

**APPLICATION OF BIOCHAR, RICE HUSK AND *Trichoderma*
BIO-FERTILIZER FOR THE GROWTH, YIELD ATTRIBUTES AND
YIELD OF WHEAT**



A THESIS

By

SADHONA ROY

Student ID: 1701054

Session: 2022-2023

Thesis Semester: January-June 2024

MASTER OF SCIENCE (M.S.)

IN

AGRONOMY

DEPARTMENT OF AGRONOMY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY

DINAJPUR-5200

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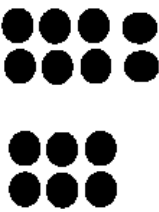
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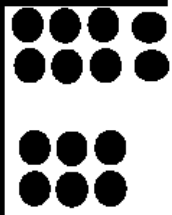
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**DEPARTMENT OF AGRONOMY
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY
DINAJPUR-5200**

JUNE 2024



Dedicated To My
Beloved Parents



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June, 2024

The Author

ABSTRACT

The experiment was conducted in Agronomy Research Field, Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh from November 2022 to April 2023 to assess the effect of Biochar, *Trichoderma* and Rice husk on the growth, yield attributes and yield of wheat. The experiment consisted of two factors where one factor was varieties namely V₁ (BWMRI Gom 2), V₂ (BWMRI Gom 3) and V₃ (BARI Gom 32) and another four treatments *e.g.*, T₁ (control), T₂ (50% Chemical fertilizer + 2 t /ha biochar), T₃ (50% Chemical fertilizer + 2 t /ha *trichoderma*) and T₄ (50% Chemical fertilizer + 2 t /ha rice husk). The experiment was laid out in a Randomized Complete Block Design (RCBD) . Parameters like plant height, number of tillers plant⁻¹, number of leaves plant⁻¹, spike length, fresh weight plant⁻¹, dry weight plant⁻¹, 1000 seeds weight, grain yield, straw yield, biological yield and harvest index were influenced by biochar, *trichoderma*, rice husk and chemical fertilizers. The BWMRI Gom 3 was found to significantly superior than BWMRI Gom 2 and BARI Gom 32 in terms of 1000 seeds weight (35.06g), grain yield (4.11 t ha⁻¹), biological yield (8.35 t ha⁻¹) and harvest index (48.77 %). T₃ (50% Chemical fertilizer + 2 t /ha *trichoderma*) showed best performance than the other treatment combinations in most of the parameters specially in 1000 seed weight (38.46g) and grain yield (5.53 t ha⁻¹), biological yield (8.84 t ha⁻¹), harvest index (53.70%). Interaction result showed that BWMRI Gom 3 along with T₃ (50% Chemical fertilizer + 2 t /ha *trichoderma*) possessed the highest grain yield 5.47 t ha⁻¹. Therefore, it can be suggested that the combined use of chemical fertilizers with *Trichoderma* for the improving of growth, yield attributes and yield of wheat in Bangladesh.

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LIST OF ABBREVIATIONS

| | | |
|------|---|--|
| AEZ | - | Agro-Ecological Zone |
| CF | - | Chemical Fertilizer |
| FAO | - | Food and Agriculture Organization |
| BARI | - | Bangladesh Agricultural Research Institute |
| CF | - | Chemical Fertilizer |
| CV | - | Coefficient of Variance |
| LSD | - | Least Significant Difference |
| RCBD | - | Randomized Complete Block Design |
| MoP | - | Muriate of Potash |
| TSP | - | Triple Supperphosphate |
| BC | - | Biochar |
| HI | - | Harvest Index |
| TGW | - | Thousand Grain Weight |
| BY | - | Biological Yield |
| GY | - | Grain Yield |
| DAS | - | Days After Sowing |
| G | - | Green Manure |
| FYM | - | Farm Yard Manure |

CHAPTER I

INTRODUCTION

Wheat crop belongs to the genus *Triticum*, especially, *T. aestivum*, of the family Graminae. Wheat (*Triticum aestivum* L.) is a grass widely cultivated for its seed, a cereal grain that is a worldwide dietary staple food and an excellent source of vegetable protein in the human diet worldwide (James and Mauseth, 2018). Wheat is a staple for millions of people around the world. Wheat grain constitutes a major food item and an important commodity in the world grain market. After rice and corn (maize), wheat is the third most-produced cereal worldwide, and the second most produced for human consumption (World Economic Forum, 2022) while in Bangladesh it ranks as the second most important cereal crop after rice. Wheat is one of the first grains domesticated by humans and bread wheat is known to have been grown in the Nile Valley by 5000 BC (Shewry, 2009). It is believed that the civilization of West Asia and European peoples have been largely dependent on wheat, while rice has been more important in East Asia (Avraham and Moshe, 2022). Although it is one of the oldest cereal crops and it was introduced in Bengal in 1930-31 and its importance as a food crop was recognized around 1942-43 (Banglapedia, 2021).

Wheat has contributed more calories and protein to the world's diet than any other food crop (Hanson et al., 2021). The area under wheat increased from only 132,000 ha in 1971 to 832,000 ha in 2000 but declined sharply to 479,050 ha in 2006. Consequently, total production and yield grew at an annual rate of 6.9% (in 1971) and 1.9% (in 2000), respectively. The actual yield level increased from 0.9 t/ha to 1.5 t/ha over this 36 years period (Rahman and Hasan, 2022). While in 2020, wheat production for Bangladesh was 1.18 million tonnes. Between 2009 to 2020 wheat production in Bangladesh was decreasing on average by 0.44% each year, although before that, it grew from 1.11 million tonnes in 2007 to 1.98 million tonnes in 2008 (FAO, 2020). The production of wheat crop is official estimated at 1.15 million tonnes for the (2021-2022) cropping years (FAO, 2022).

Wheat is one of the major cereal crops in Bangladesh. Over the last two decades, wheat consumption has been dramatically improved in Bangladesh but its production has declined due to various stressful environments. Recurrent drought event due to climate change that threatens the country's food safety has become a serious concern (Hannan *et al.*, 2021).

Drought stress adversely affects physiological and biochemical processes of wheat leading to a reduction in crop productivity (Nowsherwan *et al.*, 2018). Plants try to protect themselves via activation of their internal defense system, but severe drought causes disruption of this defense system (Naeem *et al.*, 2015). Drought, one of the significant abiotic stresses, occurs when water potential and turgor are reduced to the point where they impair normal metabolic functions and the plant's reproductive capacity (Nowsherwan *et al.*, 2018). If the water holding capacity of the soil is low then it will be a vital problem for the wheat plant to survive. As wheat is sown in the winter season, low rainfall is there and water scarcity is experienced in Bangladesh (Hannan *et al.*, 2021). Therefore, drought has been dubbed one of the most severe threats to the environment and Bangladesh. It is predicted to become more prevalent and severe in many locations of Bangladesh due to reduced rainfall and higher evaporation owing to climate change (Hannan *et al.*, 2021). Additionally, global warming has led to unpredictable rainfall patterns, resulting in the recurrence of extended drought periods throughout the globe. The continuous radial drought events significantly affect wheat development causing growth to be delayed, physiology to be disrupted, and reproduction to be harmed (Bijalwan *et al.*, 2022). Therefore, adopting appropriate drought management strategies can help to ensure food security in Bangladesh. In this crucial situation, biochar application can be one of the important tools to mitigate this drought in Bangladesh.

In addition, soil problem is a vital issue of wheat production in Bangladesh. The fertility of soils is depletion day after day due to the use of more chemical fertilizers. Another way, continuous crop cultivation without adding sufficient inputs to soil seriously influence soil fertility, soil health, and productivity (Mahbub *et al.*, 2020). Soil organic matter content is reportedly decreasing in the soils of Bangladesh, which is viewed as an important issue in soil health (Ahmmed *et al.*, 2018). The excessive use of chemical fertilizers coupled with intensive crop production with less organic fertilizer uses is the primary cause of soil fertility difficulties in Bangladesh. Traditional organic amendments like composts, manures, and crop residues have limited longevity in the soil, and the practice of applying them in large amounts on a regular basis has distracted the focus of scientists away from this activity. Improving soil fertility in drought regions to ensure food security through increased crop production is a great concern in Bangladesh for wheat production (Aktar *et al.*, 2021). However, recently some problems are identified within the soil that is an important cause of the reduction in wheat production in Bangladesh. As biochar helps to increase the water- holding capacity of

soil and make the nutrients available to the plants, it can be used as a good soil amendment in the field for wheat production (Abdullah-Al Baquy *et al.*, 2022). Therefore, there is no way to improve the health of the soil in Bangladesh or increase its productivity until resource conservation strategies are used (Mia *et al.*, 2014; Rahman *et al.*, 2022).

Since 2013, the non-profit organization Christian Commission for Development in Bangladesh (CCDB) has launched the Bangladesh Biochar Initiative (BBI; www.biochar-bangladesh.org). BBI is a two-pronged program and it provides biochar using to mitigate drought for wheat (BBI, 2021 and Karim *et al.*, 2020). Albuquerque *et al.* (2013) defined biochar as a carbon-containing substance obtained via the pyrolysis of biomass residues. Additionally, Ahmad *et al.*, (2016) concluded that biochar is a viable option for resolving drought-related problems and improve wheat productivity (Iqbal, 2017). Biochar is created by heating organic material under conditions of limited or no oxygen (Lehman, 2015). Several kinds of research showed that biochar has contents of carbon (C), nitrogen (N), phosphorus (P) potassium (K), and other essential macro and micronutrients depending on the types of biochar and help many agricultural crops (Lehmann and Stephen, 2015). Biochar can increase microbial activity, reduce nutrient loss, improve the efficiency of inorganic and organic fertilizers, minimize chemical fertilizers, make nutrients more available to plants and reduce nutrient losses during the drought of wheat (Haider *et al.*, 2020; Iqbal, 2017).

Trichoderma species are the fungi has the capacity to produce antibiotics, parasitize other fungi, and compete with deleterious microorganisms which were considered to be the basis for how *Trichoderma* exert beneficial effects on plant growth and development (Harman *et al.*, 2004). The benefits of *Trichoderma* species in improving plant growth can be realized through several mechanisms which include mycoparasitism, antibiosis, degradation of toxins, inactivation of pathogenic enzymes pathways, resistance against pathogens, enhanced nutrient uptake, solubilization, sequestration of inorganic nutrients and enhanced root hair development (Harman, 2006; Lorito *et al.*, 2010). *Trichoderma* helps to increase plant hormone which helps to increase root growth and root hair formation that results in the more efficient use of nitrogen, phosphorus, potassium and micronutrient and increase seedling vigor and germination (Mastouri *et al.*, 2010). *T. viride* displayed antagonism with inorganic fertilizer. When *T. viride* and NPK were accompanied with farmyard manure, most of the growth and yield parameter showed the highest value. Though *Trichoderma viride* decreases several growth parameters, it still can be used as biofertilizer which increases the grain yield

(Mahato *et al.*, 2018). Using *T. viride* with a full dose of NPK during sowing stage may not be efficient and economical in terms of productivity of wheat. A group researcher documented that *Trichoderma harzianum* and *Trichoderma asperellum* are highly rhizosphere competent and able to stimulate the growth and immune defense of plants (Harman *et al.*, 2004). *Trichoderma harzianum* and *Trichoderma viride* enhanced rice and tomato root and shoot length (Balasubramanian *et al.*, 2014 and Shukla *et al.*, 2012). Seed germination, root length, shoot length, fresh weight, dry weight, and vigor index were significantly increased by *T. viride* and *P. fluorescens* (Shanmugaiah *et al.*, 2009).

Rice husk is an agricultural waste material, mainly used for energy generation, and also used as raw materials to develop technological products such as high purity silica ash, silicon carbide and zeolites (Pode 2016). Rice husk is the important agro-industrial waste by-products that are generally used as fuel in rice mill industry, respectively. Rice husk as the main by-product in rice mills is being produced in more than 75 countries around the world and the annual world output is about 116 million (FAO, 2022). Rice husk is generally used as furnace fuel producing huge quantities of rice husk ash (RHA), ranging from 16 to 23%; an agro waste that causes serious environmental problems.

Integration of biochar and chemical or organic fertilizers generally provides for better nutrient management and wheat yield (Al- Wabel *et al.*, 2018). Therefore, the combined application of biochar with chemical fertilizers could be a step forward in ameliorating the adverse effects of drought on critical growth stages of wheat. Hence, considering the important of biochar *Trichoderma* and rice husk application the objectives are -

1. To study the effects of biochar, *Trichoderma* and rice husk on yield and yield components of wheat.
2. To find out the best treatment combination of chemical fertilizer with biochar, *Trichoderma* and rice husk application for improving the yield.
3. To find out the best performing variety of wheat with enhancing soil properties by applying biochar, *Trichoderma* and rice husk to mitigate drought.

CHAPTER II

REVIEW OF LITERATURE

This chapter provides a thorough review of the studies on the benefits of using biochar, *Trichoderma* and rice husk along with chemical fertilizer to increase wheat crop performance. The recent literature has received special attention.

2.1 Biochar on yield and yield components of wheat:

2.1.1 Plant height

Barman *et al.* (2019) was conducted on experiment in Completely Randomized Design with three repetitions in the field of School of Agriculture, Lovely Professional University, from 31st November 2017 to 28th April 2018 to study Impact of rice husk biochar and inorganic amendments on growth attributes parameter of wheat. Different pots were treated with different level of biochar and inorganic amendments viz., T₁ (100% RDF), T₂ (3% Biochar+50% RDF), T₃ (3% Biochar+75% RDF), T₄ (3% Biochar+100% RDF), T₅ (5% Biochar+50% RDF), T₆ (5% Biochar+75% RDF), T₇ (5% Biochar+100% RDF) with control. Result revealed that application of 3% Biochar+75% RDF recorded significantly highest growth attributes (Plant height (cm), Number of tillers, Leaf length (cm)) after 30, 45, 60, 75 and 90 DAS.

Abbas *et al.* (2017a) carried out a field experiment to assess the impact of urea supplemented with biochar on the nitrogen economy of soil in order to enhance wheat development and production in a field setting. The twelve treatments in the experiment plan included four replications: urea only, urea plus biochar (control), and no urea at all. For each treatment, 1–10% of the weight of urea fertilizer was applied as biochar. The results indicated that, when compared to a treatment consisting of the recommended rate of nitrogen without biochar, the application of 10% biochar combined with the recommended dose of urea considerably increased plant height by 6.0%.

Haider *et al.* (2020) conducted an experiment in a semi-arid climate with three different biochar treatments (B₀ = Control, B₁ = 27.88 g kg⁻¹, and B₂ = 37.18 g kg⁻¹) to observe the negative effects of drought at critical wheat growth stages, *i.e.*, tillering (DTS), flowering (DFS), and grain filling stage (3DGFS). When DGFS, DFS, and DTS were irrigated normally

(control), a reduction in plant height of 8.70, 6.24, and 3.69% was observed, respectively. With increased plant height, biochar greatly mitigates the negative impacts of drought. In comparison to plants that did not receive any biochar treatment, wheat plants treated with biochar rose in height by 4.32 and 3.78%, respectively.

Abbas *et al.* (2017b) looked into how wheat straw with biochar affected the immobilization of Cd in soil and how wheat absorbed Cd from polluted agricultural soil. Following two weeks of incubation, various concentrations of rice straw biochar (0.5%, 1.5%, 3.0%, and 5% w/w) were added to the soil. After that, wheat plants were raised until they reached maturity in the altered soil. According to the findings, the biochar treatments raised the pH of the soil and soil solution as well as the silicon contents of the plant tissues and soil solution, but they lowered the amount of bio-available Cd in the soil. Comparing the biochar application to the control treatment, the plant height grew in a dose-additive way.

