010) conducted an experimentation on chickpea and reported that vermicompost can alleviate the deleterious effect on grain yield of water stress.

4.10 100 grain weight

4.10.1 Effect of drought stress

Grain weight is a major yield attributing characters. Different physiological and yield attributes of wheat had sensitivity to water scarcity in growing period. The weight of 100 grains was significantly differed from stressful condition to well watered condition. The result displayed that 17.83% grains weight was diminished under water deficit condition showed in figure 10(A).

4.10.2 Effect of organic amendments

The effect of different organic amendments on 100 grain weight had a difference. 100 grain weight convey the grain size of wheat grain. The highest 100 grain weight as received from vermicompost treatment which was 17.18% more than control condition. Although, vermicompost and poultry manure showed the statistically similar result and chitosan and control condition also showed statistically similar result, other treatment had statistically differed.

4.10.3 Interaction effect of drought stress and organic amendments

Sharply reduction of grain weight was recorded with the combined effect of drought and different organic amendments. The highest 100 grain weight was obtained from vermicompost treatment and it was 11.11% more than the control treatment. Under well watered condition. Oppositely, under water deficit condition highest result was found from vermicompost treatment and lowest received from biochar that was 3.7% less than control treatment.

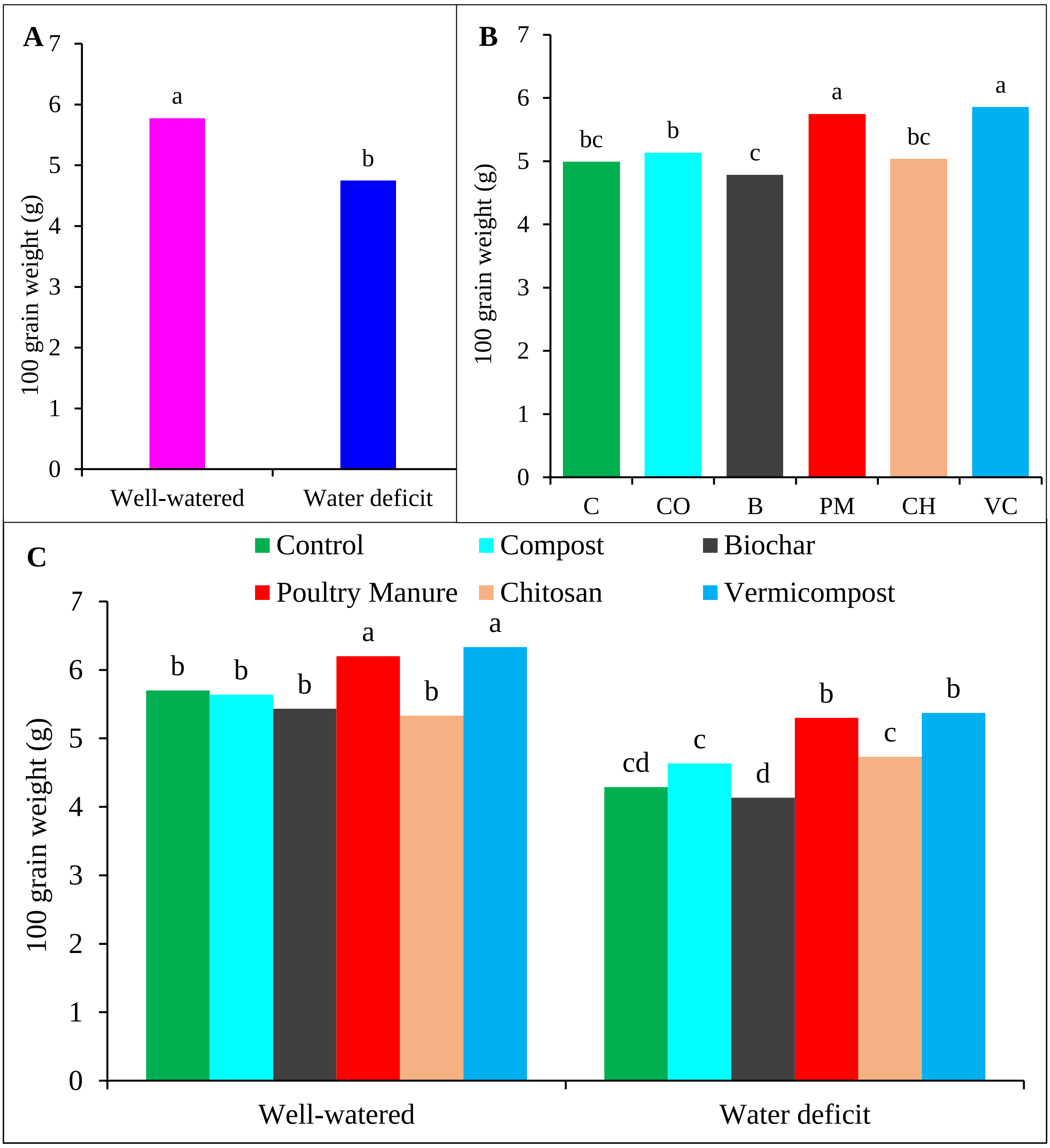

Figure 10. Effect of drought stress (A), effect of organic amendments (B), and interaction effect of drought stress and organic amendments (C) on 100 grain weight. In a column different letter(s) indicates significance of values at 5% probability following LSD test

