ENHANCEMENT OF GROWTH AND YIELD OF WHEAT THROUGH BIOCHAR AND POTASSIUM MANAGEMENT UNDER DIFFERENT IRRIGATION REGIMES

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June, 2021

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A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE
IN
AGRONOMY

SEMESTER: JANUARY- JUNE, 2021

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CERTIFICATE

*This is to certify that thesis entitled, "**ENHANCEMENT OF GROWTH AND YIELD OF WHEAT THROUGH BIOCHAR AND POTASSIUM MANAGEMENT UNDER DIFFERENT IRRIGATION REGIMES**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRONOMY,** embodies the result of a piece of bona-fide research work carried out by **MOUMITA SARKAR,** Registration no. **13-5608** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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DEDICATED TO

MY

BELOVED PARENTS

ACKNOWLEDGEMENTS

All gratefulness to Omnipotent "Almighty God" Who enabled the author to pursue higher study and to complete the research work as well as to submit the thesis for the degree of Master of Science (M.S.) in Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

The author would like to express her heartiest respect, deepest sense of gratitude, profound appreciation to her supervisor, ***Professor Dr. Md. Abdullahil Baque****, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for his sincere guidance, constructive criticism and constant inspiration throughout the course and in preparation of the manuscript of the thesis.*

The author would like to express her heartiest respect and profound appreciation to her co-supervisor, ***Professor Dr. Md. Jafar Ullah****, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for his full co-operation and constructive suggestions to conduct the research work as well as preparation of the thesis.*

The author expresses her sincere respect to the Chairman, ***Professor Dr. Tuhin Suvro Roy****, Examination Committee, Department of Agronomy and all the teachers of the department of Sher-e-Bangla Agricultural University, Dhaka, for providing the facilities to conduct the research work and for their valuable advice and sympathetic consideration in terms with the study.*

The author avails this opportunity to express her sincere thanks and gratitude to the Government of Bangladesh through its Ministry of Science and Technology (NST) for providing financial support to conduct thesis research work.

The author would like to thank all of her roommates and friends specially Ishrat Anjum, Bristy Basak, Sangita Sharmin who have helped her with technical support to prepare this thesis paper. Special thanks to them for their support and encouragement to complete this study.

Mere diction is not enough to express her unfathomable gratitude and heartfelt indebtedness from core of heart to her father Dulal Chandra Sarkar, her mother Chabi Rani Sarkar and her brother Deb Kumar Sarkar for their ever ending prayer, dedicated effort, sacrifice and moral support that opened the gate and paved to way of her higher study.

Finally, the author appreciates the assistance rendered by the staff of the Department of Agronomy and farm, Sher-e-Bangla Agricultural University, Dhaka-1207, who have helped her during the period of study.

The Author

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ABSTRACT

A field experiment was conducted at the Agronomy research field of Sher-e-Bangla Agricultural University in Dhaka from November 2019 to March 2020 to study the influence of biochar and Potassium on the enhancement of growth and yield of wheat (BARI Gom 31) under different irrigation regimes. In the experiment, the treatments consisted of four doses of biochar and Potassium *viz.* B_0K_0= 5 t ha^{-1} Biochar + 0 kg ha^{-1} K, B_1K_1= 5 t ha^{-1} Biochar + 48 kg ha^{-1} K, B_2K_2= 5 t ha^{-1} Biochar + 36 kg ha^{-1} K, B_3K_3= 0 t ha^{-1} Biochar + 48 kg ha^{-1} K and four different irrigation levels *viz.* I_0 = Control, I_1= Irrigation at crown root initiation stage, I_2= Irrigation at crown root initiation stage + Flowering stage, I_3= Irrigation at crown root initiation stage + Flowering stage + Grain filling stage. The experiment was laid out in 2 Factor Split Plot Design with three replications by assigning irrigation to main plot and biochar and Potassium to sub-plots. There were 16 treatments combination. The collected data were statistically examined to determine the effectiveness of the treatments. Results revealed that there were significant variations among the treatments in the most of the examined parameters. As for growth parameters, the highest plant height (87.42 cm), no. of tillers/plant (6.60), leaf area index (42.21) and for yield parameters, the highest ear length (17.01 cm), no. of spikelets/ear (18.13), no. of grains/ear (37.70), 1000-grain wt. (46.66 gm), grain yield (3.53 t ha^{-1}), straw yield (3.56 t ha^{-1}) and harvest index (49.80) were recorded under $I_2B_2K_2$ due to irrigation at crown root stage and flowering stage interaction with Biochar: 5 t ha^{-1} and K: 36 kg ha^{-1}. On the contrary, lowest values for above mentioned cases were obtained with $I_0B_0K_0$. The results revealed that irrigation at crown root initiation and at flowering stage with 5 t ha^{-1} biochar and 36 kg ha^{-1} Potassium enhance both growth and yield of wheat.

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LIST OF ACRONYMS

ABBREVIATIONS	ELABORATIONS
AEZ	Agro-Ecological Zone
Anon.	Anonymous
ANOVA	Analysis of Variance
@	At the rate of
Agron.	Agronomy
Agril.	Agricultural
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
Cm	Centimeter
CV %	Percent Coefficient of Variation
DAS	Days after sowing
et al.	And others
i. e.	For example
FAO	Food and Agriculture Organization
Gm	Gram
HI	Harvest Index
K	Potassium
Kg ha^{-1}	Kilogram per hectare
LSD	Least Significant Difference
MoP	Muriate of Potash
m^2	Meter squares
N	Nitrogen
NS	Non-significant
No.	Number
t ha^{-1}	Ton per hectare
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Super Phosphate
viz.	As follows
Wt.	Weight
WG	Wettable granule

CHAPTER 1
INTRODUCTION

Wheat (*Triticum aestivum* L.) belongs to the family Poaceae (Gramineae). Wheat (*Triticum aestivum* L.*)* is one of the world's most important cereals. It is grown mostly in a widely different variety of conditions. Wheat is the second most important grain crop after rice and occupies third position in production in Bangladesh. In Bangladesh, 1029354 M. tons of wheat were produced from 3,32,274 hectares of land in 2019–20, with an average yield of 3.098 metric tons per hectare (BBS, 2020). Wheat consumption is increasing on a daily basis. Wheat grain is rich in food value. It contains 69.60% carbohydrate, 12% protein, 1.72% fat and 27.20% minerals (BARI,1997). Wheat is superior to rice in terms of nutrition due to its higher protein content. In that situation, wheat could be an excellent supplement to rice, as rice is essential for feeding such a large population. Wheat and its straw, in addition to these, are utilized as animal feed. Wheat straw is also used as a fuel source and a building material by Bangladesh's underprivileged. Bangladesh's agriculture has numerous obstacles in growing crops from its limited land resources in order to meet the ever-increasing demand of the country's population. Climate change, biological variety loss, deterioration of land quality, loss of soil fertility, water scarcity, and other major issues make agriculture susceptible. Furthermore, agricultural land is shrinking every year as a result of human settlement, growing urbanization, and industrialization. For this reason, crop productivity must be increased by land intensification and the use of high-yielding crop varieties, as well as improved crop management.

Wheat is cultivated in Bangladesh during the Rabi (winter) season, which is dry. Because of this, the lack of soil moisture during this season limits the usage of fertilizers, resulting in lower grain yields. Irrigation is crucial for proper wheat growth and development. Inadequate soil moisture impacts both seed germination and nutrient uptake from the soil. Unfortunately, most farmers in Bangladesh are unable to supply irrigation during several important stages of wheat production due to a lack of irrigation systems and irrigation supplies. At the early stages of the wheat, residual soil moisture from the rainy season is abundant, but it is rarely retained in the later stages. As a result, water is the most essential constraint to wheat production. The groundwater table is steadily declining at a pace of around 1 meter per year, with the primary causes being the expanding wheat area irrigated with groundwater and low crop water-use efficiency (Xia *et al*., 2002). Consequently, increasing irrigation water availability and decreasing irrigation demand while preserving agricultural output is critical.

Biochar is a carbon-rich material made from the thermo-chemical conversion of biomass in an oxygen-limited environment (slow, intermediate, and quick pyrolysis or gasification). Its porous nature allows it to hold large amounts of extractable humic and fluvic chemicals (Lin *et al*. 2012).

Biochar, when used as a soil conditioner, improves plant growth by delivering and, more crucially, storing nutrients, as well as enhancing soil physical and biological qualities and, as a result, boosting soil water holding capacity (Lehmann *et al*., 2006; Leach *et al.,* 2010); The use of biochar in the soil has been shown to boost agricultural output without the use of inorganic fertilizers, or with much decreased use of inorganic fertilizer. Environmental benefits of biochar include decreased groundwater pollution, lower cost of water filtration, reduced amounts of waste and higher profitability for farmers. This technology also contributes to food security by increasing crop yields and retaining water in areas prone to drought. The production of wheat varied by many factors like irrigation levels, fertilizers, high yielding varieties and adoption of improved cultural practices like adding biochar. Regardless of nitrogen or water conditions, the addition of biochar increased wheat production under varied mineral fertilization levels. (Alburquerque *et al.,* 2013).

The addition of biochar also significantly increases the content of available water in the soil by increasing the amount of water retained in the soil (field capacity) and allowing plants to draw the soil water content and lower it before wilting (Koide *et al.*, 2015). This is mostly due to the increased capillary water capacity of the soil as a result of biochar application.

Potassium (K) is necessary to many plant functions, including carbohydrate metabolism, enzyme activation, osmotic regulation and efficient use of water, N uptake and protein synthesis and translocation of assimilates. Potassium (K) is an essential nutrient that regulates water balance and improves water intake. Aside from its role in giving pest and disease resistance, it is involved in practically all processes required to support plant life. Potassium has significant effect on dry matter accumulation and productivity of wheat under water stress condition (Baque *et al.,* 2006). Wheat requires potassium for physiological growth and yield development. Sufficient potassium results in stronger wheat straw and assists in grain filling. Potassium has been shown to improve water relations as well as crop yield under water-stressed conditions (Johnson, 1983; Islam *et al.,* 2004).

Many studies have been conducted to evaluate the effect of nutrient management on enhancement of wheat physiology and yield under water stress but the information on the effect of combined management of biochar and potassium is scarce. This study was undertaken to find out the change of growth and yield of wheat through biochar and potassium management under water stress condition.

In light of the aforementioned circumstances of wheat growing in Bangladesh, the current research was carried out with the cultivar of BARI Gom 31 with the following goals in mind:

- To find out the suitable dose of K fertilizer and level of biochar for maximizing yield along with optimum growth of wheat under different irrigation regime, and
- To find out interaction effect of irrigation with biochar and K fertilizer for maximum growth and yield of wheat

CHAPTER 2

REVIEW OF LITERATURE

Biochar has a number of advantages for soil health. Biochar is currently the topic of intense research around the world because it has the potential to be a viable choice for sustainable agriculture due to its ability to operate as a long-term carbon sink in soil and provide agricultural advantages. On the other hand, Potassium (K) is one of the most important plant nutrients, as it is essential for plant growth and physiology. Potassium plays a regulatory role in various metabolic processes such as protein synthesis, glucose metabolism, and enzyme activation, in addition to being a part of plant structure. Potassium (K) significantly reduces the negative effects of drought stress on plants.

However, studies on the impact of biochar and potassium on the response of wheat plant are very limited. Some of the relative and informative works and research findings on cereals and other crops are presented here.

Role of biochar on plant under water stress condition:

For soil health, biochar has a number of benefits. Because of its versatile physicochemical characteristics, biochar is getting attention as a low-cost, sustainable, and emerging material which can be widely used in the fields of energy, agriculture, and environment during the last two decades. Biochar can improve water holding capacity of soil, reduce soil emissions of greenhouse gases, reduce nutrient leaching, reduce soil acidity, and reduce irrigation and fertilizer requirements (Laird, 2010, Novak *et al*., 2009). Modest additions of biochar to soil reduce nitrous oxide N_2O emissions by up to 80% and eliminate methane emissions (Lehmann, 2007a). Biochar could possibly be part of a long-term adaptation strategy, as it could improve soil physical properties including the increase of porosity and water storage capacity, as well as the decrease of bulk density (Lu *et al.*, 2014; Nelissen *et al.*, 2015).

Wheat productivity and soil fertility increases on sustainable basis under wheat-maize-wheat cropping pattern using biochar. The interaction of biochar with synthetic fertilizer and farmyard waste was studied over the course of two years in the field. In comparison to non-biochar, biochar application increased spikes per m^2, grains per spike, 1000 grain weight, grain yield, biological yield, phosphorus use efficiency, and grain phosphorus uptake. Similarly, biochar application increased soil carbon (C), phosphorus (P), and potassium (K). Biochar, used alone or in combination with FYM or mineral nitrogen, boosted wheat yield and yield components, as well as soil quality, under a wheat-maize cropping pattern (Ali *et al.*, 2015). Moreover, biochar decreases soil pH and increases organic matter in soil. Several yield parameters were similar between Bangladesh Agricultural Research Council (BARC) recommended fertilizer and half of BARC recommended fertilizer plus rice straw added treatment. Research revealed that combining rice straw biochar with half of the Bangladesh Agricultural Research Council (BARC) recommended fertilizer had a better effect than single application rice straw biochar and resulted in the highest wheat production in the same treatment. Rice straw biochar has the potential to reduce wheat production's reliance on chemical fertilizers. As a result, using biochar to increase wheat yield in Bangladesh is a realistic choice (Iqbal, 2017).

On the other hand, biochar showed beneficial effect on wheat production in saline sodic soil. The addition of biochars had significant effects on the saturated hydraulic conductivity, infiltration rate, available water capacity, and enhanced the grain yield of wheat. Based on the findings of the study, it was concluded that extremely large volumes of biochar would be required to significantly alter soil physical attributes and boost wheat yield in salt-affected soils (Mahmoud *et al.*, 2017).

Biochar and nitrogen fertilizer showed positive effect on soil physicochemical properties, nitrogen use efficiency and yield of upland rice (*Oryza sativa)*. Result showed that combination of biochar and N fertilizer exerted significant interactive effect on rice harvest index, grain and straw yield and N-use efficiency. Interaction between biochar and N fertilizer increased agronomic efficiency by 140% and grain nutrient recovery by 191% over 2 years. Combination of biochar and N fertilizer reduced soil bulk density, increased water holding capacity and soil chemical status such as pH, N, P, K, Ca, CEC and base saturation, all within the top 10 cm depth of the soil. Overall, the results established that rice husk biochar can be used as a soil conditioner to enhance upland rice yield on an Alfisol (Oladele *et al.*, 2019). Biochar has also impact on rice growth and yield in tropical riparian wetland. Results showed that, applying biochar increased rice yield, but restrained shoot elongation rate and plant height. During the vegetative growth phase, applying biochar significantly increased the number of tillers, leaves, shoot dry weight, and root dry weight. Biochar significantly affected the yield components: number of tillers, percentage of productive tiller, number of grains per panicle, panicle density, percentage of filled grain, and weight of 1,000 grains (Lakitan *et al.*, 2018).

Biochar helps to alleviate the negative effects of drought and salinity stress on soybean productivity and water use efficiency. Drought stress reduced soybean phenology (e.g. flowering time) and all leaf gas exchange metrics significantly, but had mixed impacts on soybean root growth and WUE at the leaf and yield levels. Photosynthetic rate, stomatal conductance, intercellular CO_2 concentration, and transpiration rate were all reduced by salinity stress. Drought and salinity stress slowed photosynthesis, which resulted in lower biomass production and grain yield. In these situation, soybean grain yield was increased with the addition of biochar. Drought stress raised WUE-yield by 27.5 percent and 15.6 percent, respectively, while salinity stress decreased. Soybean productivity and leaf gaseous exchange were negatively affected by drought and salinity stress. However, adding biochar to the mix reduces the deleterious impacts of drought and salinity on soybean productivity and water efficiency. This study's findings indicated that drought stress could drastically reduce soybean growth and production. Drought stress has interaction impacts on soybean yield and water usage efficiency, and biochar can be used to mitigate the unfavorable consequences (Zhang *et al.*, 2020).