Shi *et al.* (2022) investigated the efficacy of *Trichoderma* and biochar co-application on tomato productivity, nutritional quality and soil health improvements under reduced N-P-K fertilizer application. The study comprised of five treatments: (i) standard application of N-P-K, (ii) 50% dose of N-P-K (control), (iii) *Trichoderma* + 50% dose of N-P-K, (iv) biochar+50% dose of N-P-K and (v) biochar+*Trichoderma* + 50% dose of N-P-K. The growth, yield, and antioxidant properties of tomatoes, as well as their mineral composition, were analysed. The results showed that the combined application of *Trichoderma* and biochar increased the growth attributes positively and produced 101.45% and 11.33% higher yield compared to half dose and standard dose of N-P-K, respectively. The combined application also elicited an increase in mineral contents, total soluble solids as well as bioactive molecules such as lycopene and ascorbic acid, thereby increased the nutritional and functional quality of the tomato fruits. Collectively, *Trichoderma* and biochar improved soil fertility, nutrient uptake and promoted the growth of rhizosphere fungal and bacterial populations, which combined resulted in higher tomato yields, antioxidants, and minerals. Therefore, the co-application of *Trichoderma* and biochar with a 50% dose of N-P-K can be considered an effective technique for the sustainable production of tomato with higher yield and superior quality.

Singh *et al.* (2019) studied the impact of various soil amendments *viz.*, rice-husk ash (RHA) and farm-yard manure (FYM) along with mineral fertilizer on soil biophysical and agronomic

parameters of wheat crop. We specifically explored the impact of the amendments on soil CO₂ efflux (SCE, under different growth stages) and the harvest index of wheat crop, which are considered as the key indicators of soil viability and agronomic efficiency, respectively. SCE, soil moisture, soil temperature, soil N, microbial biomass and soil pH were found significantly varying under different treatments ($P < 0.05$). SCE was found maximum under sole FYM applied and minimum under mineral fertilizer applied treatments, whereas RHA application lowered the SCE as compared to sole FYM application. Moreover, SCE showed variation with plant growth stages, and found maximum during stem elongation followed by heading stage whereas minimum during ripening stage. Soil moisture was found to have considerable regulation for the overall variation in SCE ($r^2 = 0.17$; $P = 0.04$). In contrast to the soil properties, agronomic parameters (except harvest index) were found higher under mineral fertilizer applied treatments followed by sole FYM and combined FYM+RHA treatments, whereas sole RHA applied treatment showed minimum values. However, significant variations were observed only for harvest index, above ground dry matter, grain and straw yields ($P < 0.05$). Further, harvest index was found highest under sole and combined FYM and RHA applied treatments whereas lowest in mineral fertilizer applied treatments. Soil C/N ratio ($r^2 = 0.16$; $P = 0.04$) and panicle length ($r^2 = 0.18$; $P = 0.03$), respectively as soil and agronomic parameters, have been found to have considerable control over harvest index. The findings revealed that soil viability is higher under sole FYM and combined FYM+RHA treatments whereas mineral fertilization enhances agronomic performance.

2.1.2 Number of tillers plant⁻¹

Zulfiqar *et al.* (2022) reported that organic amendments could be the possible option in semi-arid climatic conditions to mitigate the adverse effects of drought at critical growth stages. Wheat straw biochar (BC₀ = Control, BC₁ = 3 % biochar and BC₂ = 5 % biochar) was used to alleviate the drought stress at tillering (DTS), flowering (DFS), and grain filling (DGFS) stages. Drought stress significantly reduced the growth and yield of wheat at critical growth stages, with DGFS being the most susceptible stage, resulting in significant yield loss. Biochar application substantially reduced the detrimental effects of drought by improving fertile tiller count (17.14 %) improved by biochar application.

Haider *et al.* (2020) stated that biochar is an organic soil amendment that is used to improve soil carbon, organic contents, improve water holding capacity of soil, enhance soil fertility and maintain desired soil. They carried out an experiment under semi-arid climatic conditions

to mitigate the adverse effects of drought at critical wheat growth stages *i.e.*, tillering (DTS), flowering (DFS) and grain filling stage (DGFS) by using three biochar treatments viz. B0 = Control, B1 = 27.88 g kg⁻¹ and B2 = 37.18 g kg⁻¹. Results revealed that drought stress negatively affected the growth and yield attributes of wheat at all critical growth stages, while, grain filling stage was found the most sensitive stage resulted severe yield reduction. However, biochar application significantly mitigated the detrimental effects of drought by improving number of fertile tillers (19.50 %) as compared to control treatment.

Ahmad *et al.* (2016) conducted a pot experiment was conducted by at the Soil and Water Testing Laboratory for Research, Multan, Pakistan during 2013. The treatments included different levels of biochar with NPK and micronutrients before sowing the crop *i.e.* T₁: Control, T₂: NPK + micronutrients (as recommended), T₃: NPK + Biochar (1 %), T₄: NPK + micronutrients (as recommended) + Biochar (1 %), T₅: NPK + Biochar (2 %) and T₆: NPK + micronutrients (as recommended) + Biochar (2 %). The layout of the experiment was CRD (complete randomized design) with six treatments and four replications. The recommended doses of NPK @ 103:84:62 kg ha⁻¹ was applied in the form of urea, diammonium phosphate and potassium sulphate respectively. Micronutrients (B, Mn, Zn and Cu @ 1.5:5:5:5 kg ha⁻¹) were applied in liquid form in the form of H₃BO₃, MnSO₄, ZnSO₄ and CuSO₄ respectively. As far as tillering is concerned, biochar application had a significant impact over other treatments when used in combination with macro and micronutrients. The highest tiller number was observed on T₆, 2 % biochar application.

Iqbal *et al.* (2017) was conducted field experiment for three and half years to explore the possibilities to utilize these waste materials as soil amendments to improve productivity of rice–wheat system (RWS). The treatments consisted of application of RHA and BA at 10 Mg ha⁻¹ to either wheat or to rice or to both wheat and rice and 20 Mg ha⁻¹ to rice alone. The rates used for FA were 15 and 30 Mg ha⁻¹. Addition of RHA and BA significantly increased the grain yield of wheat and rice but FA caused small increases in crop yields. Direct application of RHA and BA to wheat was significantly superior than their application to rice in the RWS. Direct application of RHA and BA to wheat resulted in 25 and 24% increase in mean grain yield of wheat and 10 and 11% increase in subsequent rice crop, respectively. However, direct application to rice resulted in 8 and 11% yield increase in rice and 10 and 14% increase in subsequent wheat for RHA and BA, respectively. Application of RHA and BA at 20 Mg ha⁻¹ to rice resulted in lower RWS productivity than that applied at

10 Mg ha⁻¹ to wheat. There was no significant effect of these ashes on heavy metal contents in grain and straw of the 7th crop of wheat. Application of three types of ashes generally resulted in positive P balance in RWS, however, K balance remained negative. These results suggest that RHA and BA can be recycled successfully in rice–wheat system to improve its productivity with no adverse effect on soil health.

2.1.3 Number of leaves plant⁻¹

The impact of biochar and chitosan on barley plants under drought stress conditions was investigated during two field experiments by Hafez *et al.* (2020). Their results confirmed that drought stress negatively affected number of leaves, significantly decreased in stressed barley plants, also anatomical traits such as upper epidermis, lower epidermis, lamina, and mesophyll tissue thickness as well as vascular bundle diameter of flag leaves significantly decreased compared with control. The use of biochar and chitosan led to significant increases in number of leaves, and chlorophyll concentrations in the stressed plants. Moreover, anatomical and yield characters of stressed barley plants were improved with application of biochar and chitosan. The results proved the significance of biochar and chitosan in alleviating the damaging impacts of drought.

Manli Duan *et al.* (2023) study was to improve the phytoremediation efficiency of *Brassica juncea* and the rhizosphere soil micro-ecology in cadmium (Cd) and arsenic (As) contaminated soil. A field experiment was conducted with six treatments, including a control treatment (CK), two treatments with two contents of *Trichoderma harzianum* (T1: 4.5 g m⁻²; T2: 9 g m⁻²), one biochar treatment (B: 750 g m⁻²), and two combined treatments of T1B and T2B. The results showed that *Trichoderma harzianum* promoted the total chlorophyll and translocation factor of *Brassica juncea*, while biochar promoted plant biomass compared to CK. T2B treatment showed the best results, which significantly increased Cd accumulation by 187.49–308.92%, and As accumulation by 125.74–221.43%. As a result, the soil's total Cd content was reduced by 19.04% to 49.64% and total As contents by 38.76% to 53.77%. The combined amendment increased the contents of soil available potassium, phosphorus, nitrogen, and organic matter. Meanwhile, both the activity of glutathione and peroxidase enzymes in plants, together with urease and sucrase enzymes in soil, were increased. Firmicutes (dominant bacterial phylum) and Ascomycota (dominant fungal phylum) showed positive and close correlation with soil nutrients and plant potentially toxic elements contents. This study demonstrated that phytoremediation assisted by biochar and *Trichoderma*

harzianum is an effective method of soil remediation and provides a new strategy for enhancing plant remediation efficiency.

2.1.4 Spike length plant⁻¹

Abbas *et al.* (2017a) conducted a field experiment to evaluate effect of biochar-amended urea on nitrogen economy of soil for improving the growth and yield of wheat under field condition. Experiment plan was comprised of twelve treatments with four replications including treatments without application of urea and biochar (control) and urea only. Biochar was applied at 1–10 % of the weight of urea fertilizer applied each treatment. Results showed that application of biochar at 10 % with recommended dose of urea significantly improved spike length by 11.1 % as compared to treatment comprised of recommended rate of nitrogen without biochar.

Zulfiqar *et al.* (2022), organic amendments may be a viable solution in semi-arid climates to lessen the negative impacts of drought during crucial growth stages. In order to reduce the effects of drought stress during the tillering (DTS), flowering (DFS), and grain filling (DGFS) stages, wheat straw biochar (BC0 = Control, BC1 = 3% biochar, and BC2 = 5% biochar) was employed. Wheat at important growth stages was severely stunted by drought stress, with DGFS being the most vulnerable stage, leading to a large yield loss. The application of biochar boosted spike length (16.61%), which significantly lessened the negative effects of drought.

Haider *et al.* (2020) used three different biochar treatments B₀ = Control, B₁ = 27.88 g kg⁻¹, and B₂ = 37.18 g kg⁻¹ to reduce the negative effects of drought at crucial wheat growth stages, namely tillering (DTS), flowering (DFS), and grain filling stage (DGFS). The study was conducted in semi-arid climates. The findings showed that wheat under drought stress suffered adverse effects on growth and yield characteristics at all crucial growth phases; the most sensitive stage, which led to a significant drop in yield, was the grain filling stage. In contrast to the control treatment, biochar application improved spike length (6.52%) and hence greatly reduced the negative impacts of drought.

Zehui Niu *et al.* (2022) investigated the effects of different amendments (2% rice husk biochar, 2% limestone, and 1% rice husk biochar+1% limestone) on the growth and Cd accumulation of wheat in pot and field experiments. The results showed that under the low

soil Cd condition, the maximum increase of soil pH (1.83) was found in the limestone treatment compared to CK in pot experiment. Compared with the CK, the treatment of rice husk biochar decreased soil Cd availability and grain Cd content by about 25% and 31.2%, respectively. In contrast, under high soil Cd condition, the highest soil pH was observed in limestone, while the lowest soil Cd availability and grain Cd concentrations were found in rice husk biochar treatment. In the field experiment, the treatment of 1% rice husk biochar + 1% limestone caused a significant increase of soil pH by about 28.2%, whereas the treatment of 2% rice husk biochar reduced soil Cd availability and grain Cd content by about 38.9% and 38.5% compared to the CK. Therefore, rice husk biochar showed great potential to reduce Cd availability and ensure safe food production.

2.1.5 Dry weight plant⁻¹

Mahmoud *et al.* (2020) conducted an experiment and found that soil contamination with heavy metals has resulted in a reduction of crop productivity and soil quality. They studied the effects of rice straw biochar (RB), rice straw compost (RC), and their mixtures at rates 0.5 % and 1.0 % on soil biochemistry and dry weight of the canola plant (*Brassica napus*) grown in contaminated soil with heavy metals. The results showed that the addition of the RB or RC alone or their mixtures together significantly increased contents of soil exchangeable cations, microbial biomass carbon (MBC), organic matter (OM), cations exchange capacity (CEC), availability of nutrients, NPK uptake, and dry weight of the canola plant. Soil microbial biomass carbon increased by 20.2 % and 59.3 % for RB, while it increased by 69.5 % and 79.8 % for RC with the addition of 0.5 % and 1.0 %, respectively, compared to the control. The results of this study reveal that the co-application of biochar with compost can be a promising strategy for improving soil productivity and soil quality in soil contaminated with heavy metals.

Ozge *et al.* (2023) aimed to study a newly developed P fertilizer, phosphorus-enriched biochar (PEB), to evaluate and compare for its agronomic performance on wheat and maize. Rice husk biochar was enriched with concentrated phosphoric acid (PA), (500/84: w/v). X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR) were used to determine PEB's functional and structural properties. Under controlled conditions, a greenhouse experiment was conducted with wheat followed by maize to determine the main and residual effects of P. The four treatments were control (no P), triple superphosphate

(TSP), PA, and PEB (200 mg·P·kg⁻¹). The experiment was designed using completely randomized design with five replications. Incorporation of PEB in the form of biochar (BC) integrated with PA significantly increased plant dry weight in both crops. PEB resulted in the highest P concentration in wheat (6.38 g kg⁻¹). Similarly, the residual effects were seen in maize (3.18 g kg⁻¹). In both plants, treatments did not significantly affect N and K concentrations. Calcium concentration in the wheat plants increased significantly. Different P sources had different effects on Fe (wheat remained un-changed; decreased in maize), Si, Zn, Cu, and Mn (decreased in both plants). Biochar enriched with PA decreased the soil pH and increased the P concentration in soil, and plant, hence, can replace inorganic P fertilizers as an alternative and in eco-friendly manner.

2.1.6 Fresh weight plant⁻¹

Hussien *et al.* (2020) conducted an experiment at the experimental farm of Yangzhou University, Yangzhou, in the sorghum growing season (summer 2018). They found that fresh weight affected by biochar and the Salinity × Biochar interaction. At the 12.6 dS m⁻¹ rate, the highest fresh weight value was recorded with BC 5 % (105.4 g plant⁻¹) followed by BC 10 % (83.5 g plant⁻¹), BC 2.5 % (74.9 g plant⁻¹), and BC 0 % (38.8 g plant⁻¹).

Pratibha Sharma *et al.* (2012) studied on the validation of the *Trichoderma* technology for growth promoting ability of *Trichoderma harzianum* (Th3) was evaluated in the popular wheat (*Triticum aestivum* L.) variety Raj 3765 at farmer's field through TIFAC-DST project entitled "On Farm Demonstration and Commercial Production of *Trichoderma* as Biopesticide and Growth Promoter". The biological formulation was developed at Biological Control Laboratory, Division of Plant Pathology, IARI, New Delhi, and was successfully demonstrated in two districts of Rajasthan viz., Jaipur and Kota belonging to different agro climatic zones. Rhizospheric Competence Index along with its growth promotion effect on rootlets, tillers, weight of grains and grain yield were evaluated by using it at three stages of crop viz., seed, flowering and preharvesting @ 4g/kg and @ 4ml/L along with soil treatment with a mixture of farm yard manure and formulation @ 50:1 before sowing. Compared to the first year where the farmers were unaware of *Trichoderma* in 2008-09, a significant increase in yield of wheat from 36.25 to 46.73Q/ha (29% in Jaipur) and from 36.88 to 50.12Q/ha (36% in Kota) has been observed after continuous application for three years (2008-2011)

The total income and the benefit cost ratio of farmers increased both at Jaipur (Rs 56242/ha, 1:1.8) and Kota (Rs 60332/ha, 1:1.9).

