INFLUENCE OF SOIL ORGANIC AMENDMENTS ON MORPHOLOGY AND YIELD OF RICE UNDER DROUGHT STRESS

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INFLUENCE OF SOIL ORGANIC AMENDMENTS ON MORPHOLOGY AND YIELD OF RICE UNDER DROUGHT STRESS

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CERTIFICATE

This is to certify that the thesis entitled **"INFLUENCE OF SOIL ORGANIC AMENDMENTS ON MORPHOLOGY AND YIELD OF RICE UNDER DROUGHT STRESS"** submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRICULTURAL BOTANY**, embodies the result of a piece of bonafide research work carried out by **SAMAR BARAI**, Registration No. 12-04791 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

June, 2020
Dhaka, Bangladesh

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Dedicated To

My Beloved Parents

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The Author

INFLUENCE OF SOIL ORGANIC AMENDMENTS ON MORPHOLOGY AND YIELD OF RICE UNDER DROUGHT STRESS

ABSTRACT

A pot experiment was conducted to investigate the influence of soil organic amendments-cowdang and humic acid on morphology and yield of rice under drought stress at the net-house,Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka during the period from July 2018 to November 2018. In this two factorial experiment pots where arranged in a randomized complete block design with four replications. The factors are (A) Four different levels of water deficiencies *viz*. D_1 = Well watered condition (Control), D_2 = Irrigation at 7 days interval, D_3 = Irrigation at 14 days interval and D_4 = Irrigation at 21 days interval and (B) Four different levels of soil organic amendments *viz*. SM_1 = Soil + inorganic fertilizer (control), SM_2 = Soil + cowdung + inorganic fertilizer, SM_3 = Soil + inorganic fertilizer + humic acid and SM_4 = Soil + inorganic fertilizer + cowdung + humic acid. The morphological characters such as plant height, tiller number plants^{-1} at different days after transplanting and yield contributing characters such as days required to flowering, panicle length, number of grains per panicles, grain weight and yield of rice varied significantly followed by different levels of water deficiency. The results showed that more than 36% yield was reduced under drought condition where the plants were irrigated with 21 days interval. In this experiment, cow dung and humic acid were used to find the interaction of soil organic amendments for changing the adverse effect of drought on rice cultivation. The results showed that morphological characters and yield of rice significantly increased with addition of cowdung and humic acid into the soil. This experimental results highlighted that together use of cowdung and humic acid increased the grain weight plants^{-1} more than 150% compared to controlled condition. The interaction effect of drought and soil organic matter also significantly changed the morphological characters and yield of rice. It is noted that rice plant failed to survive 70 DAT from the treatments of $D_3SM_{1,}$ $D_3SM_{2,}$ $D_4SM_{1,}$ $D_4SM_{2..}$ In terms of combined effect of different levels of water deficiency and humic acid the highest panicle length (26.25 cm), number of grains panicle^{-1} (255.80), grain weight hill^{-1} (29.30 g) and straw weight hill^{-1} (35.38 g) were recorded from D_1H_4 whereas the lowest performance was observed from the treatment combination of D_4H_1. Finally, it concluded that application of cowdung and humic acid as soil organic amendments increases the yield of rice by increasing the plant hight, tiller number, penicle length, grain weight undetr water deficit condition and/or drought stress.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
HA	=	Humic Acid
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food of Bangladesh and over 95% people depend on rice for their daily diets and it engages over 85% of the total agricultural labour force in Bangladesh. Transplant *aman* rice varieties are generally cultivated in rainfed ecosystem which covers about 48.97% of total rice area and contributes to 38.14% of total rice production in the country (BRRI, 2018). Modern varieties of T. *aman* cover about 67% of rice area in the aman season (BBS, 2019).

Bangladesh is predominantly an agrarian country. Due to its very fertile land and favorable weather, varieties of crops grow abundantly in this country. Agriculture sector contributes about 13.31 percent to the country's Gross Domestic Product (GDP) and employs more than 49 percent of total labour force (BBS, 2019). Rice is cultivated in Bangladesh throughout the year as Aus, *Aman* or Boro. *Aman* (broadcast and transplanted) is generally cultivated from June-July to October-November, Boro from December-January to April-May, and Aus from March-April to June-July. *Aman* rice is one of the main rice crops in Bangladesh. It is the second largest rice crop in the country in respect to the volume of production while boro rice tops the production. It is notable that the area coverage of aman rice is the largest as a single crop and boro rice remains the second. Total *Aman* production of 2019 has been estimated 1.53 crore (15.34 million) metric tons compared to 1.4 crore metric tons of 2018 and 1.36 crore metric tons in 2017. It covers 58.76 lakg hectares of land area of *Aman* season in 2019 (BBS, 2019).

Water deficit condition is generally known as drought and is expressed as the absence of the necessary water for normal plant growth and life cycle (Zhu 2002). Drought or water deficit considerably affects vegetable production in many parts of the world. It disturbs plant water relationships, reducing leaf size, root growth and root multiplication. Plants exhibit various physiological and biochemical responses to drought stress at cellular and whole organism levels. In leaves, closure of the stomata, membrane damage and changes in the activation of various enzymes occur (Zhang *et al*. 2013; Ariafar and Forouzande 2017; Hatami 2017; Kaya *et al*. 2018).

Among different stresses; flood (50%), drought (20%) and salinity (30%) are the main stressor in Bangladesh where rice frequently suffers from considerable shock to maintain its full yield potential. The nature and extent of these environments vary with season, topography and location (Biswas, 2015). Drought occurs mainly due to uneven distribution of rainfall. It is one of the major abiotic constraints for rice grown (5.7 m ha) under rain-fed conditions in Bangladesh and causes a substantial reduction of yield. It is a common feature that appears to affect a rice crop in any of the growth stages (early drought) (Biswas, 2015). Transplanted Aman (T. *Aman*: Rainfed lowland rice) cultivators usually suffer from water stress at reproductive (Terminal drought) and/or early ripening phases to incur heavy loss to crop yield. The impact of drought depends not only on the duration and intensity but also on the nature of crop along with its stage of growth and soil characteristics. The drought management practices used in crop production.

Tolerance to drought is a complex phenomenon involving a number of physiochemical processes at different stages of plant development. Various mechanisms have been developed by drought-tolerant plants to adapt to the stress. Examples of these mechanisms are: increased water uptake by developing large and deep root systems, reduction of water loss by accumulation of osmolites, prevention of membrane disintegration and enzyme activation, and increase in K^+ and Ca^{2+} ions uptake (Mahajan and Tuteja 2005; Lotfi *et al*. 2015; Kaya *et al*. 2018). Development of irrigation facilities is the main solution if possible in the drought prone areas.

It has been stated that application of soil organic amendments-humic acid and cowdung can also be the alternative to management of drought in rice. The use of humic substances in agriculture as fertilizer and soil conditioner were tried on limited scale. Significant impact of these humic substances on soil structure and plant growth was reported earlier by Ihsanullah and Bakhashawin (2013); El-Razek *et al*. (2012) and Fong *et al*. (2007). HA in proper concentration can enhance plant and root growth (Ahmed *et al*., 2013). Humic substances (humic, fulvic acid) attracts positive ions, forms chelates with micronutrients and releases them slowly when required by plants. According to Kadam *et al*. (2010) the humic substances act as chelating agents there by prevents formation of precipitation, fixation, leaching and oxidation of micronutrients in soil. Humic acid is technically not a fertilizer, although people consider it that humic acid is an effective agent to use as a complement to synthetic or organic fertilizers. Humic acid, it's a water soluble organic acid, naturally, presented in soil organic matter; it could be recognized that humic acid substances have many beneficial effects on soil structure and soil microbial populations as well as increase modify mechanisms involved in plant growth stimulation, cell permeability and nutrient uptake and increasing yield. Mayhew (2004) showed that humic substances may possibly enhance the uptake of minerals through the stimulation of microbiological activity. Pettit (2004) reported that humic substances have a very profound influence on the growth of plant roots. Since, humic and fulvic acids are applied to the soil enhancement of root initiation and increased root growth. Daur and Bakhashwain (2013) stated that significant differences were observed for all the studied parameters across the humic acid levels. Aisha *et al*. (2014) reported that increasing rate of humic acid increased growth characters, yield characters and increase the percentage of protein. The highest mean values of the growth characters, roots characters and the percentage of protein were associated with plants which received higher level of humic acid (14.40 l/ha.) with cowdung.

However, to my knowledge little in known about the use of different soil organic amendments as humic acid and cowdung on morphological and yield characters of rice under the water stress condition at SAU environmental condition. The main purpose of this study was to improve the morphological characters yield potential of rice under water deficit condition using cowdung and humic acid as soil organic amendments. Therefore, the present study has been undertaken with the following specific objectives:

1. To investigate the response of T. *Aman* rice to different level of water deficiency
2. To investigate the effects of soil organic amendments-cowdung and humic acid on rice morphology and yield.
3. To find out the effects of soil organic amendments-cowdung and humic acid to alter adverse effects of drought on T. *Aman* rice.

CHAPTER II

REVIEW OF LITERATURE

Life is not possible without water in any living beings. Drought (water deficit) affects plant through depression in growth and development and in turn productivity. There are abundant information about morphological, physiological and biochemical responses of crop plants to moisture deficits (drought). The dimension of water-stress-effect on different plant growth stages might be different. Some growth stages may be more critical towards stresses then the others. There might be differences in cultivars response to the water stress. The influence of drought on crop production is still being studied and results are published in different scientific journals. Some of the relevant findings are cited in this chapter.

2.1 Drought

Drought or water deficit considerably affects vegetable production in many parts of the world. It disturbs plant water relationships, reducing leaf size, root growth and root multiplication. Plants exhibit various physiological and biochemical responses to drought stress at cellular and whole organism levels. In leaves, closure of the stomata, membrane damage and changes in the activation of various enzymes occur (Zhang *et al*. 2013; Ariafar and Forouzande 2017; Hatami 2017; Kaya *et al*. 2018).

Drought stress is usually unpredictable in its timing, duration and intensity. Plant response to drought stress is complex as it involves a number of physiobiochemical processes at the cellular level and different interacting component traits with different responses at the whole plant level (Witcombe *et al.,* 2008; Kadam, 2012).

There are three components of drought resistance viz. dehydration avoidance, dehydration tolerance and dehydration escapes. Dehydration avoidance is the ability of the plant to maintain its hydration state whereas dehydration tolerance refers to a plants' ability to function after dehydration (Blum, 2011).

Drought in agriculture refers to water deficit in the root zone of plants and results in yield reduction during the crop life cycle (Rampino *et al.,* 2006; Passioura, 2007; Nevo and Chen, 2010; Ji *et al.,* 2010). Therefore, drought tolerance is defined as the ability of plants to survive and reproduce under water deficit conditions (Fleury *et al.,* 2010).

Kirigwi *et al.* (2004) developed six-hundred entries derived from ten crosses by selection under continuous high moisture, alternating high with low moisture, alternating low with high moisture, and continuous low moisture conditions for five generations in the Yaqui Valley, Sonora, Mexico. The results showed that alternating selection between high and low yielding environments is the most effective way to develop wheat germplasm adapted to environments where intermittent drought occurs.

Turner (1981) classified drought tolerance of plants in the following manners:

i) Drought escape or ability of plants to complete the life cycle before being subjected to serious water stress.

ii) Drought tolerance with high tissue water potential

iii) Drought tolerance with low tissue water potential

Schimper (1998) and Jones (1992) found that the degree of plant water stress depends on the degree of reduction of potentials below the optimum levels of soil moisture potential (4 bars) and cell turgid. Plant water stress may not always be associated with the availability of soil moisture level. Excessive transpiration, physiological inhibition of water absorption, excess of salt in the soil solution, deficit aeration or injury to root systems etc. may cause plant water stress even in absence of true drought.

2.2 Drought susceptibility indicators

Marcinska *et al.* (2013) conducted a experiment with salicylic acid (SA) and abscisic acid (ABA) in osmotic stress tolerance of both drought susceptible (SQ1) and drought resistant (CS) wheat cultivars, used SA (0.05mM) or ABA ((0.1 pM) to solutions containing half-strength Hoagland medium and PEG 6000 (-0.75 MPa). The most noticeable result that an increase in proline in both cultivars and carbohydrate content, antioxidant activity in (SQ1) and reduces length of leaves and roots in both cultivars, gas exchange parameters, chlorophyll content in CS, and osmotic potential.

Rashid *et al.* (2003) found from a field study of wheat in Pakistan that drought susceptibility index (DSI) and relative yield (RY) values were useful to describe yield stability and yield potential. There were high variations in DSI and RY values among cultivars. The DSI values ranged from 0.62 to 1.26 and the mean RY values were 0.81 for well watered plots and 0.83 for water stressed plots.Parwaz-94, Pasban-90, and Punjab-96 showed high yield potential and stability thus, these cultivars could be further tested for drought tolerance.

Jharna *et al*. (2001) used PEG-6000 for imposing water stress in groundnut plant. They made screening of groundnut varieties for drought tolerance on the basis of their ability to accumulate higher amount of proline in water deficit condition.

Ismail *et al*. (1999) conducted a pot experiment with durum wheat genotypes Hourani and Stork and 4 genotypes derived from crosses between them were tested for drought response under water stress during tillering, stem extention, heading or ripening, or during the entire growth period. The results suggested that drought susceptibility index and regression slope were not found to be correlated, showing that they may be independent parameters which could both be used to characterize drought tolerance of durum wheat genotypes.

Srivastaava and Kamalesh (1998) conducted an experiment with nine genotypes of sesame *[Sesame indicum* (L)]subjected to four soil moisture regimes i.e., field capacity and irrigated at 20, 30, and 40 percent depletion of available soil moisture. Yield stability analysis and estimation of drought susceptibility index indicated that the genotypes which have poor yield potential under non stress condition are more resistant to moisture stress.

2.3 Drought tolerance mechanism in plants

Tolerance to water stress is a complex phenomenon involving a number of physiochemical processes at different stages of plant development. Various mechanisms have been developed by drought-tolerant plants to adapt to the stress. Examples of these mechanisms are: increased water uptake by developing large and deep root systems, reduction of water loss by accumulation of osmolites, prevention of membrane disintegration and enzyme activation, and increase in K and Ca ions uptake (Mahajan and Tuteja 2005; Lotfi *et al*. 2015; Kaya *et al*. 2018).

As an integrated process, the entire plant growlh may be affected in terms of dry matter accumulation (DMA) and partitioning efficiency, due to moisture stress, this means genotypes possessing higher DMA could be drought tolerant and more productive (Arjunan *et al* 1992). Decreased water application results reduced total dry matter production (TDM) and that resulted from decline in conversion of the intercepted radiation (Collinson *et al.* 1996) by plant structures.

Osmotic adjustment appeared to be the main mechanism of stomatal adjustment which allowed stomata to open partially with increasing water stress (Ludlow and Muchow 1990). According to Neumann (1995) in water deficits cell wall hardening might act as an adaptive feed forward mechanism that prolongs the survival of individual plants by limiting increase in leaf area and transpirational water loss under terminal drought. Ali (1992) reported that water stress had inhibited leaf initiation, suppressed node formation and decreased axilary growth rate which together reduced the number of leaves of the maize plant.

Malik (1992) while studying selection criteria in sugarcane reported that, lower total leaf area was associated with reduce leaf number and size in drought resistant varieties. He further suggested that total leaf area of the lower leaves should be considered as a selection criteria in sugarcane. The total leaf area of a plant may be changed due to changes either in leaf number or in leaf size.

Grzesiak *et al.* (1997) reported significant decrease in lateral root number and dry matter production when the crop experienced moisture stress. They also observed smaller shoots and larger roots in resistant cultivar of field bean and field pea crops.

Ludlow *et al.* (1990) had reported that in dry ing soil environments lower shoot dry weight or harvest index could result from the higher partitioning of dry matter to roots at the expenses of shoot. However, variable growth response of genotypes, in terms ot root and shoot traits under water deficits help select drought resistant traits (Ball *et al.* 1994).