Under semiarid climatic conditions the adverse effects of drought at critical wheat growth stages i.e., tillering, flowering and grain filling stage mitigated by using biochar. Results revealed that drought stress significantly affected wheat growth and yield properties at all crucial growth phases, with grain filling being the most vulnerable stage, resulting in substantial yield reduction. Biochar application significantly reduced the negative effects of drought by increasing the number of fertile tillers, spike length, number of grains per spike, thousand grain weight, biological and economic yield. Furthermore, drought-stressed wheat's water use efficiency and physiological characteristics were dramatically improved by biochar. In the end, biochar treatment can be an effective strategy for increasing wheat grain yield by reducing the negative effects of drought stress (Haider *et al.*, 2020).

Role of potassium on plant under water stress condition:

Potassium (K) plays a crucial role in a number of physiological processes that are vital to growth, yield, quality, and stress resistance in all crops (Zo¨rb *et al*., 2014). K is required for a number of physiological activities, including stomatal control and photosynthesis. K has just been discovered to provide abiotic stress tolerance. When exposed to salt, K aids in ion homeostasis and osmotic balance management. K controls stomatal opening in drought-stressed plants, allowing them to adjust to droughts (Hasanuzzaman *et al.*, 2018). During drought stress, root growth and the rates of K+ diffusion in the soil towards the roots were both restricted, thus limiting K acquisition. The resulting lower K concentrations can further depress the plant resistance to drought stress, as well as K absorption. Maintaining adequate plant K is, therefore, critical for plant drought resistance (Wang *et al.* 2013)

Maize (*Zea mays* L., cv. Azam) showed increased growth and productivity due to foliar and soil applied K. Applying foliar K and foliar Zn was helpful in terms of better growth, greater yield, and yield components of maize under moisture stress conditions. Spraying in vegetative stage resulted in better growth and higher yield than spraying in reproductive stage. Soil K treated plots performed better than control (K not applied) in terms of improved growth, higher yield and yield components of maize crop. The findings also show that increasing the rate of soil applied K up to 90 kg ha^{-1} in two equal splits (50 percent at sowing and knee height) improves growth and maize productivity in semiarid conditions (Amanullah *et al.*, 2016). Potassium levels and its application periods had a significant influence on wheat production and yield components. In the case of K timings application, the higher grain yield was achieved when K was applied one time at sowing time. It is concluded that K should be applied in full at sowing for achieving higher wheat production (Ali *et al.*, 2019).

Potassium-Nitrate containing chitosan alleviates drought stress on spinach. Results showed that drought stress decreased physiological parameters and increased oxidative stress indicators in spinach. Applying Potassium nitrate significantly increased root and shoot length, shoot fresh weight and shoot dry weight, chlorophyll a, carotenoids, total soluble proteins, soluble sugars, potassium, and phosphorous concentrations over no potassium nitrate at severe drought. While stress indicators, like glycine betaine, malondialdehyde, hydrogen peroxide, electrolyte leakage, peroxidase, superoxide dismutase, and ascorbic acid levels, were increased in stress. Potassium nitrate treatment was proved efficient and effective in improving spinach physiological status in both mild drought stress and severe drought stress (Bukhkari *et al.*, 2021). In addition, potassium fertilizer showed positive effect on growth, yield and nutrient uptake of wheat variety (Shatabdi) under water stress. Water stress significantly affected dry matter accumulation in leaf, stem, spikes and roots. Also nutrient uptake such as N, P and K was negatively affected in water stress. As a result, the majority of the yield contributing characters were drastically reduced. Higher K levels increased dry matter production in several plant parts. Wheat yield and yield contributing characteristics were also improved as a result of the high quantity of potassium application, regardless of soil moisture conditions. Nutrient uptake was also increased with increasing levels of K application especially under water stress condition. High potassium application could enhance wheat production by reducing the negative impacts of water stress (Baque *et al.*, 2006).

Potassium fertilizers such as K-Silicate, K-Citrate and K-Nitrate showed effect on biochemical changes of growth and yield parameters of some sensitive barley varieties (Giza 125, Tombari, Ksar Megrine, Tamellat) under water stress conditions. Water stress has a negative effect on yield characters of barley varieties. Application of K Citrate followed by K Silicate gained the highest values of the yield and yield components under water stress treatment, while the opposite was true in case of the control. Nitrogen, phosphorus and protein content in barley grain of the examined varieties were higher under normal than water stress ones, where barley Giza 125 scored the highest nitrogen values and protein content under water stress conditions. The barley varieties Tombari and Ksar Megrine gained the highest values for most studied stress tolerance indices indicating enhancement in their drought tolerance after application of K-Citrate and the opposite was true in case of K Silicate applied for barley Giza 125 and Tamellat. It can be concluded that application of potassium fertilizers enhances yield of every barley variety under water stress (Hellal *et al.*, 2020).

In another finding, Potassium silicate (K-silicate) increased maize productivity and water use efciency (WUE). The highest yield was obtained by spraying K-silicate three times on the leaves. Even when water was scarce, irrigation every fifteen days combined with three foliar applications of K-silicate resulted in the maximum grain yield and component values. These findings suggest that using K-silicate to boost WUE and create a high grain yield with minimal watering is possible (Gomaa *et al.*, 2021). Tobacco plant that grown under drought stress condition showed optimum shoot growth only after application of potassium, whereas root biomass and length responded under both watering regimes. Analyses of water relation parameters in different aged leaves showed lower susceptibility of the middle-aged leaves to both K deficiency and drought stresses than the upper and lower leaves; this phenomenon was accompanied by a more conservative control of water loss in the middle-aged leaves. In contrast, proline was accumulated in the young leaves, and K application increased it further. Although various organic osmolytes were accumulated under the combinative effect of K deficiency and drought stress, they did not exceed the amounts found in the control (well-watered +K) plants and were merely a result of the concentration effect. The majority of leaf biochemical responses to drought stress are developmentally controlled mechanisms, according to the findings. Furthermore, the relieving effect of both RA and LA despite greater water loss indicated that better stomatal function following K treatment permitted carbohydrates synthesis, hence boosting plant growth under water stress (Bahrami and Hajiboland, 2017).

Foliar potassium influences wheat productivity under water stress condition. The yield and nutrient uptake performance of two wheat (*Triticum aestivum* L.) varieties (Pirsabak-2013 and Atta Habib) to foliar feeding of 2% potassium (K) at three various growth phases of wheat (Zadoks Growth Scale-22, Zadoks Growth Scale-60 and Zadoks Growth Scale-73) was explored under water restricted environment. According to the findings, drought stress had an unfavorable effect on plant height, spike length, number of spikelets per spike, number of grains per spike, 1000-grain weight, grain production, and nutrient uptake of the wheat plant during all three acute growth stages. The exogenous K application under drought stress at all three acute growth phases boosted tolerance of wheat by decreasing noxious nutrient’s uptake and augmenting the yield and yield characters. In this regard, both types demonstrated unusual behavior. When K was applied during the grain filling stage of both kinds, it resulted in a dramatic improvement in all of the documented yield parameters and nutrient uptake (Shah *et al.*, 2017).

Role of biochar and potassium management on plant under water stress condition:

Potassium (K) is absorbed by the plants from relatively dilute soil solutions. However, because biochar can boost soil CEC, it can improve the soil's ability to hold K and store it for plant absorption (Gunaratne *et al.* 2017). Furthermore, biochar may include exchangeable Potassium for plant absorption. K content in plant biomass had increased by 57 percent one year following biochar application, whereas manure application had increased by 43 percent at the same time period (Lentz and Ippolito 2012). A great availability of Potassium in soil, soon after biochar application, has been reported (Cheng *et al.*, 2008). Furthermore, K absorption by maize grain was significantly increased following the application of cow manure biochar (Uzoma *et al.*, 2011). Several researchers suggested that increased K availability in soil could be attributed to enhanced soil pH by biochar (Manolikaki and Diamadopoulos 2016; Smider and Singh 2014). The increase in soil pH may cause less accessible Potassium Ion to be released into the soil solution, as it remains strongly linked to the clay particles. The K given by biochar has been shown to boost rice and cowpea biomass. (Lehmann *et al.,* 2003a). Biochar produced from plant biomass increased Potassium uptake in common bean (Rondon *et al.*, 2007). Additionally, increased K concentrations in legume biomass have been recorded following the addition of grass-derived biochar. In the same study, it had been found that available K in biochar applied treatment soils was even exceeding concentrations in the treatments that received K fertilizer (Oram *et al.,* 2014). The authors had highlighted that decrease in net nitrification resulted reduced N uptake and thereby enhanced K uptake as there could be a competition in legume plants for N and K. Particularly, fresh biochar is considered to have available K that can be rapidly taken by plants (Karer *et al.,* 2013). However, some researchers have suggested that high availability of K for plants with biochar may not persist beyond the year after application (Steiner *et al.*, 2007).

In moderate acidic soil, biochar and potassium alleviate nutrient stress on maize growth. Study showed that biochar addition increased soil moisture, potassium (K) and plant available phosphorous (P), which all showed significant positive relationship with above ground biomass of maize. However, biochar was much more effective at abundant soil watering (+311% biomass) than at water-starved conditions (+67% biomass), indicating that biochar did increase soil moisture, though this was not the main reason for the positive biomass growth effects (Pandit *et al.*, 2018). Another study showed, residual effect of potassium fertilizer and biochar on growth and yield of maize. Through a field experiment on an Inceptisol showing that application of biochar can increase availability of plant nutrients and yield. The findings revealed that residual biochar, alone or in combination with various levels of potassium application, increased maize yield. Also, the availability of N, P, K, Ca, and Na in the soil was increased by residual biochar (Widowati *et al.*, 2017).

A combination of Potassium Solubilizing Bacteria (KSB) and biochar showed effect on growth indices and Phosphorous, Potassium and chlorophyll content in sorghum under drought stress. It stated that, drought has become a major danger to crop production in recent years, particularly in arid and semi-arid countries. In this context, appropriate macronutrient availability and uptake, as well as soil moisture conservation, are important considerations. At 30 percent of field capacity moisture level, KSB and biochar boosted plant height, root length, shoot fresh biomass, root fresh biomass, potassium, and phosphorus content shoots increased over control. At a moisture level of 30% of field capacity, chlorophyll a and chlorophyll b content were found higher than control. The combined application of KSB and biochar is found to be extremely beneficial in enhancing sorghum growth under drought conditions (Hye *et al*., 2020). Biochar and Potassium also showed positive impact in acidified paddy soils by verifing the connection between tobacco potassium (K) accumulation and soil chemical properties along with K bacteria activity for biochar addition. Biochar was added once into the soil to evaluate the release and transformation characteristics of K and tobacco growth sown in paddy soil. Compared to K accumulation value from the control treatment, applied Biochar improved K accumulation value in each year. It also improved tobacco plant height and roots fresh weight. Besides, it increased soil available potassium for three consecutive years. In conclusion, addition of Biochar is seemed beneficial to improve soil K status, tobacco growth and K contents of tobacco leaf (Zhang *et al.*, 2020).

CHAPTER 3
MATERIALS AND METHOD

This experiment was conveyed at the Research Field of Sher-e- Bangla Agricultural University (SAU), Dhaka-1207, during the period of November 27, 2019 to March 21, 2020. This chapter shows a brief description on experimental site, experiment period, climatic condition, experimental design and layout, land preparation, intercultural operations, data collection and their statistical analysis.

3.1 Experimental Site Description

3.1.1 Location

During the Rabi season of 2019, the experiment was carried out at the Sher-e-Bangla Agricultural University farm in Dhaka, under the Agro-ecological zone of Madhupur Tract, AEZ-28. The land area is located at 23°41′N latitude and 90°22′E longitude at an elevation of 8.6 meters above sea level. The experimental site is shown in the AEZ Map of Bangladesh in Appendix 1.

3.1.2 Soil

The texture of the top soil was silty clay, olive-gray in color with fine to medium noticeable dark yellowish brown mottles. The pH of the soil ranged from 5.48 to 5.63, with 0.44 percent organic carbon. The test area was flat, with an irrigation and drainage system in place, and was above flood levels (Appendix 3). The chosen plot was a medium-high piece of land.

3.1.3 Climate

The experimental site was in the subtropical monsoon climatic zone, with winter months from November to April separating it from the rest of the year (Rabi season). During the trial period, there is plenty of sunshine and a rather cool temperature, ideal for wheat cultivation in Bangladesh.

3.2 Planting Materials

BARI Gom 31 was the wheat cultivar used in this investigation. This variety's seeds collected from the Bangladesh Agricultural Research Institute (BARI) in Gazipur. This variety was first introduced in 2017. The variety is high yielding, matures early and is tolerant to terminal heat stress. The variety is BLB disease tolerant and resistant to leaf rust.

3.3 Treatments

The experiment consists of two factors and they were different level of irrigation and biochar and K management. Four different levels of irrigation and four biochar and K management were used under the present study. The treatments of the experiment were as follows:

Factor A: Level of Irrigation

1. I_0 = Control (without irrigation)

2. I_1 = Irrigation at crown root initiation stage

3. I_2 = Irrigation at crown root initiation stage and flowering stage

4. I_3 = Irrigation at crown root initiation stage, flowering stage and grain filling stage

Factor B: Biochar and Potassium(K) management

1. B_0K_0 = Biochar: 5 t ha^{-1} and K: 0 kg ha^{-1}

2. B_1K_1 = Biochar: 5 t ha^{-1} and K:48 kg ha^{-1}

3. B_2K_2 = Biochar: 5 t ha^{-1} and K:36 kg ha^{-1}

4. B_3K_3 = Biochar: 0 t ha^{-1} and K: 48 kg ha^{-1}

3.4 Description of field operations

3.4.1 Land preparation

On November 27, 2019, the final land was prepared after repeated ploughing with a power tiller and a country plough. Plowing was followed by laddering, which was used to break up clods and level the ground. The experimental plot was cleaned of all weeds, stubbles, and agricultural residues. The experiment was set up according to statistical design.

3.4.2 Experimental design

The experiment was designed as a Split-plot with three replications. To indicate replications, the field was divided into three blocks. Each block was divided into four main plots for irrigation treatments, and each main plot was divided into 4 sub-plots for Biochar and Potassium management treatments. Each unit plot was 2 m x 1 m in size. The space between rows was 75cm. The layout of the experiment has been shown in Appendix 2.

3.4.3 Fertilizer application

The following doses of manure and fertilizers were used:

Cowdung: 10 t ha^{-1}

Biochar: as per treatment

Urea: 220 kg ha^{-1}

TSP: 150 kg ha^{-1}

MoP: as per treatment

Gypsum: 110 kg ha^{-1}

Zinc oxide: 4 kg ha^{-1}

Boric acid: 5 kg ha^{-1}

Cowdung was applied 10 days before final land preparation. The unit plots were fertilized with Biochar (as per treatment), Urea, TSP, MoP (as per treatment), Gypsum, Zinc Oxide, Boric acid. Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MoP) and gypsum were used as source of nitrogen, phosphorus and potassium, and sulfur respectively. One-third of the urea and the whole amount of Biochar (as per treatment), triple super phosphate (TSP), Gypsum Zinc oxide, Boric acid and muriate of potash (as per treatment) were incorporated in each plot (except control plot in case of Biochar and MoP) at the time of final land preparation. Rest two third of urea was applied in two equal splits at crown root initiation stage (21 DAS) and spike initiation stage (55 DAS).

3.4.4 Preparation and application of biochar

Biochar was bought from Manikgonj. After that, it was powdered and sieved before being used in the field. Then, at the time of final field preparation, biochar was put to the soil of each (except control) plot in accordance with the treatment dosages (5 t ha^{-1}), along with other fertilizers.

3.4.5 Collection and sowing of seeds

As per treatment seeds of wheat variety (BARI Gom 31) were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur. Furrows were prepared with hand rakes under good tilth conditions for sowing. Seeds were treated with Provax 200-EC @ 2.5 g powder per kg seed prior to sowing. Seeds were sown continuously in line having a depth of 2-3 cm from the soil surface on 27 November 2019 @ 125 kg ha^{-1}. The line to line distance was maintained 25 cm. After sowing, the seeds were covered with soil and lightly pressed by hand.