2.1.7 Thousand seed weight

Haider *et al.* (2020) observed that drought stress decreased the number of 1000 grain weight (12.33, 5.40, 2.04%) in DGFS, DFS, and DTS, respectively. Under both water stress and control circumstances, the detrimental effects of drought were lessened by biochar amendments. When applied, biochar greatly increased all of the yield components mentioned above when compared to the control treatment. But in contrast to the control group.

According to research by Zulfiqar *et al.* (2022), using biochar improved thousand grain weights (10.4%) in comparison to the control treatment, significantly lessening the negative effects of drought.

Abbas *et al.* (2017a) carried out a field experiment to assess the impact of urea modified with biochar on the nitrogen economy of the soil. The twelve treatments in the experiment consisted of four replications, two of which included urea alone and one that included biochar as a control. 1%–10% of the weight of the urea fertilizer applied for each treatment was made up of biochar. As compared to a treatment consisting of the prescribed rate of nitrogen without biochar, the results demonstrated a substantial 5.4% improvement in 1000 grain weight when 10% biochar was applied along with the recommended dose of urea.

Anwar *et al.* (2023) conducted an experiment to investigate the effect of foliar applied copper and boron alone and in combination with *Trichoderma harzianum* on yield attributes, grain quality, and nutrient contents of wheat. Wheat plants were treated with copper and boron in combination with or without *T. harzianum*. The applied treatments included Cu (0.05 M), Cu (0.1 M), *T. harzianum*, Cu (0.05 M)/*T. harzianum*, Cu (0.1 M)/*T. harzianum*, B (0.05 M), B (0.1 M), B (0.05 M)/*T. harzianum*, B (0.1 M)/*T. harzianum*, Cu (0.05 M)/B (0.05 M)/*T. harzianum*, and Cu (0.1 M)/B (0.1 M)/*T. harzianum* along with a control set for comparison. Results revealed significant enhancement in different studied growth traits including plant height, spike length, kernels per spike, harvest index, and chlorophyll content. In addition, this approach also enriched wheat grains with various micro/macronutrients including Cu, Fe, Zn, K, and P. This study concludes that the bioreagent *T. harzianum* along with foliar copper and boron may lead to reasonably enhanced grain quality and growth characteristics of wheat,

2.1.8 Seed yield

Sun *et al.* (2019) reported that biochar can potentially increase crop production in saline soils. However, the appropriate amount of biochar that should be applied to benefit from resource preservation and increase both grain yield (GY) and quality is not clear. A pot experiment was conducted by them to evaluate the effects of biochar applied at various rates (i.e., 0, 5, 10, 20, 30, 40 and 50 t ha⁻¹) on the nitrogen use efficiency (NUE), GY and amino acid (AA) contents of wheat plants in saline soils. The results showed that the application of 5–20 t ha⁻¹ biochar increased wheat NUE by 5.2–37.9 % and thus increased wheat GY by 2.9–19.4 %. However, excessive biochar applications (more than 30 t ha⁻¹) had negative effects on both the NUE and GY of wheat.

Khan *et al.* (2022) aimed to evaluate the impact of biochar (0, 10, 20, and 30 t ha⁻¹) on the quality and N uptake of wheat in a calcareous soil under integrated N management (90, 120, and 150 kg N ha⁻¹), which included control and application of urea, farmyard manure (FYM), and poultry manure (PM) every two years. The application of 150 kg N ha⁻¹ and 20 t BC as poultry manure significantly increased wheat grain by 14.6%. Nevertheless, compared to the first year (2015–2016), their influence was more noticeable in the second year (2016–2017) following application.

Dong *et al.* (2022) conducted an experiment and found that the effect of biochar on the improvement of soil properties and crop yield was varied from soil properties and limited for medium–low-yield farmland in the North China. During the completely randomized field experiment, SIX treatments (biochar applied as 0, 15 and 30 t ha⁻¹, under 240 and 300 kg N ha⁻¹ nitrogen fertilizer) were applied in wheat season and examined to reveal changes in the SOC and other properties of 0- to 10-cm and 10- to 20-cm soil layers. The results showed that two years after the application of biochar, a significant increase in the SOC was observed, ranging from 19.52 % to 97.50 % ($p < 0.05$) in the 0- to 20-cm soil layer. Wheat yield and SOC content increased with increasing amount of biochar applied under the same amount of nitrogen fertilizer. The content of soil available potassium increased significantly under 30 t·ha⁻¹ biochar application ($p < 0.05$). Both biochar and nitrogen fertilizer application could increase wheat yield, and the effect of biochar application for increasing wheat yield was better than that of nitrogen fertilizer. Wheat yield and SOC content increased with increasing nitrogen fertilizer at the same amount of biochar application. The principal component

analysis results showed that biochar input, SOC, available potassium and total nitrogen were the key factors affecting wheat yield. Biochar application is a fast and effective measure to improve SOC and wheat yield in medium- and low-yield farmlands.

2.1.9 Straw yield

Korai *et al.* (2021) assessed the impact of several biochars on grain yield, phyto-availability, and macro- and micronutrient absorption by rice and wheat planted in paddy soil rotation. Untreated soil served as the control (CF), and the following biochar treatments were applied to the soil: i) maize raw (un-washed) biochar (MRB), ii) maize water-washed biochar (MWB), iii) wheat raw biochar (WRB), or iv) wheat water-washed biochar (WWB). All soils received inorganic fertilizers, but soils treated with biochar got 20 tons ha⁻¹ of specific biochar prior to rice planting in a rice-wheat rotation. In comparison to the CF, the WRB enhanced straw and rice grain yield by as much as 49% ($P < 0.05$). The addition of biochar, especially WRB, greatly enhanced the amount of N, P, and K available in rice and wheat grain (26–37%) and straw (22–37%).

Zhao *et al.* (2014) conducted an experiment to investigate the effects of two consecutive applications of rice-straw biochar on crop development and soil parameters in China's acidic oxisols and alkaline cambosols, using a pot experiment utilizing a wheat-millet rotation. At the start of each crop season, biochar was added to the soil at rates of 0, 2.25, or 22.5 mg/ha while receiving the same amounts of NPK fertilizer treatments. The largest biochar treatment in the oxisols increased wheat and millet yields by 157 and 150 percent for wheat grain and straw, respectively, and 72.6% for millet straw. It also decreased soil bulk density, improved soil pH and cation exchange capacity, and improved soil P, K, Ca, and Mg availability and enhanced their uptake. The biochar treatment in the cambosols resulted in a decrease in soil bulk density, an improvement in P and K availability, an increase in N, P, and K uptake by crops, and yield increases of 19.6% and 60.6%, respectively, for wheat and millet straw.

2.1.10 Biological yield

Abbas *et al.* (2017a) assessed the impact of urea modified with biochar on the nitrogen economy of the soil in order to enhance wheat yield and growth in a field setting. The study plan included twelve treatments, each with four replications: treatments with biochar as a control, treatments with urea alone, and treatments without biochar. Each treatment involved

applying biochar at a rate of 1%–10% of the weight of urea fertilizer. Based on the recommended dose of urea and 10% biochar application, the results demonstrated a substantial 19.0% increase in total biomass compared to the treatment consisting of a recommended rate of nitrogen without biochar.

Ali *et al.* (2019) with the aim of assessing the impact of different inorganic (nitrogen, urea) and organic (biochar and FYM) amendments on the growth and yield of wheat and related soil attributes. Maintaining soil fertility and productivity may be greatly aided by the use of biochar in agricultural fields. Biochar (0,25 and 50 tons ha⁻¹), FYM (5 and 10 tons ha⁻¹), and nitrogen (60 and 120 kg ha⁻¹) were the three components of the trials. One of the experimental treatments was a controlled one. At the New Developmental Farm of the University of Agriculture Peshawar, Pakistan, during the winters of 2012–13 and 2013–14, each treatment was duplicated three times using the RCBD architecture. When BC was applied in conjunction with 60 kg N ha⁻¹, it was discovered to increase wheat grain yield and biological yield by 23% and 17%, respectively, over non-BC plots. Additionally, when BC was applied in conjunction with biochar at a rate of 25 tons per ha⁻¹, it was found to increase wheat leaf chlorophyll content and relative water content by 49% and 31%, respectively. Applying FYM also increased biological yield and wheat grain yield over control by 16% and 33%, respectively.

In order to evaluate the interacting effects of biochar with synthetic fertilizer and farmyard manure, Ali *et al.* (2015) carried out two-year field tests. The biological yield rose by 15.36% with the application of biochar at a rate of 25 t ha⁻¹.

2.1.11 Harvest index

A field experiment was carried out by Huang *et al.* (2019) in the winter wheat seasons of 2016–2017 and 2017–2018 in a clay loam soil from eastern China. There were five different treatments: 0.3 dS m⁻¹, 10 dS m⁻¹, 0.3 dS m⁻¹, and 10 dS m⁻¹ paired with 10, 20, or 30 t ha⁻¹ of biochar. B₁₀ and B₂₀ had harvest indices that were 6.8% and 5.4% greater than B₀, respectively.

In contrast to the well-watered treatment, Haider *et al.* (2020) found that drought stress decreased the harvest index (11.79, 7.44, and 4.18 %) in DGFS, DFS, and DTS, respectively.

Both in water-stressed and control situations, the detrimental effects of drought were lessened by biochar amendments.

Mahato *et al.* (2018) was conducted to find out the effects of *Trichoderma viride* on growth and yield of wheat at Institute of Agriculture and Animal Science, Lamjung Campus, Sundarbazar, Lamjung during December 2016 – April 2017. The experiment consisted of seven treatments; (T1: Control; T2: Soil + NPK; T3: Soil inoculated *Trichoderma*; T4: *Trichoderma* + FYM; T5: *Trichoderma* + ½ NPK; T6: *Trichoderma* + NPK and T7 = *Trichoderma* + NPK + FYM) laid out in completely randomized design (CRD) with three replications. The results showed that *Trichoderma viride* increased the plant height (4.6%), root weight (1.5%), leaf length (0.3%), panicle weight (9.1%), number of grains (3.8%), grain yield (36.5%), biological yield (13.7%), and biomass yield (2.7%) over control; while root length (-17.4%), number of leaves (-8.4%), tiller number (-10.8%), panicle number (-6.7%), panicle length (-8.4%) highlighted the negative impact of *T. viride* on wheat plant. *T. viride* displayed antagonism with inorganic fertilizer. When *T. viride* and NPK were accompanied with farmyard manure, most of the growth and yield parameter showed the highest value. Though *Trichoderma viride* decreases several growth parameters, it still can be used as biofertilizer which increases the grain yield. Using *T. viride* with a full dose of NPK during sowing stage may not be efficient and economical in terms of productivity. Introducing farmyard manure to *T. viride* gives better yield than *T. viride* alone.

Mitra *et al.* (2022) conducted an experiment to investigate the effect of the application of rice husk (RH) and rice husk charcoal (RHC) on soil properties and rice production, pot experiment comprising of five treatments was conducted. Soil was mixed at the rate of 0 (control), 2% and 4% (w/w) with RH and RHC, respectively with randomized complete block design (RCBD). RHC incorporation had a potential to reduce the acidity of the soil, whereas, RH incorporation had almost no effect on the pH of the soil. RH and RHC amendment both increased the saturated hydraulic conductivity, saturated water content, plant available water and field capacity but decreased the bulk density of soil. Crop growth components at harvest revealed that the highest plant height was recorded in RH4%. However, for the panicle length, panicle weight and number of tillers, the highest value was found in RHC2%, 14.2 cm, 4.0 g and 28.8 cm, respectively. Furthermore, number of panicle, 1000-grains weight and grain yield were also found highest in RHC2%, 22.4 g and 4.41 t/ha, respectively. However, for the number of grain per panicle and percentage of filled grain, the

highest value was found in RH4%, 79.0 and 88.5, respectively. The grain yield increased by 38%, 28%, 18% and 22% and the biological yield increased by 27%, 18%, 14%, and 16% for RHC2%, RHC4%, RH2%, and RH4%, respectively, compared to that of the control; however, the significant difference was found only for RHC 2% for both. The harvest index increased under all application rates of RH and RHC compared to that of control.

Singh *et al.* (2019) conducted an experiment to observe the impact of various soil amendments *viz.*, rice-husk ash (RHA) and farm-yard manure (FYM) along with mineral fertilizer on soil biophysical and agronomic parameters of wheat crop. We specifically explored the impact of the amendments on soil CO₂ efflux (SCE, under different growth stages) and the harvest index of wheat crop, which are considered as the key indicators of soil viability and agronomic efficiency, respectively. SCE, soil moisture, soil temperature, soil N, microbial biomass and soil pH were found significantly varying under different treatments ($P < 0.05$). SCE was found maximum under sole FYM applied and minimum under mineral fertilizer applied treatments, whereas RHA application lowered the SCE as compared to sole FYM application. Moreover, SCE showed variation with plant growth stages, and found maximum during stem elongation followed by heading stage whereas minimum during ripening stage. Soil moisture was found to have considerable regulation for the overall variation in SCE ($r^2 = 0.17$; $P = 0.04$). In contrast to the soil properties, agronomic parameters (except harvest index) were found higher under mineral fertilizer applied treatments followed by sole FYM and combined FYM+RHA treatments, whereas sole RHA applied treatment showed minimum values. However, significant variations were observed only for harvest index, above ground dry matter, grain and straw yields ($P < 0.05$). Further, harvest index was found highest under sole and combined FYM and RHA applied treatments whereas lowest in mineral fertilizer applied treatments. Soil C/N ratio ($r^2 = 0.16$; $P = 0.04$) and panicle length ($r^2 = 0.18$; $P = 0.03$), respectively as soil and agronomic parameters, have been found to have considerable control over harvest index. The findings revealed that soil viability is higher under sole FYM and combined FYM+RHA treatments whereas mineral fertilization enhances agronomic performance. Based on the studied two indicators, we conclude that both soil and agronomic sustainability can be maintained by using a combination of organic (FYM and RHA) fertilization with reduced inputs from mineral fertilizers.

CHAPTER III

MATERIALS AND METHODS

The materials and methods followed in this experiment to achieve the intended objectives are described in details in this chapter. For convenience, this chapter has been divided into several sections such as site and soil, climate, crop, land preparation, experimental design, treatments, fertilizer application, seed sowing, intercultural operations, data collection, harvesting, and statistical analysis.

3.1 Location of experimental field

The experiment was conducted in the Agronomy Research Field, Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh from November 2022 to April 2023. The geographical position of the experimental area and location is between $25^{\circ}44.574''\text{N}$ and $88^{\circ}40.344''\text{E}$ and 40 m above sea level shown in (Figure 1a and 1b).