2.4 Effect of drought

2.4.1 *Leaf water parameters*

Moradia *et al.,* (2008) exposed mung bean plants to different durations and severity of drought stress under field condition and found that water stress reduced net photosynthesis rate (PR), stomatal conductance (SC), transpiration rate (TR) and leaf relative water content (RWC) while increased leaf temperature (T).

Jongdee *et al*. (2002) found that a sample of recombinant inbred lines (RILs) was derived from bi-parental cross between Lemont and BK88-BR6, which contrasted in maintenance of leaf water potential (LWP) and expression of osmotic adjustment (OA), was studied in a series of five field experiments. Negative phenotypic and genetic correlations between LWP and percentage spikelet sterility suggests that traits contributing to the maintenance of high LWP minimized the effects of water deficit on spikelet sterility and consequently grain yield.

Yadav *et al*. (2001) conducted a pot experiment genotypes (K8027, C306, K65, UP2003, K8708, HD 2329, HUW 206 and HUW 234) of wheat grown under 60% and 30% available soil water (ASW) conditions, to study the effect of different soil moisture regimes on flag leaf area, relative water content, water potential (at anthesis and milk stages) and grain and stover yield. These parameters decreased significantly under soil water stress conditions, compared to normally irrigated conditions.

Vinod *et al*. (2001) observed that two pearl millet hybrids viz. HHB-67 and their respective parents MS-81 A, H-90/4-5 and MS-843-2 were raised in earthen pots under natural conditions of green house. A significant reduction in RWC (%), water potential, osmotic potential and transpiration rate and increase in proline and leaf diffusive resistance were observed during stress condition. The recovery was better in HHB-67 and its parents and decrease in percentage of RSI due to water stress was low.

2.4.2 *Morpho-physiological characters*

Peymaninia *et al*. (2012) carried out an experiment of 12 bread wheat genotypes to a liquid humic fertilizer based on Leonardite against terminal drought stress. Analysis of variance of data showed that grain yield of wheat genotypes was reduced under drought stress condition. But fluorescence parameter increased in drought stress condition and humic fertilizer didn't affect genotypes. Genotype MV17/zrn produced the highest biological yield, spike weight, spike length, number of grain per spike and grain yield.

Therefore, Genotype MV17/zrn performed better than others.

In Nebraska, the seed vigor, fall stand establishment, and also the effect of water deficit on three winter wheat cultivars ('Goodstreak', 'Harry' and 'Wesley') specifically selected due to their superior adaptation to rainfed or irrigated wheat production systems. The results showed that the root dry matter, root-to-shoot length ratio and root-to-shoot mass ratio of winter wheat were significantly greater in the water stress than in the well-watered conditions, indicating that root growth had increased under water stress. (Hamid *et al.,* 2012).

Lonbani *et al.* (2011) conducted an experiment on Morpho-physiological traits associated with terminal drought stress tolerance in triticale ('Zoro', 'Moreno', 'Lasko', 'Prego' and 'Alamos 83'), one bread wheat ('Roshan') and one durum wheat ('Osta-Gata') cultivars. Results of combined analyses of variances indicated that under drought stress conditions excised leaf water retention (ELWR) showed significant and negative correlation with grain yield, while their correlation was significant and positive under non-stress conditions.

Plant growth and productivity is adversely affected by nature's wrath in the form of various biotic and abiotic stress factors. Water deficit is one of the major abiotic stresses, which adversely affects crop growth and yield. These changes are mainly related to altered metabolic functions, one of those is either loss of or reduced synthesis of photosynthetic pigments, are closely associated to plant biomass yield. This review describes some aspects of drought induced changes in morphological, physiological and pigments composition in higher plants. (Jaleel *et al.,* 2009).

Shao *et al.* (2004) showed that the percentage of ripened grains,1000 grain weight & grain yield of most of 6 two-line hybrid rice cultivars under water stress were lower than those under well watered conditions. The differences in the chlorophyll content & photosynthetic rate in the flag leaves of stressed &

unstressed plants were not significant in the early grain filling stages, but these parameters were reduced in the flag leaves of stressed plants compared to the unstressed ones during the late grain filling stages.

Taub (2003) conducted a pot experiment to know the effects of three levels of water stress (40, 60, 80%FC) on morphological &yield attributes of six chickpea and found that water stress induced a marked reduction in plant height, branch number, leaf area as well as plant biomass production of the study. Similar type of result was also reported by Gupta *et al*. (1995) and Islam *et al*. (1994).

Siddique *et al*. (1999) conducted an experiment with four wheat cultivars (Kanchan, Sonalika, Kalyansona & C306) grown in pots to evaluate the drought stress effect on phonological characters under semi-controlled conditions. The reduction of plant height was severe in those plants which were subjected to drought stress both at vegetative & reproductive stage. Drought decreased tiller number at vegetative stage & leaf area at one or both stages.

2.4.3 *Yield and yield contributing parameters*

Mahmoodian *et al.,* (2012) studied the response of Parto, Govhar and Mehr wheat cultivars to drought stress (0, -0.5 and -1.5 Mega Pascal) under field conditions. The results of analysis of variance indicated that drought stress had significant effect on grain yield, yield components, harvest index and biologic yield. The Parto cultivar was the best cultivar compared to other cultivars. Selection of the best variety and avoid from severe drought stress were recommended for production of the highest grain yield under semi-arid conditions.

Twelve wheat cultivars of diverse characters and origin were studied at Sindh Agriculture University, Tandojam, Pakistan. The experiment was laid-out in factorial design with two treatments (non-stress and stress atanthesis) and three replications during crop season 2007-08. Correlations among morphological, physiological and morpho-physiological traits were generally reliable indicators for screening drought tolerant wheat cultivars and potentially with higher yields. The results showed that improvement in any of these traits will lead to increased grain yield under water stress conditions. (Jatoi *et al.* 2011).

Allahmoradi *et al.,* (2011) conducted field experiment to investigate the resistance of mung bean and its physiological responses to drought stress. Results showed that there was no significant difference in yield and yield components between control and drought stress during reproductive growth stage, where as drought stress during vegetative growth stage significantly decreased yield and yield components. Relative water content of leaves appeared to be the most limiting factor responsible for the differences in yield between treatments.

The major environmental factor that constrains the productivity of crops is water stress. A number of experiments on water stress in Bangladesh demonstrated that water deficit conditions decreased leaf relative water contents, water potential, osmotic potential, turgor potential, growth and yield components of wheat cultivars (Akram, 2011) and yield attributes of rice (Bakul *et al.,* 2009).

Hossain *et al.,* (2010) conducted an experiment at Bangladesh Agricultural University, Mymensingh to investigate the effect of drought stress at various levels with a view to studying the physiological characters of sunflower associated with yield under drought condition. Two varieties (Kironi and Hysan-55) and five drought cycles were i) Daily watering, ii) 1 day without water, iii) 2 days without water, iv) 3 days without water, and v) 4 days without water imposed in the study. As a whole, drought treatment reduced the yield and yield contributing characters of sunflower.

Nouri-Ganbalani (2009) conducted an experiment on yield and yield components of 13 advanced winter and intermediate wheat genotypes with two advanced genotypes as control under normal irrigation and after anthesis drought stress condition in a randomized complete block design with three replications. Combined analysis variance indicated that Genotype SG-U7067 produced the highest yield under both normal irrigation and drought stress conditions. Under the drought stress conditions there were positive highly significant correlations between the grain yield and the 1000 grain weight and number of tillers per plant.

Jalalpoori *et al*. (2013) investigate the effects of water stress on the total chlorophyll content of alfalfa (vs. Nick Urban) on the climate South-West of Iran, Randomized complete block design experiment with three replications performance. To induce drought stress, irrigation treatments (natural irrigation, irrigation to cut off last water and irrigation to cut off the last two of water) was considered. The results of data analysis showed that there was a significant difference in of total chlorophyll and with increasing drought stress on total chlorophyll content to cope with drought was added.

Pirzad *et al.* (2011) observed that water stress resulted in significant decreases in chlorophyll content and leaf relative water content. Water stress reduced CO_2 intake, chlorophyll contents and photosynthetic capacity of plants as well as impaired metabolic systems associated with PSII and PSI (Lwalor and Cornic, 2002; Athar and Ashraf, 2005; Lawlor and Tezara 2009; Chaves *et al*., 2009).

Mafakheri *et al.* (2010) carried out an experiment to investigate the effect of drought stress on proline content, chlorophyll content, photosynthesis and transpiration, stomatal conductance and yield characteristics in three varieties of chickpea (drought tolerant Bivaniej and ILC482 and drought sensitive Pirouz), in a randomized complete block design with three replications and four irrigations. Results showed that drought stress imposed during vegetative growth or anthesis significantly decreased chlorophyll *a,* chlorophyll *b* and total chlorophyll content.

Nooruddin (2004) reported that the rice yield and productions are strongly affected by the ever-changing weather and climate. Bangladesh is very much exposed to weather vagaries. Much of the country is flooded every year, and agriculture systems to a large extent have been adapted to this normal flooding. Drought occurs occasionally, mainly in the western part of the country when pre-monsoon and monsoon rains start late or less than normal. More than by drought, in Bangladesh agriculture and food security system is often threatened by natural calamity such as cyclones and floods.

Quadir *et al* (2004) reported that especially the north-west area in Bangladesh was experiencing chronic water deficit in dry period varying from 3-9 months on an average. In 1979, Bangladesh had passed through a major drought year. Bangladesh experiencing drought conditions having disastrous crop failure. As economy of Bangladesh is mainly agriculture oriented. Crop failure either by the drought and excess rainfall comes as significant strain to its socioeconomic structure.

Islam *et al.* (1997) observed that grain yield of T. aman rice was affected on the amount and distribution of rainfall during lean period and October - November. Yield losses occurred due to high percent of sterility by drought followed by less spikelet number per panicle and reduced 1000 grain weight.

Armstrong (1996) observed that drought during 1994 in 8 northern districts of Bangladesh due to light rainfall during June to September. 20-30% of planted area and 25-30% in yield was reduced. This created a disaster situation in the area. Again, absence of rainfall from November to March also affected cultivation of winter vegetables, *aus* and kharif crops.

2.5 Effect of humic acid for crop production

Eshwar *et al*. (2017) conducted pot culture experiment conducted in green house, to study the effect of humic substances and chemical fertilizers on nutrient uptake, dry matter production of aerobic rice (*Oryza sativa* L.). Humic and fulvic acid was applied along with iron as Fe-fulvate and Fehumate in 1:1.5 molar ratio along with Fe-chelate and FeSo4 @ 2.5 mg/kg as soil application and 0.25% as foliar application at vegetative and panicle initiation stage with recommended dose of fertilizers. The results concluded that nutrient uptake, dry matter production was increased with foliar application of FeSo4 @ 0.25% at vegetative and panicle initiation stage among other imposed treatments.

Ajalli *et al*. (2013) revealed that significant effect of potassium Humate, variety and interaction of potassium humate and variety on the studied traits. Savalan and Agra produced the most stem numbers per plant when 300 ml ha-1 Potassium humate was used.

Miyauchi *et al*. (2012) obtained that the humic substance had no significant effect on stem length, node number and branch number, but improved seed yields by 6 to 32%. It increased pod number per plant by increasing pod setting, although there was no significant effect on cumulated flower number. The humic substance did not affect the mean leaf area in dices, crop growth rates and net assimilation rates, but increased pod growth rates during the later pod filling period. It also did not affect the CO_2 assimilation rate, quantum yield of photo-system II or chlorophyll content. Thus, increasing pod number by plant hormone-like substances in the humic substance was considered to stimulate the trans-location of assimilate toward pods, leading to an increase in seed yield.

Rafat *et al*. (2012) studied that drought reduced seed number in row, seed number per ear, seed weight per ear, seed length, seed weight, grain yield and harvest index. Potassium humate application increased drought tolerance. Grain yield under water deficit situation was higher than in control, but reduction by using potassium humate was lower. The highest grain yield (1539 g m-2) was obtained under irrigation after 100 mm evaporation and 2% potassium humate application and the least grain yield (1186 g m-2) was obtained without application of potassium humate.

Saruhan *et al*. (2011) reported that humic acid treatments raised the yield and yield components, and this raising was found to be significant statistically. The highest value for plant heights, bunch lengths, grain yields, 1000 grain weight, crude protein concentrations and grain number per bunch were obtained from leafs (100%) fertilizations and the highest hectoliter weight was obtained from seeds (100%) fertilizations.

Bama (2009) conducted a field experiment to study the influence of different concentrations of foliar application of lignite humic acid (0.1, 0.5, 1.0, 1.5 & 2.0 per cent) on rice. The application of humic acid upto 1.5 per cent increased the grain yield of 4263 kg ha^{-1} markedly; beyond that level the grain yield was reduced. The uptake of N, P and K nutrients increased with increasing concentrations of humic acid i.e, 59.4, 8.18, 13.9 kg ha^{-1} in grain for 1.5 per cent HA compared to control of 48.9, 6.9 and 12.1 kg ha^{-1}, respectively. The N, P and K recorded in the straw were 30.1, 16.5 and 78.4 kg ha^{-1} compared to control of 26.1, 14.4 and 66.6 kg ha^{-1}, respectively.

Delfinea *et al*. (2005) studied the effect of foliar application of humic acid on plant growth, photosynthetic metabolism and grain quality of durum wheat. Four fertilization treatments were applied: a non-fertilized control, a crop fertilized with foliar application of humic acid, a crop fertilized with mineral N on soil at sowing, tillering and stem elongation, and a crop fertilized with foliar application of N (ammonium-nitrate solution). The foliar application of humic acid caused a transitional production of plant dry mass with respect to unfertilized control and split soil N application. This effect was also evident for grain yield, spike fertility and grain protein content during the two years of the study. They concluded that humic acid had limited promoting effects on plant growth, grain yield and quality, and photosynthetic metabolism of durum wheat, with respect to split soil N application.

Nandakumar *et al*. (2004) conducted field experiments to evaluate the effects of humic acid (HA) in the form of potassium humate on soil nutrient availability at different growth stages of rice. The treatments consisted of NPK at 75 and 100% of the recommended dose (100:50:50 kg ha^{-1}) alone, HA at 10 or 20 kg ha^{-1} (soil application) in combination with the NPK fertilizers, and integrated treatments involving soil application, foliar spraying and root dipping with HA in combination with the NPK fertilizers. Application of HA in combination with NPK increased soil nutrient availability at all growth stages (tillering, flowering and harvest) of rice in both Vertisol and Alfisol. HA at 10 kg ha^{-1} as soil application + 0.1% HA as foliar spray (twice) + 0.3% HA as root dip + 100% NPK, and HA at 20 kg ha^{-1} as soil application + 100% NPK, were the best treatments for improving soil nutrient availability.

Jones *et al*. (2004) found that humic substances in organic matter are known to help with crop growth when present in high enough quantities. Commercial humic acid (HA) is sometimes applied at low application rates (1 – 3 lb/ac) to enhance P or metal availability, yet growth responses are mixed. The objectives of this study were to 1) determine if available P concentrations increase in the presence of low rates of HA in Montana soil, and 2) determine the inter-actions between P fertilization and HA on crop yield.

Veeral *et al*. (2003) conducted field experiments to evaluate the direct and residual effects of lignite flyash (LFA) at three levels viz., 10, 15 and 20 t ha^{-1} with or without farmyard manure (FYM) at 12.5 t ha^{-1} and humic acid (HA) at 30 kg ha^{-1} on riceblackgram cropping system. Lignite flyash at 10 t ha^{-1} with FYM at 12.5 t ha^{-1} and HA at 30 kg ha^{-1} exerted a remarkable influence on all the yield attributes, ultimately leading to increased rice yields of 35% over control. With respect to the residual crop, blackgram, the above treatment showed distinct influence on both grain and haulm yields.