3.4.6 Fencing of experimental field

The entire experimental area was surrounded by a net to keep birds and other animals out.

3.5 Cultural and Management Practices:

3.5.1 Irrigation and drainage

In this experiment, irrigations were delivered according to the treatment. For I_0 leveled plot no irrigation was provided, for I_1 leveled plot one irrigation was provided at 20 DAS (at crown root initiation-CRI stage), for I_2 leveled plot two irrigation provided at 20 DAS (at crown root initiation-CRI stage) and 55 DAS (at flower initiation stage) and for I_3 leveled plot three irrigation was provided at 20, 55 and 75 DAS (at crown root initiation stage, flowering stage and at grain filling stage). During irrigation, sufficient care was taken to ensure that water can't run from one plot to another or overflow the plot's boundaries. The field's excess water was drained.

3.5.2 Weeding, mulching, thinning

Weeding and mulching were required to keep the plots weed-free and to retain soil moisture. Weeding was done twice during the growing period, the first time after 20 days and the second after 40 days. Mulching was done after sowing and when needed. Thinning was done carefully in each unit plot once to maintain a balanced plant population in each plot. Thinning was carried out at 20 DAS (Days after sowing).

3.5.3 Sampling

From each plot, five plants were chosen at random. Data on growth and yield characteristics were collected from the five sample plants.

3.5.4 Insect and pest control

Throughout the growing season, the crop was attacked by some insects (cereal aphid, grass hopper, and fall armyworm). To control the Aphids, the experimental plot was sprayed 35 days later with Aktara 25 WG. After watering in the afternoon at 60 DAS, Virtako insecticides were applied to the plots.

3.5.5 Harvesting and post-harvest operations

The crop was harvested when the leaves and stems turned yellowish in color manually from each plot 21 March, 2020. Each plot's harvested crop was bagged separately, carefully labelled, and carried to the threshing floor. Enough care was taken during threshing and cleaning period of wheat grain. The grains were cleaned and weighted. The weight was adjusted to a moisture content of 14%. The straw was sun dried and the yields of wheat grain and straw from one m^2 area per plot were recorded and converted to t ha^{-1}.

3.6 Data Collection

3.6.1 Growth parameters

1. Plant height (cm)
2. No. of tillers/plant
3. Leaf Area Index (LAI)

3.6.2 Yield parameters

1. Ear length (cm)
2. No. of spikelets/ear
3. No. of grains/ear
4. 1000-grain weight (g)
5. Grain yield (t ha^{-1})
6. Straw yield (t ha^{-1})
7. Harvest index (%)

3.6.1.1 Plant height(cm)

The heights of five sampled plants were measured with a meter scale from the ground level to the top of the plants and the mean height was recorded in centimeter. The plant height was measured at 20, 40, 60, 80 DAS and at harvest.

3.6.1.2 No. of tillers/plant

At 40, 60, 80 DAS and at harvest the number of total tiller per plant counted from five sampled plant separately and then averaged.

3.6.1.3 Leaf Area Index (LAI)

Leaf area index was estimated measuring the length and width of leaf and multiplying by a factor 0.75 as suggested by Yoshida (1981). Data were counted from five sampled plant separately at 40, 60 and 80 Days after sowing (DAS) and then averaged.

3.6.2.1 Ear length (cm)

After harvest, ear length was measured with a meter scale from the base level to the top of the ear on five sampled plants, and the mean length was represented in centimeters.

3.6.2.2 No. of spikelets/ear

Total number of spikelets per ear were counted from five sampled plants and then averaged and presented as number of spikelets/ear.

3.6.2.3 No. of grains/ear

Total number of grains was counted by observing from each spikelets that was obtained from pre-selected five plants. After that it was averaged and presented as number of grains/ear.

3.6.2.4 1000-grain weight (g)

One thousand cleaned dried seeds were counted randomly from harvest area of each plot and weighed by using digital electric balance and the mean weight was expressed in gram.

3.6.2.5 Grain yield (t ha^{-1})

Wheat was harvested from selected $1m^2$ area of land of each plot. Then the seeds were threshed, cleaned and sun-dried. After that the grain yield recorded and converted into t ha^{-1}.

3.6.2.6 Straw yield (t ha^{-1})

Straw from each individual plot was dried and properly weighed. The straw yield was then converted to t ha^{-1}.

3.6.2.7 Harvest index (%)

Harvest index was calculated from per hectare grain yield and straw yield that were obtained from each unit plot and expressed in percentage using the following formula-

$$HI = \frac{Grain\ Yield}{Biological\ Yield} \times 100$$

Here, Biological yield (t ha^{-1}) = Grain Yield (t ha^{-1}) + Straw Yield (t ha^{-1})

3.7 Analysis of data

The data obtained for different parameters were statistically analyzed following computer based software Statistix 10 and mean separation was done by LSD at 5% level of significance.

CHAPTER 4

RESULT AND DISCUSSION

This chapter presents and discusses the outcome of the study for various growth and yield parameters of wheat (BARI Gom 31) under water stress conditions which were influenced by different irrigation levels and different doses of biochar and Potassium (K), as well as other analyses. Data on different crop characteristics have been presented through Figures (1-12) and Tables (1-7). The analysis of variance on different parameters have been presented in Appendices (4-22).

4.1 Crop growth parameters

4.1.1 Plant height (cm)

4.1.1.1 Effect of irrigation

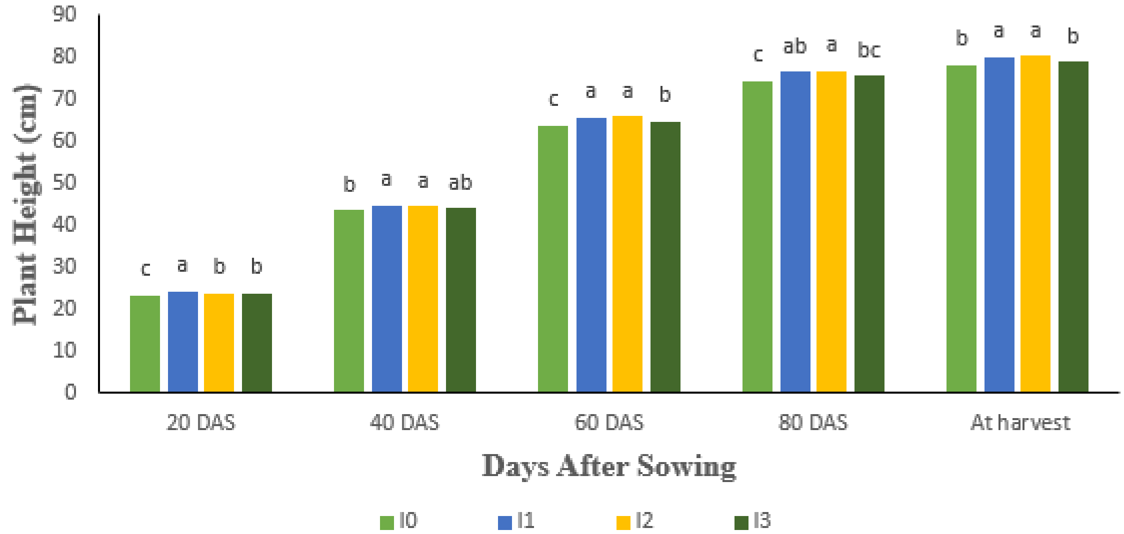
Plant height of wheat was influenced significantly in different stage of growth due to different levels of irrigation (Figure. 1). At 20 DAS, the tallest plant height was 24.30 cm that recorded from I_1 (one irrigation) and the shortest plant (23.44 cm) recorded from I_0 (no irrigation). And data recorded 23.83 cm and 23.74 cm obtained from I_2 (two irrigation) and I_3 (three irrigation), respectively were statistically similar. At 40 DAS the longest (44.67 cm) and shortest plant (43.64 cm) was recorded from I_1 (one irrigation) and I_0 (no irrigation) respectively. Accordingly, at 60 DAS, 80 DAS and at harvest the longest (65.97, 76.77, 80.30 cm) and the shortest (63.81, 74.30, 78.10 cm) plant heights were measured from I_2 (two irrigation) and I_0 (no irrigation) respectively. Irrigation at critical stages is important for plant height. Hwary and Yagoub (2011) and Dang *et al.* (2012) studied the impact of irrigation at various stages of wheat plant growth and observed that irrigation at various levels had a substantial impact on plant height.

4.1.1.2 Effect of Biochar and Potassium (K) management

Because of different dosages of biochar and K, plant height varied significantly (Figure 2.). At 20, 40, 60, 80 DAS and at harvest the highest plant height (26.41,48.38, 69.07,79.85 and 85.02 cm respectively) were recorded from B_2K_2 (K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}) followed by B_1K_1 (K:48 kg ha^{-1}+ Biochar: 5 t ha^{-1}) and B_3K_3 (K: 48 kg ha^{-1} + Biochar: 0 t ha^{-1}). And the lowest plant height (at 20.40,60,80 and at harvest were 21.50, 39.93, 60.48, 70.38, 73.12 cm respectively) were recorded from B_0K_0 (K: 0 kg ha^{-1} + 5 t ha^{-1} biochar). Zee *et al.* (2017), Iqbal (2017), Li and Shangguan (2018) analyzed the effect of biochar and observed that varying levels of biochar application boosted wheat plant height. Saren and Jana (2008) discovered that applying 50 kg of potassium per hectare as a top dressing after irrigation resulted in the longest plant.

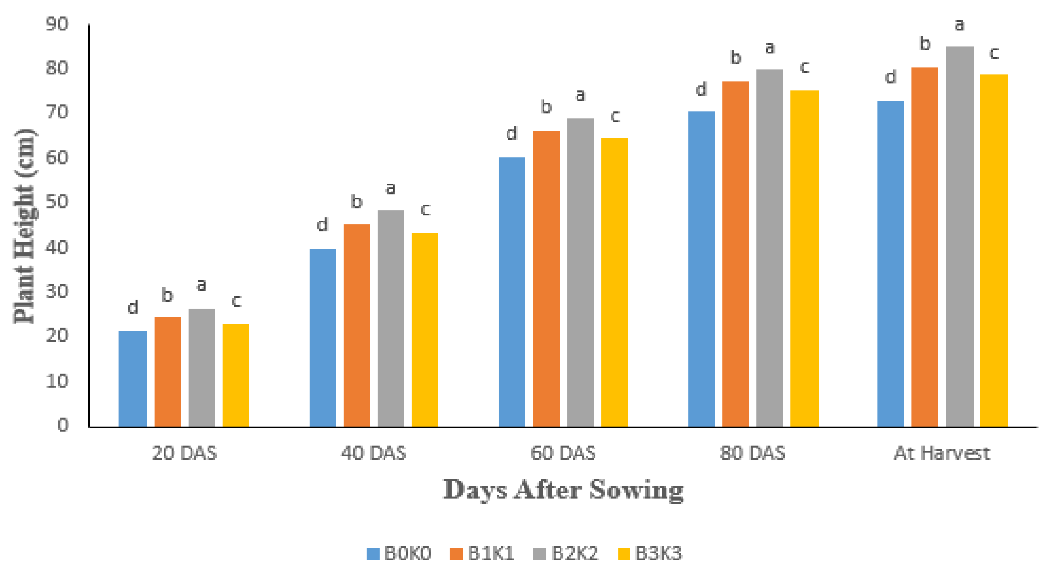
4.1.1.3 Interaction effect of irrigation and Biochar and Potassium (K) management

Interaction effects of different levels of irrigation and biochar and potassium (K) on plant height showed significant differences (Table 1). The highest plant height is showed at 20, 40, 60, 80 and at harvest were 27.08, 49.12, 70.81, 81,83 and 87.42 cm respectively from $I_2B_2K_2$ (two irrigations with K:36 kg ha^{-1} + Biochar: 5 t ha^{-1}). And the lowest height (20.67, 35.95, 54.47, 63.45 and 67.03 cm at 20,40,60,80 DAS and at harvest respectively) recorded from $I_0B_0K_0$ (no irrigation with K: 0 kg ha^{-1} + 5 t ha^{-1} Biochar). Without irrigation and potassium plant height drastically reduced.



Here, **I_0** = Control, **I_1**= Irrigation at crown root initiation stage, **I_2**= Irrigation at crown root initiation stage + Flowering stage, **I_3**= Irrigation at crown root initiation stage + Flowering stage + Grain filling stage.

Figure 1. Influence of different levels of irrigation on plant height at different stages of wheat ($LSD_{0.05}$= 0.1921, 0.550, 0.847, 1.261 and 1.027 at 20,40,60,80 DAS and at harvest respectively).



Here, **B_0K_0**=5 t ha^{-1} Biochar + 0 kg ha^{-1} K, **B_1K_1**=5 t ha^{-1} Biochar + 48 kg ha^{-1}, **B_2K_2**= 5 t ha^{-1} Biochar + 36 kg ha^{-1} K, **B_3K_3**= 0 t ha^{-1} Biochar + 48 kg ha^{-1} K,

Figure 2. Influence of biochar and potassium (K) management on plant height at different stages of wheat ($LSD_{0.05}$= 0.506, 0.692, 0.862, 1.181 and 0.841 at 20,40,60,80 DAS and at harvest respectively)

Table 1. Interaction effects of Irrigation and Biochar and Potassium(K) on plant height at different growth stage of wheat:

Interactions	Plant height (cm)				
	20DAS	40DAS	60DAS	80DAS	At Harvest
$I_0 B_0 K_0$	20.67 k	35.95 j	54.47 l	63.45 k	67.03 j
$I_0 B_1 K_1$	23.97 ef	46.14 c	66.92 c-e	78.23 b-e	81.56 de
$I_0 B_2 K_2$	26.19 ab	48.34 ab	68.43 bc	79.31 b	84.24 bc
$I_0 B_3 K_3$	22.93 g-i	44.14 d-f	65.43 e-h	76.23 e-g	79.57 f-h
$I_1 B_0 K_0$	22.31 ij	42.10 gh	62.41 jk	72.93 ij	75.05 i
$I_1 B_1 K_1$	25.21 cd	45.30 cd	66.65 c-e	77.43 b-f	81.28 d-f
$I_1 B_2 K_2$	26.60 ab	48.43 ab	69.47 ab	79.72 ab	85.59 b
$I_1 B_3 K_3$	23.07 g-i	42.83 fg	64.79 f-h	75.95 e-h	78.61 gh
$I_2 B_0 K_0$	21.05 k	41.39 hi	62.91 i-k	73.77 hi	75.85 i
$I_2 B_1 K_1$	24.47 de	44.76 de	66.23 d-f	77.09 c-f	79.96 e-g
$I_2 B_2 K_2$	27.08 a	49.12 a	70.81 a	81.83 a	87.42 a
$I_2 B_3 K_3$	22.71 h-j	43.04 fg	63.92 h-j	74.37 g-i	77.96 h
$I_3 B_0 K_0$	21.97 j	40.26 i	62.13 k	71.35 j	74.56 i
$I_3 B_1 K_1$	23.68 e-g	44.45 de	65.72 e-g	76.80 df	79.57 f-h
$I_3 B_2 K_2$	25.76 bc	47.63 b	67.55 cd	78.53 b-d	82.79 cd
$I_3 B_3 K_3$	23.54 f-h	43.79 ef	64.22 g-i	75.24 f-i	78.50 gh
$LSD_{0.05}$	1.01	1.383	1.724	2.363	1.683
CV(%)	2.52	1.86	1.57	1.85	1.26

DAS= Days after sowing. In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.

Here, $\mathbf{I_0}$ = Control, $\mathbf{I_1}$= Irrigation at crown root initiation stage, $\mathbf{I_2}$= Irrigation at crown root initiation stage + Flowering stage, $\mathbf{I_3}$= Irrigation at crown root initiation stage + Flowering stage + Grain filling stage.