Height of the plant, number of filled grains panicle^{-1}, 1000 grains weight and harvest index were greatly reduced upon the exposure of drought stress (Zubaer *et al.,* 2007). Artiola *et al., (*2012) reported that soil organic amendment with 2% and 4% biochar had more yields than control treatments after undergoing drought stress.

4.11 Lipid peroxidation (MDA content)

Drought induced oxidative stress is responsible for deteriorating lipid membrane, termed as lipid peroxidation. MDA content is an indicator of lipid peroxidation. To quantify the lipid peroxidation level or oxidative stress, MDA content is measured (Hasanuzzaman *et al*., 2014). Under normal conditions, a variety of ROS such as superoxide anion, hydrogen peroxide and hydroxyl radical produced continuously as byproducts of various metabolic pathways that are localized in different cellular compartments like chloroplast and mitochondria (Navrot *et al*., 2007; Sun, 2004). MDA act as an indicator of oxidative damage due to increasing production of ROS. ROS production increases under various abiotic stresses including drought stress.

4.11.1 Effect of drought stress

Under drought stress MDA content was increased. In this experiment under stressful condition MDA content was increased by 134.34% than well watered plant.

4.11.2 Effect of organic amendments

In the present study it was found that highest MDA content was produced by poultry manure treatment and lowest by control condition. A significance difference of 16.75% MDA content was declined by vermicompost treatment than control treatment while 11.08, 15.26 and 16.37% MDA content enhanced by compost, biochar and poultry manure, respectively showed in figure 11(B).