Bhattacharya *et al*. (2003) studied the effects of humic acid and farmyard manure on the performance of rice. Humic acid was sprayed to the soil at 2 days before transplanting. Plant height at 45 and 90 days after transplanting was highest in plots treated with 9.0 t FYM, 7.0 t FYM and 1.0 litre humic acid

ha^{-1} (60.9 and 83.4 cm). The application of 7.0 t FYM and 1.0 litre humic acid ha^{-1} resulted in the highest dry matter accumulation at 45 and 90 days after transplanting. The highest number of effective tillers (288/m2) and number of filled grains per panicle (72.2) were obtained with 1.0 litre humic acid ha^{-1} . The application of 7.0 t FYM, 1.0 litre humic acid and 1.5 litre humic acid ha^{-1} gave the highest grain and straw yields.

2.6 Effect of humic acid on drought tolerance of crops

Application of humic acid (HA) to increase the resistance of drought tolerant melon genotypes is considered as a permanent method due to its anti-stress effects. Kulikova *et al*. (2005) reported that humic substances may work against environmental stresses. HA caused some changes in physical and chemical properties of the soil, such as water retention capacity, airing, pH and ion transportation (Lodhi *et al*. 2013).

Humic acid, an important component of organic fertilizers and humic substances, can be used to improve plant growth by improving its leaves' water content, photosynthesis, antioxidant metabolism and enzymes activity, thus enhancing its tolerance contribute to increase yield and yield components of crops like panicle length, grains per panicle, early maturity of crops and stover yield (Fu Jiu *et al*. 1995; Al-Shareef *et al*. 2017).

Humic substances are well known as stimulators of plant germination and growth (Dell'Amico *et al.* 1994). Arancon *et al*. (2006) reported that humic substances, which stimulate plant germination and growth, behave very similar to growth hormones. HA could promote plant growth by increasing the permeability of cell membrane, facilitate transport of essential elements within the roots and favor respiration (Cacco and Dell Agnolla 1984; Masciandaro *et al*. 2002). HA also positively affects the nutrient intake of plants and is particularly important for the transport and the availability of micronutrients (Sharif *et al*. 2002).

Kıran *et al*. (2019) studied different responses of two melon (*Cucumis melo* L.) genotypes (Şemame, drought and salt-tolerant and Ananas, drought and salt-sensitive) to drought stress with or without humic acid (HA) treatment. HA treatment increased the shoot fresh and dry weights and leaf area of both genotypes under drought stress. HA stimulated accumulation of K and Ca ions, chlorophyll (SPAD value) and antioxidant enzyme activity (superoxide dismutase-SOD, catalase-CAT and glutathione reductase-GR) in both genotypes. This effect was more clear in the Şemame genotype than in Ananas. As a result, HA treatment has been proved to influence the ability of melon genotypes to cope with drought stress and to increase their tolerance.

Gomaa *et al*. (2011) carried out two field experiments during two successive seasons of 2013 and 2014 to study the combined effect of water stress and humic acid on the growth analysis, yield and components of three maize hybrids. The main results could be summarized as follow; the irrigation interval had significant effects on growth analysis characters, where irrigation every 15 days recorded higher mean value for most of studied characters i.e., growth, yield and its components attributes as compared with irrigation every 20 days. Increasing irrigation interval, significantly, decreased grain yield and its components. On other hand, irrigation every 20 days increased grain protein content. Maize hybrids significantly differed in some growth analysis, yield, its components, and protein percentage. The“T.W.C.352” hybrid followed by “S.C.168” was superior to“S.C.166” hybrid in yield and its components under the irrigation intervals treatments. Also, application of 14.40 kg/ha of humic acid significantly increased growth analysis, grain yield, and its components the untreated treatment (control). Generally, it can be concluded that application humic acid at 14.4 kg/ha., was effective to avoid a significant increase in growth analysis and grain yield when the irrigation analysis interval was 10 and 15 days with “T.W.C.352”and “S.C.168”hybrids understudy.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from July 2018 to November 2018. The materials and methods those were used and methods followed for conducting the experiment have been presented under the following headings.

3.1 Experimental site

This study was conducted in the research field of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. The location of the experimental site is 23°′74°N latitude and 90°35′ E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004).

3.2 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract (Anon., 1988) under AEZ No. 28. The characteristics of the soil under the experiment were analyzed in the Laboratory of Soil science Department, SAU, Dhaka and details of soil characteristics have been presented in Appendix I.

3.3 Climatic condition of the experimental site

The experimental site is situated in the subtropical monsoon climatic zone, which is characterized by heavy rainfall during the months from April to September (*Kharif* season) and scanty of rainfall during rest of the year (*Rabi* season). Plenty of sunshine and moderately low temperature prevail during October to March (*Rabi* season), which are suitable for growing of rice in Bangladesh.

3.4 Planting materials

The variety BRRI dhan-49 was used. The seeds of rice were grown at the research field in Sher-e-Bangla Agricultural University.

3.5 Treatments of the experiment

The two factorial experiments will be carried out in Randomized Complete Block Design (RCBD) with four replications having

Factor A: Different levels of water deficiency

1. D_1 = Well watered condition (Control)
2. D_2 = Irrigation at 7 days interval
3. D_3 = Irrigation at 14 days interval
4. D_4 = Irrigation at 21 days interval

Factor B: Different levels of soil organic amendments – humic acid and cowdung

1. SM_1 = Soil + inorganic fertilizer (control)
2. SM_2 = Soil + cowdung + inorganic fertilizer
3. SM_3 = Soil + inorganic fertilizer + humic acid
4. SM_4 = Soil + inorganic fertilizer + cowdung + humic acid

3.6 Design and layout of the experiment

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with four levels of water deficiency and four levels of soil organic amendments-humic acid and cowdung. Four replications were maintained in this experiment. The total number of unit pots was 64 (16×4). Each pot was 35 cm (14 inches) in diameter and 30 cm (12 inches) in height. The experiment was placed under the net house which was made by bamboo with net and pots were kept on the individual earthen plate.

3.7 Crop cultivation

3.7.1 Pot preparation

Soils were collected from the Soil Science Field Laboratory, SAU and equal size plastic pots were prepared with equal amount of soil (about 12 kg).

3.7.2 Preparation of nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared with 1 m wide adding nutrients as per the requirements of soil. Seeds were sown in the seed bed in order to transplant the seedlings in the selected pot.

3.7.2 Uprooting of seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted without causing much mechanical injury to the roots.

3.7.3 Transplanting of seedlings in the selected pots

Thirty days old seedlings were transplanted in pots.

3.7.4 Fertilizer application

Experimental pot was fertilized as per treatment. Full doses of fertilizers *viz.* cowdung, TSP, MoP, and one third of urea were applied as basal dose. Remain urea was applied as top dressed at two times. The following fertilizer doses was used for pot preparation

Urea = 1.25 g pot^{-1} (200 kg ha^{-1}), TSP = 0.22 g pot^{-1} (35 kg ha^{-1}), MoP = 0.56 g pot^{-1} (90 kg ha^{-1}), $ZnSO_4$ = 0.03 g pot^{-1} (5 kg ha^{-1}), Gypsum = 0.25 g pot^{-1} (40 kg ha^{-1}), Cowdung = 62.5 g pot^{-1} (10 t ha^{-1}) and Humic acid = 0.025 g pot^{-1} (6 kg ha^{-1})

3.7.5 Exogenous application of humic acid

Humic acid was applied during pot preparation as basal mixing with cowdung, TSP, MoP when these were mixing with soil.

3.8 Intercultural operations

3.8.1 Weeding

Weeds were uprooted by hand when necessary.

3.8.2 Irrigation

Irrigation was done as per treatment

3.8.3 Plant protection measures

There were some incidence in insects specially grasshopper, stem borer, rice ear cutting caterpillar, thrips and rice bug which was controlled by spraying Curatter 5G and Sumithion. Brown spot of rice was controlled by spraying Tilt.

3.8.4 General observation of the experimental pots

Observations were regularly made. All the stages of plants and plant's response as per treatments were observed carefully.

3.9 Harvesting

The rice plant was harvested depending upon the maturity of plant and harvesting was done manually from each pot. The BRRI dhan 49 was harvested on 24 November 2018. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of rice seed. Fresh weight of grain and straw were recorded pot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 12%. The straw was sun dried and the yields of grain and straw pot^{-1} were recorded.

3.10 Collection of data

3.10.1 Plant height

The height of plant was recorded in centimeter (cm) at different growth stage of crop duration. Data were recorded as the average of same 4 plants pre-selected at random of each pot. The height was measured from the ground level to the tip of the plant.

3.10.2 Number of tillers hill^{-1}

Total tillers which had at least one leaf visible were counted. It includes both productive and unproductive tillers. Tillers number was collected at different growth stage of crop duration. Data were recorded as the average of same 4 plants pre-selected at random of each pot.

3.10.3 Days to 1st flowering

Days to 1st flowering were counted when first flower was appeared in plants from transplanting date of seedling.

3.10.4 Days to 1st maturity

Days to maturity were counted when maturity was found in plants from transplanting date of seedling.

3.10.5 Panicle length

The length of panicle was measured with a meter scale from 10 selected panicles and the average value was recorded.

3.10.6 Number of filled grains panicle^{-1}

The total number of filled grains was collected from each replication and then average number of filled grains panicle^{-1} was recorded.

3.10.7 Number of unfilled grains panicle^{-1}

The total number of unfilled grains was collected from each replication and then average number of unfilled grains panicle^{-1} was recorded.

3.10.8 Number of grains panicle^{-1}

The total number of grains was calculated by adding filled and unfilled grains and then average number of grains panicle^{-1} was recorded.

3.10.9 Grain weight hill^{-1} (g)

Grain weight from each hill from each replication was collected and average weight was recorded as Grain weight hill^{-1} in gram

3.10.10 Straw weight hill^{-1} (g)

Straw weight from each hill of each replication was collected and average weight was recorded as Grain weight hill^{-1} in gram

3.10.11 Root length at harvest (cm)

Root length was measured after harvest from each replication and average root length was recorded in centimeter

3.10.12 Harvest index (%)

Harvest index was recorded by the following formula

$$\text{Harvest index} = \frac{\text{Grain yield hill}^{-1}}{\text{Grain yield hill}^{-1} + \text{Straw yield hill}^{-1}} \times 100$$

3.11 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means were estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

This experiment was carried out in order to clarify the role of soil organic amendments-cowdung and humic acid on the morphology and yield of rice under drought stress.

4.1 Growth parameters

4.1.1 Plant height

Effect of different levels of water deficiency

Significant variation was found for plant height of rice as influenced by different levels of water deficiency at different ages of the plants (Table 1 and Appendix V). The highest plant height (77.25, 90.16, 95.50 and 114.60 cm at 40, 55, 70 DAT and at harvest, respectively) was recorded from D_1, Well watered condition which was significantly different from other situations at different ages of plants followed by D_2, Irrigation at 7 days interval. The lowest plant height (68.00, 78.59, 84.68 and 85.74 cm at 40, 55, 70 DAT and at harvest, respectively) was recorded from D_4, Irrigation at 21 days interval. Results suggested from the present study that plant height was decreased with the increasing of deficiency of water to plants. The application of insufficient water which creates water deficiency/drought D_4, Irrigation at 21 days interval showed lowest plant height. Decreased water application results reduced total dry matter production ultimately affect the morphological characters like plant height of rice.

Effect of different levels of soil organic amendments

Application of different levels of soil organic amendments showed significant variation on plant height of rice at different ages of the plants (Table 1 and Appendix V). The highest plant height (74.56, 86.96, 93.21 and 112.90 cm at 40, 55, 70 DAT and at harvest, respectively) was achieved from SM_4 (Soil +

inorganic fertilizer + cowdung + humic acid) situations which was significantly different from other treatments at different ages of plants followed by SM_3 (Soil + inorganic fertilizer + humic acid). The lowest plant height (69.53, 79.16, 85.88 and 99.90 cm at 40, 55, 70 DAT and at harvest, respectively) was found from control situations SM_1 (Soil + inorganic fertilizer) without soil organic amendments. Under the present study, it was found that soil organic amendments-humic acid and cowdung had significant influence on growth parameters of rice. Results showed that application of humic acid gave higher plant height compared to the situations without humic acid. Similar result was also observed by Arancon *et al*. (2006) who reported that humic substances, which stimulate plant germination, growth and believe that humic acid functions as plant growth hormone.behave very similar to growth hormones. HA could promote plant growth by increasing the permeability of cell membrane, facilitate transport of essential elements within the roots and favor respiration (Cacco and Dell Agnolla 1984; Masciandaro *et al*. 2002). The results of the study are consistent with different findings and suggest that humic acid application to the soil improve soil health and morphological characters including plant hight of rice.

Interacted effect of different levels of water deficiency and soil organic amendments

Plant height of rice at different growth stages varied significantly due to combined effect of different levels of water deficiency and soil organic amendments (Table 1 and Appendix V). The highest plant height (79.75, 94.00, 100.50 and 121.50 cm at 40, 55, 70 DAT, respectively) was recorded from the treatment combination of D_1SM_4 which was statistically identical with the treatment combination of D_1SM_3 at the time of harvest. The lowest plant height (66.00, 72.51, 78.75 and 84.60 cm at 40, 55, 70 DAT and at harvest, respectively) was found from the treatment combination of D_4SM_1. Plant death was occurred from 70 DAT to till harvest from treatment combinations of D_3SM_1, D_3SM_2, D_4SM_1 and D_4SM_2 and from these treatment combinations plant height was not detected at the time of harvest. At the time of harvest lowest plant height (84.60 cm) was found from D_4SM_3 which was statistically identical with the treatment combination of D_3SM_3.

Table 1. Plant height of rice as influenced by soil organic amendments under water deficit condition

Treatment	Plant height (cm)			
	40 DAT	55 DAT	70 DAT	At harvest
Effect of different levels of water deficiency				
D_1	77.25 a	90.16 a	95.50 a	114.60 a
D_2	74.31 b	86.22 b	91.69 b	103.30 b
D_3	69.91 c	80.53 c	87.47 c	97.15 c
D_4	68.00 c	78.59 c	84.68 d	87.74 d
$LSD_{0.05}$	2.03	2.28	2.04	1.72
CV(%)	6.94	5.82	7.18	9.35
Effect of soil organic amendments-humic acid and cowdung				
SM_1	69.53 c	79.16 c	85.88 c	99.90 d
SM_2	72.50 b	84.31 b	89.75 b	105.30 c
SM_3	72.88 b	85.06 b	90.50 b	103.37 b
SM_4	74.56 a	86.96 a	93.21 a	112.90 a
$LSD_{0.05}$	1.45	1.46	1.77	1.98
CV(%)	6.94	5.82	7.18	9.35
Interacted effect of different levels of water deficiency and soil organic amendments				
D_1 SM_1	73.00 cde	85.50 de	90.75 c	103.3 cd
D_1SM_2	77.25 b	89.50 bc	94.75 b	113.8 b
D_1SM_3	79.00 a	91.63 b	96.00 b	120.0 a
D_1SM_4	79.75 a	94.00 a	100.5 a	121.5 a
D_2SM_1	72.00 ef	84.00 ef	89.50 cd	96.50 e
D_2SM_2	74.50 c	87.00 d	91.50 c	105.8 c
D_2SM_3	74.25 cd	86.38 d	91.25 c	104.3 cd
D_2SM_4	76.50 b	87.50 cd	94.50 b	106.5 c
D_3SM_1	67.75 gh	77.75 h	85.75 ef	ND
D_3SM_2	69.00 g	81.63 g	86.75 ef	ND
D_3SM_3	71.00 f	82.75 fg	89.25 cd	92.00 f
D_3SM_4	72.75 de	84.10 ef	90.38 c	102.3 d
D_4SM_1	66.00 i	72.75 i	78.75 g	ND
D_4SM_2	67.13 hi	74.38 i	84.50 f	ND
D_4SM_3	68.75 g	80.88 g	85.75 ef	84.60 g
D_4SM_4	69.25 g	82.25 fg	87.45 de	90.88 f
$LSD_{0.05}$	1.50	2.16	2.49	3.45
CV(%)	6.94	5.82	7.18	9.35

D_1 = Well watered condition (Control), D_2 = Irrigation at 7 days interval, D_3 = Irrigation at 14 days interval, D_4 = Irrigation at 21 days interval

SM_1 = Soil + inorganic fertilizer (control), SM_2 = Soil + cowdung + inorganic fertilizer, SM_3 = Soil + organic fertilizer + humic acid, SM_4 = Soil + inorganic fertilizer + cowdung + humic acid

4.1.2 Number of tillers plant^{-1}

Effect of different levels of water deficiency

Significant variation was found for number of tillers plant^{-1} of rice as influenced by different levels of water deficiency at different ages of plants (Table 2 and Appendix VI). The highest number of tillers plant^{-1} (5.38, 9.88, and 11.50 at 40, 55 and 70 DAT respectively) was recorded from control treatment D_1 (Well watered condition) which was significantly different from other treatments followed by D_2 (Irrigation at 7 days interval). The lowest number of tillers plant^{-1} (3.81, 5.84 and 6.81 and 3.50 at 40, 55 and 70 DAT respectively) was recorded from D_4 (Irrigation at 21 days interval). Results revealed that number of tillers plant^{-1} was increased with the increasing of water supply to plants and as result, treatment of higher water supply (Well watered condition) showed highest number of tillers plant^{-1}. Schimper (1998) and Jones (1992) found that the degree of plant water stress depends on the degree of reduction of potentials below the optimum levels of soil moisture potential (4 bars) and cell turgid. Sufficient irrigation can remove drought stress due to increasing of soil moisture which contributes to increase dry matter production in plants and resulted higher growth parameters like number of tillers plant^{-1}.