Here, $\mathbf{B_0K_0}$=5 t ha^{-1} Biochar + 0 kg ha^{-1} K, $\mathbf{B_1K_1}$=5 t ha^{-1} Biochar + 48 kg ha^{-1}, $\mathbf{B_2K_2}$= 5 t ha^{-1} Biochar + 36 kg ha^{-1} K, $\mathbf{B_3K_3}$= 0 t ha^{-1} Biochar + 48 kg ha^{-1} K,

4.1.2 Number of tillers/plant

4.1.2.1 Effect of irrigation

Different levels of irrigation varied significantly in terms of number of tillers/plant of wheat at 40 ,60, 80 DAS and at harvest in this experiment (Figure 3). At 40 DAS the highest number of tillers/plant viz. 2.77 was recorded from I_2 (two irrigation) which is statistically similar to I_3. But in case of 60, 80 DAS and at harvest the highest number of tillers/plant *viz.* 4.90, 6.01 and 5.76 were recorded from I_3 (three irrigation) which are statistically similar to I_2 (two irrigation). While corresponding the lowest number of tillers/plant (2.05, 3.78, 4.63 and 4.40 at 40, 60, 80 DAS and at harvest respectively) was recorded in I_0 (no irrigation). However, I_1 (one irrigation) showed intermediate result. The current study's findings are consistent with those of Sher and Parvender (2006), who showed that increased irrigation levels increased the number of tillers/plant.

4.1.2.2 Effect of Biochar and Potassium (K) management

The number of tillers/plant were significantly influenced by different doses of Biochar and Potassium (K) management (Figure 4). At 40, 80 DAS and at harvest in this experiment the number of tillers/plant were the highest (2.83, 5.97, 5.73) respectively at B_2K_2 (36 kg ha^{-1} K with 5 t ha^{-1} biochar). At 60 DAS the highest number of tillers/plant *viz.* 4.90 was recorded from B_1K_1 (48 kg ha^{-1} K with 5 t ha^{-1} biochar). Data recorded from B_1K_1 and B_2K_2 were statistically similar. On the other hand, B_0K_0 (no Potassium with 5 t ha^{-1} biochar) showed the lowest number of tiller/plant (2.13, 3.93, 4.88, 4.65 at 40, 60, 80 DAS and at harvest respectively). Meanwhile, B_3K_3 (no biochar with 48 kg ha^{-1} K) showed intermediate result.

4.1.2.3 Interaction effect of irrigation and Biochar and Potassium (K) management

Interaction effects of different levels of irrigation and biochar and potassium (K) on no. of tillers/plant indicated significant differences (Table 2). The highest no. of tillers/plant were showed at 40, 60, 80 DAS and at harvest were 3.47, 5.53, 6.80 and 6.60 respectively from $I_2B_2K_2$ (two irrigations with K:36 kg ha^{-1} + Biochar: 5 t ha^{-1}). On the other hands, the lowest no. of tillers/plant (1.87, 3.27, 4.40 and 4.13 at 40, 60, 80 DAS and at harvest respectively) were obtained from $I_0B_0K_0$ (no irrigation with K: 0 kg ha^{-1} + 5 t ha^{-1} biochar). From this result of interaction effect it reveals that irrigation at crown root initiation and flowering stage with 5 t ha^{-1} biochar and 36 kg ha^{-1} K showed the best result.

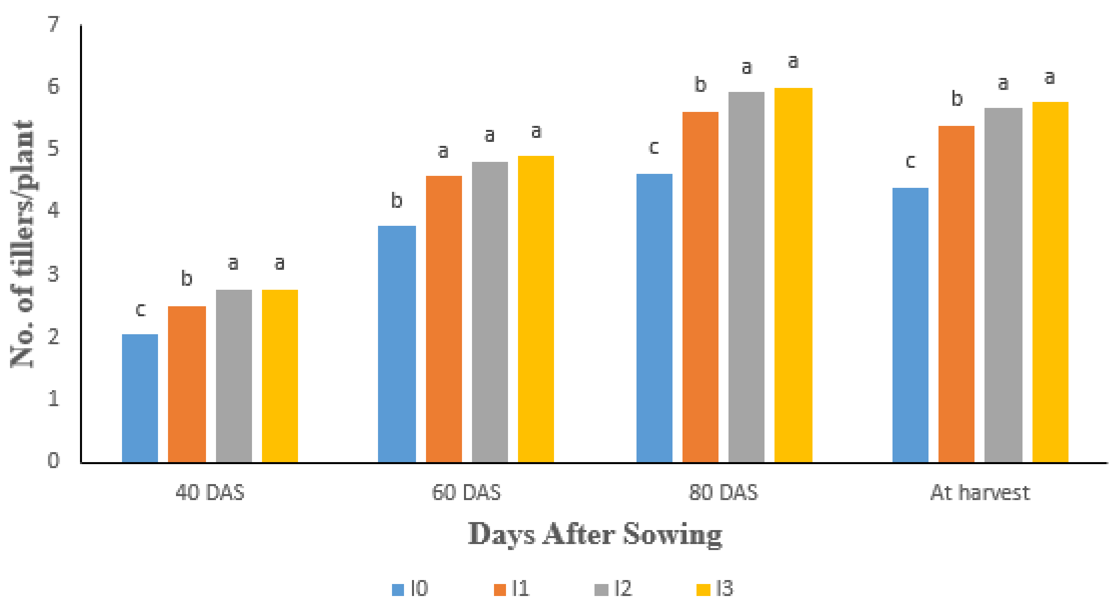
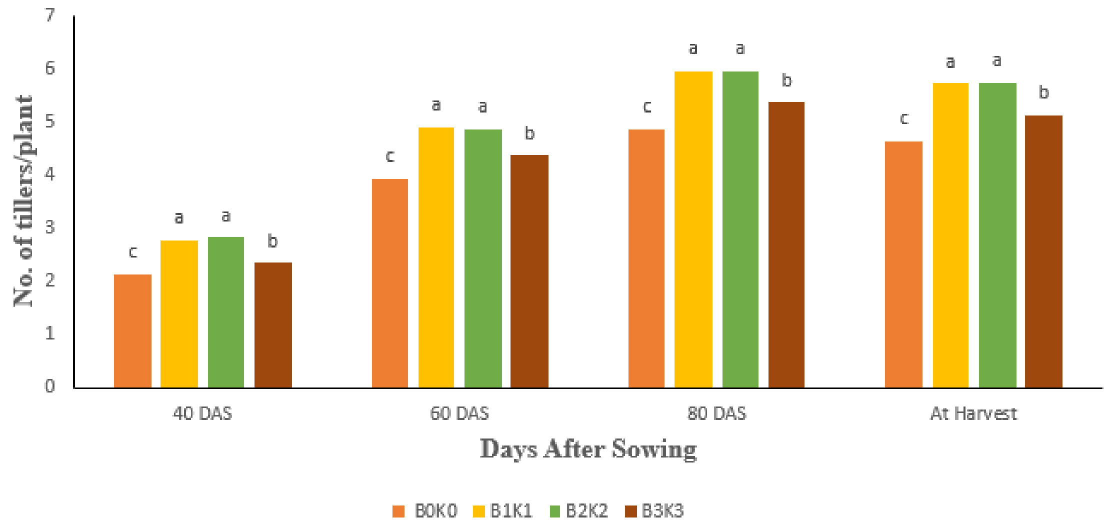


Figure 3. Influence of different levels of irrigation on no. of tillers/plant at different stages of wheat ($LSD_{0.05}$= 0.145, 0.362, 0.240, and 0.130 at 40,60,80 DAS and at harvest respectively)

Here, $\mathbf{I_0}$ = Control, $\mathbf{I_1}$= Irrigation at crown root initiation stage, $\mathbf{I_2}$= Irrigation at crown root initiation stage + Flowering stage, $\mathbf{I_3}$= Irrigation at crown root initiation stage + Flowering stage + Grain filling stage.



Here, **B0K0**=5 t ha^{-1} Biochar + 0 kg ha^{-1} K, **B1K1**=5 t ha^{-1} Biochar + 48 kg ha^{-1}, **B2K2**= 5 t ha^{-1} Biochar + 36 kg ha^{-1} K, **B3K3**= 0 t ha^{-1} Biochar + 48 kg ha^{-1} K,

Figure 4. Influence of biochar and K management on no. of tillers/plant at different stages of wheat ($LSD_{0.05}$= 0.146, 0.162, 0.108, and 0.106 at 40,60,80 DAS and at harvest respectively)

Table 2. Interaction effects of Irrigation and Biochar and Potassium (K) on no. of tillers/plant at different growth stages of wheat:

Interactions	No. of tillers/plant			
	40DAS	60DAS	80DAS	At Harvest
$I_0 B_0 K_0$	1.87 k	3.27 k	4.40 i	4.13 i
$I_0 B_1 K_1$	2.20 h-j	4.33 gh	5.13 ef	5.00 g
$I_0 B_2 K_2$	2.13 i-k	3.80 j	4.53 hi	4.33 hi
$I_0 B_3 K_3$	2.00 jk	3.73 j	4.47 i	4.13 i
$I_1 B_0 K_0$	2.20 h-j	4.13 hi	5.07 fg	4.87 g
$I_1 B_1 K_1$	2.67 d-f	4.73 de	5.93 d	5.60 e
$I_1 B_2 K_2$	2.73 c-e	4.93 cd	6.07 cd	5.87 d
$I_1 B_3 K_3$	2.40 f-i	4.53 e-g	5.40 e	5.27 f
$I_2 B_0 K_0$	2.13 i-k	3.93 ij	4.80 gh	4.53 h
$I_2 B_1 K_1$	2.93 cd	5.13 bc	6.27 bc	6.00 cd
$I_2 B_2 K_2$	3.47 a	5.53 a	6.80 a	6.60 a
$I_2 B_3 K_3$	2.53 e-g	4.67 d-f	5.80 d	5.53 e
$I_3 B_0 K_0$	2.33 g-i	4.40 f-h	5.27 ef	5.07 fg
$I_3 B_1 K_1$	3.27 ab	5.40 b	6.53 ab	6.27 b
$I_3 B_2 K_2$	3.00 bc	5.27 abc	6.47 b	6.13 bc
$I_3 B_3 K_3$	2.47 e-h	4.53 e-g	5.80 d	5.60 e
$LSD_{0.05}$	0.292	0.324	0.218	0.212
CV (%)	6.87	4.25	2.33	2.37

DAS= Days after sowing. In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.

Here, I_0 = Control, I_1= Irrigation at crown root initiation stage, I_2= Irrigation at crown root initiation stage + Flowering stage, I_3= Irrigation at crown root initiation stage + Flowering stage + Grain filling stage.

Here, B_0K_0=5 t ha^{-1} Biochar + 0 kg ha^{-1} K, B_1K_1=5 t ha^{-1} Biochar + 48 kg ha^{-1}, B_2K_2= 5 t ha^{-1} Biochar + 36 kg ha^{-1} K, B_3K_3= 0 t ha^{-1} Biochar + 48 kg ha^{-1} K,

4.1.3 Leaf Area Index (LAI)

4.1.3.1 Effect of irrigation

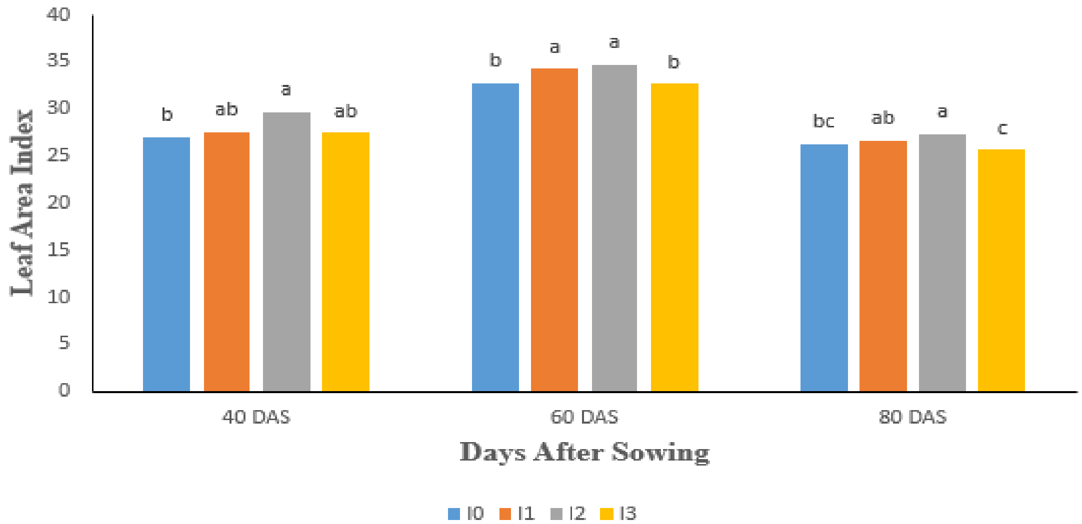
Leaf area index was significantly affected by different irrigation levels (Figure 5). The highest leaf area index was found from I_2 (two irrigation) at 40, 60 and 80 DAS (29.71, 34.75, 27.33 respectively). And lowest leaf area index was recorded 27.04 at 40 DAS from I_0 (no irrigation), 32.72 and 25.7 at 60 and 80 DAS respectively from I_3 (three irrigation). It is shown that LAI increased up to 60 DAS the it decreased in 80 DAS at all irrigation treatment. With maximum irrigation leaf area index showed highest value.

4.1.3.2 Effect of Biochar and Potassium (K) management

Different doses of biochar and K had also significant effect on leaf area index at 40, 60 and 80 DAS (Figure 6). The highest value was found from B_2K_2 (K:36 kg ha^{-1} + Biochar: 5 t ha^{-1}) at 40, 60 and 80 DAS (31.08, 38.47 and 31.45 respectively). And the lowest leaf area index was found from B_0K_0 (K: control + 5 t ha^{-1} biochar). In case of 40 DAS, LAI of B_1K_1 and B_3K_3 was statistically similar whereas, at 60 DAS and 80 DAS all treatment showed significantly different records.

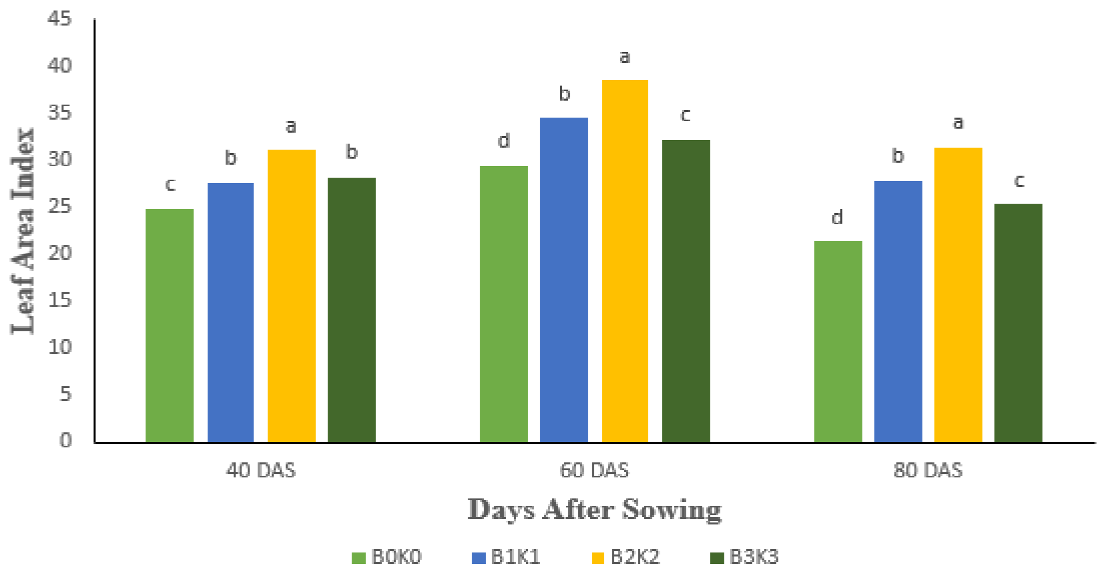
4.1.3.3 Interaction effect of irrigation and Biochar and Potassium (K) management

The interaction effects of varied degrees of irrigation, biochar, and potassium (K) on the Leaf Area Index (LAI) reported significant variances (Table 3). The highest were showed at 40, 60 and 80 DAS were 32.15, 42.41 and 34.23 respectively from $I_2B_2K_2$ (two irrigations with K:36 kg ha^{-1} + Biochar: 5 t ha^{-1}). On the other hands, the lowest leaf area index (22.46, 26.29 and 19 at 40, 60 and 80 DAS respectively) were obtained from $I_0B_0K_0$ (no irrigation with K: control + 5 t ha^{-1} biochar). Based on the interaction impact, irrigation at the crown root initiation and flowering stages with 5 t ha^{-1} biochar and 36 kg ha^{-1} K showed the greatest results. As both biochar and potassium increase water holding capacity of soil with two irrigations with biochar and potassium management shows highest leaf area index.