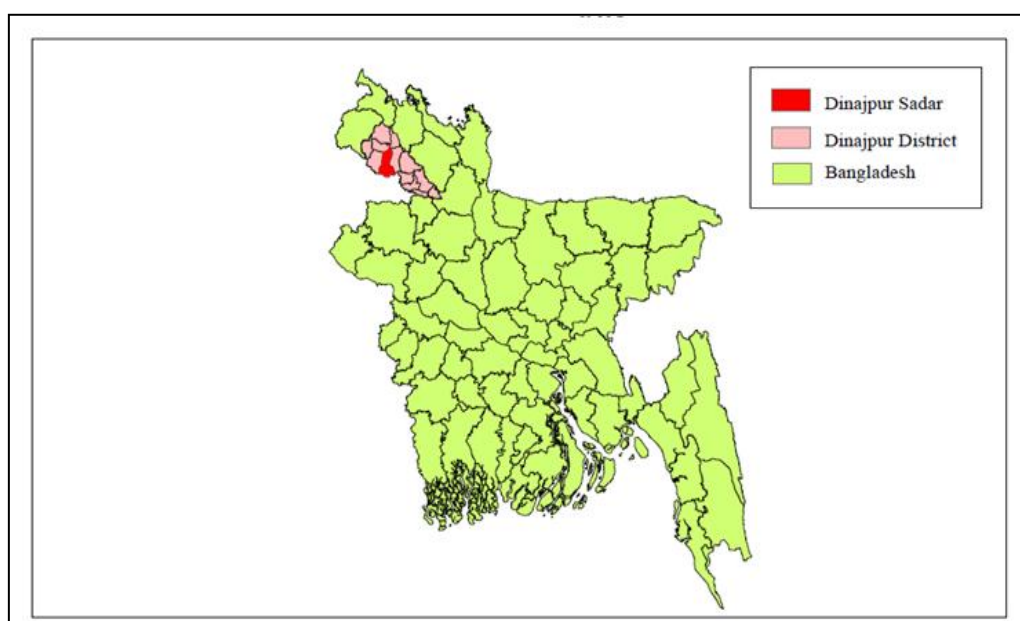


Figure 1 (a) Location of experimental area

The Agro Ecological Zone (AEZ) of the area is the Old Himalayan Piedmont Plain (AEZ-1). This has largest wheat area and also produces largest amount of wheat in the country.

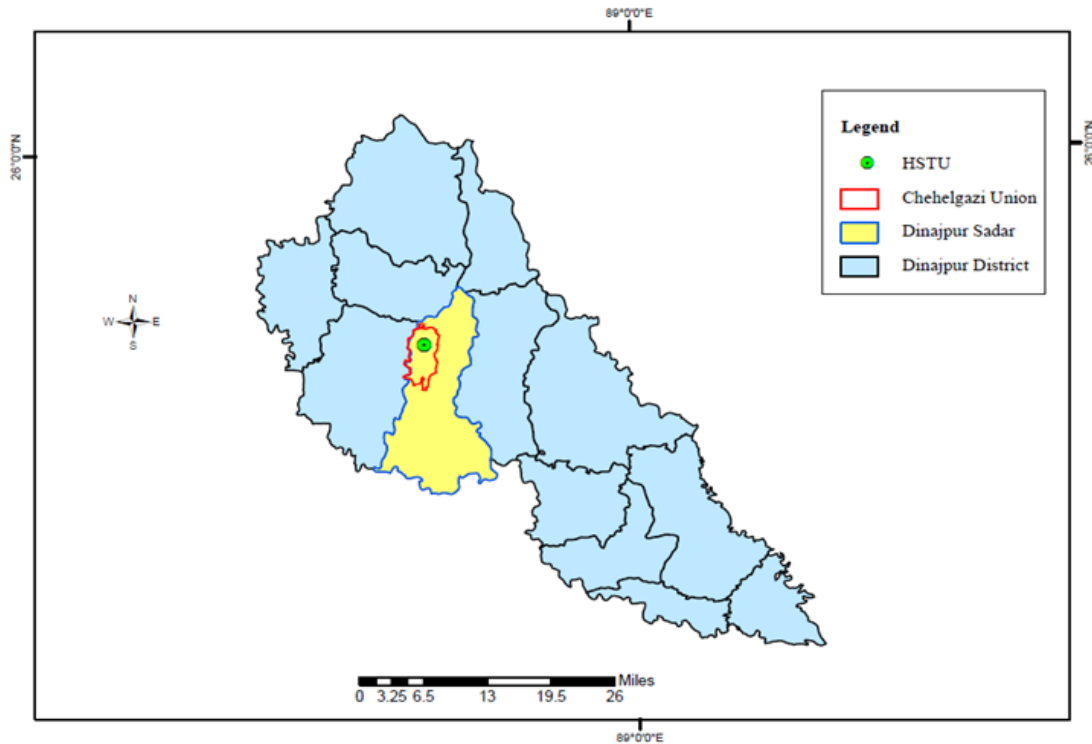


Figure 1(b): Location of experimental field

3.2 Climatic conditions

The climate was subtropical with low temperatures and minimum rainfall from December to April which is the main feature of the Rabi season. The highest maximum temperature was shown in the month of April *i.e.*, 35.0⁰C. The lowest maximum temperature was shown in January at 24.0⁰C. While the highest minimum temperature was recorded in the month of April at 18.0⁰C and the lowest in the month of December at 13.0⁰C shown in (Figure 2a).

Besides, the highest humidity was shown in the month of December 2022 with 1.8% lowest at 1.3% recorded in the month of March 2023. There was no rainfall at the beginning but little bit rain before harvesting the experiment. The highest rainfall month was in April with the data being 80 mm. While very low percentage was shown from December 2022 to February 2023 and the range was between 5-10 mm shown in (Figure 2b).

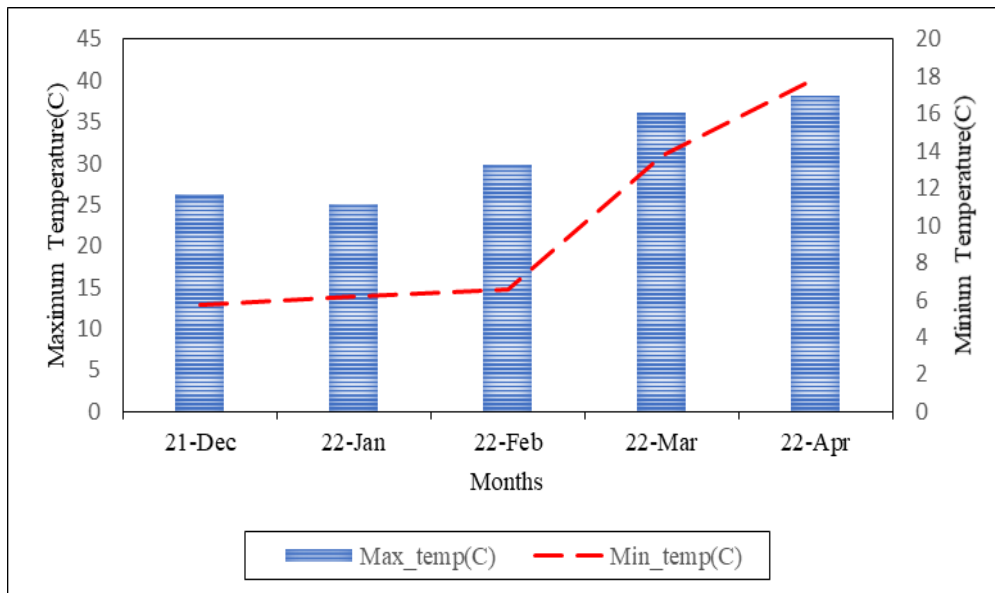


Figure 2(a): Maximum and minimum temperatures between 2022-2023

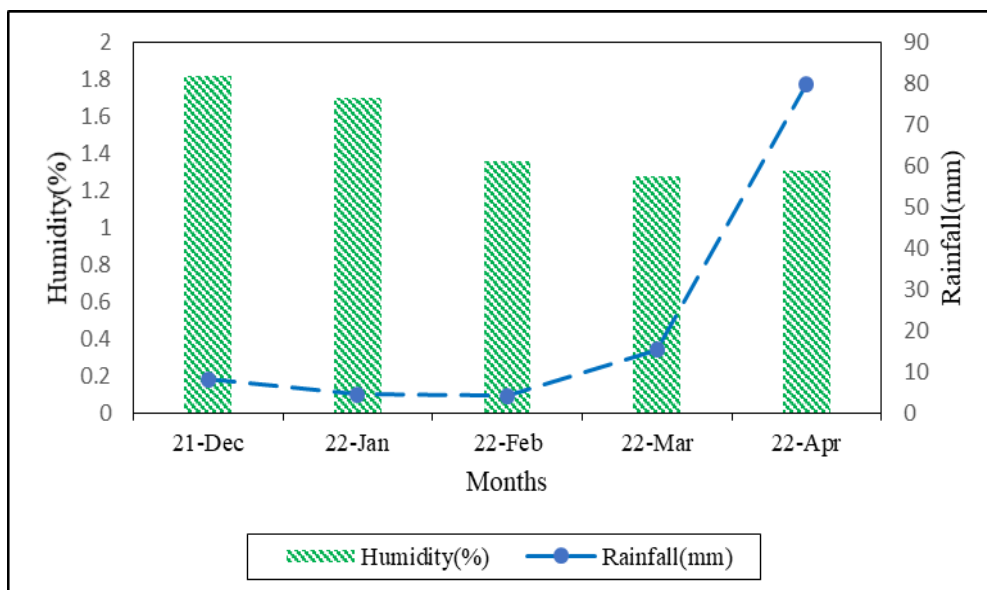


Figure 2(b): relative humidity and rainfall between 2022-2023

3.3 Soil type

The soil of the experimental field belongs to the old Himalayan Piedmont Plain (AEZ-1). Initial soil samples were collected randomly from each unit plot at a depth of 0-30 cm before final land preparation and the samples were mixed to make a bulk sample.

Table 1: Soil physical and chemical properties of the experimental location

| Parameters measured | Soil Layer between (0-40) cm |
|-----------------------|------------------------------|
| Soil textural classes | Sandy loam |
| Sand | 47.60 % |
| Silt | 36.00 % |
| clay | 16.40 % |
| Organic matter | 0.31 % |
| Organic carbon | 0.18 % |
| Total N | 0.007 % |
| Total P | 14.30 % |
| Available K | 0.05 mgkg ⁻¹ |
| Available S | 18.09 mgkg ⁻¹ |
| Field capacity | 10.50 % |
| CEC | 1.00 Meq 100g |
| Ec | 87.30 mgkg ⁻¹ |
| pH | 6.12 |

The bulk sample was air dried ground and sieved to remove unwanted materials then preserved in polythene bags for future laboratory studies. After that, Soil analysis was done at the Soil Science department of Hajee Mohammad Danesh Science and Technology University, Dinajpur and Soil Resource Development Institute (SRDI), Dinajpur, Bangladesh. Soil analysis showed that the soil of the experimental plot was sandy loam with good drainage capacity. The experiment plot was medium high land with the pH range of 6.12 *i.e.*, the soil is acidic soil. The soil physical and chemical properties of the experimental site were analyzed before started the experiment and presented in (Table 1).

3.4 Duration of the experiment

The experiment was conducted during the period from 7th December 2022 to 10th April 2023.

3.5 Varieties/ planting material

Bangladesh Wheat and Maize Research Institute (BWMRI), Dinajpur and Bangladesh Agricultural Research Institute (BARI), Gazipur, released recognized varieties namely BWMRI Gom-1, BWMRI Gom-2 and BARI Gom-32 were used in this experiment. Seeds were collected from Bangladesh Wheat and Maize Research Institute, Dinajpur (BWMRI). The planting materials used in this experiment were-

- BWMRI Gom 2,
- BWMRI Gom 3 and
- BARI Gom 32

3.6 Main features of the varieties

The wheat varieties were BWMRI Gom-2, BWMRI Gom-3 and BARI Gom 32. All of the varieties are popular and developed by Bangladesh Agricultural Research Institute (BARI), Gazipur.

3.6.1 Varietal characteristics of BWMRI Gom 2

- The height of the plant is 97-106 cm with four to six buds.
- The leaves are broad and dark green.
- It takes 68-72 days to start flowering and 108-115 days to get maturity from sowing.
- The pods are long and the number of grains is 45-48.
- The color of the grains is white, shiny and medium in size.
- The variety is resistant to leaf rust, spot disease and blast disease and heat tolerant.
- Yield per hectare is 4500-5800 kg under suitable conditions.
- 1000 grains weight 45-50 grams.

3.6.2 Varietal characteristics of BWMRI Gom 3

- The height of the plant is 96-106 cm with four to six buds.
- The leaves are broad and dark green.
- It takes 68-70 days to start flowering and 108-114 days to get maturity from sowing.
- The pods are long and the number of grains per is 48-54.
- The color of the grains is white, shiny and medium in size.

- The variety is resistant to leaf rust, spot disease and blast disease and heat tolerant.
- Yield per hectare is 4000-4500 kg under suitable conditions.
- 1000 grains weight 40-45 grams.

3.6.3 Varietal characteristics of BARI Gom 32

- BARI Gom 32 is high yielding variety.
- Early in maturity and tolerant to terminal heat stress.
- Grains are white amber in colour and large in size.
- Spikes are long with 42-47 average grains per spike.
- Leaves are broad and recurved.
- Glaucoisity is medium in spike, culm and flag leaf sheath.
- Few hairs present in upper culm node. Lower glume beak (LGB) length is medium in length (7.0 mm).
- LGB spicules - numerous, LGB shoulder medium in width and elevated.
- Resistant to leaf rust and *Bipolaris* leaf blight.
- The variety also shows tolerance to wheat blast disease.

3.7 Treatments

Two factors were included in the experiment namely variety and different treatments. The treatments were designated as follows: The experiment consists of the following treatments.

Factor A: Four treatments of biochar, *Trichoderma* and rice husk with chemical fertilizer.

T₁ = Control *i.e.*, no treatment application

T₂ = 50 % chemical fertilizer + 2 t ha⁻¹ biochar

T₃ = 50 % chemical fertilizer + 2 t ha⁻¹ *Trichoderma*

T₄ = 50 % chemical fertilizer + 2 t ha⁻¹ Rice Husk

Factor B: Consist of three varieties. Namely

V₁ = BWMRI Gom 2

V₂ = BWMRI Gom 3

V₃ = BARI Gom 32

3.8 Experimental design, layout and treatment combination

3.8.1 Experiment design:

The experiment consists of two factorial designs. One is variety and another one is chemical fertilizer and Biochar, *Trichoderma* and Rice Husk combination.

3.8.2 Experimental layout

The experiment was laid out in a Randomized Complete Block Design (RCBD).

3.8.3 Treatment combination

The experimental layout and treatment combinations are shown in (Figure 3). The experiment consists of four treatment combinations where each treatment with each varieties replicated three times. The treatments were randomly distributed to the plots within a block. Thus the number of the plot was $3 \times 12 = 36$. The unit plot size was (4 m x 2.5 m) *i.e.*, 10 m². Irrigation and drainage channel was made by maintaining 50 cm width and 30 cm between the blocks and 25 cm wide and 25 cm depth between plots.