Effect of different levels of soil organic amendments

Application of different levels of soil organic amendments showed significant variation on number of tillers plant^{-1} of rice at different ages of the plants (Table 2 and Appendix VI). The highest number of tillers plant^{-1} (4.94, 8.94 and 10.38 at 40, 55 and 70 DAT respectively) was achieved from SM_4 (Soil + inorganic fertilizer + cowdung + humic acid) situation. Number of tillers plant^{-1} obtained from SM_3 (Soil + inorganic fertilizer + humic acid) at 55 DAT and 70 DAT showed nonsignificant different from SM_4 (Soil + inorganic fertilizer + cowdung + humic acid). Again, the lowest number of tillers plant^{-1} (4.06, 6.38 and 6.88 at 40, 55 and 70 DAT respectively) was found from control situation

SM_1 (Soil + inorganic fertilizer). Results showed that soil organic amendments had significant effect on number of tillers plant^{-1} and found that the treatments with soil organic amendments gave higher number of tillers plant^{-1} compared to the treatments without soil organic amendments. Similar result was also observed by Gomaa *et al*. (2011) who reported that application of 14.40 kg/ha of humic acid significantly increased growth parameters like number of tillers plant^{-1} compared to untreated situation (control).

Interacted effect of different levels of water deficiency and soil organic amendments

Number of tillers plant^{-1} of rice at different ages of plants varied significantly due to combined effect of different levels of water deficiency and soil organic amendments (Table 2 and Appendix VI). The highest number of tillers plant^{-1} (5.75, 11.00 and 12.25 at 40, 55 and 70 DAT respectively) was recorded from the treatment combination of D_1SM_4 which was significantly similar with D_1SM_2 and D_1SM_3 at 70 DAT. The lowest number of tillers plant^{-1} (3.25, 4.25 and 4.00 at 40, 55 and 70 DAT respectively) was found from the treatment combination of D_4SM_1. At the time of harvest lowest number of tillers plant^{-1} (3.75) was found from D_4SM_1 which was statistically identical with the treatment combination of D_4SM_4 and D_3SM_3.

Table 2. Number of tillers plant^{-1} of rice as influenced by soil organic amendments under water deficit condition

Treatment	Number of tillers plant^{-1}		
	40 DAT	55 DAT	70 DAT
Effect of different levels of water deficiency			
D_1	5.38 a	9.88 a	11.50 a
D_2	4.88 b	8.81 b	10.44 b
D_3	4.13 c	6.75 c	7.56 c
D_4	3.81c	5.94 d	6.81 d
$LSD_{0.05}$	0.34	0.694	0.64
CV(%)	10.60	12.36	9.88
Effect of different levels of soil organic amendments			
SM_1	4.06 c	6.38 c	6.88 c
SM_2	4.50 b	7.69 b	9.18 b
SM_3	4.69 b	8.38 a	9.88 a
SM_4	4.94 a	8.94 a	10.38 a
$LSD_{0.05}$	0.23	0.65	0.64
CV(%)	10.60	12.36	9.88
Interacted effect of different levels of water deficiency and soil organic amendments			
D_1 SM_1	5.00 cd	8.50 de	10.00 e
D_1SM_2	5.50 ab	10.25 ab	12.00 a
D_1SM_3	5.25 bc	9.75 bc	11.75 ab
D_1SM_4	5.75 a	11.00 a	12.25 a
D_2SM_1	4.50 ef	8.00 ef	9.00 f
D_2SM_2	5.00 cd	9.00 cd	11.00 cd
D_2SM_3	5.00 cd	9.00 cd	10.50 de
D_2SM_4	5.00 cd	9.25 cd	11.25 bc
D_3SM_1	3.50 h	4.75 i	4.50 j
D_3SM_2	4.00 g	6.50 h	7.50 h
D_3SM_3	4.25 fg	7.75 efg	9.00 f
D_3SM_4	4.75 de	8.00 ef	9.25 f
D_4SM_1	3.25 h	4.25 i	4.00 j
D_4SM_2	3.50 h	5.00 i	6.25 i
D_4SM_3	4.25 fg	7.00gh	8.25 g
D_4SM_4	4.25 fg	7.50 fg	8.75fg
$LSD_{0.05}$	0.46	0.94	0.65
CV(%)	10.60	12.36	9.88

D_1 = Well watered conditions (Control), D_2 = Irrigation at 7 days interval, D_3 = Irrigation at 14 days interval, D_4 = Irrigation at 21 days interval

SM_1 = Soil + inorganic fertilizer (control), SM_2 = Soil + cowdung + inorganic fertilizer, SM_3 = Soil + inorganic fertilizer + humic acid, SM_4 = Soil + inorganic fertilizer + cowdung + humic acid

4.2 Yield contributing parameters

4.2.1 Days to 1st flowering

Effect of different levels of water deficiency

Significant variation was found for days to 1st flowering of rice as influenced by different levels of water deficiency (Table 3 and Appendix VII). The lowest days to 1st flowering (69.00 days) was recorded from D_4 (Irrigation at 21 days interval) situation which was significantly different from other situation. Similarly, the highest days to 1st flowering (73.94 days) was recorded from control situation D_1 (Well watered condition).

Effect of different levels of soil organic amendments

Application of different levels of soil organic amendments showed significant variation on days to 1st flowering of rice (Table 3 and Appendix VII). The lowest days to 1st flowering (70.13 days) was achieved from SM_1 (Soil + inorganic fertilizer) situation which was significantly different from other situation whereas the highest days to 1st flowering (72.75) was found SM_4 (Soil + inorganic fertilizer + cowdung + humic acid) situation followed by SM_3 (Soil + inorganic fertilizer + humic acid).

Interacted effect of different levels of water deficiency and soil organic amendments

Days to 1st flowering of rice varied significantly due to combined effect of different levels of water deficiency and soil organic amendments (Table 3 and Appendix VII). The lowest days to 1st flowering (61.75 days) was recorded from the treatment combination of D_4SM_1 which was significantly different from other treatment combinations. The highest days to 1st flowering (75.25 days) was found from the treatment combination of D_1SM_4 which was significantly similar with the treatment combination of D_3SM_1.

4.2.2 Days to 1st maturity

Effect of different levels of water deficiency

Significant variation was found for days to 1st maturity of rice as influenced by different levels of water deficiency (Table 3 and Appendix VII). The lowest days to 1st maturity (120.10 days) was recorded from control situation D_4 (Irrigation at 21 days interval) which was statistically identical with D_2 (Irrigation at 7 days interval) whereas the highest days to 1st maturity (123.50 days) was recorded from D_1 (Well watered condition).

Effect of different levels of soil organic amendments

Application of different levels of soil organic amendments showed significant variation on days to 1st maturity of rice (Table 3 and Appendix VII). The lowest days to 1st maturity (120.00 days) was achieved from SM_1 (Soil + inorganic fertilizer) which was significantly different from other situation. The highest days to 1st maturity (122.05 days) was found from control situation SM_4 (Soil + inorganic fertilizer + cowdung + humic acid) followed by SM_2 (Soil + cowdung + inorganic fertilizer) and SM_3 (Soil + inorganic fertilizer + humic acid). Similar result was also observed by Fu Jiu *et al*. (1995) and Al-Shareef *et al*. (2017) who reported soil organic amendments contributed to early maturity of crops.

Interacted effect of different levels of water deficiency and soil organic amendments

Days to 1st maturity of rice varied significantly due to combined effect of different levels of water deficiency and soil organic amendments (Table 3 and Appendix VII). The lowest days to 1st maturity (119.30 days) was recorded from the treatment combination of D_4SM_1 which was significantly similar with the treatment combination of D_4SM_3 and D_3SM_4. The highest days to 1st maturity (125.30 days) was found from the treatment combination of D_1SM_4 which was statistically identical with the treatment combination of D_1SM_3 and

D_1SM_4. Plant death was occurred before harvest from treatment combinations of D_3SM_1, D_3SM_2, D_4SM_2 and D_3SM_3 and from these treatment combinations, days to 1st maturity were not detected.

4.2.3 Panicle length (cm)

Effect of different levels of water deficiency

Significant variation was found for panicle length of rice as influenced by different levels of water deficiency (Table 3 and Appendix VII). The highest panicle length (24.94 cm) was recorded from control situation D_1 (Well watered condition) which was statistically identical with D_2 (Irrigation at 7 days interval). The lowest panicle length (16.95 cm) was recorded from D_4 (Irrigation at 21 days interval).

Effect of different levels of soil organic amendments

Different levels of humic acid application showed significant variation on panicle length of rice (Table 3 and Appendix VII). The highest panicle length (24.94 cm) was achieved from SM_4 (Soil + inorganic fertilizer + cowdung + humic acid) which was significantly different from other situations followed by SM_2 (Soil + cowdung + inorganic fertilizer). The lowest panicle length (21.82 cm) was found from control situation SM_1 (Soil + inorganic fertilizer). Fu Jiu *et al*. (1995) and Al-Shareef *et al*. (2017) also found similar result with the present study.

Interacted effect of different levels of water deficiency and soil organic amendments

Panicle length of rice varied significantly due to combined effect of different levels of water deficiency and soil organic amendments (Table 3 and Appendix VII). The highest panicle length (26.25 cm) was recorded from the treatment combination of D_1SM_4 which was significantly similar with the treatment combination of D_1SM_2 and D_1SM_3. The lowest panicle length (16.86 cm) was found from the treatment combination of D_4SM_1 which was statistically identical with D_4SM_4. Plant death was occurred till harvest from treatment combinations of D_3SM_1, D_3SM_2, D_4SM_2 and D_3SM_3 and from these treatment combinations, panicle length was not detected.

4.2.4 Number of filled grain panicle^{-1}

Effect of different levels of water deficiency

Significant variation was found for number of filled grain panicle^{-1} of rice as influenced by different levels of water deficiency (Table 3 and Appendix VII). The highest number of filled grain panicle^{-1} (224.70) was recorded from control situation D_1 (Well watered condition) which was significantly different from other situations followed by D_2 (Irrigation at 7 days interval). The lowest number of filled grain panicle^{-1} (92.45) was recorded from D_4 (Irrigation at 21 days interval).

Effect of different levels of soil organic amendments

Application of different levels of soil organic amendments showed significant variation on number of filled grain panicle^{-1} of rice (Table 3 and Appendix VII). The highest number of filled grain panicle^{-1} (221.40) was achieved from SM_4 (Soil + inorganic fertilizer + cowdung + humic acid) followed by SM_2 (Soil + cowdung + inorganic fertilizer) and SM_3 (Soil + inorganic fertilizer + humic acid). The lowest number of filled grain panicle^{-1} (160.90) was found from control situation SM_1 (Soil + inorganic fertilizer).

Interacted effect of different levels of water deficiency and soil organic amendments

Number of filled grain panicle^{-1} of rice varied significantly due to combined effect of different levels of water deficiency and soil organic amendments (Table 3 and Appendix VII). The highest number of filled grain panicle^{-1} (237.50) was recorded from the treatment combination of D_1SM_4 which was statistically identical with the treatment combination of D_1SM_2 and D_1SM_3. The lowest number of filled grain panicle^{-1} (91.40) was found from the treatment combination of D_4SM_1. Plant death was occurred till harvest from treatment combinations of D_3SM_1, D_3SM_2, D_4SM_2 and D_3SM_3 and from these treatment combinations, number of filled grain panicle^{-1} was not detected.

4.2.5 Number of unfilled grain panicle^{-1}

Effect of different levels of water deficiency

Significant variation was found for number of unfilled grain panicle^{-1} of rice as influenced by different levels of water deficiency (Table 3 and Appendix VII). The highest number of unfilled grain panicle^{-1} (44.13) was recorded from D_4 (Irrigation at 21 days interval) which was significantly different from other situations followed by D_2 (Irrigation at 7 days interval). Again, the lowest number of unfilled grain panicle^{-1} (17.50) was recorded from D_1 (Well watered condition) which was statistically identical with D_3 (Irrigation at 14 days interval.)

Effect of different levels of soil organic amendments

Application of different levels of soil organic amendments showed significant variation on number of unfilled grain panicle^{-1} of rice (Table 3 and Appendix VII). The highest number of unfilled grain panicle^{-1} (42.25) was achieved from SM_1 (Soil + inorganic fertilizer) which was significantly different from other situations followed by SM_2 (Soil + cowdung + inorganic fertilizer). The lowest number of unfilled grain panicle^{-1} (20.63) was found from control situation SM_4 (Soil + inorganic fertilizer + cowdung + humic acid).

Interacted effect of different levels of water deficiency and soil organic amendments

Number of unfilled grain panicle^{-1} of rice varied significantly due to combined effect of different levels of water deficiency and soil organic amendments

(Table 3 and Appendix VII). The highest number of unfilled grain panicle^{-1} (52.85) was recorded from the treatment combination of D_4SM_3 which was significantly different from other treatment combinations followed by D_4SM_2. The lowest number of unfilled grain panicle^{-1} (23.00) was found from the treatment combination of D_1SM_4 which was significantly similar with the treatment combination of D_2SM_1 and D_3SM_4 and D_4SM_4. Plant death was occurred till harvest from treatment combinations of D_3SM_1, D_3SM_2, D_4SM_1 and D_4SM_2 and from these treatment combinations, number of unfilled grain panicle^{-1} was not detected.

4.2.6 Root length at harvest (cm)

Effect of different levels of water deficiency

Significant variation was found for root length of rice as influenced by different levels of water deficiency (Table 3 and Appendix VII). The highest root length (17.83 cm) was recorded from treatment D_4 (Irrigation at 21 days interval) which was statistically identical with D_3 (Irrigation at 14 days interval). Similarly, the lowest root length (13.50 cm) was recorded from D_1 (Well watered condition) which was statistically identical with D_2 (Irrigation at 7 days interval.) Similar result was also observed by Mahajan and Tuteja (2005), Lotfi *et al*. (2015) and Kaya *et al*. (2018).

Effect of different levels of soil organic amendments

Application of different levels of soil organic amendments showed significant variation on root length of rice (Table 3 and Appendix VII). The highest root length (13.79 cm) was achieved from SM_1 (Soil + inorganic fertilizer) which was significantly different from other situations followed by SM_2 (Soil + cowdung + inorganic fertilizer) whereas the lowest root length (11.33 cm) was found from SM_4 (Soil + inorganic fertilizer + cowdung + humic acid). Similar result was also observed by Nandakumar *et al*. (2004) which supported the present study.

Interacted effect of different levels of water deficiency and soil organic amendments

Root length of rice varied significantly due to combined effect of different levels of water deficiency and soil organic amendments (Table 3 and Appendix VII). The highest root length (14.90 cm) was recorded from the treatment combination of D_4SM_3 which was statistically identical with the treatment combination of D_4SM_4. The lowest root length (12.80 cm) was found from the treatment combination of D_1SM_4 which was significantly different from other treatment combinations. Plant death was occurred till harvest from treatment combinations of D_3SM_1, D_3SM_2, D_4SM_1 and D_3SM_2 and from these treatment combinations, root length was not detected.