Here, **I$_0$** = Control, **I$_1$**= Irrigation at crown root initiation stage, **I$_2$**= Irrigation at crown root initiation stage + Flowering stage, **I$_3$**= Irrigation at crown root initiation stage + Flowering stage + Grain filling stage.

Figure 5. Influence of different levels of irrigation on Leaf area index(LAI) at different stages of wheat (LSD$_{0.05}$= 2.392, 1.475, and 0.7635 at 40,60 and 80 DAS respectively)



Here, **B$_0$K$_0$**=5 t ha^{-1} Biochar + 0 kg ha^{-1} K, **B$_1$K$_1$**=5 t ha^{-1} Biochar + 48 kg ha^{-1}, **B$_2$K$_2$**= 5 t ha^{-1} Biochar + 36 kg ha^{-1} K, **B$_3$K$_3$**= 0 t ha^{-1} Biochar + 48 kg ha^{-1} K,

Figure 6. Influence of biochar and potassium (K) management on Leaf area index(LAI) at different stages of wheat (LSD$_{0.05}$= 1.499, 1.204, and 0.7526 at 40,60 and 80 DAS respectively)

Table 3. Interaction effects of Irrigation and Biochar and Potassium (K) on Leaf Area Index(LAI) at different growth stage of wheat:

Interactions	Leaf Area Index (LAI)		
	At 40DAS	At 60DAS	At 80DAS
$I_0 B_0 K_0$	22.46 f	26.29 j	19 k
$I_0 B_1 K_1$	26.89 c-e	34.55 d-f	28.79 d
$I_0 B_2 K_2$	31.17 ab	37.12 bc	30.87 bc
$I_0 B_3 K_3$	27.65 cd	33.04 f-h	26.40 fg
$I_1 B_0 K_0$	24.73 d-f	30.62 hi	21.88 j
$I_1 B_1 K_1$	26.71 c-e	35.60 c-e	28.06 de
$I_1 B_2 K_2$	31.88 a	38.54 b	31.23 b
$I_1 B_3 K_3$	26.90 c-e	32.41 f-h	25.46 gh
$I_2 B_0 K_0$	28.35 bc	30.74 hi	23.48 i
$I_2 B_1 K_1$	29.20 a-c	34.56 d-f	27.24 ef
$I_2 B_2 K_2$	32.15 a	42.41 a	34.23 a
$I_2 B_3 K_3$	29.16 c	31.48 g-i	24.36 hi
$I_3 B_0 K_0$	23.91 ef	29.80 i	20.99 j
$I_3 B_1 K_1$	27.81 b-d	33.38 e-g	27.20 ef
$I_3 B_2 K_2$	29.11 a-c	35.99 cd	29.46 cd
$I_3 B_3 K_3$	28.99 a-c	31.72 g-i	25.14 gh
$LSD_{0.05}$	2.997	2.408	1.505
CV (%)	6.37	4.25	3.37

DAS= Days after sowing. In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.

Here, **I_0** = Control, **I_1**= Irrigation at crown root initiation stage, **I_2**= Irrigation at crown root initiation stage + Flowering stage, **I_3**= Irrigation at crown root initiation stage + Flowering stage + Grain filling stage.

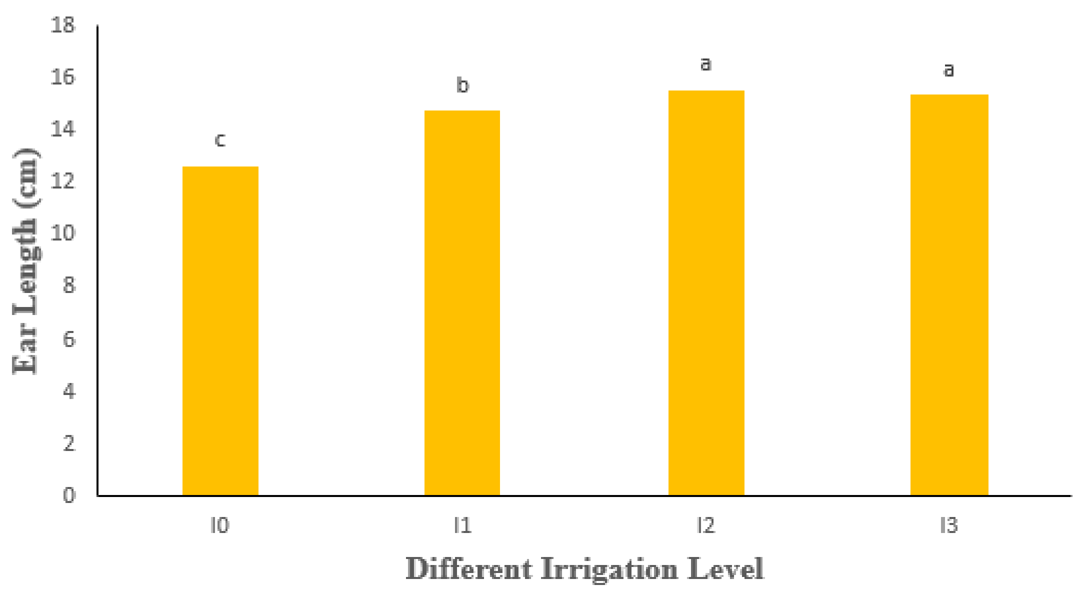
Here, **B_0K_0**=5 t ha^{-1} Biochar + 0 kg ha^{-1} K, **B_1K_1**=5 t ha^{-1} Biochar + 48 kg ha^{-1}, **B_2K_2**= 5 t ha^{-1} Biochar + 36 kg ha^{-1} K, **B_3K_3**= 0 t ha^{-1} Biochar + 48 kg ha^{-1} K,

4.2 Crop yield parameters

4.2.1 Ear length (cm)

4.2.1.1 Effect of irrigation

Ear length (cm) of wheat was significantly varied with different irrigation level (Figure 7). Record collected from I_2 (two irrigation) showed the highest length (15.54 cm) which was statistically similar (15.35 cm) to I_3 (three irrigation). On the other hand, lowest ear length was 12.62 that was recorded from I_0 (no irrigation).

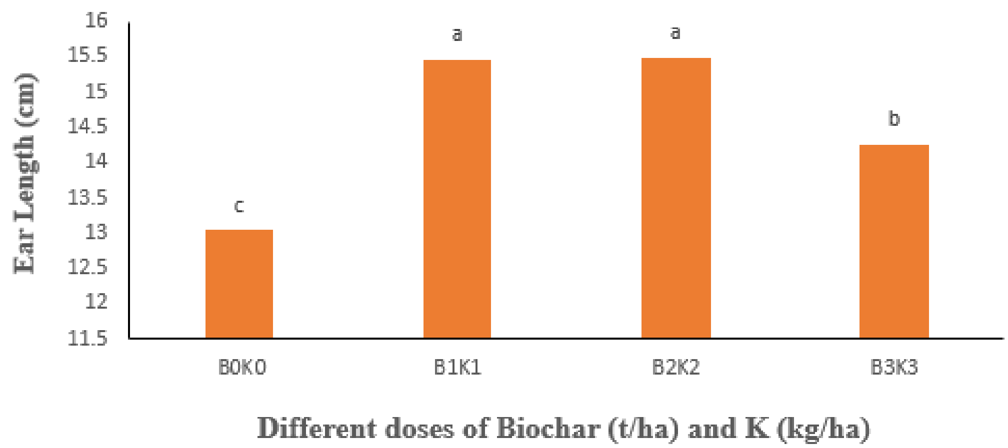


Here, $\mathbf{I_0}$ = Control, $\mathbf{I_1}$= Irrigation at crown root initiation stage, $\mathbf{I_2}$= Irrigation at crown root initiation stage + Flowering stage, $\mathbf{I_3}$= Irrigation at crown root initiation stage + Flowering stage + Grain filling stage.

Figure 7. Influence of different levels of irrigation on ear length of wheat ($LSD_{0.05}$= 0.453)

4.2.1.2 Effect of Biochar and Potassium (K) management

Different doses of biochar and K had also shown significant differences on ear length (Figure 8). From B_2K_2 (K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}) showed the highest length (15.49 cm) which was statistically similar to 15.46 cm that recorded from B_1K_1 (K:48 kg ha^{-1}+ Biochar: 5 t ha^{-1}). And the least value of ear length of wheat was collected from B_0K_0 (K: 0 kg ha^{-1} + 5 t ha^{-1} biochar) that was 13.04 cm.



Here, **B_0K_0**=5 t ha^{-1} Biochar + 0 kg ha^{-1} K, **B_1K_1**=5 t ha^{-1} Biochar + 48 kg ha^{-1}, **B_2K_2**= 5 t ha^{-1} Biochar + 36 kg ha^{-1} K, **B_3K_3**= 0 t ha^{-1} Biochar + 48 kg ha^{-1} K,

Figure 8. Influence of biochar and potassium (K) management on ear length of wheat ($LSD_{0.05}$= 0.262)

4.2.1.3 Interaction effect of irrigation and Biochar and Potassium (K) management

Different levels of irrigation and different doses of biochar and potassium (K) showed significant differences on ear length of wheat due to interaction effect (Table 4). The highest ear length (17.01 cm) was observed from $I_2B_2K_2$ (two irrigations with K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}) which is statistically similar (16.71 cm) to $I_2B_1K_1$ (two irrigations with K:48 kg ha^{-1}+ Biochar: 5 t ha^{-1}). On the contrary, lowest ear length (10.14 cm) was recorded from $I_0B_0K_0$ (no irrigation with K: control + 5 t ha^{-1} Biochar).

Table 4. Interaction effects of Irrigation and Biochar and K on Ear Length, No. of Spikelets/Ear & No. of Grains/Ear of Wheat:

Interaction	Ear Length (cm)	No. of Spikelets/Ear	No. of Grains/Ear
$I_0 B_0 K_0$	10.14 m	10.80 l	23.70 j
$I_0 B_1 K_1$	14.03 hi	15.33 g-i	31.90 fg
$I_0 B_2 K_2$	13.41 kl	14.53 jk	30.17 h
$I_0 B_3 K_3$	12.88 l	14.13 k	29.00 i
$I_1 B_0 K_0$	13.99 ij	15.20 hi	30.90 gh
$I_1 B_1 K_1$	15.11 ef	16.00 d-f	34.20 cd
$I_1 B_2 K_2$	15.33 de	16.20 c-e	34.33 cd
$I_1 B_3 K_3$	14.53 gh	15.60 f-h	32.83 ef
$I_2 B_0 K_0$	13.55 jk	14.87 ij	30.37 h
$I_2 B_1 K_1$	16.71 ab	17.20 b	36.97 a
$I_2 B_2 K_2$	17.01 a	18.13 a	37.70 a
$I_2 B_3 K_3$	14.87 e-g	16.00 d-f	33.40 de
$I_3 B_0 K_0$	14.49 g-i	15.53 f-h	32.57 ef
$I_3 B_1 K_1$	15.97 cd	16.33 cd	34.93 bc
$I_3 B_2 K_2$	16.21 bc	16.67 bc	35.67 b
$I_3 B_3 K_3$	14.73 fg	15.80 e-g	33.13 e
$LSD_{0.05}$	0.524	0.517	1.003
CV (%)	2.14	1.97	1.82

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.

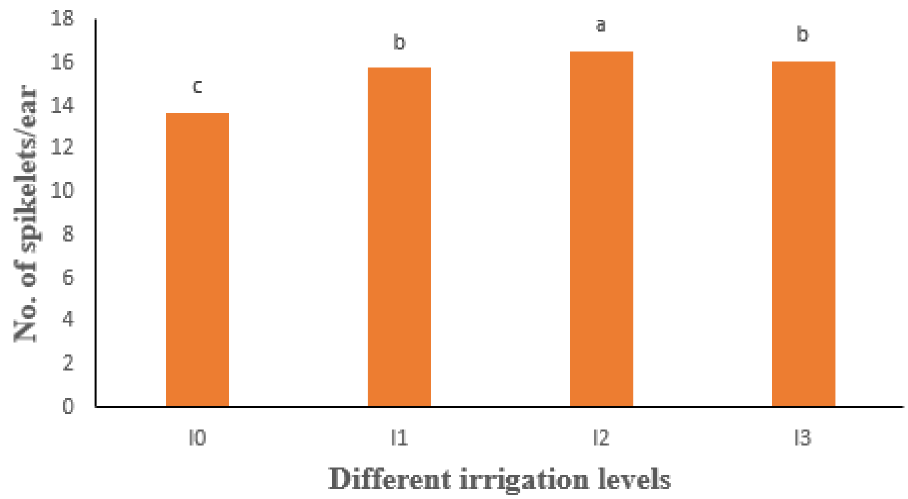
Here, I_0 = Control, I_1= Irrigation at crown root initiation stage, I_2= Irrigation at crown root initiation stage + Flowering stage, I_3= Irrigation at crown root initiation stage + Flowering stage + Grain filling stage.

Here, B_0K_0=5 t ha^{-1} Biochar + 0 kg ha^{-1} K, B_1K_1=5 t ha^{-1} Biochar + 48 kg ha^{-1}, B_2K_2= 5 t ha^{-1} Biochar + 36 kg ha^{-1} K, B_3K_3= 0 t ha^{-1} Biochar + 48 kg ha^{-1} K,

4.2.2 No. of spikelets/ear

4.2.2.1 Effect of irrigation

Number of spikelets/ear of wheat showed significant variation due to different levels of irrigation (Figure 9). The highest number of spikelets/ear (16.55) was recorded from I_2 (two irrigation) which was closely followed by 16.08 found in I_3 (three irrigation). And the lowest number of spikelets/ear was found 13.7 from I_0 (no irrigation).

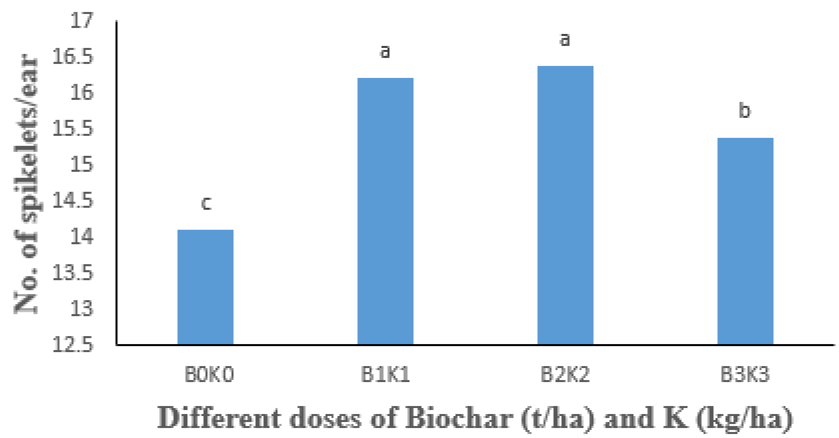


Here, **I_0** = Control, **I_1**= Irrigation at crown root initiation stage, **I_2**= Irrigation at crown root initiation stage + Flowering stage, **I_3**= Irrigation at crown root initiation stage + Flowering stage + Grain filling stage.