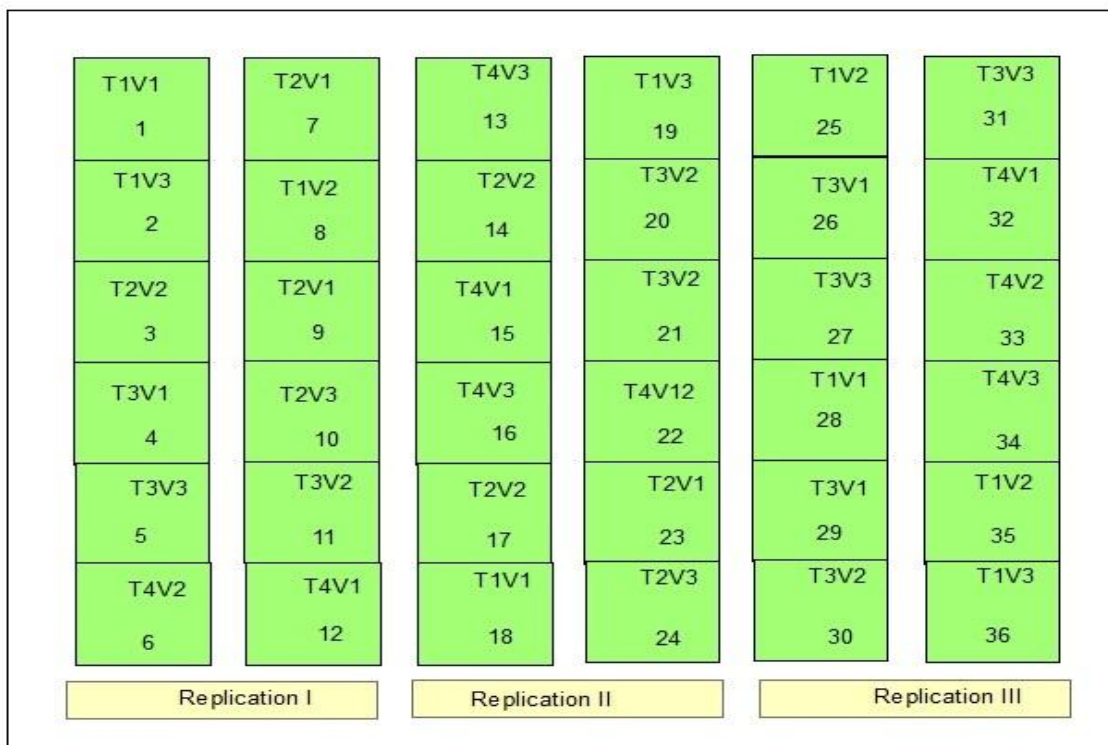


Figure 3: Layout of experimental plot

3.9 Experimental procedure and crop management

3.9.1 Collection of seed

The varieties were collected from Bangladesh Wheat and Maize Research Institute (BWMRI), Dinajpur and Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. Before sowing, the seeds were treated with vitavax-200 for germination in the laboratory and the percentage of germination was found to be over 90 % for all the varieties.

3.9.2 Land preparation

The experimental field was first ploughed on 20 November 2022. The clods of the land were hammered to make soil into small pieces. Weeds, stubbles, and crop residues were removed from the land. The final ploughing and land preparation was done on 2 December 2022. The layout was done as per experimental design on 5 December 2022.

3.9.3 Fertilizer application

Fertilizer was applied as a source of N-P-K nutrients viz., 80 kg N₂, 40 kg P₂O₅, and 40 K₂O kg ha⁻¹ uniformly distributed through urea, DAP, and MoP. Therefore, the fertilizer requirement was urea=80gm/10 m² plot; DAP = 40 gm/10 m² plot, and MoP = 40 gm/10 m² plot respectively. Biochar, *Trichoderma* enriched biofertilizer, rice husk was applied as per the treatments.

3.9.4 Seed rate with spacing

The recommended seed rate (120 kg ha⁻¹) i.e., 0.12 kg or 120 gm/ 10 m² of wheat variety seed was used for a single plot. So, a total of 3600 gm or 3.6 kg seed was required for a 300m² area. Line to line distance was 28 cm. After placing the seeds on line, the seeds were covered with loose friable soil.

3.9.5 Seed sowing

After preparing the line spacing, seeds were sown in line on 7 December 2022 as per the experimental layout.

3.9.6 Treatment collection

- **Biochar collection:** As biochar was one treatment for my research it was collected from Bangladesh Biochar Foundation under the CHRISTIAN COMMISSION FOR DEVELOPMENT IN BANGLADESH (CCDB) project, 8, SENPARA PARBATTA, MIRPUR 10, DHAKA 1216.
- **Trichoderma biofertilizer:** Trichoderma biofertilizer (*Trichoderma viride* spp.) was collected from Global Agro Farming Ltd. Bangladesh, Birol Dinajpur.
- **Rice husk:** Rice husk was collected from a rice husking mill, Raniganj, Dinapur.

3.9.7 Treatment application

Treatments were application by following the schedule. So, the treatments with the chemical fertilizer doses were applied as;

| Treatments | Fertilizer application |
|---|---|
| T ₁ = Control | No fertilizer |
| T ₂ = 50 % chemical fertilizer + 2 t ha ⁻¹ biochar | Chemical fertilizer: Urea 87.5 g plot ⁻¹ + TSP 75 g plot ⁻¹ + MoP 80 g plot ⁻¹ + Gypsum 62.5 g plot ⁻¹ Biochar = 2 kg plot ⁻¹ |
| T ₃ = 50 % chemical fertilizer + 2.5 t ha ⁻¹ <i>Trichoderma</i> biofertilizer | Chemical fertilizer: Urea 87.5 g plot ⁻¹ + TSP 75 g plot ⁻¹ + MoP 80 g plot ⁻¹ + Gypsum 62.5 g plot ⁻¹ = 2 kg plot ⁻¹ |
| T ₄ = 50 % chemical fertilizer + 2 t ha ⁻¹ rice husk | Chemical fertilizer: Urea 87.5 g plot ⁻¹ + TSP 75 g plot ⁻¹ + MoP 80 g plot ⁻¹ + Gypsum 62.5 g plot ⁻¹ Rice Husk = 2 kg plot ⁻¹ |

3.9.8 Treatment application stage/time: Treatments were applied at three stages of the research work. First treatments were applied at vegetative stage; 2nd treatment applied at flowering stage and 3rd applied at maturity stage of the wheat crop.

3.9.9 Intercultural operations

Intercultural operations like irrigation, weeding, insect and pest control, were done to ensure the normal growth of the crop. Plant protection measures were followed when necessary. The following intercultural operations were followed:

3.9.9.1 Irrigation

Light irrigation was applied after sowing the seeds. After the emergence of the seedlings, three irrigations were given at the different critical stages, for example, first irrigation was done at the crown root initiation stage (CRI) *i.e.*, (20 DAS); second irrigation was done at maximum tillering stage (40 DAS) and third irrigation was done at heading stage *i.e.*, (50-60 DAS). During irrigation care was taken so that water could not flow from one plot to another plot or overflow the boundary of the plots. Excess water in the field was drained out.

3.9.9.2 Weeding

The plots were infested with some common weeds that were generally found in wheat crop namely Durba (*Cynodon dactylon*), mutha (*Cyperus rotundus*), Batua (*Chenopodium album*), sushni shak (*Marsilea quadrifolia*) and Shetodrone (*Leucas aspera*) which were removed by uprooting by hand from the field near about three times during the cropping period.

3.9.9.3 Insect and pest control

There was no infection of disease in the field but termite, stem borer, and aphids were observed in the field. To control these insect pests Aktara @ 0.2 g L⁻¹ water was used.

3.9.9.4 Harvesting

The crop was harvested at maturity on 10 April 2023. The harvested crop from each plot was bundled separately and brought to the threshing floor of the HSTU farm. The crops were

threshed, cleaned, and processed on 10 April 2023. Then sundry weight of both grain and straw was recorded for every plot and the weight in the g plot was converted to $t\ ha^{-1}$.

3.10 Data collection

Data were collected based on the yield and yield characteristics of the wheat plant. The characteristics were

- Plant height (cm)
- Number of tillers $plant^{-1}$ (no.)
- Number of leaves $plant^{-1}$ (no.)
- Spike length (cm)
- Thousand seed weight (g)
- Fresh weight of $plant^{-1}$ (g)
- Dry weight of $plant^{-1}$ (g)
- Seed fresh weight $plant^{-1}$ (g)
- Seed dry weight $plant^{-1}$ (g)
- Grain yield ($t\ ha^{-1}$)
- Biological yield ($t\ ha^{-1}$)
- Straw yield ($t\ ha^{-1}$)
- Harvest Index (%)

These data were taken when the crop attained maturity. Due attention was paid to recording the data as influenced by biochar application was a prime objective of the present study. With this point of view, five plants were randomly collected from each plot. From these, spike length, the numbers of leaves $plant^{-1}$ and thousand seed weight were noted. Other parameters like the plant height and number of effective tillers $plant^{-1}$ were also recorded. Data on grain yield, and straw yield were noted down on each plot.

3.10.1 Plant height (cm)

Plant height was taken three times *i.e.*, 25 DAS, 50 DAS, and 75 DAS. The plant height was measured from the ground level to the top of the flag leaf. From each plot, fifteen plants were selected randomly, and measured the plant height. Always measured the plant height in cm.

3.10.2 Number of tillers plant⁻¹ (no.)

Randomly fifteen plants were selected from each plot and the number of tillers plant⁻¹ was counted. Effective tillers number plant⁻¹ was counted three times i.e., 25 DAS, 50 DAS and 75 DAS.

3.10.3 Number of leaves plant⁻¹ (no.)

Fifteen plants were selected randomly from each plot and number of leaves was counted and averaged. Number of leaves plant⁻¹ was taken at 25 DAS, 50 DAS and 75 DAS.

3.10.4 Spike length (cm)

Randomly selected plants from each were used to measure the spike length. Spike length was measured from basal node of the spike to the apex of the awn. It was recorded in cm.

3.10.5 Fresh Weight Plant⁻¹ (g)

Randomly selected fifteen fresh plants were taken out from each plot, then fresh weight of those plants were measured by using a weight balance. Fresh weight plant⁻¹ was taken in g.

3.10.6 Dry Weight Plant⁻¹ (g)

Dry weight was taken out from the plants which were selected for dry weight measuring. The fresh plant was kept in the oven for 3 days i.e., 72 hours, and the weight of those dry plants was measured in g.

3.10.7 Seed Fresh Weight Plant⁻¹ (g)

Seed fresh weight was taken out from the plants which were selected for fresh weight measuring. The seeds were separated from the fresh plant and the weight of those fresh seeds were measured by using a measuring balance and finally the weight expressed in g.

3.10.8 Seed Dry Weight Plant⁻¹ (g)

Seed dry weight was taken out from the plants which were selected for seed fresh weight measuring. The separated seeds were kept in the oven for 2 days i.e., 48 hours and were measured by using a measuring balance and finally the weight expressed in g.

3.10.9 Thousand grain weight (g)

Thousand grains from the dry weighted plants were counted per plot and weighed. It was expressed in g.

3.10.10 Straw yield (t ha⁻¹)

After harvesting, the straw from each unit plot was dried in the sun and weighed. The result was expressed as t ha⁻¹. Straw yield was measured by the following formula;

$$\text{Straw yield} = \text{Biological yield} - \text{Grain yield}$$

3.10.11 Seed yield (t ha⁻¹)

After harvest of the crop, grain from each unit plot was dried and weighed. The result was expressed as t ha⁻¹ on 14 % moisture basis. Seed yield was measured by the following formula;

$$\text{Grain yield} = \text{Biological yield} - \text{Straw yield}$$

3.10.12 Biological yield (t ha⁻¹)

Biological yield is the total biomass produced above the soil. Biological yield was measured by the following formula and expressed in t ha⁻¹;

$$\text{Biological yield} = \text{Seed yield} + \text{Straw yield}$$

3.10.13 Harvest index (%)

Harvest index was determined by dividing the economic yield (Seed yield) to the biological yield (Seed yield + straw yield) from the same area and then multiplied by 100. It is expressed by the following formula;

$$\text{Harvest Index (\%)} = \frac{\text{Economic Yield (Seed Yield)}}{\text{Biological Yield}} \times 100$$

3.11 Data analysis using Statistical programme

The analysis of variance (ANOVA) function, the relationship between biochar, *Trichoderma*, Rice husk treatments and variety, with yield attributes of wheat evaluated by the least significant difference (LSD) used for mean comparisons at a 5 % probability level and 1% probability level using the R program (version 4.2.1). Comparison graphs were done by using the R program (version 4.2.1). Pearson correlation and PCA (Principle Component Analysis) was done also by using R programming. Location of the experimental area, experimental research plot, weather graphs were done by using origin pro 2023 (version 9.3) software.

CHAPTER IV

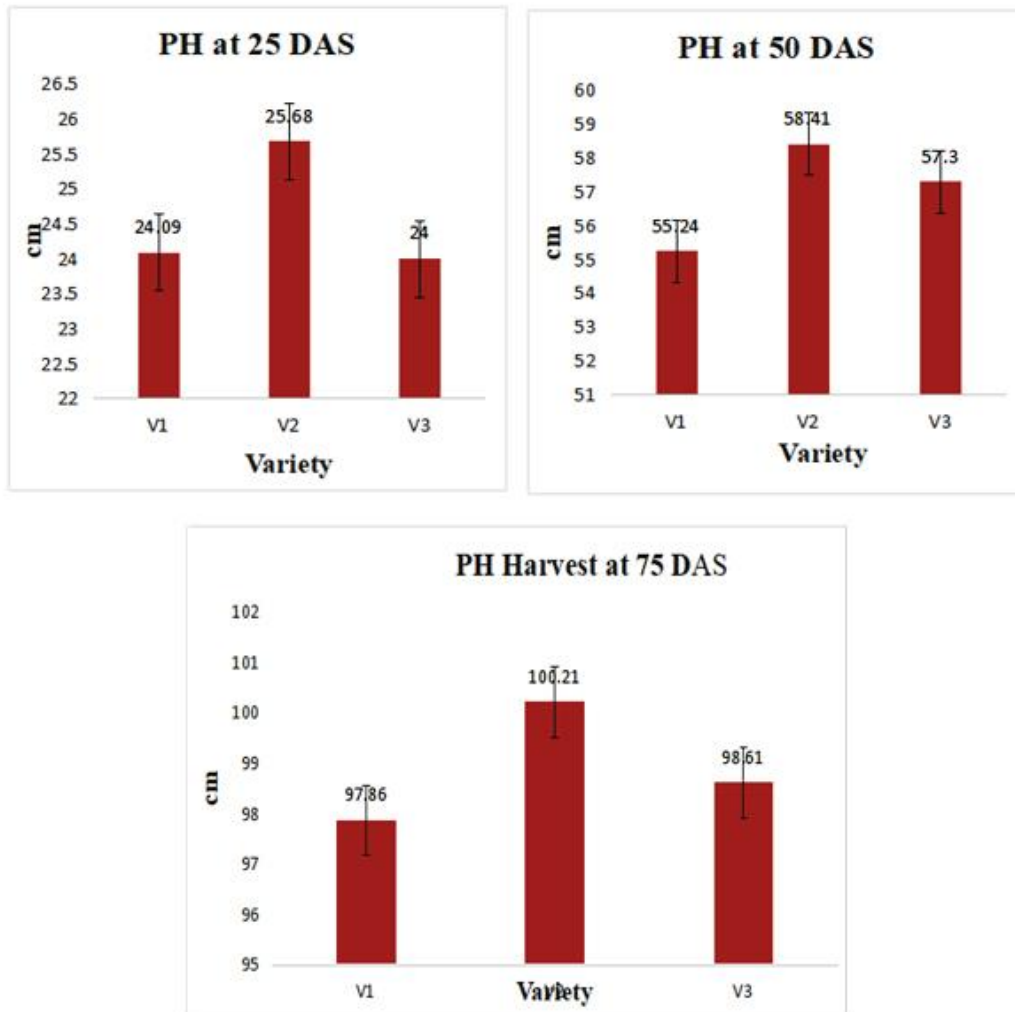
RESULTS AND DISCUSSION

The experiment was conducted to study the feasibility of replacing chemical fertilizer by using Biochar, *Trichoderma* and Rice husk like organic fertilizers in wheat. Data on different growth, yield contributing characters and yield were recorded. The analysis of variance (ANOVA) of the data on different parameters are presented in the Appendix chapter. The results have been presented and discussed with the help of tables and graphs and possible interpretations given under the following headings:

4.1. Plant Height (cm)

A sort of variation was observed in plant height with the varieties. At 25 DAS maximum height was recorded 25.68 cm from V₂ (BWMRI Gom 3) and lowest was recorded 24 cm from V₃ (BARI Gom 32) shown in (Figure 4). At 50 DAS maximum height was recorded 58.41 cm from V₂ (BWMRI Gom 3) and the lowest was recorded 55.24 cm from V₁ (BWMRI Gom 2). At 75 DAS maximum height was recorded 100.21 cm from V₂ (BWMRI Gom 3) and lowest was recorded 97.86 cm from V₁ (BWMRI Gom 2). Differences in plant height among the varieties is statistically significant shown in Figure 4.