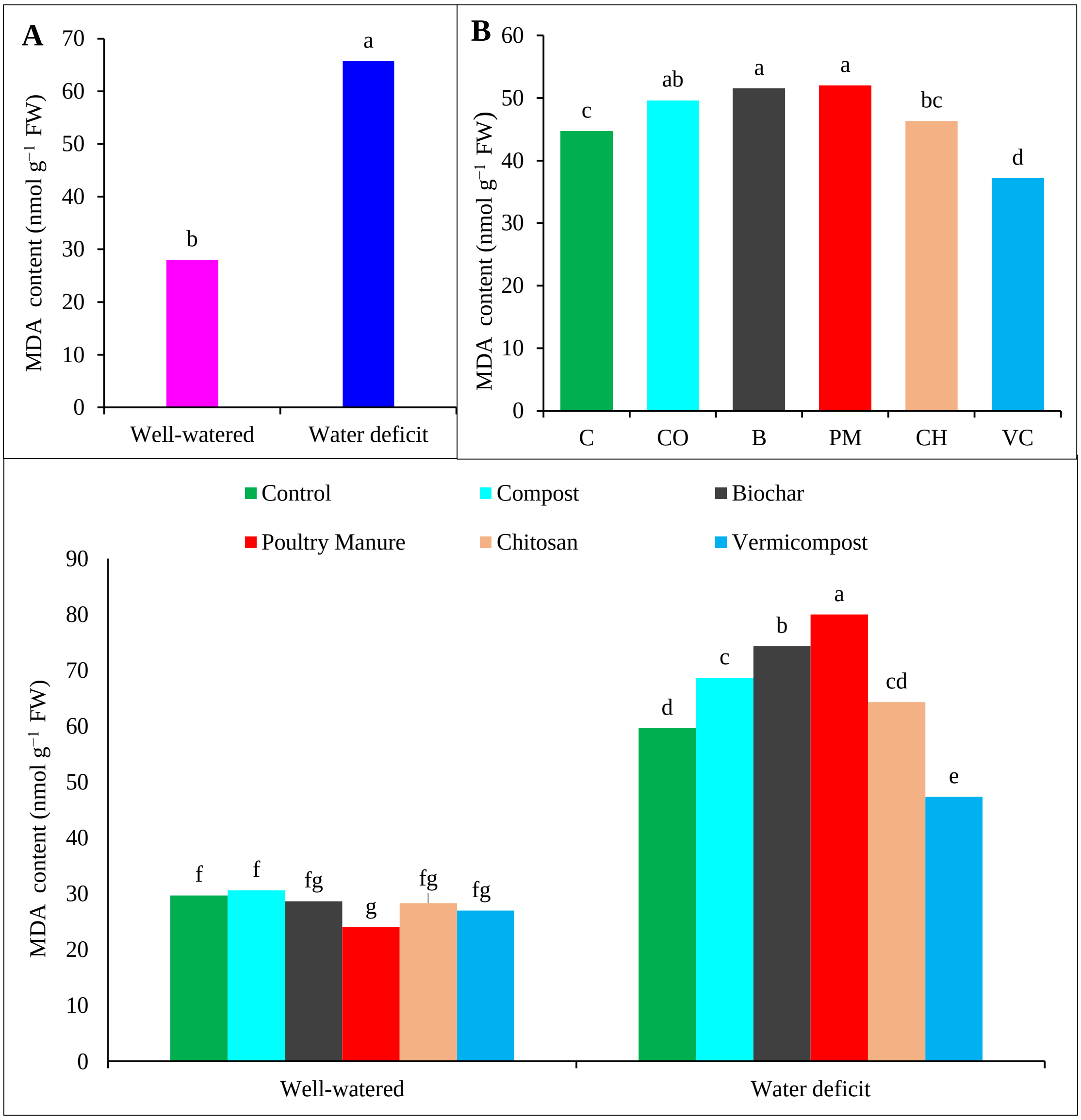

Figure 11. Effect of drought stress (A), effect of organic amendments (B) and interaction effect of drought stress and organic amendments (C) on MDA content. In a column different letter(s) indicates significance of values at 5% probability following LSD test

4.11.3 Interaction effect of drought and organic amendments on MDA content.

The combined effect of drought and organic amendments was significantly varied from treatment to treatment. Under well water condition poultry manure declined greatest amount (19.19%) of MDA content than untreated control. On the contrary, under water stress condition, vermicompost treatment reduced highest amount of MDA content than control figure 11(C).

Levels of MDA content increased markedly under drought stress condition where decreased levels of MDA content was observed in seedlings which were supplied with different organic amendments (Foyer and Noctor, 2005).

4.12 Proline Content

4.12.1 Effect of drought stress

Proline content increased in wheat seedlings under water deficit condition. In the present study, proline content increased 64.45% in water deficit plants compared to well-watered plants showed in figure 12(A).

4.12.2 Effect of organic amendments

Among all the organic amendments the highest proline content was found in poultry manure and vermicompost resulted the lowest content. However, sharp declined of proline content was observed in vermicompost treated plants by 26.63% compared to control showed in figure 12(B).

4.12.3 Interaction effect of drought stress and organic amendments

Comparing with well-watered control proline content increased markedly under water-deficit wheat. In contrast organic amendments supplementation in water deficit plants reduced proline content significantly compared to well-watered control and untreated stressed plants. Compost, biochar and vermicompost showed notable reduction of proline content by 12.67, 13.26 and 21.32%, respectively over control.

Moreover, mitigating negative effect of water deficit condition vermicompost declined proline content by 29.87% compared to untreated stressed plants. Under stress full condition proline performed as an osmolyte. Production of proline in stress condition is greatly enhanced so that plant can protect them from damage of cell membrane structure and macro molecules throughout the period (Prado *et al.*, 2000).