Figure 9. Influence of different levels of irrigation on no. of spikelets/ear of wheat ($LSD_{0.05}$= 0.364)

4.2.2.2 Effect of Biochar and Potassium (K) management

Number of spikelets/ear of wheat showed significant variation due to different doses of biochar and K (Figure 10). The highest number of spikelets/ear (16.38) was recorded from B_2K_2 (K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}) which was statistically similar to 16.22 found in B_1K_1 (K:48 kg ha^{-1}+ Biochar: 5 t ha^{-1}). And the lowest number of spikelets/ear was found 14.60 from B_0K_0 (K: control + 5 t ha^{-1} Biochar).



Here, **B_0K_0**=5 t ha^{-1} Biochar + 0 kg ha^{-1} K, **B_1K_1**=5 t ha^{-1} Biochar + 48 kg ha^{-1}, **B_2K_2**= 5 t ha^{-1} Biochar + 36 kg ha^{-1} K, **B_3K_3**= 0 t ha^{-1} Biochar + 48 kg ha^{-1} K,

Figure 10. Influence of biochar and potassium (K) management on no. of spikelets/ear of wheat ($LSD_{0.05}$= 0.2578)

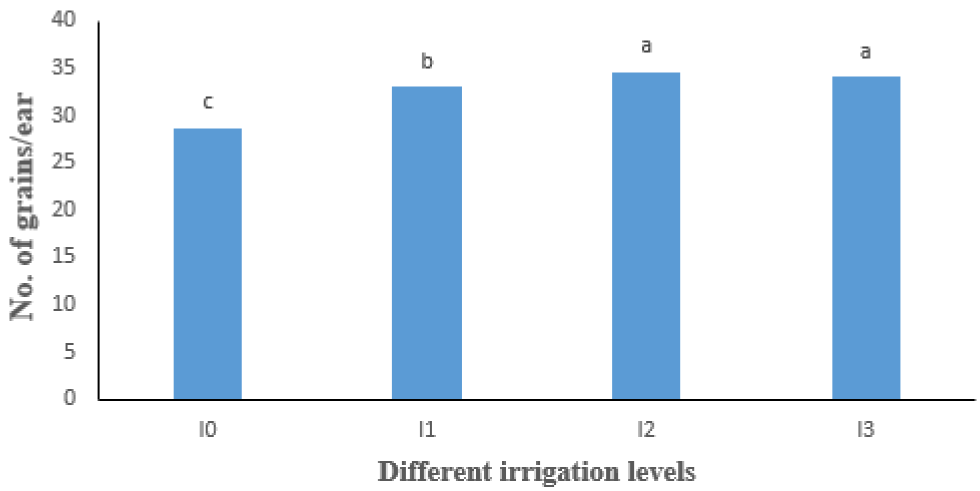
4.2.2.3 Interaction effect of irrigation and Biochar and Potassium (K) management

Different levels of irrigation and different doses of biochar and potassium (K) showed significant differences on number of spikelets/ear of wheat due to interaction effect (Table 4). The highest no. of spikelets/ear (18.13) was observed from $I_2B_2K_2$ (two irrigations with K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}). On the contrary, lowest no. of spikelets/ear (10.80) was recorded from $I_0B_0K_0$ (no irrigation with K: 0 kg ha^{-1} + 5 t ha^{-1} Biochar).

4.2.3 No. of grains/ear

4.2.3.1 Effect of irrigation

Number of grains/ear of wheat showed significant variation due to different levels of irrigation (Figure 11). The highest number of grains/ear (34.61) was recorded from I_2 (two irrigation) which was statistically similar to 34.08 that was recorded from I_3 (three irrigation). And the lowest number of grains/ear was found 28.69 from I_0 (no irrigation).

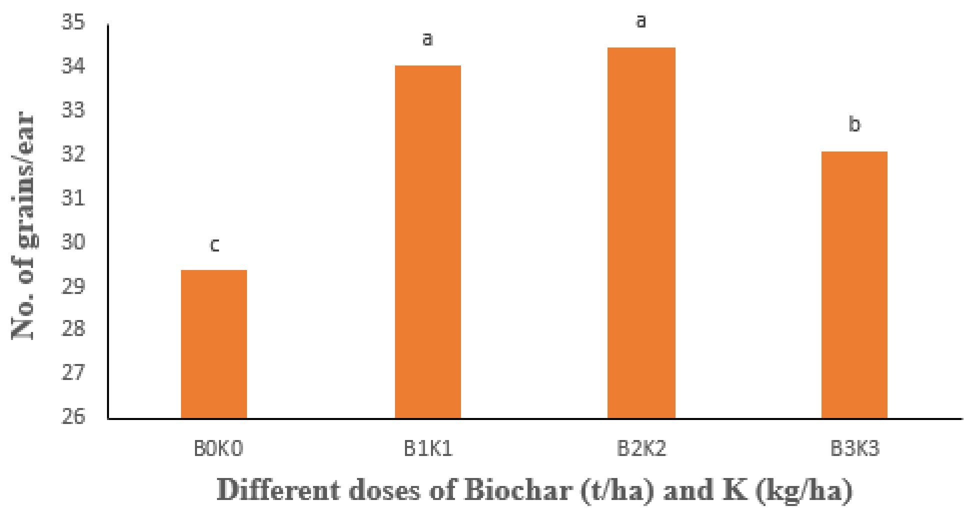


Here, **I_0** = Control, **I_1**= Irrigation at crown root initiation stage, **I_2**= Irrigation at crown root initiation stage + Flowering stage, **I_3**= Irrigation at crown root initiation stage + Flowering stage + Grain filling stage.

Figure 11. Influence of different levels of irrigation on no. of grains/ear of wheat ($LSD_{0.05}$= 0.551)

4.2.3.2 Effect of Biochar and Potassium (K) management

Number of grains/ear of wheat varied significantly due to different doses of biochar and K (Figure 12). The highest number of grains/ear (34.50) was recorded from B_1K_1 (K:48 kg ha^{-1}+ Biochar: 5 t ha^{-1}) which was statistically similar to 34.47 found in B_2K_2 (K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}). And the lowest number of grains/ear was found 29.38 from B_0K_0 (K: 0 kg ha^{-1} + 5 t ha^{-1} Biochar).



Here, **B_0K_0**=5 t ha^{-1} Biochar + 0 kg ha^{-1} K, **B_1K_1**=5 t ha^{-1} Biochar + 48 kg ha^{-1}, **B_2K_2**= 5 t ha^{-1} Biochar + 36 kg ha^{-1} K, **B_3K_3**= 0 t ha^{-1} Biochar + 48 kg ha^{-1} K,

Figure 12. Influence of biochar and potassium (K) management on no. of grains/ear of wheat ($LSD_{0.05}$= 0.501)

4.2.3.3 Interaction effect of irrigation and Biochar and Potassium (K) management

Different levels of irrigation and different doses of biochar and potassium (K) showed significant differences on number of grains/ear of wheat due to interaction effect (Table 4). The highest no. of grains/ear (37.70) was observed from $I_2B_2K_2$ (two irrigations with K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}) that was statistically similar (36.97) to $I_2B_1K_1$ (two irrigations with K:48 kg ha^{-1}+ Biochar: 5 t ha^{-1}). On the contrary, lowest no. of grains/ear (23.70) was recorded from $I_0B_0K_0$ (no irrigation with K: control + 5 t ha^{-1} Biochar).

4.2.4 1000-Grain weight (gm)

4.2.4.1 Effect of irrigation

Thousand grain weight of wheat differed significantly between irrigated and non-irrigated situations, but there was essentially little difference between the other three irrigation treatments studied (Table 7). As a consequence, it was hypothesized that a single irrigation at each stage of wheat growth bears nearly equivalent weight. I_2 (two irrigation) had the highest grain weight (45.17gm), which was statistically similar to 44.60 gm and 44.97 gm from I_1 (one irrigation) and I_3 (three irrigation), respectively. The lowest grain weight (42.28 gm), on the other contrary, was found from I_0 (no irrigation).

4.2.4.2 Effect of Biochar and Potassium (K) management

Thousand grains weight of wheat varied significantly due to different doses of biochar and K (Table 6). The highest 1000 grain wt. (45.09 gm) was recorded from B_2K_2 (K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}) that was statistically similar 45.08 gm recorded from B_1K_1 (K:48 kg ha^{-1}+ Biochar: 5 t ha^{-1}). And the lowest 1000 grain wt. was found 42.78 gm that recorded from B_0K_0 (K: control + 5 t ha^{-1} Biochar).

4.2.4.3 Interaction effect of irrigation and Biochar and Potassium (K) management

Different levels of irrigation and different doses of biochar and potassium (K) showed significant differences on 1000 grain wt. of wheat due to interaction effect (Table 7). The highest 1000 grain wt. (46.66 gm) was observed from $I_2B_2K_2$ (two irrigations with K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}). On the contrary, lowest 1000 grain wt. (40 gm) was recorded from $I_0B_0K_0$ (no irrigation with K: 0 kg ha^{-1} + 5 t ha^{-1} Biochar).

4.2.5 Grain Yield (t ha^{-1})

4.2.5.1 Effect of irrigation

It was found that grain yield of wheat showed significant variation due to different levels of irrigation (Table 5). The highest grains yield (2.74 t ha^{-1}) was recorded from I_2 (two irrigation). On the other hand, the lowest grains yield (1.72 t ha^{-1}) was found from I_0 (no irrigation). And other irrigation treatments showed no significant difference. Without irrigation plant growth was reduced as a result, grain yield also reduced. The effect of irrigation stress on wheat plants were studied by Hwary and Yagoub (2011) and Dang *et al.* (2012), they found that grain yield reduced dramatically while the plant was under water stress.

Table 5. 1000 grain wt., Grain yield, Straw yield and Harvest Index of Wheat at different levels of Irrigation:

Treatments	1000-grain wt.(gm)	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Harvest Index (%)
I_0	42.28 b	1.72 c	2.26 c	42.84 b
I_1	44.60 a	2.46 b	2.69 b	47.37 a
I_2	45.17 a	2.74 a	2.97 a	47.80 a
I_3	44.97 a	2.57 ab	2.83 ab	47.56 a
$LSD_{0.05}$	0.846	0.196	0.1613	4.099
CV (%)	1.91	8.27	6.01	8.85

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.

Here, **I_0** = Control, **I_1**= Irrigation at crown root initiation stage, **I_2**= Irrigation at crown root initiation stage + Flowering stage, **I_3**= Irrigation at crown root initiation stage + Flowering stage + Grain filling stage.

4.2.5.2 Effect of Biochar and Potassium (K) management

Grain yield of wheat varied significantly due to different doses of biochar and K (Table 6). The highest grain yield (2.72 t ha^{-1}) was recorded from B_2K_2 (K: 36 kg ha^{-1}+ Biochar: 5 t ha^{-1}) and the lowest was found 1.95 t ha^{-1} that recorded from B_0K_0

(K:0 kg ha^{-1} + 5 t ha^{-1} biochar). All four treatments showed statistically different yield.

Table 6. 1000 grain wt., Grain yield, Straw yield and Harvest Index of wheat at different application of Biochar and Potassium(K):

Treatments	1000 grain wt.(gm)	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Harvest Index (%)
$B_0 K_0$	42.78 c	1.95 d	2.32 c	45.07 b
$B_1 K_1$	45.08 a	2.55 b	2.89 a	46.47 ab
$B_2 K_2$	45.09 a	2.72 a	3.00 a	47.09 a
$B_3 K_3$	44.08 b	2.26 c	2.54 b	46.94 ab
$LSD_{0.05}$	0.577	0.147	0.126	1.455
CV(%)	1.55	7.35	5.56	3.72

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.

Here, **B_0K_0**=5 t ha^{-1} Biochar + 0 kg ha^{-1} K, **B_1K_1**=5 t ha^{-1} Biochar + 48 kg ha^{-1}, **B_2K_2**= 5 t ha^{-1} Biochar + 36 kg ha^{-1} K, **B_3K_3**= 0 t ha^{-1} Biochar + 48 kg ha^{-1} K,

4.2.5.3 Interaction effect of irrigation and Biochar and Potassium (K) management

Data revealed that interaction effect of different levels of irrigation and different doses of biochar and potassium (K) showed significant differences on grain yield of wheat (Table 7). From the result it is shown that non-irrigated condition regardless of doses of biochar and K performed worse while irrigation at crown root initiation and flowering stage with both biochar and K treatments (except control) shows better performance. The highest grain yield (3.53 t ha^{-1}) was observed from $I_2B_2K_2$ (two irrigations with K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}). On the contrary, lowest grain yield *viz*. 1.46 t ha^{-1} was recorded from $I_0B_0K_0$ (no irrigation with K: control + 5 t ha^{-1} Biochar). Alburquerque *et al*. (2013), Gebremedhin *et al*. (2015) and Svoboda *et al*. (2017) studied the effect of irrigation stress and biochar dose on wheat productivity and discovered significant results.

Table 7. Interaction effects of Irrigation and Biochar and K on 1000-grain wt., Grain yield, Straw yield, Harvest Index of Wheat:

Interaction	1000-grain wt.(gm)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Harvest Index (%)
$I_0 B_0 K_0$	40.00 j	1.46 i	2.1 j	41.01 f
$I_0 B_1 K_1$	43.88 e-h	1.90 gh	2.39 hi	43.59 d-f
$I_0 B_2 K_2$	42.78 hi	1.78 gh	2.33 hij	43.35 ef
$I_0 B_3 K_3$	42.45 i	1.72 hi	2.22 ij	43.43 ef
$I_1 B_0 K_0$	43.72 f-i	2.09 fg	2.39 hi	45.11 c-e
$I_1 B_1 K_1$	44.94 b-e	2.65 cd	2.87 de	47.92 a-c
$I_1 B_2 K_2$	45.22 b-d	2.69 b-d	2.95 cd	47.67 a-c
$I_1 B_3 K_3$	44.51 c-g	2.40 de	2.53 gh	48.77 a-c
$I_2 B_0 K_0$	43.28 g-i	1.93 gh	2.25 ij	46.36 b-d
$I_2 B_1 K_1$	46.03 ab	2.98 b	3.31 ab	47.34 a-e
$I_2 B_2 K_2$	46.66 a	3.53 a	3.56 a	49.80 a
$I_2 B_3 K_3$	44.71 c-f	2.50 de	2.74 e-g	47.69 a-c
$I_3 B_0 K_0$	44.14 d-g	2.32 ef	2.54 gh	47.81 a-c
$I_3 B_1 K_1$	45.45 a-c	2.66 b-d	2.99 cd	47.02 a-c
$I_3 B_2 K_2$	45.67 a-c	2.87 bc	3.17 bc	47.55 a-c
$I_3 B_3 K_3$	44.64 c-f	2.43 de	2.65 fg	47.87 a-c
$LSD_{0.05}$	1.1541	0.2936	0.2517	2.909
CV(%)	1.55	7.35	5.56	3.72

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.

Here, **I_0** = Control, **I_1**= Irrigation at crown root initiation stage, **I_2**= Irrigation at crown root initiation stage + Flowering stage, **I_3**= Irrigation at crown root initiation stage + Flowering stage + Grain filling stage.

Here, **B_0K_0**=5 $t\ ha^{-1}$ Biochar + 0 $kg\ ha^{-1}$ K, **B_1K_1**=5 $t\ ha^{-1}$ Biochar + 48 $kg\ ha^{-1}$, **B_2K_2**= 5 $t\ ha^{-1}$ Biochar + 36 $kg\ ha^{-1}$ K, **B_3K_3**= 0 $t\ ha^{-1}$ Biochar + 48 $kg\ ha^{-1}$ K,

4.2.6 Straw Yield ($t\ ha^{-1}$)

4.2.6.1 Effect of irrigation

Wheat straw yields per hectare varied significantly depending on irrigation levels, according to the records. (Table 5). The highest straw yield (2.97 $t\ ha^{-1}$) was recorded from I_2 (two irrigation). On the other hand, the lowest straw yield (2.26 t ha^{-1}) was found from I_0 (no irrigation). All four treatments showed statistically different yield.