In case of treatments, plant height varied significantly at 25 DAS, 50 DAS and 75 DAS. At 25 DAS the maximum plant height was obtained 27.15 cm from T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*) and the lowest height was 8.92 cm recorded from T₁ (control). Plant height 25.32 cm and 26.09 cm was recorded from T₂ (50 % CF + 2.0 t ha⁻¹ BC), and T₄ (50 % CF + 2.0 t ha⁻¹ RH) respectively. At 50 DAS the maximum plant height was obtained 62.52 cm from T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*) and lowest height was 28.71 cm recorded from T₁ (control). Plant height 60.17 cm and 60.54 cm plant height was recorded from T₂ (50 % CF + 2.0 t ha⁻¹ BC), and T₄ (50 % CF + 2.0 t ha⁻¹ RH) respectively. At 75 DAS, the maximum plant height was obtained 103.79 cm from T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*) and lowest height was 57.59cm recorded from T₁ (control). 98.4cm, and 102.29cm plant height was recorded from T₂ (50 % CF + 2.0 t ha⁻¹ BC), and T₄ (50 % CF + 2.0 t ha⁻¹ RH) respectively shown in Figure 5.



V₁ = BWMRI Gom 2 V₂ = BWMRI Gom 3 V₃ = BARI Gom 32

Figure 4: Effect of varieties on plant height at 25 DAS, 50 DAS and 75 DAS of wheat

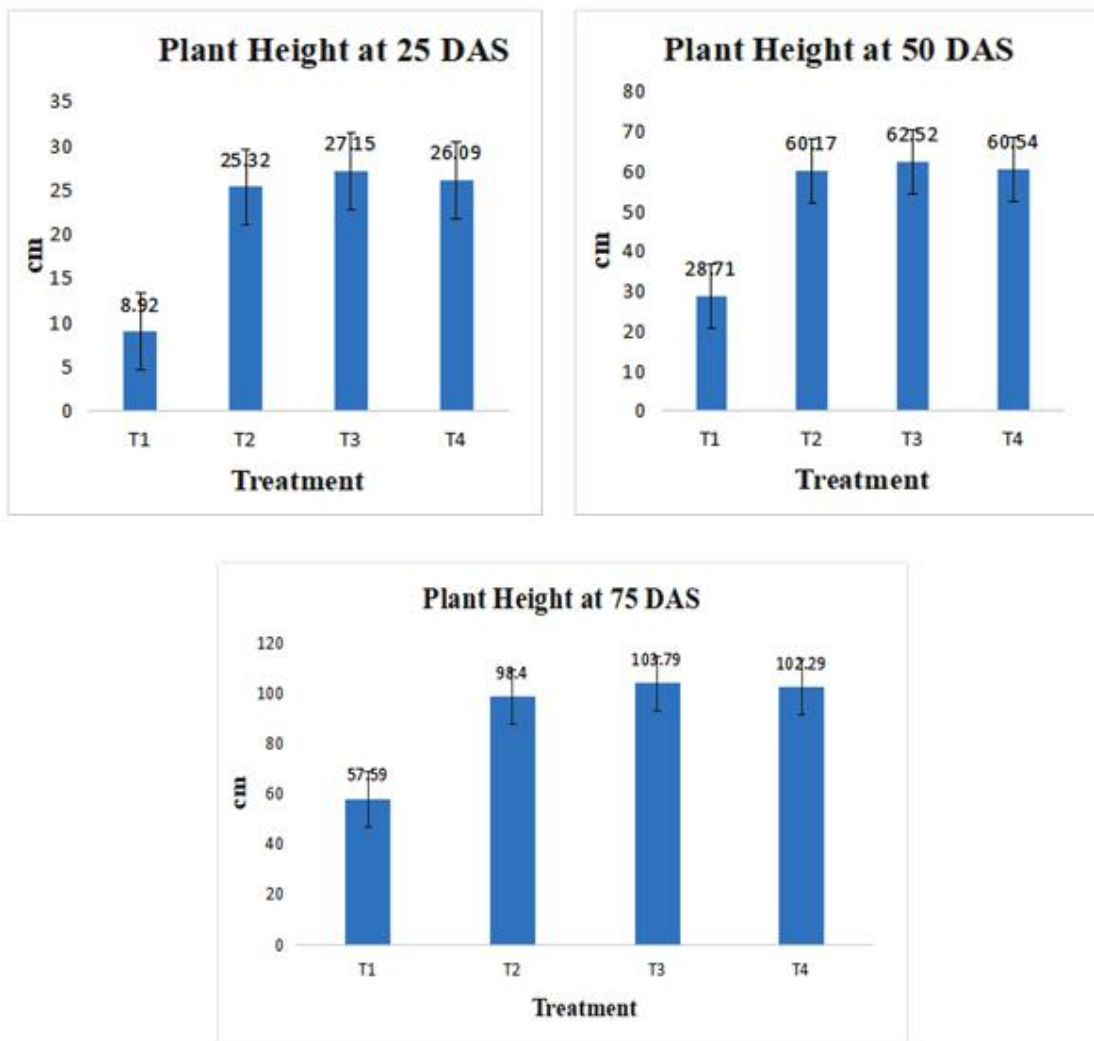


Figure 5: Effect of treatments on plant height at 25 DAS, 50 DAS and 75 DAS of wheat

V1= BWMRI Gom 2

V2=BWMRI Gom 3

V3= BARI Gom 32

T₁

Control

T₂

50% Chemical fertilizer + 2 t /ha biochar

T₃

50% chemical fertilizer + 2 t/ha *Trichoderma*

T₄

50 % chemical fertilizer + 2 t/ha rice husk

In case for interaction, the effect of biochar, *Trichoderma* and rice husk on plant height between the treatments and varieties varied significantly. At 25 DAS the maximum plant height was obtained 25.93 cm from V₃T₃ (V₃ = BARI Gom 32 and 50% chemical fertilizer + 2 t/ha *Trichoderma*) while the lowest height was 13.67 cm recorded from V₁T₁ (BWMRI Gom 2 with control). At 50 DAS plant height was recorded from V₂T₃ (V₂= BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) 87.89 cm and the lowest was recorded 51.45 cm from V₁T₁ (BWMRI Gom 2 with control). At 75 DAS, interaction V₂T₃ (V₂= BWMRI Gom 3 with 50% chemical fertilizer) had 105.00 cm plant height and was the best performance and while lowest performance showed by V₁T₁ (BWMRI Gom 2 with control). Here all of the combinations showed better performance over control. These plant heights were statistically significant to the interaction shown in (Table 2). Abbas *et al.* (2017) and Wang *et al.* (2019) also found similar types of results.

Table 2: Effect of interactions on plant height at 25 DAS, 50 DAS and 75 DAS of wheat

| Interactions | Plant Height (cm) | | |
|--------------------------------|-------------------|--------|----------|
| | 25 DAS | 50 DAS | 75 DAS |
| T ₁ xV ₁ | 13.67d | 51.45e | 68.66h |
| T ₁ xV ₂ | 14.63d | 52.44e | 80.00fg |
| T ₁ xV ₃ | 14.72d | 52.36e | 73.00gh |
| T ₂ xV ₁ | 21.71c | 73.83d | 86.66def |
| T ₂ xV ₂ | 22.57c | 73.71d | 82.00efg |
| T ₂ xV ₃ | 2.88bc | 78.06c | 94.66bcd |
| T ₃ xV ₁ | 24.78a | 86.08b | 97.33abc |
| T ₃ xV ₂ | 25.48a | 87.89a | 105.00a |
| T ₃ xV ₃ | 25.93a | 87.31a | 101.00ab |
| T ₄ xV ₁ | 24.97ab | 79.41b | 81.66efg |
| T ₄ xV ₂ | 24.56ab | 78.74b | 76.66gh |
| T ₄ xV ₃ | 24.78ab | 78.92c | 89.67cde |
| LS | * | * | * |
| LSD | 0.54 | 0.64 | 9.60 |
| CV | 3.60 | 7.60 | 6.56 |

In a column, bearing NS do not differ significantly at 5% level of significance

**= Significant at 1% level of probability

LS=Level of significance

LSD= Least Significant Difference

V₂=BWMRI Gom 3

*= Significant at 5% level of probability

CV=Co-efficient of variance

V₁=BWMRI Gom 2

V₃= BARI Gom-32

4.2. Tiller number plant⁻¹ (no.)

Biochar, *Trichoderma* and Rice husk exerted a significant effect on tiller number plant⁻¹. Result showed that the highest tiller number plant⁻¹ was obtained (6.92 no.) with the variety of v₂ (BWMRI Gom 3) and lowest was obtained (4.92 no.) from the V₁ (BWMRI Gom 2). Here tiller number plant⁻¹ was statistically significant with the variety shown in (Figure 6).

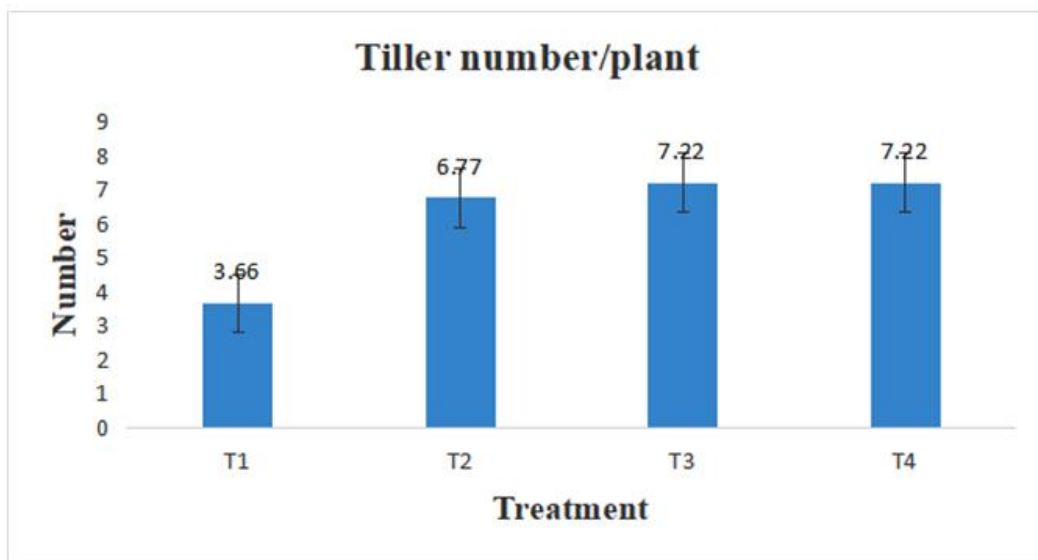


Figure 6: Effect of treatments varieties on Tiller number plant⁻¹ of wheat

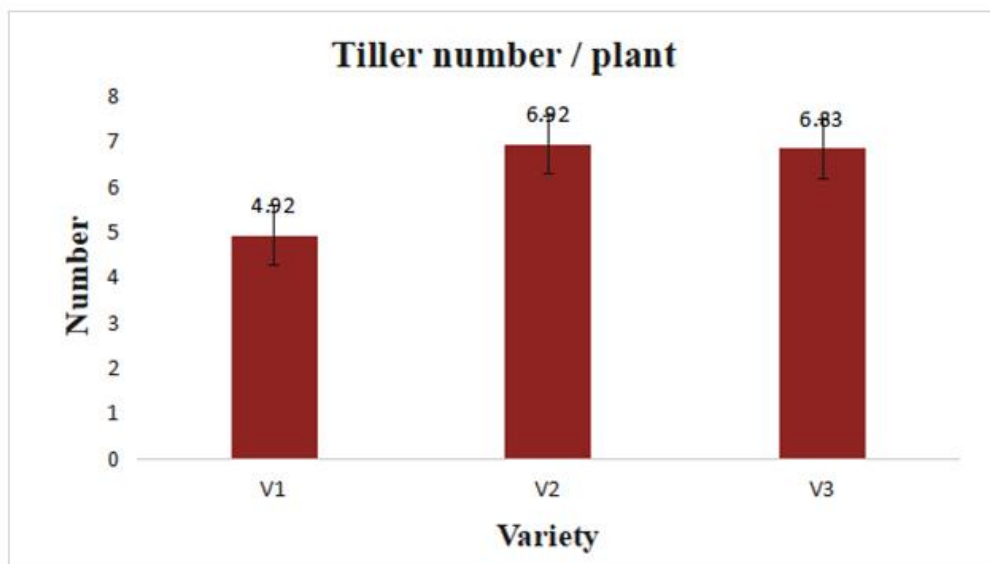


Figure 7: Effect of varieties on Tiller number plant⁻¹ of wheat

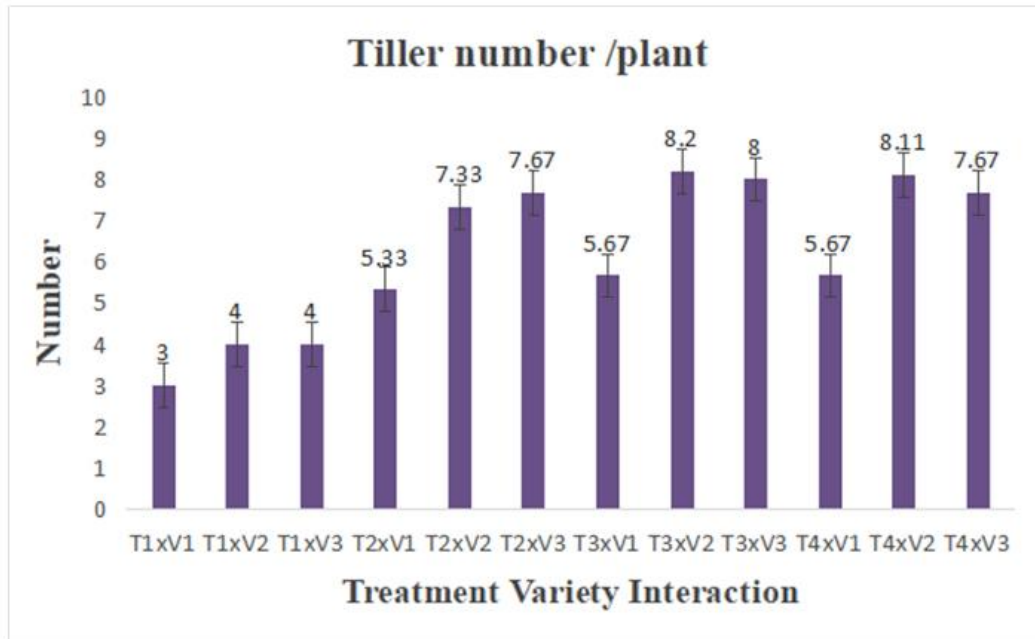


Figure 8: Effect of varieties and treatments interaction on tiller number/plant of wheat

| | | |
|---------------------|--------------------|---|
| V_1 = BWMRI Gom 2 | V_2 =BWMRI Gom 3 | V_3 = BARI Gom 32 |
| T_1 | | Control |
| T_2 | | 50% Chemical fertilizer + 2 t/ha biochar |
| T_3 | | 50% chemical fertilizer + 2 t/ha <i>Trichoderma</i> |
| T_4 | | 50 % chemical fertilizer + 2 t/ha rice husk |

In case of treatment, the highest tiller number plant⁻¹ was obtained (7.22 no.) both at the treatment of T_3 (50 % CF + 2 t ha⁻¹ *Trichoderma*) and T_4 (50 % CF + 2.0 t ha⁻¹ RH). While the lowest result was shown (3.66) in T_1 (control) condition. And, T_2 (50 % CF + 2.0 t ha⁻¹ BC) treatment tiller number plant⁻¹ recorded in (6.77). Here, tiller number plant⁻¹ increased in a positive manner which was statistically significant with the treatments shown in Figure 7.