Table 3. Yield contributing parameters of rice as influenced by soil organic amendments under water deficit condition

Treatment	Yield contributing parameters					
	Days to 1st flowering	Days to 1st maturity	Panicle length (cm)	Number of filled grain panicle^{-1}	Number of unfilled grain panicle^{-1}	Root length at harvest (cm)
Effect of different levels of water deficiency						
D_1	73.94 a	123.80 c	24.94 a	224.70 a	17.50 c	11.50 b
D_2	72.88 b	122.55 c	23.06 a	188.60 b	19.88 c	12.90 b
D_3	70.13 c	121.00 b	21.38 b	138.15 c	28.81 b	13.26 a
D_4	69.00 d	120.10 a	16.95 c	92.45 d	44.13 a	14.83 a
$LSD_{0.05}$	0.79	1.65	2.09	6.05	2.48	1.75
CV(%)	5.71	5.72	8.09	10.84	6.29	9.17
Effect of different levels of soil organic amendments						
SM_1	70.13 d	120.00 a	21.82 c	160.90 c	42.25 a	13.33 d
SM_2	71.13 c	121.07 b	22.44 b	178.40 b	34.63 b	12.93 b
SM_3	71.94 b	121.30 b	22.83 b	181.53 b	28.33 c	12.52 c
SM_4	72.75 a	122.05 c	24.94 a	221.40 a	20.63 d	11.33 a
$LSD_{0.05}$	0.75	0.65	1.18	5.84	1.76	0.72
CV(%)	5.71	5.72	8.09	10.84	6.29	9.17
Combined effect of different levels of water deficiency and soil organic amendments						
D_1 SM_1	67.25 h	121.8 bc	22.88 bc	196.3 c	51.00 a	14.20 a
D_1SM_2	70.25 ef	122.5 f	26.13 a	235.0 a	46.75 b	13.10 b
D_1SM_3	70.50 e	124.8 ef	24.50 ab	230.0 a	39.75 c	12.60 c
D_1SM_4	75.25 a	125.3 f	26.25 a	237.5 a	23.00 a	10.80 d
D_2SM_1	65.50 g	120.3 b	20.75 de	125.5 e	52.25 a	14.85 de
D_2SM_2	68.00 g	121.5 de	23.75 bc	207.8 bc	47.75 b	13.85 b
D_2SM_3	69.00 ef	122.3 cd	23.75 bc	207.3 bc	41.25 c	13.12 c
D_2SM_4	71.25 d	124.0 ef	24.00 bc	213.8 b	26.00 d	11.20 b
D_3SM_1	63.50 e	ND	ND	ND	ND	ND
D_3SM_2	65.75 d	ND	ND	ND	ND	ND
D_3SM_3	68.50 b	120.3 a	20.25 e	107.3 f	42.00 g	14.35 e
D_3SM_4	70.75 ab	121.8 bc	22.50 cd	169.0 d	28.75 fg	12.45 cd
D_4SM_1	61.75 f	ND	ND	ND	ND	ND
D_4SM_2	64.75 c	ND	ND	ND	ND	ND
D_4SM_3	66.25 c	119.3 a	16.86 f	91.40 h	52.85 g	14.90 f
D_4SM_4	68.50 b	120.0 a	17.00 f	93.50 g	30.75 g	13.20 e
$LSD_{0.05}$	0.7192	0.85	1.814	12.44	4.53	0.74
CV(%)	5.71	5.72	8.09	10.84	6.29	9.17

D_1 = Well watered condition (Control), D_2 = Irrigation at 7 days interval, D_3 = Irrigation at 14 days interval, D_4 = Irrigation at 21 days interval

SM_1 = Soil + inorganic fertilizer (control), SM_2 = Soil + cowdung + inorganic fertilizer, SM_3 = Soil + inorganic fertilizer + humic acid, SM_4 = Soil + inorganic fertilizer + cowdung + humic acid

4.3 Yield parameters

4.3.1 Number of grains panicle^{-1}

Effect of different levels of water deficiency

Significant variation was found for number of grains panicle^{-1} of rice as influenced by different levels of water deficiency (Table 4 and Appendix VIII). The highest number of grains panicle^{-1} (244.10) was recorded from control treatment D_1 (Well watered condition) which was significantly different from other situations followed by D_2 (Irrigation at 7 days interval). The lowest number of grains panicle^{-1} (147.95) was recorded from D_4 (Irrigation at 21 days interval). Similar result was also observed by Gomaa *et al*. (2011).

Effect of different levels of soil organic amendments

Application of different levels of soil organic amendments showed significant variation on number of grains panicle^{-1} of rice (Table 4 and Appendix VIII). The highest number of grains panicle^{-1} (247.40) was achieved from SM_4 (Soil + inorganic fertilizer + cowdung + humic acid) which was significantly different from other situations whereas The lowest number of grains panicle^{-1} (192.30) was found from control situation SM_1 (Soil + inorganic fertilizer). The result found from the present study was similar with the findings of Fu Jiu *et al*. (1995) and Al-Shareef *et al*. (2017) who found that humic acid has contribution to increase number of grains panicle^{-1}.

Interacted effect of different levels of water deficiency and soil organic amendments

The number of grains panicle^{-1} of rice varied significantly due to combined effect of different levels of water deficiency and soil organic amendments (Table 4 and Appendix VIII). The highest number of grains panicle^{-1} (255.80) was recorded from the treatment combination of D_1SM_4 which was significantly similar with the treatment combination of D_1SM_2, D_1SM_3 and

D_2SM_4. The lowest number of grains panicle^{-1} (155.00) was found from the treatment combination of D_4SM_3 which was statistically identical with the treatment combination of D_2SM_1 which was significantly different from other treatments. Plant death was occurred till harvest from treatment combinations of D_3SM_1, D_3SM_2, D_4SM_1 and D_4SM_2 and from these treatment combinations, number of grains panicle^{-1} was not detected.

4.3.2 Grain weight hill^{-1} (g)

Effect of different levels of water deficiency

Significant variation was found for grain weight hill^{-1} of rice as influenced by different levels of water deficiency (Table 4 and Appendix VIII). The highest grain weight hill^{-1} (25.63 g) was recorded from control treatment D_1 (Well watered condition) which was significantly different from other treatments followed by D_2 (Irrigation at 7 days interval) whereas the lowest grain weight hill^{-1} (9.30 g) was recorded from D_4 (Irrigation at 21 days interval). Gomaa *et al*. (2011) also found similar result and observed with an experiment that increasing irrigation interval, significantly decreased grain yield and its components. Yadav *et al.* (2001) found higher grain yield of wheat with 60% available soil water compared to 30% available soil water through a pot experiment and also concluded that grain yield decreased significantly under soil water stress conditions, compared to normally irrigated conditions. Drought in agriculture refers to water deficit in the root zone of plants and results in yield reduction during the crop life cycle (Rampino *et al.,* 2006; Passioura, 2007; Nevo and Chen, 2010; Ji *et al.,* 2010).

Effect of different levels of soil organic amendments

Application of different levels of soil organic amendments showed significant variation on grain weight hill^{-1} of rice (Table 4 and Appendix VIII). The highest grain weight hill^{-1} (25.17 g) was achieved from SM_4 (Soil + inorganic fertilizer + cowdung + humic acid) treatment which was significantly different from other situations followed by SM_2 (Soil + cowdung + inorganic fertilizer) and SM_3 (Soil + inorganic fertilizer + humic acid). The lowest grain weight hill^{-1} (16.75 g) was found from control situation SM_1 (Soil + inorganic fertilizer). Similar result was also observed by Gomaa *et al*. (2011) who reported that application of 14.40 kg/ha of humic acid significantly increased grain yield, and its components compared to untreated treatment (control). Humic acid as well as cowdung, an important component of organic fertilizers and humic substances, can be used to improve plant growth by improving its leaves' water content, photosynthesis, antioxidant metabolism and enzymes activity, thus enhancing its tolerance and contribute to increase yield and yield components of crops (Fu Jiu *et al*. 1995; Al-Shareef *et al*. 2017). Similar result was also observed by Gomaa *et al*. (2011).

Interacted effect of different levels of water deficiency and soil organic amendments

Grain weight hill^{-1} of rice varied significantly due to combined effect of different levels of water deficiency and soil organic amendments (Table 4 and Appendix VIII). The highest grain weight hill^{-1} (29.30 g) was recorded from the treatment combination of D_1SM_4 which was statistically identical with the treatment combination of D_1SM_2. The lowest grain weight hill^{-1} (8.64 g) was found from the treatment combination of D_4SM_3 which was significantly different from other treatment combinations. Plant death was occurred till harvest from treatment combinations of D_3SM_1, D_3SM_2, D_4SM_1 and D_4SM_2 and from these treatment combinations, grain weight hill^{-1} was not detected.

4.3.3 Straw weight hill^{-1} (g)

Effect of different levels of water deficiency

Significant variation was found for straw weight hill^{-1} of rice as influenced by different levels of water deficiency (Table 4 and Appendix VIII). The highest straw weight hill^{-1} (32.78 g) was recorded from control situation D_1 (Well watered condition) which was significantly different from other situations followed by D_2 (Irrigation at 7 days interval). Again, the lowest straw weight hill^{-1} (13.75 g) was recorded from D_4 (Irrigation at 21 days interval). Yadav *et al.* (2001) found similar result with the present study who reported higher stover yield obtained with 60% available soil water compared to 30% available soil water.

Effect of different levels of soil organic amendments

Application of different levels of soil organic amendments showed significant variation on straw weight hill^{-1} of rice (Table 4 and Appendix VIII). The highest straw weight hill^{-1} (33.26 g) was achieved from SM_4 (Soil + inorganic fertilizer + cowdung + humic acid) which was significantly different from others followed by SM_3 (Soil + inorganic fertilizer + humic acid). The lowest straw weight hill^{-1} (23.07 g) was found from control situation SM_1 (Soil + inorganic fertilizer). Fu Jiu *et al*. (1995) and Al-Shareef *et al*. (2017) also found similar result with the present study who reported that increased stover yield was found with humic acid under drought stress.

Interacted effect of different levels of water deficiency and soil organic amendments

Straw weight hill^{-1} of rice varied significantly due to combined effect of different levels of water deficiency and soil organic amendments (Table 4 and Appendix VIII). The highest straw weight hill^{-1} (35.38 g) was recorded from the treatment combination of D_1SM_4 which was statistically identical with the treatment combination of D_1SM_2 and D_4SM_3. The lowest straw weight hill^{-1} (13.25 g) was found from the treatment combination of D_4SM_1 which was significantly different from other treatment combinations. Plant death was occurred till harvest from treatment combinations of D_3SM_1, D_3SM_2, D_4SM_1 and D_4SM_2 and from these treatment combinations, straw weight hill^{-1} was not detected.

4.3.4 Harvest index (%)

Effect of different levels of water deficiency

Significant variation was found for harvest index of rice as influenced by different levels of water deficiency (Table 4 and Appendix VIII). The highest harvest index (43.76%) was recorded from control situation D_1, Well watered condition which was significantly different from other situation. The lowest harvest index (40.34%) was recorded from D_4, Irrigation at 21 days interval which was statistically identical with the situation of D_2, Irrigation at 7 days interval and D_3, Irrigation at 14 days interval.

Effect of different levels of soil organic amendments

Application of different levels of soil organic amendments showed significant variation on harvest index of rice (Table 4 and Appendix VIII). The highest harvest index (42.93%) was achieved from SM_4 (Soil + inorganic fertilizer + cowdung + humic acid) situation which was statistically identical with SM_2 (Soil + cowdung + fertilizer) whereas the lowest harvest index (40.66%) was found from control situation SM_1 (Soil + inorganic fertilizer).

Interacted effect of different levels of water deficiency and soil organic amendments

Harvest index of rice varied significantly due to combined effect of different levels of water deficiency and soil organic amendments (Table 4 and Appendix VIII). The highest harvest index (45.29%) was recorded from the treatment combination of D_1SM_4 which was statistically identical with the treatment combination of D_1SM_1 and D_1SM_3. The lowest harvest index (38.59%) was found from the treatment combination of D_4SM_3 which was statistically similar with the treatment combination of D_1SM_3, D_2SM_2, D_2SM_3, D_3SM_3 and D_3SM_4. The death of plants were occurred till harvest from treatment combinations of D_3SM_1, D_3SM_2, D_4SM_1 and D_4SM_2 and from these treatment combinations, harvest index was not detected.

Table 4. Yield parameters of rice as influenced by soil organic amendments under water deficit condition

Treatment	Yield parameters			
	Number of grains panicle^{-1}	Grain weight hill^{-1} (g)	Straw weight hill^{-1} (g)	Harvest index (%)
Effect of different levels of water deficiency				
D_1	244.10 a	25.63 a	32.78 a	43.76 a
D_2	221.20 b	20.07 b	28.63 b	40.96 b
D_3	176.90 c	14.34 c	21.01 c	40.64 b
D_4	147.95 d	9.30 d	13.75 d	40.34 b
$LSD_{0.05}$	6.28	1.23	1.26	1.54
CV(%)	9.10	12.48	9.37	7.52
Effect of different levels of soil organic amendments				
SM_1	192.30 c	16.75 c	23.07 d	41.68 b
SM_2	213.80 b	19.87 b	26.22 c	42.55 a
SM_3	211.93 b	19.37 b	28.13 b	40.66 c
SM_4	247.40 a	25.17 a	33.26 a	42.93 a
$LSD_{0.05}$	6.47	1.05	2.02	1.04
CV(%)	9.10	12.48	9.37	7.52
Interacted effect of different levels of water deficiency and soil organic amendments				
D_1SM_1	219.30 d	20.40 d	25.75 c	44.24 a
D_1SM_2	252.80 ab	28.31 a	35.13 a	44.60 a
D_1SM_3	248.80 ab	24.50 b	34.88 a	40.93 bc
D_1SM_4	255.80 a	29.30 a	35.38 a	45.29 a
D_2SM_1	165.30 f	13.10 f	20.38 d	39.11 c
D_2SM_2	242.00 bc	22.02 cd	31.38 b	41.25 bc
D_2SM_3	229.50 cd	20.88 d	30.88 b	40.32 c
D_2SM_4	248.00 ab	24.28 bc	31.88 b	43.15 ab
D_3SM_1	ND	ND	ND	ND
D_3SM_2	ND	ND	ND	ND
D_3SM_3	157.50 f	12.72 f	18.63 d	40.72 c
D_3SM_4	196.30 e	15.96 e	23.38 c	40.56 c
D_4SM_1	ND	ND	ND	ND
D_4SM_2	ND	ND	ND	ND
D_4SM_3	140.4 g	8.64 h	13.25 f	38.59 c
D_4SM_4	155.00 f	9.96 g	14.25 e	41.17 bc
$LSD_{0.05}$	12.80	2.46	2.52	2.34
CV(%)	9.10	12.48	9.37	7.52

D_1 = Well watered condition (Control), D_2 = Irrigation at 7 days interval, D_3 = Irrigation at 14 days interval, D_4 = Irrigation at 21 days interval

SM_1 = Soil + inorganic fertilizer (control), SM_2 = Soil + cowdung + inorganic fertilizer, SM_3 = Soil + inorganic fertilizer + humic acid, SM_4 = Soil + inorganic fertilizer + cowdung + humic acid

4.4 Soil moisture content

Effect of different levels of water deficiency

Significant variation was found for soil moisture content of rice as influenced by different levels of water deficiency (Fig. 1 and Appendix IX). The highest soil moisture content (21.82 and 24.16% at 55 and 70 DAT, respectively) was recorded from control treatment D_1, Well watered condition followed by D_2, Irrigation at 7 days interval whereas the lowest soil moisture content (13.78 and 7.58% at 55 and 70 DAT, respectively) was recorded from D_4, Irrigation at 21 days interval. Yadav *et al.* (2001) found higher moisture content in soil with higher frequency of irrigation which contributed to higher yield.