4.2.6.2 Effect of Biochar and Potassium (K) management

Straw yield of wheat varied significantly due to different doses of biochar and K (Table 6). The highest straw yield (3.00 t ha^{-1}) was recorded from B_2K_2 (K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}) that was statistically similar (2.89 t ha^{-1}) to B_1K_1 (K:48 kg ha^{-1}+ Biochar: 5 t ha^{-1}). And the lowest straw yield was found 2.32 t ha^{-1} that recorded from B_0K_0 (K: control + 5 t ha^{-1} Biochar).

4.2.6.3 Interaction effect of irrigation and Biochar and Potassium (K) management

The data demonstrated that the interaction impact of different levels of irrigation and varying doses of biochar and potassium (K) had a significant influence on wheat straw yield (Table 7). The results reveal that irrigation during crown root initiation and flowering stage with both biochar and K treatments (excluding control treatments) performed better than non-irrigated conditions regardless of biochar and K doses. The highest straw yield (3.56 t ha^{-1}) was observed from $I_2B_2K_2$ (two irrigations with K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}). On the contrary, $I_0B_0K_0$ (no irrigation with K: control + 5 t ha^{-1} Biochar had the lowest straw yield of 2.1 t ha^{-1}.

4.2.7 Harvest Index (HI%)

4.2.7.1 Effect of irrigation

The harvest index (%) of wheat differed significantly from irrigated to non-irrigated conditions, but there was almost little difference amongst the other three irrigation treatments investigated (Table 5). As a result, it suggested that a single irrigation at each stage of wheat growth bears roughly similar weight. The highest harvest index (%) (47.56) was recorded from I_2 (two irrigation) which was statistically similar to 47.37 and 47.56 recorded from I_1 (one irrigation) and I_3 (three irrigation) respectively. On the other hand, the lowest harvest index (%) (42.84) was found from I_0 (no irrigation).

4.2.7.2 Effect of Biochar and Potassium (K) management

Harvest index (%) of wheat varied significantly due to different doses of biochar and K (Table 6). The highest harvest index (%) (47.09) was recorded from B_2K_2 (K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}) that was statistically similar 46.94 and 46.47 recorded from B_3K_3 (K: 48 kg ha^{-1} + Biochar: control) and B_1K_1 (K:48 kg ha^{-1}+ Biochar: 5 t ha^{-1}) respectively. And the lowest harvest index (%) was found 45.07 that recorded from B_0K_0 (K: control + 5 t ha^{-1} Biochar).

4.2.7.3 Interaction effect of irrigation and Biochar and Potassium (K) management

The results indicated that the interaction effect of different irrigation levels and varying quantities of biochar and potassium (K) had a significant impact on wheat harvest index (%) (Table 7). The highest straw harvest index (%) was 49.80 that observed from $I_2B_2K_2$ (two irrigations with K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}). On the contrary, $I_0B_0K_0$ (no irrigation with K: control + 5 t ha^{-1} Biochar had the lowest harvest index (%) 41.01.

CHAPTER 5

SUMMARY AND CONCLUSION

This field experiment was conveyed at the Agronomy research field of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, during the period of November 27, 2019 to March 21, 2020 to study the enhancement of growth and yield of wheat through biochar and potassium (K) management under different water stress condition. This field location is under the Agro-ecological zone 28 (Madhupur Tract). 16 treatments with three replications, the experiment was set up in a two-factor split-plot design. Irrigation stresses were put in the main plot and the sub-plots were given varied doses of biochar and potassium (K).

The study was conducted with four different degrees of irrigation, as well as four distinct biochar and K management practices. Factor A was different irrigation stresses those were**,** I_0 = Control (without irrigation)**,** I_1 = irrigation at crown root initiation stage**,** I_3 = irrigation at crown root initiation stage and flowering stage and**,** I_4 = irrigation at crown root initiation stage, flowering stage and grain filling stage. Factor B was different Biochar and Potassium(K) managements those were B_0K_0 = Biochar: 5 t ha^{-1} and K: Control (no Potassium), B_1K_1 = Biochar: 5 t ha^{-1} and K:48 kg ha^{-1}, B_2K_2 = Biochar: 5 t ha^{-1} and K:36 kg ha^{-1}, B_3K_3 = Biochar: Control (no Biochar) and K: 48 kg ha^{-1}. There were 48 unit-plots of $2m^2$ area each (16 treatments combination with 3 replications). BARI Gom 31 were sown on 27th November 2019 and harvested on 21 March 2020. Data on different growth and yield parameters were recorded and analyzed using Statistix10 software.

To determine wheat growth habit through this study, characteristics such as plant height (cm), no. of tiller/plant, leaf area index (LAI) were measured at different day intervals. And after harvest, yield parameters like ear length (cm), number of spikelets/ear, number of grains/ear, grain yield (t ha^{-1}), straw yield (t ha^{-1}), harvest index (%), 1000 grain weight (g) were also measured to evaluate the yield of wheat.

Growth characteristics were significantly varied due to irrigation stresses. Plant height showed highest value recorded 65.97cm, 76.77cm, 80.30cm at 60,80 DAS and at harvest respectively from two irrigations treatment one at crown root initiation and other at flower initiation stage whereas at 20 and 40 DAS highest value recorded from one irrigation treatment at crown root initiation. In every cases lowest values (23.44, 43.64, 63.81, 74.30, 78.10cm at 20, 40, 60, 80 DAS and at harvest respectively) were recorded from control (no irrigation). Plant height showed significant differences due to different doses of biochar and potassium. Highest plant heights were recorded 26.41cm, 48.38cm, 69.07cm, 79.85cm, 85.02cm from 20, 40, 60, 80 DAS and at harvest respectively; while corresponding lowest height were 21.50cm, 39.93cm, 60.48cm, 70.38cm and 73.12cm. Highest height was recorded from biochar: 5 t ha^{-1} with K:36 kg ha^{-1} and lowest height was recorded from B_0K_0 (Biochar: 5 t ha^{-1} and K: Control). Interaction effect also shown significant differences. The highest plant height was recorded (27.08 cm) from $I_2B_2K_2$ and lowest value (20.67 cm) from $I_0B_0K_0$ treatment.

The highest number of tiller/plant *viz.* 2.77 was recorded from I_2 (two irrigation) at 40 DAS which is statistically similar to I_3 (two irrigation). In case of 60, 80 DAS and at harvest the highest number of tiller/plant *viz.* 4.90, 6.01 and 5.76 were recorded from I_3 (three irrigation) which are statistically similar to I_2 (two irrigation). And the lowest (2.05, 3.78, 4.63 and 4.40 at 40, 60, 80 DAS and at harvest respectively) number of tiller/plant was recorded from I_0 (no irrigation). At 40, 80 DAS and at harvest the number of tiller/plant were the highest at B_2K_2 (2.83, 5.97, 5.73 respectively). At 60 DAS the highest number of tiller/plant *viz.* 4.90 was recorded from B_1K_1. Data recorded from B_1K_1 and B_2K_2 were statistically similar. On the other hand, B_0K_0 (Biochar: 5 t ha^{-1} and K: Control) showed the lowest number of tiller/plant (2.13, 3.93, 4.88, 4.65 at 40, 60, 80 DAS and at harvest respectively). The highest no. of tiller/plant were showed at 40, 60, 80 DAS and at harvest were 3.47, 5.53, 6.80 and 6.60 respectively from $I_2B_2K_2$ (two irrigations with K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}). The lowest (1.87, 3.27, 4.40 and 4.13 at 40, 60, 80 DAS and at harvest respectively) were obtained from $I_0B_0K_0$.

Leaf area index showed significant variation from different irrigation levels. The highest leaf area index was found from I_2 (two irrigation) (29.71, 34.75, 27.33 at 40, 60 and 80 DAS respectively). And lowest leaf area index was recorded 27.04 at 40 DAS from I_0 (no irrigation), 32.72 and 25.7 at 60 and 80 DAS respectively from I_3 (three irrigation). For different doses of biochar and potassium The highest value was found from B_2K_2 (K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}) at 40, 60 and 80 DAS (31.08, 38.47 and 31.45 respectively) while the lowest leaf area index was found from B0K0 (K: control + 5 t ha^{-1} biochar). At 40 DAS, LAI of B_1K_1 and B_3K_3 were statistically similar whereas, at 60 DAS and 80 DAS all treatments were statistically different. At interaction effect the highest LAI were showed at 40, 60 and 80 DAS were 32.15, 42.41 and 34.23 respectively from $I_2B_2K_2$ (two irrigations with K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}). On the contrary, the lowest leaf area indexes were found from $I_0B_0K_0$ (no irrigation with no K and 5 t ha^{-1} biochar).

Yield parameters such as length of spike (cm), no. of spikelets/ear, no. of grain/ear, grain yield (t ha^{-1}), straw yield (t ha^{-1}) showed significant differences on different irrigation levels. From different levels of irrigation, the highest length of spike (15.54cm), no. of spikelets/ear (16.55), no. of grain/ear (34.61), grain yield (2.74 t ha^{-1}), straw yield (2.97t ha^{-1}) were recorded from I_2 (two irrigation) whereas, the lowest length of spike (12.62 cm), no. of spikelets/ear (13.70), no. of grain/ear (28.69), grain yield (1.72 t ha^{-1}), straw yield (2.26 t ha^{-1}) were obtained from control (no irrigation). On the other hand, the highest length of spike (15.49 cm), no. of spikelets/ear (16.38), no. of grain/ear (34.47), grain yield (2.72t ha^{-1}), straw yield

(3.00t ha^{-1}) were recorded from B_2K_2 (K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}) and lowest length of spike (13.04 cm), no. of spikelets/ear (14.10), no. of grain/ear (29.38), grain yield (1.95 t ha^{-1}), straw yield (2.44 t ha^{-1}) were obtained from B_0K_0 (K: control + 5 t ha^{-1} biochar). From interaction effect the highest length of spike (17.01 cm), no. of spikelets/ear (18.13), no. of grain/ear (37.70), grain yield (3.53 t ha^{-1}), straw yield (3.56 t ha^{-1}) were recorded from $I_2B_2K_2$ (two irrigations with K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}). And the lowest length of spike (10.14 cm), no. of spikelets/ear (10.80), no. of grain/ear (23.70), grain yield (1.46 t ha^{-1}), straw yield (2.10 t ha^{-1}) were resulted from $I_0B_0K_0$ (no irrigation with K: control+ 5 t ha^{-1} Biochar).

At different irrigation levels harvest index (%) (47.80) and 1000 grain wt. (45.17 gm) of wheat were recorded from I_2(two irrigation) were highest which were statistically similar to others irrigation treatments where corresponding lowest data was recorded from control (no irrigation). Different biochar and K doses shown highest harvest index (%) (47.09) and 1000 grain wt. (45.09 gm) of wheat from B_2K_2 (K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}) and lowest (HI%= 45.07, 1000 grain wt.=42.78 gm) were from B_0K_0 (K: control + 5 t ha^{-1} biochar).

From interaction effect the highest harvest index (%) (49.80) and 1000 grain wt. (46.66 gm) of wheat were recorded from $I_2B_2K_2$ (two irrigations with K:36 kg ha^{-1}+ Biochar: 5 t ha^{-1}). And the lowest harvest index (%) (41.01) and 1000 grain wt. (40 gm) were resulted from $I_0B_0K_0$ (no irrigation with K: control+ 5 t ha^{-1} Biochar).

It can be concluded that wheat cultivation with two irrigations aplication at crown root initiation and flowering stage along with 5 t ha^{-1} biochar with 36 kg ha^{-1} potassium (K) would be beneficial for the enhancement of growth and yield of wheat under water stresses as it can conserve moisture. However, in order to obtain a precise conclusion and suggestion, more study on biochar with potassium doses under water stress condition should be conducted across different agro-ecological zones.

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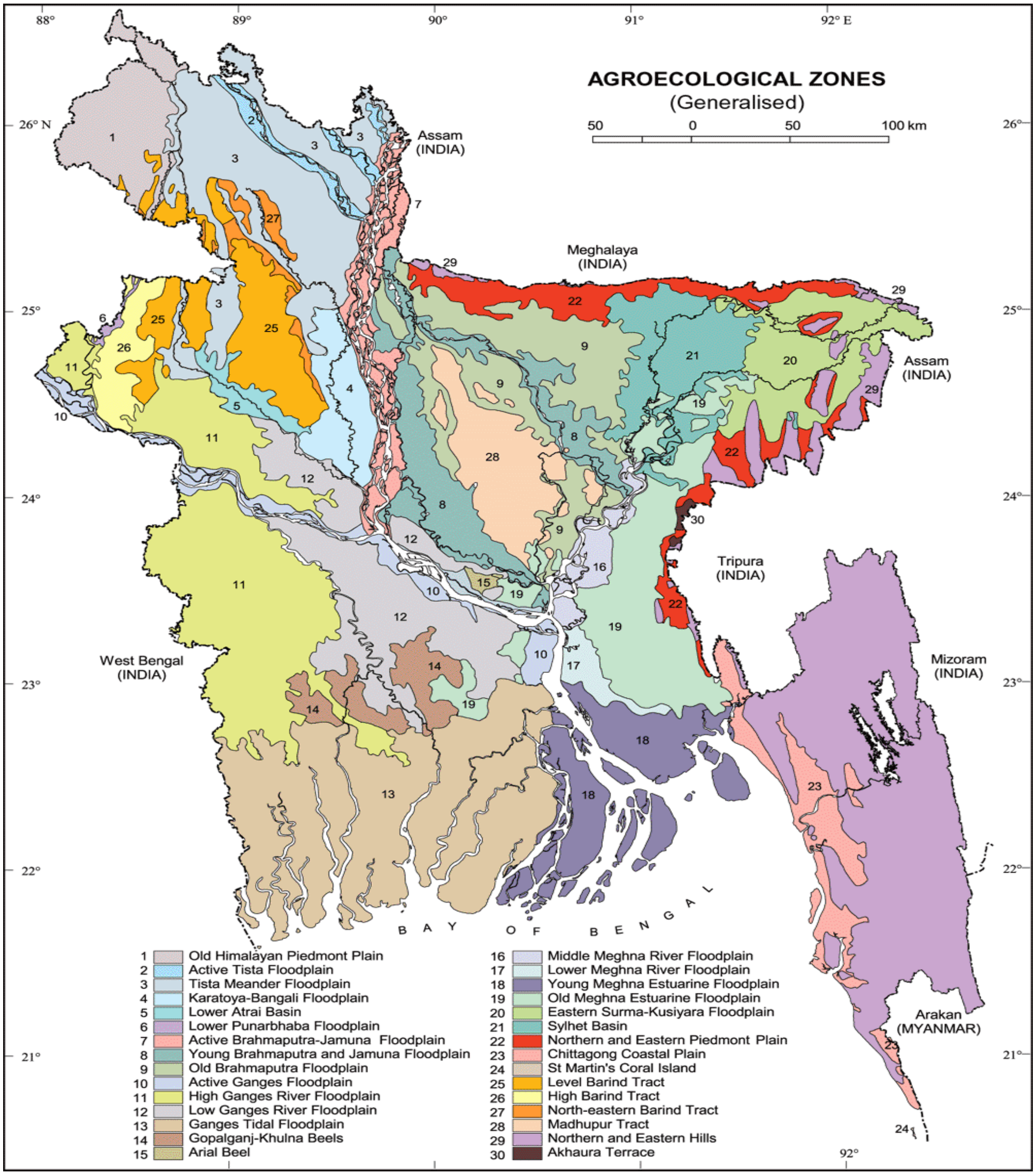
APPENDICES