Tiller number of plant⁻¹ was found statistically significant for interaction. Highest result was shown at interaction V_2T_3 (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) with (8.2 no.). And, the lowest tillers number were recorded at control V_1T_1 (BWMRI Gom 2 with control) (4.09 no.). Another combination like V_1T_2 (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ BC); V_1T_3 (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ *Trichoderma*); V_1T_4 (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ RH) obtained tiller number plant⁻¹ were (5.33, 5.67, 5.67) no. Interaction result of tiller number plant⁻¹ V_2T_1 (BWMRI Gom 3 with control); V_2T_2 (BWMRI

Gom 3 with 50 % CF + 2 t ha⁻¹ BC); V₂T₄ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ RH) were recorded in (4.0; 7.33; 8.11) no. Another interaction like V₃T₁ (BARI Gom 32 with control); V₃T₂ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ BC); V₃T₃ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ *Trichoderma*); V₃T₄ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ RH); tiller number plant⁻¹ was recorded (4.0, 7.67, 8.0, 7.67). Here all the interactions showed significant difference. Therefore, tillers number plant⁻¹ was statistically significant with the variety and treatments interaction shown in Figure 8.

4.3. Number of leaves plant⁻¹ (no.)

At 25 DAS highest number of leaves plant⁻¹ was recorded at V₁ (BWMRI Gom 2) with (4.86 no.) and the lowest was recorded at V₂ (BWMRI Gom 3) with (4.80 no.). Here number of leaves plant⁻¹ was statistically significant with the variety shown in (Table 3). At 25 DAS, highest number of leaves plant⁻¹ was recorded at T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*) with (5.93 no.) and the lowest was recorded at T₁ (Control) with (3.59 no.). While T₂ (50 % CF + 2 t ha⁻¹ BC) and T₄ (50 % CF + 2 t ha⁻¹ RH) were recorded (4.61, and 4.90) no. respectively. Here number of leaves plant⁻¹ was statistically significant to treatments (Table 4). Highest number of leaves plant⁻¹ was found at the interaction of V₂T₃ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) with (8.31 no.) and the lowest leaf number were recorded at control V₁T₁ (BWMRI Gom 2 with control) with (4.09 no.). There are very little differences among the treatments in combination with the varieties. Here, number of leaves plant⁻¹ was significantly different to interactions shown in (Table 5).

Table 3: Effect of variety on number of leaves plant⁻¹ at 25 DAS, 50 DAS and 75 DAS of wheat

| Variety | Number of leaves plant ⁻¹ (no.) | | |
|----------------|--|--------|--------|
| | 25 DAS | 50 DAS | 75 DAS |
| V ₁ | 4.86a | 17.69a | 14.18a |
| V ₂ | 4.80a | 17.58a | 13.79a |
| V ₃ | 4.81a | 17.45a | 13.22a |
| LS | NS | NS | NS |
| LSD | 0.56 | 3.01 | 2.55 |
| CV | 11.33 | 16.41 | 17.59 |

In a column, bearing NS do not differ significantly at 5% level of significance

**= Significant at 1% level of probability

*= Significant at 5% level of probability

LS=Level of significance

CV=Co-efficient of variance

LSD= Least Significant Difference

V₁=BWMRI Gom 2

V₂=BWMRI Gom 3

V₃= BARI Gom-32

Result showed that at 50 DAS highest number of leaves plant⁻¹ was recorded at V₁ (BWMRI Gom 2) with (17.69 no.) and the lowest was recorded at V₃ (BARI Gom 2) with (17.45 no.). Here number of leaf plant⁻¹ was statistically non-significant shown in (Table 4). At 50 DAS highest number of leaves plant⁻¹ was observed at T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*) with (21.8 no.) and the lowest was recorded at T₁ (Control) with (14.36 no.). For treatment T₂ (50 % CF + 2 t ha⁻¹ BC) and T₄ (50 % CF + 2 t ha⁻¹ RH) data were recorded (15.10 and 18.10) no. respectively. Here, number of leaves plant⁻¹ was statistically significant to treatments shown in (Table 4).

Table 4: Effect of treatments on number of leaves plant⁻¹ at 25 DAS, 50 DAS and 75 DAS of wheat

| Treatment | Number of leaves plant ⁻¹ (no.) | | |
|----------------|--|---------|---------|
| | 25 DAS | 50 DAS | 75 DAS |
| T ₁ | 3.59c | 14.36b | 11.17b |
| T ₂ | 4.61b | 15.10b | 11.82b |
| T ₃ | 5.93a | 21.80a | 17.59a |
| T ₄ | 4.90b | 18.10ab | 14.21ab |
| LS | * | * | * |
| LSD | 0.89 | 4.75 | 4.04 |
| CV | 11.33 | 16.41 | 17.59 |

In a column, bearing NS do not differ significantly at 5% level of significance

**= Significant at 1% level of probability

*= Significant at 5% level of probability

LS=Level of significance

CV=Co-efficient of variance

LSD= Least Significant Difference

Table 5: Effect of interactions on number of leaves plant⁻¹ at 25 DAS, 50 DAS and 75 DAS of wheat

| Interactions | Number of leaves plant ⁻¹ (no.) | | |
|-------------------------------|--|---------|---------|
| | 25 DAS | 50 DAS | 75 DAS |
| V ₁ T ₁ | 4.09d | 8.93e | 14.76d |
| V ₁ T ₂ | 7.74b | 15.26d | 22.07c |
| V ₁ T ₃ | 7.92b | 16.66c | 22.21c |
| V ₁ T ₄ | 7.50b | 16.53c | 22.00c |
| V ₂ T ₁ | 4.10d | 8.80e | 14.57d |
| V ₂ T ₂ | 6.49c | 18.93bc | 23.58b |
| V ₂ T ₃ | 8.31a | 21.53a | 25.05a |
| V ₂ T ₄ | 8.30a | 18.66b | 24.43ab |
| V ₃ T ₁ | 5.81d | 9.89e | 14.33d |
| V ₃ T ₂ | 7.00b | 18.22b | 23.43b |
| V ₃ T ₃ | 7.89b | 19.00ab | 23.67b |
| V ₃ T ₄ | 7.68b | 18.67b | 24.23ab |
| LS | ** | * | * |
| LSD | 5.71 | 6.72 | 1.27 |
| CV | 11.33 | 16.41 | 17.59 |

In a column, bearing NS do not differ significantly at 5% level of significance

**= Significant at 1% level of probability

LS=Level of significance

LSD= Least Significant Difference

V₂=BWMRI Gom 3

*= Significant at 5% level of probability

CV=Co-efficient of variance

V₁=BWMRI Gom 2

V₃= BARI Gom-32

At 50 DAS, leaves number was found at the treatments of V₂T₃ (21.53) and second highest was found at V₂T₃ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) with (19.00 no.). The lowest number of leaves plant⁻¹ were recorded at control V₂T₁ (BWMRI Gom 3 with control) was (8.80 no.). There is very little differences among the treatments in combination with the varieties (Table 5).

At 75 DAS number of leaf plant, in case of variety highest leaves number plant⁻¹ was recorded at V₁ (BWMRI Gom 2) with (14.18 no.) and the lowest was recorded at V₃ (BARI Gom 32) with (13.22 no.) Here number of leaf plant⁻¹ was statistically non-significant shown in (Table 3). Treatment result showed at 75 DAS number of leaf plant⁻¹ found in reduced

number than that of 50 DAS. Highest number of leaves plant⁻¹ was recorded from T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*) with (17.59 no.) and the lowest was recorded at T₁ (Control) with (11.17 no.). For T₂ (50 % CF + 2 t ha⁻¹ BC) and T₄ (50 % CF + 2 t ha⁻¹ RH) data were recorded (11.82, and 14.21) no. respectively. Here number of leaves plant⁻¹ was statistically significant to treatments (Table 4).

Among the interactions highest number of leaf plant⁻¹ was found at V₂T₃ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) with (25.05 no.) and the lowest was recorded at control V₃T₁ (BARI Gom 32 with control) 14.33 no. There are very few differences among the treatments in combination with the varieties. Here, the number of leaves plant⁻¹ was statistically significant to the interactions shown in (Table 5). The results of the present experiment were in close conformity with the findings of Salim et al. (2016).

4.4. Fresh weight plant⁻¹ (g)

In case of variety, fresh weight per plant was highest in V₂ (BWMRI Gom 3) with (16.84g) and lowest was recorded in V₁ (BWMRI Gom 2) with (13.16g). Fresh weight per plant varied non-significantly with the treatments (Table 6). In case of treatment highest fresh weight per plant was recorded in T₃ (50 % CF +2 t ha⁻¹ *Trichoderma*) with (14.42 g) and the lowest was recorded in control T₁ (control) with (9.29 g) Weight recorded in T₂ (50 % CF + 2 t ha⁻¹ BC) and T₄ (50 % CF + 2 t ha⁻¹ RH) were 14.05 g and 14.33 g respectively (Table 7).

In interaction we can see highest in V₂T₃ (BWMRI Gom 3 with 50 % CF +2 t ha⁻¹ *Trichoderma*) (17.54 g) weight was recorded and the lowest was recorded in V₁T₁ (BWMRI Gom 3 with control) (7.74 g). Here, it was also noticed that V₂ (BWMRI Gom 3) in combination with the treatments showed better performance than V₁(BWMRI Gom 2) in combination with the treatments (Table 8). Similar results were found by Hussien *et al.* (2020).

Table 6: Effect of varieties on fresh weight and dry weight plant⁻¹ of wheat

| Variety | Fresh weight plant ⁻¹ (g) | Dry weight plant ⁻¹ (g) |
|----------------|--------------------------------------|------------------------------------|
| V ₁ | 13.16b | 9.63b |
| V ₂ | 16.84a | 11.74a |
| V ₃ | 16.76a | 11.11a |
| LS | * | * |
| LSD | 2.11 | 1.78 |
| CV | 18.94 | 21.76 |

In a column, bearing NS do not differ significantly at 5% level of significance

**= Significant at 1% level of probability

*= Significant at 5% level of probability

LS=Level of significance

CV=Co-efficient of variance

LSD= Least Significant Difference

V₁=BWMRI Gom 2

V₂=BWMRI Gom 3

V₃= BARI Gom-32

4.5. Dry weight plant⁻¹ (g)

In V₂ (BWMRI Gom 3) with (11.74g) was recorded highest value and the lowest was recorded in V₁(BWMRI Gom 2) with (9.63 g). In case of treatments difference was significant (Table 7). The highest value was recorded in T₃ (50 % CF +2 t ha⁻¹ *Trichoderma*) with (11.20g) and the lowest was recorded in T₁ (control) with (6.79 g). Among the interactions V₂T₃(BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) with (12.06 g) the highest dry weight per plant was recorded and the lowest was recorded in V₃T₁ (BARI Gom 2 with control) (9.14 g) shown in (Table 8).

Table 7: Effect of treatments on fresh weight and dry weight plant⁻¹ of wheat

| Treatments | Fresh weight plant ⁻¹ (g) | Dry weight plant ⁻¹ (g) |
|----------------|--------------------------------------|------------------------------------|
| T ₁ | 9.29b | 6.79c |
| T ₂ | 14.05a | 10.52b |
| T ₃ | 14.42a | 11.20a |
| T ₄ | 14.33a | 11.00a |
| LS | NS | ** |
| LSD | 3.33 | 2.82 |
| CV | 18.94 | 21.76 |

In a column, bearing NS do not differ significantly at 5% level of significance

**= Significant at 1% level of probability

*= Significant at 5% level of probability

LS=Level of significance

CV=Co-efficient of variance

LSD= Least Significant Difference

In V₁T₁ (BARI Gom 1 with control), V₁T₂(BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹BC), V₁T₃(BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) and V₁T₄(BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ RH) , dry weight per plant was recorded 9.23 g,10.15 g,11.90 g and 10.05 g respectively. Again, in V₂T₁(BWMRI Gom 3 with control), V₂T₂ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹BC), and V₂T₄(BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹RH), dry weight per plant was recorded 9.31g, 10.87g and 11.85 g respectively. And again in V₃T₂ (BARI Gom 2 with 50 % CF + 2 t ha⁻¹BC), V₃T₃ (BARI Gom 2 with 50 % CF + 2 t ha⁻¹ *Trichoderma*)and V₃T₄ (BARI Gom 2 with 50 % CF + 2 t ha⁻¹RH) dry weight per plant was recorded 10.27g,11.98g,and 11.79g. Here deference in interaction was significant (Table 8). Çiğ *et al.* (2021) found similar results for dry weight plant⁻¹.

Table 8: Effect of interactions on fresh weight and dry weight plant⁻¹ of wheat

| Interactions | Fresh weight plant ⁻¹ (g) | Dry weight plant ⁻¹ (g) |
|-------------------------------|--------------------------------------|------------------------------------|
| V ₁ T ₁ | 7.74e | 9.23d |
| V ₁ T ₂ | 15.65bc | 10.15c |
| V ₁ T ₃ | 15.87bc | 11.90b |
| V ₁ T ₄ | 12.45d | 10.05c |
| V ₂ T ₁ | 8.97e | 9.31d |
| V ₂ T ₂ | 11.84c | 10.87a |
| V ₂ T ₃ | 17.54a | 12.06a |
| V ₂ T ₄ | 17.01ab | 11.85b |
| V ₃ T ₁ | 8.33e | 9.14d |
| V ₃ T ₂ | 13.62c | 10.27c |
| V ₃ T ₃ | 17.35a | 11.98b |
| V ₃ T ₄ | 17.12a | 11.79b |
| LS | * | * |
| LSD | 4.71 | 3.98 |
| CV | 18.94 | 21.76 |

In a column, bearing NS do not differ significantly at 5% level of significance

4.6. Spike length plant⁻¹ (cm)

Spike length plant⁻¹ was significantly different with the varieties. Highest length was recorded in V₂ (BWMRI Gom 3) with (15.77 cm) and lowest was obtained in V₁ (BWMRI

Gom 2) (14.76 cm) (Figure 9). In case of treatments, it varies significantly. Highest length was obtained in T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*) with (16.81cm) and lowest was obtained in T₁ (control) with (7.99 cm). In T₂(50 % CF + 2 t ha⁻¹ BC), and T₄(50 % CF + 2 t ha⁻¹ RH) spike length plant⁻¹ were recorded 16.57 cm, 16.12 cm and 18.02 cm respectively (Figure 9). Haider *et al.* (2020) found similar results.

Significant difference was found in case of interaction. Highest spike length plant⁻¹ was recorded in V₂T₃ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) with (18.95cm) and lowest was recorded in V₂T₁ (BWMRI Gom 3 with control) with (7.56cm). 8.63cm, 16.55cm, 15.91 cm and 16.94 cm were recorded in V₁T₁ (BWMRI Gom 2 with control), V₁T₂ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ BC), V₁T₃ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) and V₁T₄ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ RH) respectively (Figure 9). The results of present experiment were in close conformity with the findings of Haider *et al.* (2020).