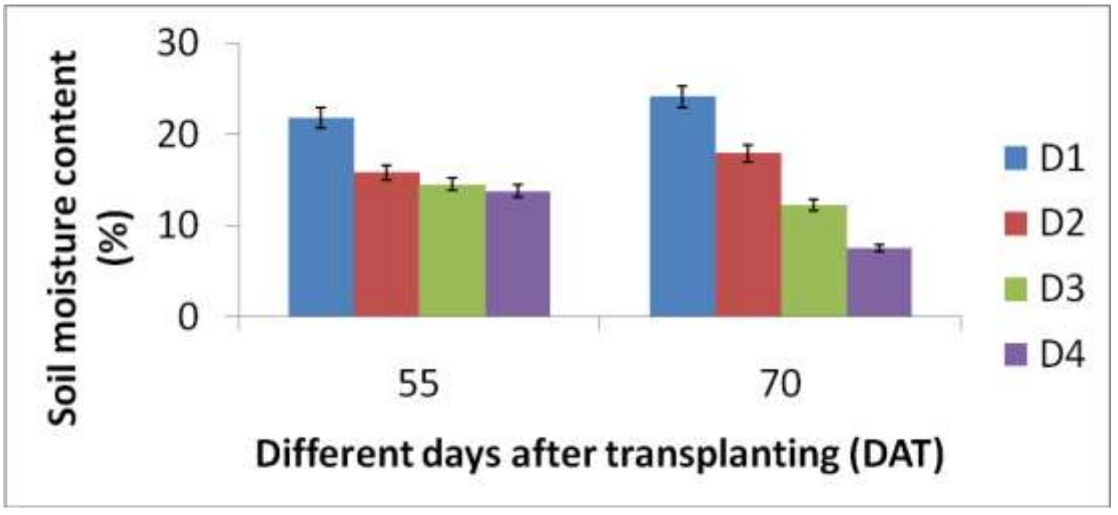


Fig. 1. Soil moisture content of rice at different days after transplanting influenced by different levels of water deficiency

D_1 = Well watered condition (Control), D_2 = Irrigation at 7 days interval, D_3 = Irrigation at 14 days interval, D_4 = Irrigation at 21 days interval

Effect of different levels of soil organic amendments

Application of different levels of soil organic amendments showed significant variation on soil moisture content of rice (Fig. 2 and Appendix IX). The highest soil moisture content (17.23 and 16.17% at 55 and 70 DAT, respectively) was achieved from SM_4 (Soil + inorganic fertilizer + cowdung + humic acid) application which was significantly different from other situations followed by SM_2 (Soil + cowdung + inorganic fertilizer) and SM_3 (Soil + inorganic fertilizer + humic acid). The lowest soil moisture content (15.90 and 15.43 at 55 and 70 DAT, respectively) was found from control situation SM_1 (Soil + inorganic fertilizer). Gomaa *et al*. (2011) also found similar result with the present study who found significant effect of soil organic amendments against drought stress which contributed to higher yield.

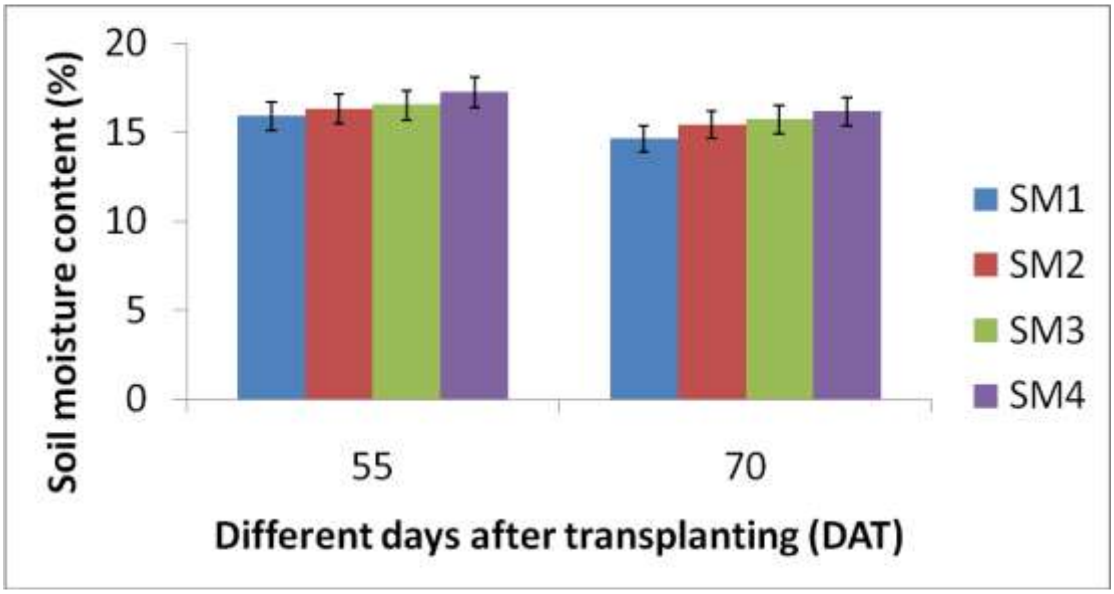


Fig. 2. Soil moisture content of rice field at different days after transplanting influenced by different levels of soil organic amendments

SM_1 = Soil + inorganic fertilizer (control), SM_2 = Soil + cowdung + inorganic fertilizer, SM_3 = Soil + inorganic fertilizer + humic acid, SM_4 = Soil + inorganic fertilizer + cowdung + humic acid

Interacted effect of different levels of water deficiency and soil organic amendments

Soil moisture content of rice varied significantly due to combined effect of different levels of water deficiency and soil organic amendments (Table 5 and Appendix IX). The highest soil moisture content (22.27 and 25.05% at 55 and 70 DAT, respectively) was recorded from the treatment combination of D_1SM_4which was statistically identical with the treatment combination of D_1SM_1 and D_1SM_2 at 70 DAT. The lowest soil moisture content (13.38 and 7.15% at 55 and 70 DAT, respectively) was found from the treatment combination of D_4SM_1 which was statistically identical with the treatment combination of D_4SM_2, D_4SM_3 and D_4SM_4.

CHAPTER V

SUMMARY AND CONCLUSION

Drought is an important concern which restricts global crop production seriously. Recent global climate change has made this situation more serious. Exogenous application of humic acid and cowdung is an important approach to mitigate the adverse effects of drought stress on plants. A pot experiments were therefore conducted to investigate the influence of soil organic amendments on morphology and yield in rice under drought stress. The pot experiments were carried out at the net-house, Department of Agricultural Botany, SAU, Dhaka. Four different levels of water deficiencies *viz*. D_1, Well watered condition (Control), D_2, Irrigation at 7 days interval, D_3, Irrigation at 14 days interval and D_4, Irrigation at 21 days interval and four different levels of humic acid *viz.* SM_1, Soil + inorganic fertilizer (control), SM_2 = Soil + cowdung + inorganic fertilizer, SM_3 = Soil + inorganic fertilizer + humic acid and SM_4 = Soil + inorganic fertilizer + cowdung + humic acid were used as treatments of the experiment. The two factor experiment was laid out in a randomized complete block design with four replications. Data on different growth and yield characters were collected and analyzed statistically and most of the cases, significant variation was found.

In case of water deficiency treatments regarding growth parameters, the highest plant height (77.25, 90.16, 95.50 and 114.60 cm at 40, 55, 70 DAT and at harvest, respectively) and number of tillers plant^{-1} (5.38, 9.88, 11.50 and 11.88 at 40, 55, 70 DAT and at harvest, respectively) were recorded from control treatment $D_{1,}$ Well watered condition whereas lowest plant height (68.00, 78.59, 84.68 and 90.88 cm at 40, 55, 70 DAT and at harvest, respectively) and number of tillers plant^{-1} (3.81, 5.84, 6.81 and 3.75 at 40, 55, 70 DAT and at harvest, respectively) were recorded from D_4, Irrigation at 21 days interval. In terms of yield contributing parameters and yield, the lowest days to 1st flowering (69.00 days) and days to 1st maturity (120.10 days) was recorded from control treatment D_1, well watered condition whereas the highest days to 1^{st} flowering (73.94 days) and days to 1^{st} maturity (124.00 days) were recorded from D_4, Irrigation at 21 days interval. Similarly, the highest panicle length (24.94 cm), number of filled grain panicle^{-1} (224.70), number of unfilled grain panicle^{-1} (44.13), root length (17.83 cm), number of grains panicle^{-1} (244.10) , grain weight hill^{-1} (25.63 g), straw weight hill^{-1} (32.78 g) and harvest index (43.76%) were recorded from control treatment D_1, well watered condition. The highest soil moisture content (21.82 and 24.16% at 55 and 70 DAT, respectively) was also recorded from control treatment D_1, well watered condition. Again, the lowest panicle length (17.00 cm), number of filled grain panicle^{-1} (93.50), number of unfilled grain panicle^{-1} (17.75), root length (14.20 cm), number of grains panicle^{-1} (155.00), grain weight hill^{-1} (9.96 g) and straw weight hill^{-1} (14.25 g) were recorded from D_4, Irrigation at 21 days interval. The lowest soil moisture content (13.78 and 7.58% at 55 and 70 DAT, respectively) was recorded from D_4, Irrigation at 21 days interval whereas the lowest harvest index (40.64%) was recorded from D_3, Irrigation at 14 days interval.

In case of soil organic amendments-humic acid and cowdung regarding growth parameters, the highest plant height (74.56, 86.96, 93.21 and 112.90 cm at 40, 55, 70 DAT and at harvest, respectively) and number of tillers plant^{-1} (4.94, 8.94, 10.38 and 11.25 at 40, 55, 70 DAT and at harvest, respectively) were achieved from the treatment SM_4 (Soil + inorganic fertilizer + cowdung + humic acid) whereas the lowest plant height (69.53, 79.16, 85.88 and 99.90 cm at 40, 55, 70 DAT and at harvest, respectively) and number of tillers plant^{-1} (4.06, 6.38, 6.88 and 8.00 at 40, 55, 70 DAT and at harvest, respectively) were found from SM_1 (Soil + inorganic fertilizer). In terms of yield contributing parameters and yield, the lowest days to 1^{st} flowering (70.13 days) and days to 1^{st} maturity (120.00 days) were achieved from SM_1 (Soil + inorganic fertilizer) whereas the highest days to 1^{st} flowering (72.75) and days to 1^{st} maturity (122.05 days) were found from control treatment SM_4 (Soil + inorganic fertilizer + humic acid + cowdung). Similarly, the highest panicle length (24.94 cm), number of filled grain panicle^{-1} (221.40), number of unfilled grain panicle^{-1} (42.25), root length (17.93 cm), number of grains panicle^{-1} (247.40), grain weight hill^{-1} (25.17 g), straw weight hill^{-1} (33.26 g) and harvest index (42.93%) were achieved from SM_4 (Soil + inorganic fertilizer + cowdung + humic acid) . The highest soil moisture content (17.23 and 16.17% at 55 and 70 DAT, respectively) was also achieved from SM_4 (Soil + inorganic fertilizer + cowdung + humic acid) . Again, the lowest panicle length (21.82 cm), number of filled grain panicle^{-1} (160.90), number of unfilled grain panicle^{-1} (20.63), root length (15.33 cm), number of grains panicle^{-1} (192.30), grain weight hill^{-1} (16.75 g) and harvest index (40.66%) were found from control treatment SM_1 (Soil + inorganic fertilizer). The lowest soil moisture content (15.90 and 15.43 at 55 and 70 DAT, respectively) was also found from control treatment SM_1 (Soil + inorganic fertilizer).

In terms of interacted effect of different levels of water deficiency and soil organic amendments regarding growth parameters, the highest plant height (79.75, 94.00, 100.50 and 121.50 cm at 40, 55, 70 DAT, respectively) and number of tillers plant^{-1} (5.75, 11.00, 12.25 and 14.75 at 40, 55, 70 DAT and at harvest, respectively) were recorded from the treatment combination of D_1SM_4 whereas lowest plant height (66.00, 72.51 and 78.75 at 40, 55 and 70 DAT, respectively) and number of tillers plant^{-1} (3.25, 4.25 and 4.00 at 40, 55 and 70 DAT, respectively) were found from the treatment combination of D_4SM_1. Regarding yield contributing parameters and yield, the lowest days to 1st flowering (67.25 days) and days to 1st maturity (119.30 days) were recorded from the treatment combination of D_1SM_4 whereas the highest days to 1st flowering (75.25 days) and days to 1st maturity (124.00 days) were found from the treatment combination of D_4SM_4. Similarly, the highest panicle length (26.25 cm), number of filled grain panicle^{-1} (237.50), number of unfilled grain panicle^{-1} (64.00), root length (19.20 cm), number of grains panicle^{-1} (255.80), grain weight hill^{-1} (29.30 g), straw weight hill^{-1} (35.38 g) and highest harvest index (45.29%) were recorded from the treatment combination of D_1SM_4. The highest soil moisture content (22.27 and 25.05% at 55 and 70 DAT, respectively) was also recorded from the treatment combination of D_1SM_4. On the other hand, the lowest panicle length (17.00 cm), number of filled grain panicle^{-1} (93.50), number of unfilled grain panicle^{-1} (17.75), root length (14.20 cm), number of grains panicle^{-1} (155.00), grain weight hill^{-1} (9.96 g) and straw weight hill^{-1} (14.25 g) were found from the treatment combination of D_4SM_4. The lowest harvest index (39.11%) was found from the treatment combination of D_2SM_1 whereas the lowest soil moisture content (13.38 and 7.15% at 55 and 70 DAT, respectively) was found from the treatment combination of D_4SM_1.

From the above results it can be concluded that drought stress caused a significant decrease in growth and yield of rice. Among different water deficiency treatments, D_1, well watered condition showed higher growth and yield of rice whereas D_4, Irrigation at 21 days interval showed inferior performance. Besides application of soil organic amendments like humic acid and cowdung resulted in a significant increase in growth and yield of rice. The highest growth and yield was observed by SM_4 (Soil + inorganic fertilizer + cowdung + humic acid). The interaction effects of humic acid and water stress were significant in aspect of growth and yield of rice. It was also observed that application of humic acid treatment of SM_4 (Soil + inorganic fertilizer + cowdung + humic acid) with D_1, well watered condition combination resulted in an increase of growth and yield of rice. So, this treatment combination can be treated as best treatments.

REFERENCES

Ahmed, A.H.H., Darwish, E., Hamoda, S.A.F. and Alobaidy, M.G. (2013). Effect of putrescine and humic acid on growth, yield and chemical composition of cotton plants grown under saline soil conditions. *American-Eurasian J. Agric. Environ. Sci*. **13**: 479-497.

Aijunan, A., Monoharan, V. and langavelu, S. (1992). Field screening for drought resistance in groundnut. Int. Arachis Newsl. 12 Nov. 1992. pp. 11-12.

Aisha, H., Ali, M.R. Shafeek, M., Asmaa, R. and El- Desuki, M. (2014). Effect of various Levels of organic fertilizer and humic acid on the growth and roots. Curr. Sci. Int. **3**(1): 7-14.

Ajalli, J., Vazan, S., Paknejad, F., Ardekani, M. R. and Kashani, A. (2013). Effect of potassium humate on yield and yield components of different potato varieties as a second crop after barley harvest in Ardabil region, Iran. *Annals Biol. Res*. **4**(2):85- 89.

Akram, M. (2011). Growth and yield components of wheat under water stress of different growth stages. *Bangladesh Journal* of *Agricultural Research* **36**: 455-468.

Ali, M. A. (1992). Effect of water stress on the growth features and anatomical characters of maize plants. MS Thesis. Dept. Crop Bot. BAU, Mymensingh.

Allahmoradi, P., Ghobadi, M., Taherabadi, S., Taherabadi, S. (2011). Physiological aspects of mungbean (*Vigna radiata* L. Wilczek) in response to drought stress. *Int. Conf. Food Eng. Biotechnol.* **9**: 272-275.