Appendix 1. AEZ Map of Bangladesh showing the experimental sites



Appendix 2: Layout of the experimental plot

Replication -1	Replication -2	Replication -3
$I_0B_0K_0$	$I_1B_1K_1$	$I_2B_3K_3$
$I_0B_1K_1$	$I_1B_2K_2$	$I_2B_0K_0$
$I_0B_2K_2$	$I_1B_3K_3$	$I_2B_1K_1$
$I_0B_3K_3$	$I_1B_0K_0$	$I_2B_2K_2$
$I_1B_0K_0$	$I_3B_1K_1$	$I_0B_3K_3$
$I_1B_1K_1$	$I_3B_2K_2$	$I_0B_0K_0$
$I_1B_2K_2$	$I_3B_3K_3$	$I_0B_1K_1$
$I_1B_3K_3$	$I_3B_0K_0$	$I_0B_2K_2$
$I_2B_0K_0$	$I_0B_1K_1$	$I_3B_3K_3$
$I_2B_1K_1$	$I_0B_2K_2$	$I_3B_0K_0$
$I_2B_2K_2$	$I_0B_3K_3$	$I_3B_1K_1$
$I_2B_3K_3$	$I_0B_0K_0$	$I_3B_2K_2$
$I_3B_0K_0$	$I_2B_1K_1$	$I_1B_3K_3$
$I_3B_1K_1$	$I_2B_2K_2$	$I_1B_0K_0$
$I_3B_2K_2$	$I_2B_3K_3$	$I_1B_1K_1$
$I_3B_3K_3$	$I_2B_0K_0$	$I_1B_2K_2$

Here,

Area: 243 m^2 (27 m×9 m)

Plot size: 2 m×1 m

Spacing: 25 cm×15 cm

Spacing between plots: 0.50 m

Spacing between replication: 0.75 m

Crop: Wheat
Variety: BARI Gom 31
Experimental design: 2 Factor Split-Plot Design
No of Treatment: 16
No of Replication: 3
No of plots: 48

Factor A: Levels of Irrigation
i. I_0 =Control
ii. I_1 =At crown root initiation stage
iii. I_2 =At crown root initiation and flowering stage
iv. I_3 =At crown root initiation, flower initiation and grain filling stage

Factor B: Boichar and K management
i. B_0 K_0 =K: 0 kg ha^{-1} + Biochar: 5 t ha^{-1}
ii. B_1 K_1 =Biochar: 5 t ha^{-1} + K:48 kg ha^{-1}
iii. B_2K_2=Biochar: 5 t ha^{-1} + K:36 kg ha^{-1}
iv. B_3 K_3=K: 48 kg ha^{-1} + Biochar: 0 t ha^{-1}

Appendix 3: **Soil characteristics of experimental farm of Sher-e-Bangla Agricultural University are analyzed by soil Resources Development Institute (SRDI), Farmgate, Dhaka.**

Soil Characteristics	**Analytical Results**
Agro-ecological Zone	Modhupur Tract
Particle size analysis	
Sand(%)	28
Silt(%)	45
Clay(%)	32
Textural Class	Silty-clay
pH	5.48-5.63
Organic carbon (%)	0.44
Organic matter (%)	0.76
Total N(%)	0.03
Available P (ppm)	20.00
Exchangeable K (meq/100g soil)	0.11
Available S (ppm)	44

Source: SRDI (Soil Resources Development Institute), Farmgate, Dhaka.

Appendix 4. Split-plot AOV Table for Plant Height(cm) at 20 DAS:

Source	**DF**	**SS**	**MS**	**F**	**P**
Replication	2	23.637	11.8186		
Irrigation (A)	3	4.508	1.5026	40.65**	0.0002
Error (replication × A)	6	0.222	0.0370		
BC and K (B)	3	155.023	51.6745	143.55**	0.0000
AB	9	8.754	0.9727	2.70*	0.0250
Error (replication × AB)	24	8.639	0.3600		
Total	47	200.784			
Grand Mean	23.825				
CV(replication × AB)	2.52				

(**) indicates 1% level of significance and (*) indicates 5% level of significance

Appendix 5. Split-plot AOV Table for Plant Height(cm) at 40 DAS:

Source	DF	SS	MS	F	P
Replication	2	44.493	22.246		
Irrigation (A)	3	8.306	2.769	9.15**	0.0117
Error (replication × A)	6	1.816	0.303		
BC and K (B)	3	447.008	149.003	221.18**	0.0000
AB	9	71.761	7.973	11.84**	0.0000
Error (replication × AB)	24	16.168	0.674		
Total	47	589.552			
Grand Mean	44.232				
CV (replication × AB)	1.86				

(**) indicates 1% level of significance and (*) indicates 5% level of significance

Appendix 6. Split-plot AOV Table for Plant Height(cm) at 60 DAS:

Source	DF	SS	MS	F	P
Replication	2	48.710	24.355		
Irrigation (A)	3	35.688	11.896	16.57**	0.0026
Error (replication × A)	6	4.309	0.718		
BC and K (B)	3	467.508	155.836	148.89**	0.0000
AB	9	133.762	14.862	14.20**	0.0000
Error (replication × AB)	24	25.120	1.047		
Total	47	715.096			
Grand Mean	65.129				
CV(replication × AB)	1.57				

(**) indicates 1% level of significance and (*) indicates 5% level of significance

Appendix 7. Split-plot AOV Table for Plant Height(cm) at 80 DAS:

Source	DF	SS	MS	F	P
Replication	2	40.902	20.451		
Irrigation (A)	3	45.195	15.065	9.45**	0.0109
Error (replication × A)	6	9.565	1.594		
BC and K (B)	3	581.371	193.790	98.57**	0.0000
AB	9	183.420	20.380	10.37**	0.0000
Error (replication × AB)	24	47.186	1.966		
Total	47	907.638			
Grand Mean	75.765				
CV(replication × AB)	1.85				

(**) indicates 1% level of significance and (*) indicates 5% level of significance

Appendix 8. Split-plot AOV Table for Plant Height(cm) at harvest:

Source	DF	SS	MS	F	P
Replication	2	58.91	29.455		
Irrigation (A)	3	39.57	13.189	12.49**	0.0054
Error (replication × A)	6	6.34	1.056		
BC and K (B)	3	874.99	291.663	292.38**	0.0000
AB	9	159.05	17.672	17.72**	0.0000
Error (replication × AB)	24	23.94	0.998		
Total	47	1162.80			
Grand Mean	79.348				
CV(replication × AB)	1.26				

(**) indicates 1% level of significance and (*) indicates 5% level of significance

Appendix 9. Split-plot AOV Table for No. of tillers/plant at 40 DAS:

Source	DF	SS	MS	F	P
Replication	2	0.4067	0.20333		
Irrigation (A)	3	4.1158	1.37194	64.99**	0.0001
Error (replication × A)	6	0.1267	0.02111		
BC and K (B)	3	4.0492	1.34972	44.99**	0.0000
AB	9	1.3608	0.15120	5.04**	0.0007
Error (replication × AB)	24	0.7200	0.03000		
Total	47	10.7792			
Grand Mean	2.5208				
CV(replication × AB)	6.87				

(**) indicates 1% level of significance and (*) indicates 5% level of significance

Appendix 10. Split-plot AOV Table for No. of tillers/plant at 60 DAS:

Source	DF	SS	MS	F	P
Replication	2	4.6717	2.33583		
Irrigation (A)	3	9.3492	3.11639	23.72**	0.0010
Error (replication × A)	6	0.7883	0.13139		
BC and K (B)	3	7.7292	2.57639	69.74**	0.0000
AB	9	1.5942	0.17713	4.79**	0.0010
Error (replication × AB)	24	0.8867	0.03694		
Total	47	25.0192			
Grand Mean	4.5208				
CV(replication × AB)	4.25				

(**) indicates 1% level of significance and (*) indicates 5% level of significance

Appendix 11. Split-plot AOV Table for No. of tillers/plant at 80 DAS:

Source	DF	SS	MS	F	P
Replication	2	2.8817	1.44083		
Irrigation (A)	3	14.3625	4.78750	83.26**	0.0000
Error (replication × A)	6	0.3450	0.05750		
BC and K (B)	3	9.9025	3.30083	198.05**	0.0000
AB	9	2.8075	0.31194	18.72**	0.0000
Error (replication × AB)	24	0.400	0.01667		
Total	47	30.6992			
Grand Mean	5.5458				
CV(replication × AB)	2.33				

(**) indicates 1% level of significance and (*) indicates 5% level of significance

Appendix 12. Split-plot AOV Table for No. of tiller/plant at harvest:

Source	DF	SS	MS	F	P
Replication	2	2.7717	1.38583		
Irrigation (A)	3	14.0633	4.68778	276.66**	0.0000
Error (replication × A)	6	0.1017	0.01694		
BC and K (B)	3	9.7367	3.24556	204.98**	0.0000
AB	9	3.0233	0.33593	21.22**	0.0000
Error (replication × AB)	24	0.3800	0.01583		
Total	47	30.0767			
Grand Mean	5.3083				
CV(replication × AB)	2.37				

(**) indicates 1% level of significance and (*) indicates 5% level of significance

Appendix 13. Split-plot AOV Table for Leaf area index (LAI) at 40 DAS:

Source	DF	SS	MS	F	P
Replication	2	9.055	4.5273		
Irrigation (A)	3	52.041	17.3471	3.03NS	0.1153
Error (replication × A)	6	34.396	5.7327		
BC and K (B)	3	233.551	77.8503	24.61**	0.0000
AB	9	43.830	4.8700	1.54NS	0.1908
Error (replication × AB)	24	75.926	3.1636		
Total	47	448.799			
Grand Mean	27.941				
CV(replication × AB)	6.37				

(**) indicates 1% level of significance and (*) indicates 5% level of significance and NS for non-significant

Appendix 14. Split-plot AOV Table for Leaf area index (LAI) at 60 DAS:

Source	DF	SS	MS	F	P
Replication	2	157.829	78.914		
Irrigation (A)	3	39.406	13.135	6.03*	0.0305
Error (replication × A)	6	13.072	2.179		
BC and K (B)	3	534.386	178.129	87.28**	0.0000
AB	9	77.688	8.632	4.23**	0.0022
Error (replication × AB)	24	48.983	2.041		
Total	47	871.363			
Grand Mean	33.627				
CV(replication × AB)	4.25				

(**) indicates 1% level of significance and (*) indicates 5% level of significance

Appendix 15. Split-plot AOV Table for Leaf area index (LAI) at 80 DAS:

Source	DF	SS	MS	F	P
Replication	2	46.548	23.274		
Irrigation (A)	3	16.861	5.620	9.62**	0.0104
Error (replication × A)	6	3.505	0.584		
BC and K (B)	3	650.895	216.965	271.97**	0.0000
AB	9	62.260	6.918	8.67**	0.0000
Error (replication × AB)	24	19.146	0.798		
Total	47	799.215			
Grand Mean	26.487				
CV(replication × AB)	3.37				

indicates 1% level of significance and (*) indicates 5% level of significance

Appendix 16. Split-plot AOV Table for ear length (cm):

Source	DF	SS	MS	F	P
Replication	2	5.126	2.5632		
Irrigation (A)	3	64.765	21.5882	104.88**	0.0000
Error (replication × A)	6	1.235	0.2058		
BC and K (B)	3	48.779	16.2598	168.10**	0.0000
AB	9	11.594	1.2882	13.32**	0.0000
Error (replication × AB)	24	2.321	0.0967		
Total	47	133.820			
Grand Mean	14.561				
CV(replication × AB)	2.14				

(**) indicates 1% level of significance and (*) indicates 5% level of significance

Appendix 17. Split-plot AOV Table for no. of spikelets/ear:

Source	DF	SS	MS	F	P
Replication	2	9.012	4.5058		
Irrigation (A)	3	56.923	18.9742	143.20**	0.0000
Error (replication × A)	6	0.795	0.1325		
BC and K (B)	3	39.189	13.0631	139.55**	0.0000
AB	9	19.014	2.1127	22.57**	0.0000
Error (replication × AB)	24	2.247	0.0936		
Total	47	127.179			
Grand Mean	15.521				
CV(replication × AB)	1.97				

(**) indicates 1% level of significance and (*) indicates 5% level of significance

Appendix 18. Split-plot AOV Table for no. of grains/ear:

Source	DF	SS	MS	F	P
Replication	2	17.220	8.6102		
Irrigation (A)	3	260.417	86.8058	285.45**	0.0000
Error (replication × A)	6	1.825	0.3041		
BC and K (B)	3	212.392	70.7974	200.02**	0.0000
AB	9	45.975	5.1084	14.43**	0.0000
Error (replication × AB)	24	8.495	0.3540		
Total	47	546.325			
Grand Mean	32.610				
CV(replication × AB)	1.82				

(**) indicates 1% level of significance and (*) indicates 5% level of significance

Appendix 19. Split-plot AOV Table for 1000 grain wt. (gm):

Source	DF	SS	MS	F	P
Replication	2	19.487	9.7435		
Irrigation (A)	3	64.591	21.5304	30.02**	0.0005
Error (replication × A)	6	4.304	0.7173		
BC and K (B)	3	42.714	14.2380	30.36**	0.0000
AB	9	10.178	1.1309	2.41*	0.0412
Error (replication × AB)	24	11.257	0.4690		
Total	47	152.531			
Grand Mean	44.255				
CV(replication × AB)	1.55				

(**) indicates 1% level of significance and (*) indicates 5% level of significance and NS for non-significant

Appendix 20. Split-plot AOV Table for grain yield (t ha^{-1}):

Source	DF	SS	MS	F	P
Replication	2	0.3567	0.17834		
Irrigation (A)	3	7.3030	2.43435	63.42**	0.0001
Error (replication × A)	6	0.2303	0.03838		
BC and K (B)	3	4.0679	1.35596	44.66**	0.0000
AB	9	1.6458	0.18287	6.02**	0.0002
Error (replication × AB)	24	0.7288	0.03036		
Total	47	14.3325			
Grand Mean	2.3702				
CV(replication × AB)	7.35				

(**) indicates 1% level of significance and (*) indicates 5% level of significance

Appendix 21. Split-plot AOV Table for straw yield (t ha^{-1}):

Source	DF	SS	MS	F	P
Replication	2	0.44558	0.22279		
Irrigation (A)	3	3.38169	1.12723	43.23**	0.0002
Error (replication × A)	6	0.15645	0.02608		
BC and K (B)	3	3.61081	1.20360	53.95**	0.0000
AB	9	1.08919	0.12102	5.42**	0.0004
Error (replication × AB)	24	0.53543	0.02231		
Total	47	9.21915			
Grand Mean	2.6873				
CV(replication × AB)	5.56				

(**) indicates 1% level of significance and (*) indicates 5% level of significance

Appendix 22. Split-plot AOV Table for Harvest Index (%):

Source	DF	SS	MS	F	P
Replication	2	110.055	55.0273		
Irrigation (A)	3	202.684	67.5613	4.01NS	0.0697
Error (replication × A)	6	101.054	16.8423		
BC and K (B)	3	30.442	10.1475	3.41*	0.0339
AB	9	25.848	2.8720	0.96NS	0.4924
Error (replication × AB)	24	71.520	2.9800		
Total	47	541.603			
Grand Mean	46.393				
CV(replication × AB)	3.72				

(**) indicates 1% level of significance and (*) indicates 5% level of significance and NS for non-significant

PLATES

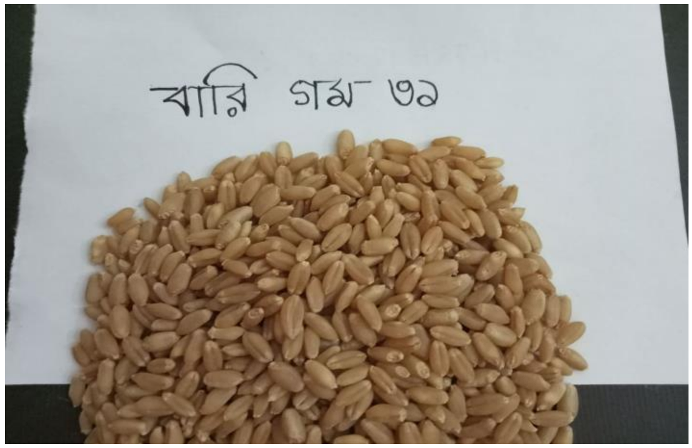


Plate 1. Planting Material

Plate 2: Difference between irrigated (left) and non- irrigated plot (right)

20 DAS

60 DAS

Plate 3. Field view at different days after sowing

Plate 4. Pest attack at experimental plot

Plate 5. Experimental Plot at maturity