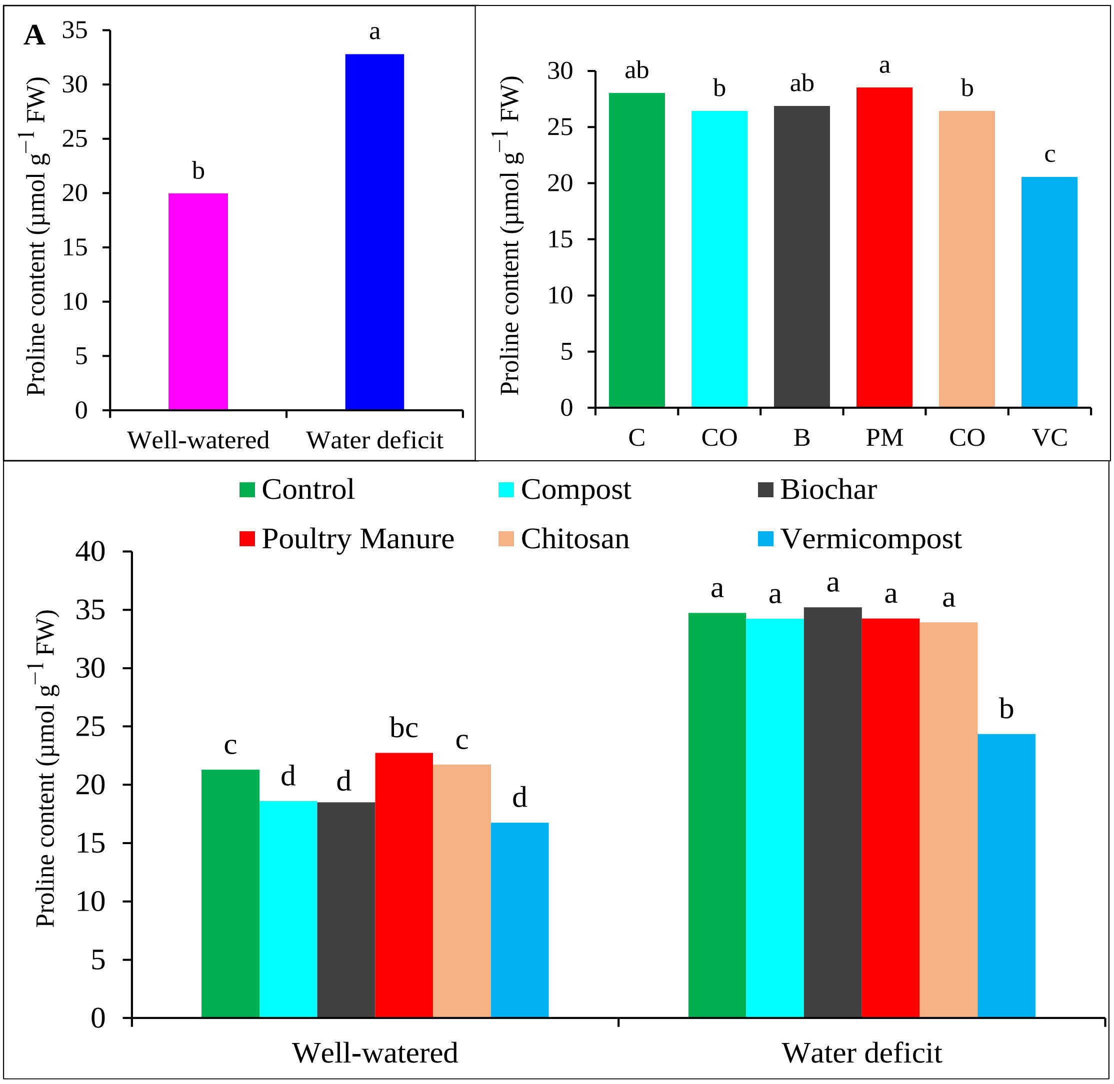

Figure 12. Effect of drought stress (A), effect of organic amendments (B) and interaction effect of drought stress and organic amendments (C) on proline content. In a column different letter(s) indicates significance of values at 5% probability following LSD test

Procurement of proline helps the plant for by energy supplementation so that plant growth and survival mechanism developed and can avoid the abiotic stress (Chandrashekar and Sandhyarani, 1996). During water scarcity proline level increased in wheat (Demir, 2000).

Chapter V

SUMMARY AND CONCLUSION

A pot experiment was taken on hand to look into organic amendments and the effect of drought stress on crop growth, physiological and biochemical responses and to acquire a knowledge in mitigating the adverse effect of drought stress on growth, development and yield in wheat. Different organic amendments such as biochar @ 2.5% w/w soil, chitosan @1% w/w soil, compost @10 t ha^{-1}, vermicompost @10 t ha^{-1}and poultry manure @10 t ha^{-1} were taken under experiment both in stress full and stress less condition.

The experiment was performed at the net house in the experimental site of the department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207. During wheat growing season the effect of drought stress on different organic amendments on crop growth parameters and yield attributes were observed. The experiment was carried out in RCBD with three replications.