Arancon, N. Q., Edwards, C. A., Lee, S. and Byrne, R. (2006). Effects of humic acids from vermicomposts on plant growth. *European J. Soil Biol*. **42**: 65-69.

Ariafar, S. and Forouzandeh, M. (2017). Evaluation of humic acid application on biochemical composition and yield of black cumin under limited irrigation condition. *Bulletin de la Societé Royale des Sci. de Liège*, **86**: 13-24.

Armstrong. A. M. (1996). Relief and development: Some observations from RDRS- ODA Drought Response Project. *Grassroots*. **8**(5): 43-53.

Athar, H.R. and Ashraf, M. (2005): Photosynthesis under drought stress. *In: Handbook of Photosynthesis,* (Ed.): M. Pessarakli, CRC Press, Taylor and Francis Group, NY, pp. 793-804.

Bakul, M.R.A., Akter, M.S., Islam, M.N., Chowdhury, A.A. and Amin, M.H.A. (2009). Water stress effect on morphological characters and yield attributes in some mutants T-aman rice lines. *Bangladesh Res. Publ. J.* **3**: 934-944.

Ball, R. A., Oosterhuis, D. M. and Mouromoustakos. (1994). Growth dynamics of the cotton plants during water deficit stress. *Agron. J*. **86**: 788-795.

Bama, K. S. (2009). Foliar application of humic acid for rice yield and nutrition. *J. Ecol*. **25**(3): 241-244.

BBS (Bangladesh Bureau of Statistics). (2012). Statistical Year Book of Bangladesh. Stat. Div., Minst. Planning, Bangladesh Bur. Stat., Govt. People’s Repub. Bangladesh, Dhaka, pp. 123–125.

BBS. (2016). Yearbook of Agricultural Statistics. Bangladesh Bureau of Statistics, Statistics and Informatics Division (SID), Ministry of Planning, Government of the People’s Republic of Bangladesh.

Bhattacharya, S.P., Sitangshu, S., Karmakar, A.J., Bera, P.S. and Latika, M. (2003). Effects of humic acid (Earth) on the growth and yield of transplanted summer rice. *Environ. Ecol.* **21**(3): 680-683.

Biswas, J.K. (2015). Growing rice under stress environment, BRRI (Bangladesh Rice Research Institute). LAST MODIFIED: March 08, 2015.

Blum, A. (2011): Drought resistance - is it really a complex trait? *Functional Plant Biol.* **38**: 753-757.

BRRI (Bangladesh Rice Research Institute). (2012). Modern Rice Cultivation, 18th Edition. Bangladesh Rice Res. Inst., Joydebpur, Gazipur, Bangladesh.**113**: 40.

Cacco, G. and Dell'Agnolla, G. (1984). Plant growth regulator activity of soluble humic substances. *Canadian J. Soil Sci*. **64**: 25-28.

Chaves, M.M., Flexas, J. and Pinheiro, C. (2009): Photosynthesis under drought and salt stress: regulation mechanisms from whole plant to cell. *Annals of Bot.* **103**: 551-560.

Collinson. S. T. Azam, A. Chanda, S. N. and Hodsin, D. A. (1996). Growth. development and yield of bambara groundnut in response to soil moisture. J. Agril. Sci. 126(3): 307-318. In: *Plant physiol. Abst*. **22**(5): 613.

Daur, I. and Bakhashwain, A.A. (2013). Effect of humic acid on growth and quality ofmaize fodder production. *Pak. J. Bot*. **45**(1): 21-25.

Delfinea, S., Roberto, T., Ersilio, D. and Arturo, A. (2005). Effect of foliar application of N and humic acids on growth and yield of durum wheat. *Agron. Sustain. Dev*. **25**(2): 183 –191.

Dell-Amico, C., Masciandaro, G., Ganni, A., Ceccanti, B., Garcia, C., Hernandez, T. and Costa, F. (1994). Effects of specific humic fractions on plant growth. In N. Senesi and T. M. Miano (Eds.), Humic Substances in the Global Environment and Implications on Human Health, Amsterdam, Netherlands, *Elsevier Sci*. pp. 563-566

El-Razek, E.A., Abd-Allah, A.S.E. and Saleh, M.M.S. (2012). Yield and fruit quality of Florida Prince peach trees as affected by foliar and soil applications of humic acid. *J. Appl. Sci.* Res. **8**(12): 5724-5729.

Eshwar, M., Srilatha, M., Rekha, K.B. and Sharma, S.H.K. (2017). Effect of humic substances (humic, fulvic acid) and chemical fertilizers on nutrient uptake, dry matter production of aerobic rice (*Oryza sativa* L.). *J. Pharma. Phytochem*. **6**(5): 1063-1066.

Fleury, D., Jefferies, S., Kuchel, H. and Langridge, P. (2010): Genetic and genomic tools to improve drought tolerance in wheat. *J. Expt. Bot.* **61**: 3211-3222.

Fong, S.S., Seng, L. and Mat, H.B. (2007). Reuse of nitric acid in the oxidative pretreatment step for preparation of humic acids from low rank coal of mukash, Sarawak. *J. Brazil Chem. Soc*. **18**: 41-46.

Fu-Jiu, C., Dao-Qi, Y. and Quing-Sheng, W. (1995). Physiological effects of humic acid on drought resistance of wheat (in Chinese). *Yingyong Shengtai Xuebao*, **6**: 363-367.

Gomaa, M.A., Radwan, F.I., Khalil, G.A.M., Kandil, E.E. and El-Saber, M.M. (2014). Impact of Humic Acid Application on Productivity of some Maize Hybrids under Water Stress Conditions. *Middle East J. Appl. Sci*. **4**(3): 668-673.

Grzesiak, S., Itjma, M., Kono. Y. and Yamauchi, A. (1997). Differences in drought tolerance between cultivars of field bean and field pea. A comparison of drought resistant and drought sensitive cultivars. In: *Field Crop Abst*. **51**(2): 150.

Gupta, S.N., Dahiya, B.S., Malik, B.P.S. and Bishnoi, N.R. (1995). Response of chickpea to water deficits & drought stress. *Haryana Agric. Univ. J. Res.* **25**: 11-19.

Hamid, S.B.H.A. (2012): Studies of drought tolerance of hard red winter wheat *(Triticum aestivum* L.) cultivars in Nebraska. *Agron. crop Sci*. p. 56.

Hatami, H. (2017). The effect of zinc and humic acid applications on yield and yield components of sunflower in drought stress. J. *Adv. Agric. Technol*. **4**: 36-39.

Hossain, M.I., Khatun, A., Talukder, M.S.A., Dewan, M.M.R., Uddin, M.S. (2010): Effect of drought on physiology and yield contributing characters of sunflower. Bangladesh J. Agric. Res. **35**(1): 113-124.

Ihsanullah, D. and Bakhashwain, A.A. (2013). Effect of humic acid on growth and quality of maize fodder production. *Pakistan J. Bot*. **45**: 21-25.

Islam, M.T., Kubuta, F. and Agata, W. (1994): Growth, canopy structure and seed yield of mungbean as influenced by water stress. *J. Faculty Agric. Kyushu Univ.* **38**: 213-224.

Islam, M. S., Haque. M. Z., Jabber, M. A., Bashak, A. K. and Paul. N. K. (1997). Effects of simulated rainfall at reproductive to ripening stages on the growth and yield of Transplant Aman rice. *Ann. Bangladesh Agric*. **7**(2): 105-110.

Ismail, M.I., Duwayri, M., Nachit, M. and Kafawin, O. (1999). Association of yield and drought susceptibility index with morphophysiological traits among related durum wheat genotypes subjected to water stress at various growth stages. *Dirasat, Agric. Sci.* **26**(2): 198-204.

Ismail, A.M., Platten, J.D. and Milo, B. (2013). Physiological bases of tolerance of abiotic stresses in rice and mechanisms of adaptation. In "Sustainable Rice Production and Livelihood Security: Challenges& Opportunities" (K. S. Behera, S. Saha, S. K. Nayak, K. S. Rao, S. K. Pradhan, A. Poonam, D. P. Singh, M. Jena, M. Din and P. Samal). Association of Rice Research Workers, CRRI, Cuttack, India. Pp 233-38.

Jaleel, C.A., Manivannan, P., Wahid, A., Farooq, M., Al-juburi, H.J., Somasundaram, R., Panneerselvam, R. (2009). Drought stress in plants: A review on morphological characteristics and pigment composition. *Int. J. Agric. Biol.* **11**(1): 100-105.

Jatoi, W.A., Baloch, M.J., Kumbhar, M.B., Khan, N.U. and Kerio, M.I. (2011). Effect of water stress on physiological and yield parameters at anthesis stage elite spring wheat cultivars. *Sarhad J. Agric.* **27** (1) 59-65.

Jharna, D.E., Chowdhury, B.l.D., Haque, M.A., Bhuiyan, M.R.H. and Husain MM (2001). Biochemical screening of some groundnut *(Arachis hypagaea* L.) genotypes for drought tolerance. *Online J. Biol. Sci.* **1**(11): 1009-1011.

Ji, X.M., Shiran, B., Wan, J.L., Lewis, D.C. and Jenkins, C.L.D. (2010). Importance of pre-anthesis anther sink strength for maintenance of grain number during reproductive stage water stress in wheat. *Plant, Cell Environ.* **33**: 926-942.

Jones, C.A., Jacobsen, J.S. and Mugaas, A. (2004). Effect of humic acid on phosphorus availability and spring wheat yield. *Environ. Exp. Bot*. **25**(3): 245-252.

Jongdee, B. and Fukal, S., Cooper M (2002). Leaf water potential and osmotic adjustment as physiological traits to improve drought tolerance in rice. *Field-Crops-* Res. **76**(3) 153-163.

Kadam, S., Singh, K., Shukla, S., Goel, S. and Vikram, P. (2012). Genomic associations for drought tolerance on the short arm of wheat chromosome 4B. *Functional and Integrative Genomics.* **12**: 447-464.

Kadam, S.R., Amrutsagar, V.M. and Deshpande, A.N. (2010). Influence of organic nitrogen sources with fulvic acid spray on yield and nutrient uptake of soyabean on inceptisol. *J. Soils Crops*. 20(1):58-63.

Kaya, C., Akram, N. A., Ashraf, M. and Sonmez, O. (2018). Exogenous application of humic acid mitigates salinity stress in maize (*Zea mays* L.) Plants by improving some key physico-biochemical attributes. Cereal Res.Communic. **46**: 67-78.

Kıran, S., Furtana, G.B., Talhouni, M. and Ellialtıoglu, S.S. (2019). Effect of humic acid on drought tolerance in melon. *Bragantia, Campinas*. **78**(4): 490-497.

Kirigwi, F.M., Ginkel, M.V., Trethowan, R., Sears, R.G., Rajaram, S. (2004). Evaluation of selection strategies for wheat adaptation across water regimes. *Euphytica.* **135**(3): 361-371.

Lawlor, D.W. and Cornic, G. (2002). Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. *Plant, Cell* Environ. **25**: 275-294.

Lawlor, D.W. and Tezara, W. (2009). Causes of decreased photosynthetic rate and metabolic capacity in water-deficient leaf cells: a critical evaluation of mechanisms and integration of processes. *Annals Bot.* **103**: 561-579.

Lodhi, A., Tahir, S., Iqbal, Z., Mahmood, A., Akhtar, M. and Qureshi, T. M. (2013). Characterization of commercial humic acid samples and their impact on growth of fungi and plants. *Soil Environ*. **32**: 63-70.

Lonbani, M. and Arzani, A. (2011). Morphophysiological traits associated with terminal drought-stress tolerance in triticale and wheat. *Agron. Res*. **9**(1-2): 315-329.

Lotfi, R., Kouchebagh, P.G. and Khoshvaghti, H. (2015). Biochemical and physiological responses of Brassica napus plants to humic acid under water stress. *Russian J. Plant Physiol*. **62**: 480-486.

Ludlow, M. M. and Muchow, R. C. (1990). A critical evaluation of traits for improving crop yields in water-limited environments. *Adv. Agron*. **43**: 107-153.

Ludlow, M.M., Santamaria, J.M. and Fukai, S. (1990). Contribution of osmotic adjustment to grain yield in *Sorghum bicolor* L. Monech under water limited conditions. II. Water stress after anthesis. *Aust. J. Agril.* Res. **41**:67-78.

Mafakheri, A., Siosemardeh, A., Bahramnejad, B., Struik, P.C. and Sohrabi, Y. (2010). Effect of drought stress on yield, proline and chlorophyll contents in three chickpea cultivars. *Australian J. Crop Sci*. **4**(8): 580-585.

Mahajan, S. and Tuteja, N. (2005). Cold, salinity and drought stresses: an overview. *Archives of Biochemistry and Biophysics*. **444**: 139-158.

Mahmoodian, L., Naseri, R. and Mirzaei, A. (2012). Variability of grain yield and some important agronomic traits in mungbean (*Vigna radiata* L.) cultivars as affected by drought stress. *Int.* Res. *J. Appl*. *Basic Sci*. **3**: 486-492.

Malik. B.K. (1992). Effect of drought stress on the yield and recovery of sugarcane. *Pak. Sugar. J.* **6**(1): 17-23.

Marcinska, I., Czyczylo-Mysza, I. and Skrzypek E, (2013). Alleviation of osmotic stress effects by exogenous application of salicylic or abscisic acid on wheat seedlings. *Int. J. Molecular Sci*. **14**: 13171-13193.

Masciandaro, G., Ceccanti, B., Ronchi, V., Benedicto, S., and Howard, L. (2002). Humic substances to reduce salt effect on plant germination and growth. Communications in Soil Science and Plant Analysis. **33**: 365-378.

Mayhew, I., (2004). Humic substances in biological agriculture available at humic 20% substances. *Int.* Res. *J. Appl*. *Basic Sci*. **3**: 220-226.

Miyauchi, Y., Isoda, A., Li-Zhi-Yuan, and Wang, P.W. (2012). Effects of foliar application of humic substance on growth and yield of soybean in arid areas of Xinjiang, China. [Japanese] *Japanese. J. Crop Sci*. **81**(3):259-266.

Moradia, A., Ahmadia, A. and Hossain, Z.A. (2008). The effects of different timings and severity of drought stress on gas exchange parameters of mungbean. *Desert*. **13**: 59-66.

Nandakumar, R., Saravanan, A., Singaram, P. and Chandrasekaran, B. (2004). Effect of lignite humic acid on soil nutrient availability at different growth stages of rice grown on vertisols and alfisols. *Acta Agronomica Hungarica*. **52**(3): 227-235.

Neumann, P.M. (1995). Role of cell wall adjustment in plant resistance to water deficits. *Crop Sci*. **35**: 1258-1266.

Nevo, E. and Chen, G.X. (2010). Drought and salt tolerances in wild relatives for wheat and barley improvement. *Plant, Cell Environ*. **33**: 670-685.

Nooruddin. M. (2004). Forecasting of rice yield using agro-meteorological variables at Rajshahi district in Bangladesh. In Proc. SAARC Seminar on Agricultural Applications of Meteorology during 23-24 December, 2003 held in Dhaka. Bangladesh. pp. 1-4.

Nouri-Ganbalani, A., Nouri-Ganbalani, G. and Hassanpanah, D. (2009). Effects of drought stress condition on the yield and yield components of advanced wheat genotypes in Ardabil, Iran. J. *Food,* Agric. Environ. **7**(3&4): 228-234.

Passioura, J. (2007). The drought environment: physical, biological and agricultural perspectives. *J. Bot.* **58**: 113-117.

Pettit, R.E., (2004). Organic matter ,humus ,humate ,humic acid ,fulvic acid and humin their importance in soil fertility and plant health available at www humate info/mainpage htm C.F.Computer search.

Peymaninia, Y., Valizadeh, M., Shahryari, R., Ahmadizadeh, M. (2012). Evaluation of morpho-physiological responses of wheat genotypes against drought stress in presence of a leonardite derived humic fertilizer under greenhouse condition. *J. Animal Plant Sci*. **22**(4): 1142- 1149.