Morphological, physiological and yield and yield attributing data and biochemical data were collected throughout the growing season Growth parameters were collected after a definite period of time and the yield data was collected after harvest. It was observed that upon exposure of drought stress on wheat 15.02% of the plant height was declined. Highest plant height was found in compost treatment which was 16.55% more than control treatment under stress full condition. Analysis of variance indicated that 15.91% SPAD value was reduced in drought condition and but highest SPAD value was found in vermicompost and it was 17.24% more than control under water stress.

Drought stress reduced germination capacity of wheat seedlings. Under stressful condition 7.48% germination capability declined. Drought stress had significant effect on the physiological parameters such as relative water content on leaf.

Under drought stress condition 13.44% relative water content was reduced and maximum relative water content was found in vermicompost which was 5.24% more than control. Yield and yield contributing attributes viz. length of spikelet, number of spikelet per spike, grains per spike, 100 grain weight was greatly reduced. Under drought condition organic amendments like vermicompost application was increased spikelet spike-^{1} and grains spike^{-1} of 19.91% and 16.62%, respectively than untreated control. Sharp reduction of 100 grain weight was accomplished under water scarcity. The result revealed that drought stress declined 17.83% grains weight. Maximum result was gained from vermicompost treatment on the other hand minimum result from biochar which was 3.7% less than control treatment.

Lipid per oxidation (MDA content) and proline content was increased in drought stress but when organic amendments were used they were found in lower amount. Under water scarcity 64.45% more MDA was produced but with application of vermicompost 20.56% MDA content was reduced compared with control treatment. Proline was also increased under drought 134.34% than control but practice with organic amendments minimizes proline content. Among these organic amendments vermicompost minimizes greatest amount of proline content under drought stress condition.

Drought stress caused great reduction of growth and development, yield and yield attributes. Application of organic amendments played a significant role to increase in these cases both in well watered and water deficit and it protected the crop from stressful condition. Reduced spike length, lower numbers of spikelet spike^{-1}, declined numbers of grain spike^{-1} and diminished grain weight were responsible for decreased yields. Wheat cultivation with the application of organic amendments under drought condition enhanced these attributes.

Overall findings in this experiment indicated that drought stress caused oxidative damage and addition of organic amendments prevents the production of ROS and consequently plant get release from stress damage and in most cases it enhanced above these growth, physiological, yield and yield attributes. Based on the present result along with the available literature, we therefore conclude that organic amendments acts as a protectant and mollified drought stress condition and vermicompost performed better over the organic amendments in the study.

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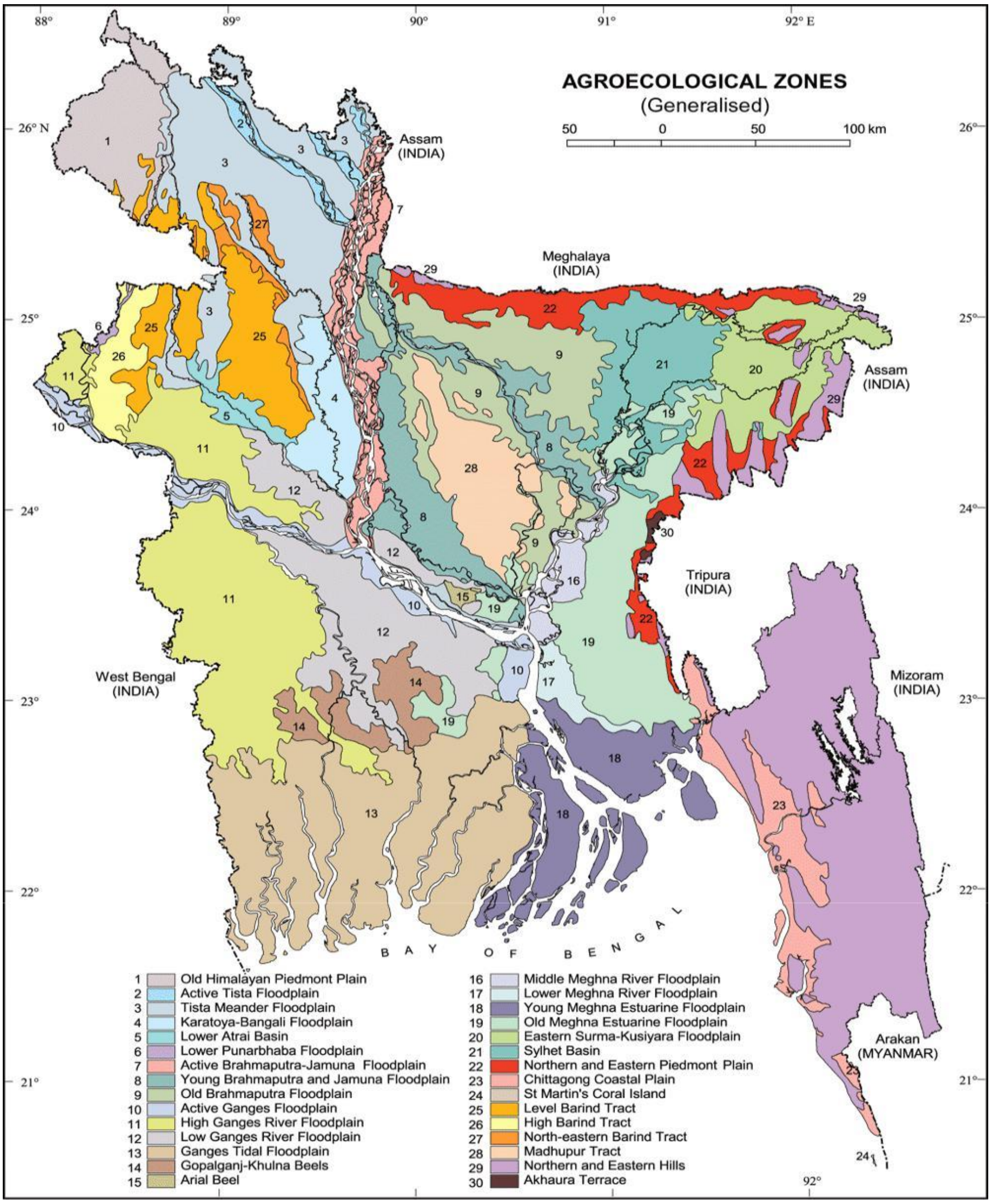
APPENDICES