Pirzad, A., Shakiba, M.R., Zehtab-Salmasi, S., Mohammadi, S.A., Darvishzadeh, R. and Samadi, A. (2011): Effect of water stress on leaf relative water content, chlorophyll, proline and soluble carbohydrates in *Matricaria chamomilla* L. *Journal of Medicinal Plants Research* 5 2483-2488.

Quadir, D.A., Hussain. M.A., Hossain, M.A. and Ahasan. M.N. (2004). Deficit and Excess Rainfall Conditions over Bangladesh. In Proc. SAARC Seminar on Agricultural Applications of Meteorology during 23-24 December. 2003 held in Dhaka. Bangladesh. pp.25-32.

Rafat, N., Mehrdad-Yarnia and Davood, H.P. (2012). Effect of drought stress and potassium humate application on grain yield-related traits of corn (cv. 604). *J. Food, Agric. Environ*. **10** (2): 580-584.

Rampino, P., Pataleo, S., Gerardi, C., Mita, G. and Perrotta, C. (2006). Drought stress response in wheat: physiological and molecular analysis of resistant and sensitive genotypes. *Plant, Cell Environ*. **29**: 2143-2152.

Rashid, A., Saleem, Q., Nazir, A. and Shah, K.H. (2003). Yield potential and stability of nine wheat varities under water stress conditions. *Int. J. Agric. Biol.* **5**(1): 7-9.

Saruhan, V., Alpaslan, K. and Sevgi, B. (2011). The effect of different humic acid fertilization on yield and yield components performances of common millet (*Panicum miliaceum* L.). *Sci. Res. Essays*. **6**(3): 663-669.

Schimper, A. (1898). Pflanzengeographiaut physiologischer grundlage. Oxford at the Clarendon Press 1993.

Shao, B., Yuxiu, Y., Chen, X., Wanq, Z., Yanq, J., Zhu, Q. and Zhanq, H. (2004). Effect of water stress during grain filling on the grain yield & quality of two line hybrid rice. *J. Yanq Zhau University, Agric. Life Sci*. **25**(1): 46-50.

Sharif, M., Khattak, R. A. and Sarir M. S. (2002). Effect of different levels of lignitic coal derived humic acid on growth of maize plants. *Communications in Soil Sci. Plant Anal*. **33**: 3567-3580.

Siddique, M.R., Hamid, B.A. and Islam, M.S. (1999). drought stress effect on phonological characters of wheat. *Bangladesh J. Agric.* Res. **24**(2): 255263.

Srivastava, J.P. and Kamalesh, R. (1998). Analysis of yield stability in sesame *(Sesamum indicum* L.). Department of plant physiology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221005. *Indian J. Plant Physiol.* **3**(4): 256-259.

Taub, A.S.M. (2003). effect of water stress on the growth and yield attributes of chickpea. M.S. thesis, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Turner, N.C. (1981). Designing crops for dry land Australia: can the desert help us. *J. Australian Inst. Agric. Sci*. **47**: 29-34.

Veeral, D.K., Kuppuswamy, G. and Thanunathan, K. (2003). Direct and residual effects of lignite flyash and humic acid on rice-blackgram cropping system. *Res. Crops*. **4**(2): 206-209.

Vinod, G., Sudha, J., Bishnol, N.R. and Renu, M. (2001). Leaf water relations, Diffusive resistance & proline accumulation in hybrid pearl millet under depleting soil moisture content. *Indian J. Plant Physiol.* **6**(1): 41-45.

Witcombe, J.R., Hollington, P.A., Howarth, C.J., Reader, S. and Steele, K.A. (2008). Breeding for abiotic stresses for sustainable agriculture. Philosophical Transactions of the Royal Society. *B-Biol. Sci*. **363**: 703-716.

Yadav, R.S., Gayadin, A.K. and Jaiswal, A.K. (2001). Morphophysiological changes variable yield of wheat genotypes under moisture stress conditions. *Indian J. Plant Physiol*. **5**(4): 390-394.

Zhang, L., Gao, M., Zhang, L., Li, B., Han, M., Alva, A.K. and Ashraf, M. (2013). Role of exogenous glycinebetaine and humic acid in mitigating drought stress-induced adverse effects in Malus robusta seedlings. *Turkish J. Bot*. **37**: 920-929.

Zhu, J. K. (2002). Salt and drought stress signal transduction in plants. *Ann. Rev. Plant Biol*. **53**: 247-273.

APPENDICES

Appendix I. **Agro-Ecological Zone of Bangladesh showing the experimental location**

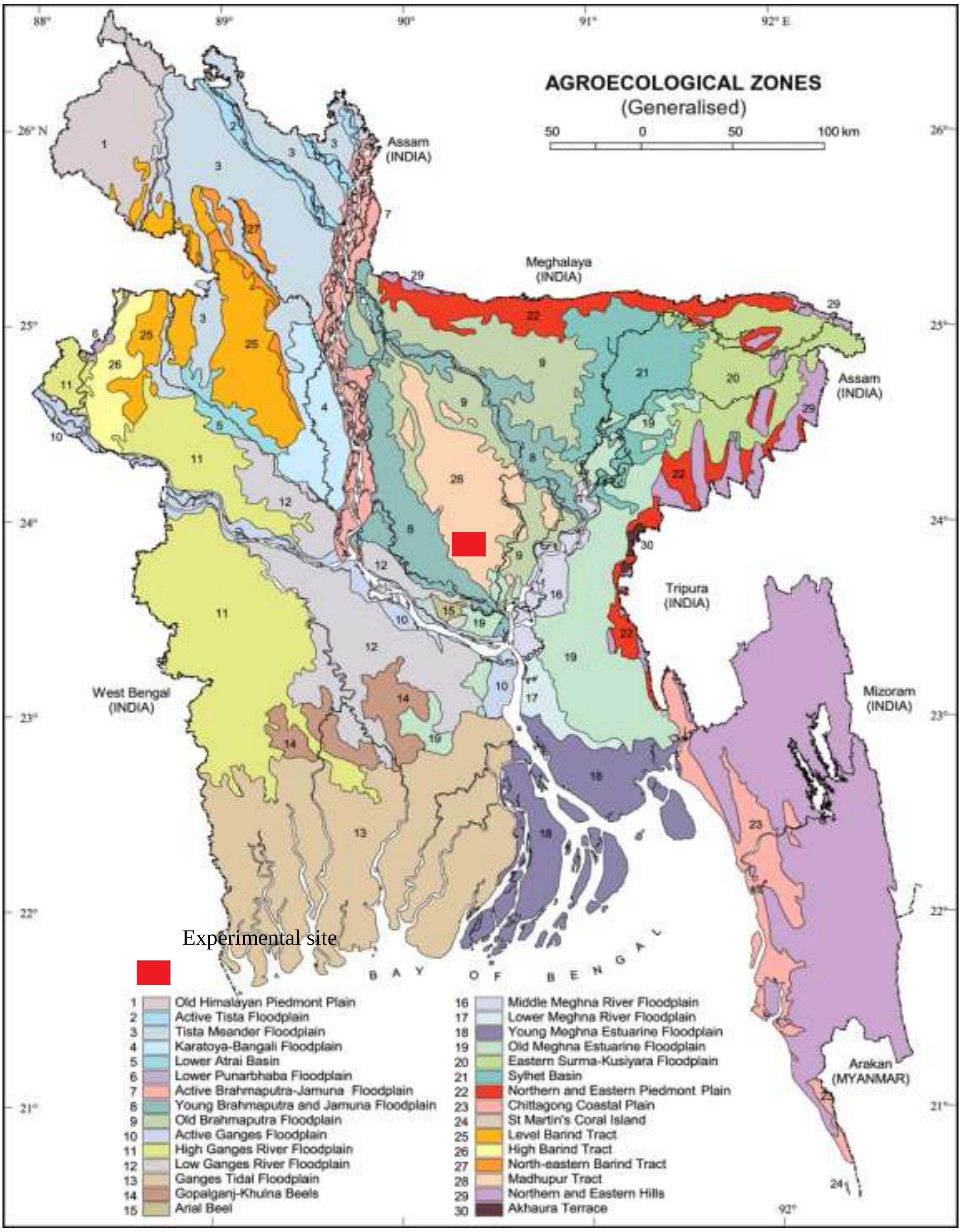


Fig. 3. Experimental site

Appendix II**. Monthly records of air temperature, relative humidity and rainfall during the period from July 2018 to November 2018.**

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2018	July	30.52	24.80	27.66	78.00	536
2018	August	31.00	25.60	28.30	80.00	348
2018	September	30.8	21.80	26.30	71.50	78.52
2018	October	30.42	16.24	23.33	68.48	52.60
2018	November	28.60	8.52	18.56	56.75	14.40

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. **Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka**.

A**.** ***Morphological characteristics of the experimental field***

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

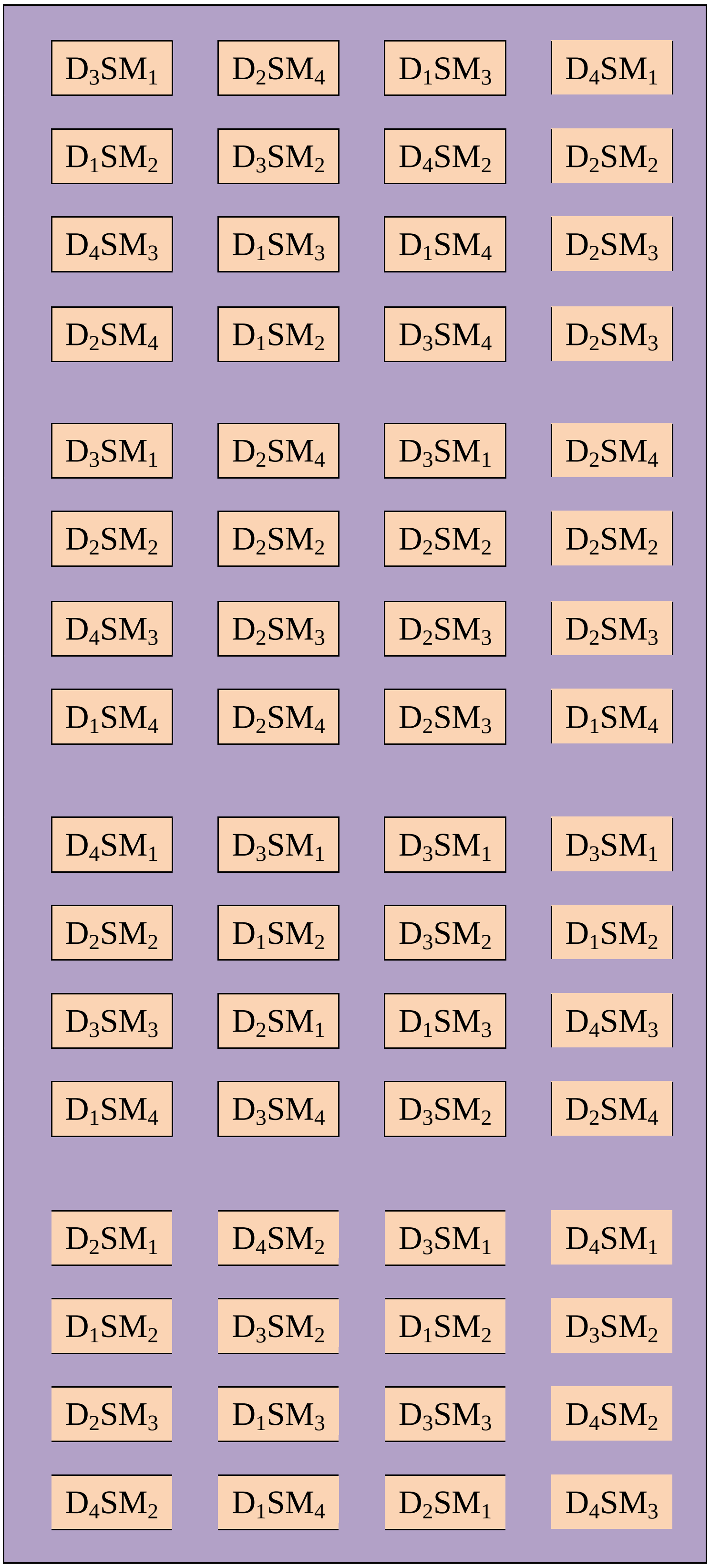
Source: Soil Resource Development Institute (SRDI)

B. ***Physical and chemical properties of the initial soil***

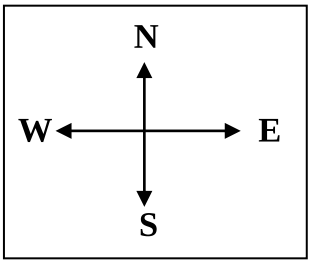
Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. **Layout of the experiment field**



Legend



Treatment

Factor A: Different levels of water deficiency

1. D_1 = Well watered condition (Control)
2. D_2 = Irrigation at 7 days interval
3. D_3 = Irrigation at 14 days interval
4. D_4 = Irrigation at 21 days interval

Factor B: Different levels of humic acid

1. SM_1 = Soil + inorganic fertilizer (control)
2. SM_2 = Soil + cowdung + inorganic fertilizer
3. SM_3 = Soil + inorganic fertilizer + humic acid
4. SM_4 = Soil + inorganic fertilizer + cowdung + humic acid

Fig. 4. Layout of the experimental plot

Appendix V. **Analysis of the variance of the data on plant height of rice as influenced by soil organic amendments under water deficit condition**

Sources of variation	Degrees of freedom	Plant height (cm)			
		40 DAT	55 DAT	70 DAT	At harvest
Replication	3	1.087	1.704	2.110	8.493
Factor A	3	70.06**	178.13*	146.64*	995.681*
Factor B	3	281.3*	448.32*	361.32*	3077.07*
AB	9	4.434**	11.437**	10.207**	377.299*
Error	45	3.115	4.290	8.178	15.855

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. **Analysis of the variance of the data on number of tillers plant^{-1} of rice as influenced by soil organic amendments under water deficit condition**

Sources of variation	Degrees of freedom	Number of tillers plant^{-1}			
		40 DAT	55 DAT	70 DAT	At harvest
Replication	3	0.266	1.063	2.682	1.557
Factor A	3	2.182**	19.521*	38.307*	83.724*
Factor B	3	8.057*	52.771*	80.766*	431.724*
AB	9	0.210**	1.563**	2.571**	10.418*
Error	45	0.232	0.940	0.805	1.046

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. **Analysis of the variance of the data on soil moisture content of rice field as influenced by soil organic amendments under water deficit condition**

Sources of variation	Degrees of freedom	Soil moisture content	
		55 DAT	70 DAT
Replication	3	1.621	5.015
Factor A	3	4.954**	6.385*
Factor B	3	21.004*	82.464*
AB	9	2.518*	5.432*
Error	45	1.828	2.744

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. **Analysis of the variance of the data on yield contributing parameters of rice as influenced by soil organic amendments under water deficit condition**

Sources of variation	Degrees of freedom	Yield contributing parameters				
		Days to 1st flowering	Days to 1st maturity	Panicle length (cm)	Number of filled grain $panicle^{-1}$	Number of unfilled grain $panicle^{-1}$
Replication	3	1.432	5.016	0.214	12.432	12.141
Factor A	3	20.18*	135.05*	431.151*	530.182*	158.05*
Factor B	3	85.12*	396.39*	1577.39*	1273.84*	527.68*
AB	9	4.682**	78.613*	163.359*	592.530*	23.182*
Error	45	0.255	6.360	1.622	62.255	10.107

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. **Analysis of the variance of the data on yield parameters of rice as influenced by soil organic amendments under water deficit condition**

Sources of variation	Degrees of freedom	Yield parameters				
		Number of grains $panicle^{-1}$	Grain weight $hill^{-1}$ (g)	Straw weight $hill^{-1}$ (g)	Root length at harvest (cm)	Harvest index (%)
Replication	3	23.042	1.739	3.046	3.375	24.418
Factor A	3	411.625*	36.364*	68.514*	24.807*	48.451*
Factor B	3	1604.62*	187.40*	316.98*	257.44*	419.14*
AB	9	108.528*	38.642*	29.105*	38.622**	75.553*
Error	45	20.786	2.983	3.123	1.069	4.697

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level