Appendix I: Research site showed in the map of agro-ecological zones of Bangladesh.



Appendix II: Layout of the experiment

R1		R2		R3	
C_{ww}	PM_{ww}	B_{dw}	CH_{ww}	VC_{ww}	CO_{dw}
CO_{dw}	B_{dw}	VC_{ww}	PM_{dw}	C_{dw}	CH_{dw}
VC_{ww}	CH_{ww}	CH_{dw}	B_{ww}	CO_{ww}	PM_{ww}
PM_{dw}	C_{dw}	CO_{ww}	VC_{dw}	B_{dw}	C_{ww}
B_{ww}	CO_{ww}	C_{dw}	CO_{dw}	CH_{ww}	VC_{dw}
CH_{dw}	VC_{dw}	PM_{ww}	C_{ww}	PM_{dw}	B_{ww}

Factor A: Drought

1. Well-watered

2. Deficit water

Factor B: Organic amendments

1. C=Control

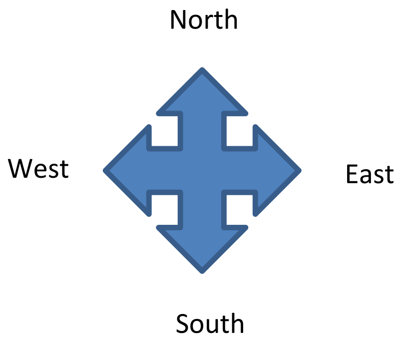
2. CO=Compost

3. PM=Poultry manure

4. B=Biochar

5. CH=Chitosan

6. VC=Vermicompost



Appendix III: Mean square values and degree of freedom of germination , root length, shoot length and plant height of wheat as under drought stress condition.

Source	DF	Mean square values			
		Germination	Root length	Shoot length	Plant height
Model	11	19.058	4.768	1.741	91.690
Error	24	3.472	0.345	0.607	3.267

Appendix IV: Mean square values and degree of freedom of SPAD value, Leaf RWC, spike length, number of spikelet spike^{-1} of wheat under drought stress condition.

Source	DF	Mean square values			
		SPAD value	Leaf RWC	Spike length	Number of spikelet spike^{-1}
Model	11	85.586	102.755	4.728	13.088
Error	24	5.267	10.304	0.422	0.706

Appendix V: Mean square values and degree of freedom (DF) of number of grain spike$^{-1,}$ 100 grains weight, MDA content, Proline content of wheat under drought stress condition.

Source	DF	Mean square values			
		Number of grain spike^{-1}	100 grain weight	MDA content	Proline content
Model	11	59.097	1.447	1349.528	165.907
Error	24	4.108	0.085	10.042	2.069