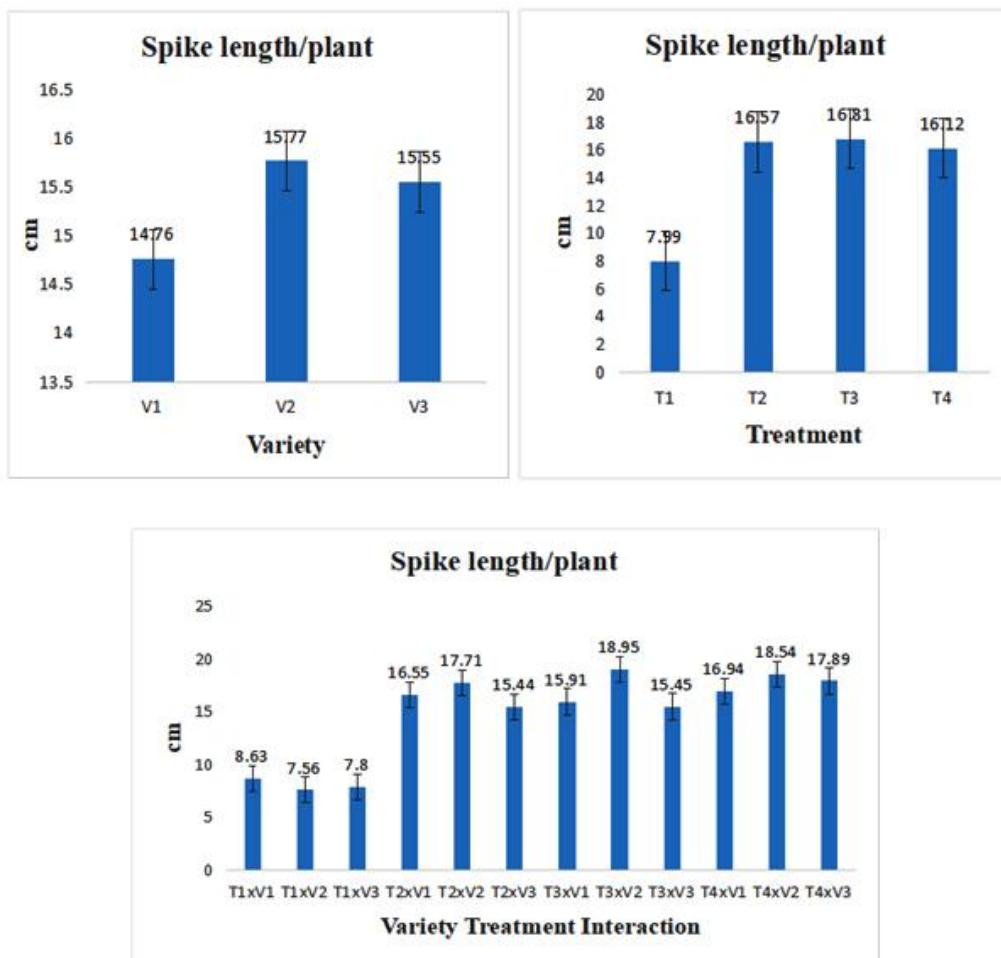


Figure 9: Effect of different variety and treatments on Spike length/plant of wheat

| V ₁ = BWMRI Gom 2 | V ₂ =BWMRI Gom 3 | V ₃ = BARI Gom 32 |
|------------------------------|-----------------------------|---|
| T ₁ | | Control |
| T ₂ | | 50% Chemical fertilizer + 2 t/ha biochar |
| T ₃ | | 50% chemical fertilizer + 2 t/ha <i>Trichoderma</i> |
| T ₄ | | 50 % chemical fertilizer + 2 t/ha rice husk |

4.7. Thousand seed weight (g)

Thousand seed weight varies non-significantly with the varieties. The highest was recorded in V₂ (BWMRI Gom 3) with (35.06g) and the lowest was recorded in V₁ (BWMRI Gom 2) with (32.98 g) (Figure 10). On the other hand, thousand grain weight varied significantly with the treatments. The highest value was recorded in T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*) (38.46g) and the lowest value was recorded in T₁ (control) (20.47g). In case of T₂ (50 % CF + 2 t ha⁻¹ BC) and T₄ (50 % CF + 2 t ha⁻¹ RH) thousand seed weight were recorded 36.72 g, and 37.51 g respectively (Figure 10). Rahim *et al.* (2020) ran an experiment and found similar results.

In case of interactions highest thousand seed weight was obtained in V₂T₃ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) (48.73 g) and lowest was recorded in V₁T₄ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ RH) (20.2 g). Here V₁T₁ (BWMRI Gom 2 with control), (20.87g) was non-significant with V₁T₂ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ BC) (20.6g). V₁T₁ (BWMRI Gom 2 with control), V₁T₃ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ *Trichoderma*), V₁T₂ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ BC) were thousand seed weight were recorded 28.28g, 38.37g, 20.6g. Again V₂T₁ (BWMRI Gom 3 with control), V₂T₂ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ BC), and V₂T₄ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ RH) were recorded in 40.6g, 40.53g, 39.27g. And again V₃T₁ (BARI Gom 32 with control), V₃T₂ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ BC), V₃T₃ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) and V₃T₄ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ RH) were found in 38.27g, 35.02g, 39.39g, 37.07g respectively (Figure 10). Similar type result was found by Abbas *et al.* (2017).

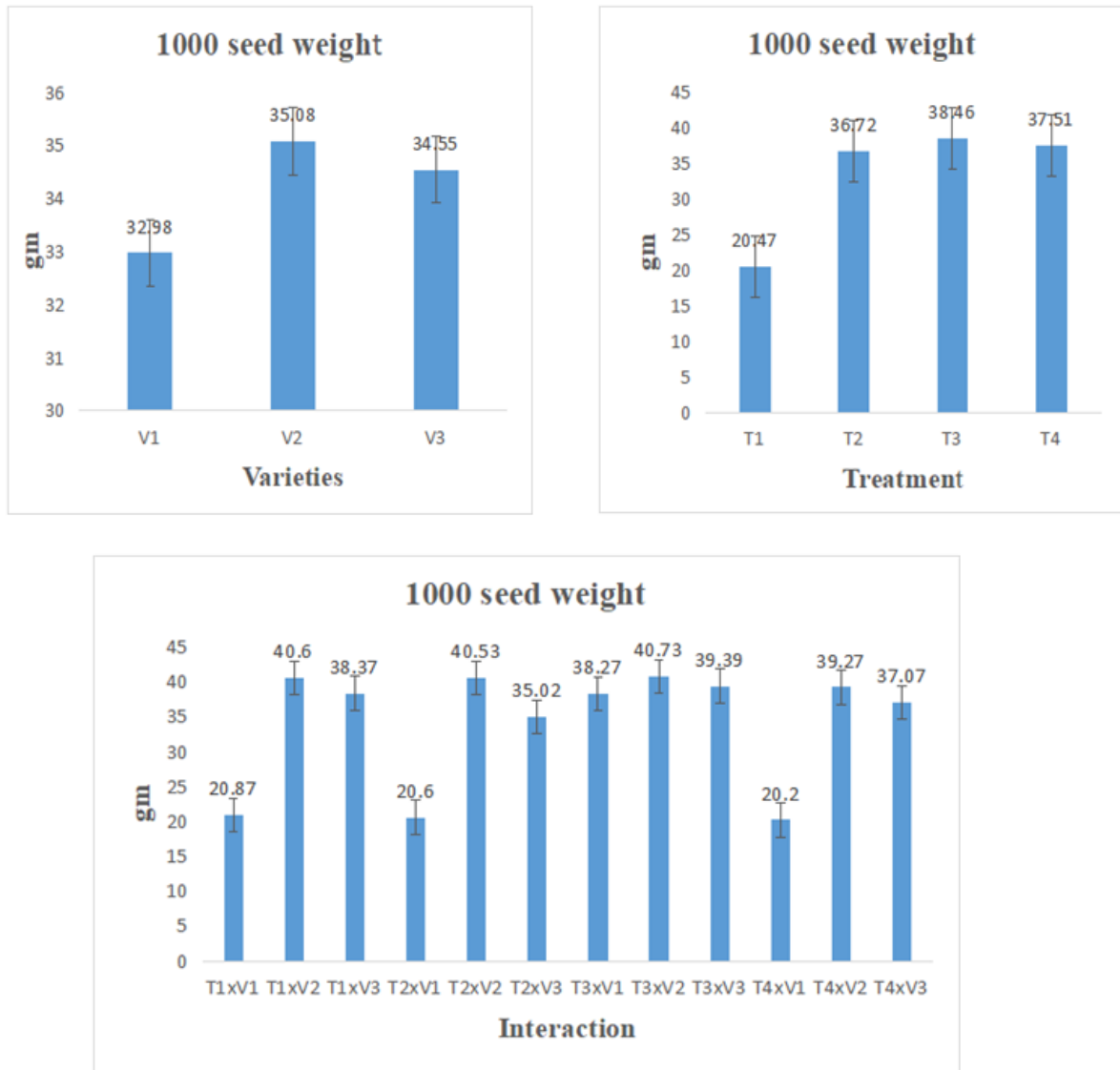


Figure 10: Effect of different treatments on 1000 seed weight/plant of wheat

V₁= BWMRI Gom 2

V₂=BWMRI Gom 3

V₃= BARI Gom 32

T₁

Control

T₂

50% Chemical fertilizer + 2 t/ha biochar

T₃

50% chemical fertilizer + 2 t/ha *Trichoderma*

T₄

50 % chemical fertilizer + 2 t/ha rice husk

4.8 Seed Fresh weight plant⁻¹ (g)

Seed Fresh weight/plant varies non-significantly with the varieties. The highest was recorded in V₂ (BWMRI Gom 3) with (2.30g) and the lowest was recorded in V₁(BWMRI Gom 2) (9.82 g) (Table 9). On the other hand, Seed Fresh weight varied significantly with the treatments. The highest value was recorded in T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*) (13.76g) and the lowest value was recorded in T₁ (Control) (6.11g). In case of T₂ (50 % CF + 2 t ha⁻¹ BC) and T₄ (50 % CF + 2 t ha⁻¹ RH) seed fresh weight were recorded 12.55 g, and 13.59 g respectively (Table 10). Rahim *et al.* (2020) ran an experiment and found similar results.

In case of interactions highest Seed Fresh weight was obtained in V₂T₃ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) (17.54 g) and lowest was recorded in V₁T₁(BWMRI Gom 2 with control) (8.78g). Here V₂T₁ (BWMRI Gom 3 with control) (8.97g) was non-significant with V₃T₁ (BARI Gom 32 with Control) (8.33g) and V₁T₁ (BWMRI Gom 2 with control), (8.78g). Again, V₂T₂ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ BC) (11.84 g) was non-significant with V₃T₂ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ BC) (13.62g). V₂T₃ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) (17.54g), and V₃T₃ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) (17.35 g) was non-significant with V₃T₄ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ RH) (17.12g), V₁T₂ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ BC) (15.65 g) and V₁T₃ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) (15.87 g), V₁T₄(BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ RH) (12.45g), V₂T₄ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ RH) (17.01g) were also non-significant (Table 11) with each other. Similar type result was found by Abbas *et al.* (2017).

4.9 Seed dry weight plant⁻¹ (g)

Seed dry weight plant⁻¹ varied non-significantly with the varieties. The highest was recorded in V₂ (BWMRI Gom 3) with (7.97g) and the lowest was recorded in V₁ (BWMRI Gom 2) (6.71g) (Table 9). On the other hand, Seed dry weight varied significantly with the treatments. The highest value was recorded in T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*) with (10.28g) and the lowest value was recorded in T₁ (control) (4.25g). In case of T₂ (50 % CF + 2 t ha⁻¹ BC), and T₄ (50 % CF + 2 t ha⁻¹ RH) seed dry weight were recorded 8.59 g, and 9.56 g respectively (Table 10). Rahim *et al.* (2020) ran an experiment and found similar results.

In case of interactions highest Seed dry weight was obtained in V₂T₃ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) (10.87 g) and lowest was recorded in V₃T₁ (BARI Gom 32 with Control) (4.21g). Here V₁T₃ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) (10.37g) was non-significant with V₂T₄ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ RH) (10.22g) and V₃T₂ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ BC) (10.37g), V₃T₃(BARI Gom 32

Table 9: Effect of varieties on Seed fresh weight and dry weight plant⁻¹ of wheat

| Variety | Seed Fresh weight/plant (g) | Seed dry weight plant ⁻¹ (g) |
|----------------|-----------------------------|---|
| V ₁ | 9.82a | 6.71b |
| V ₂ | 12.30a | 7.97a |
| V ₃ | 12.00a | 7.13a |
| LS | * | * |
| LSD | 2.11 | 1.78 |
| CV | 8.94 | 2.76 |

In a column, bearing NS do not differ significantly at 5% level of significance

**= Significant at 1% level of probability

LS=Level of significance

LSD= Least Significant Difference

V₂=BWMRI Gom 3

*= Significant at 5% level of probability

CV=Co-efficient of variance

V₁=BWMRI Gom 2

V₃= BARI Gom-32

With 50 % CF + 2 t ha⁻¹ *Trichoderma*) (17.35 g) . Again, V₁T₄ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ RH) (9.35 g) was non-significant with V₃T₄ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ RH) (9.41g). Again V₁T₂ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ BC) (7.91g), was non-significant with V₂T₂ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ BC) (8.89g). And again V₁T₁ (BWMRI Gom 2 with control) (4.85 g) and V₃T₁ (BARI Gom 32 with Control) (4.21g) were also non-significant (Table 11) with each other. Similar type result was found by Abbas *et al.* (2017).

Table10 : Effect of treatments on Seed fresh weight and dry weight plant⁻¹ of wheat

| Treatments | Seed Fresh weight plant ⁻¹ (g) | Seed dry weight plant ⁻¹ (g) |
|----------------|---|---|
| T ₁ | 6.11c | 4.25d |
| T ₂ | 12.55b | 8.59c |
| T ₃ | 13.76a | 10.28a |
| T ₄ | 13.59a | 9.56b |
| LS | NS | ** |
| LSD | 3.33 | 2.82 |
| CV | 18.94 | 21.76 |

In a column, bearing NS do not differ significantly at 5% level of significance

**= Significant at 1% level of probability

*= Significant at 5% level of probability

LS=Level of significance

CV=Co-efficient of variance

LSD= Least Significant Difference

Table 11 : Effect of interactions on seed fresh weight and seed dry weight plant⁻¹ of wheat

| Interactions | Seed Fresh weight plant ⁻¹ (g) | Seed Dry weight plant ⁻¹ (g) |
|-------------------------------|---|---|
| V ₁ T ₁ | 8.78e | 4.85e |
| V ₁ T ₂ | 15.65bc | 7.91d |
| V ₁ T ₃ | 15.87bc | 10.37a |
| V ₁ T ₄ | 12.45d | 9.35b |
| V ₂ T ₁ | 8.97e | 3.69e |
| V ₂ T ₂ | 11.84c | 8.89d |
| V ₂ T ₃ | 17.54a | 10.87a |
| V ₂ T ₄ | 17.01ab | 10.22a |
| V ₃ T ₁ | 8.33e | 4.21e |
| V ₃ T ₂ | 13.62c | 10.37a |
| V ₃ T ₃ | 17.35a | 10.57a |
| V ₃ T ₄ | 17.12a | 9.41b |
| LS | * | * |
| LSD | 4.71 | 3.40 |
| CV | 18.94 | 0.47 |

In a column, bearing NS do not differ significantly at 5% level of significance

**= Significant at 1% level of probability

*= Significant at 5% level of probability

LS=Level of significance

CV=Co-efficient of variance

LSD= Least Significant Difference

V₁=BWMRI Gom 2

V₂=BWMRI Gom 3

V₃= BARI Gom-32

4.10. Seed yield (t ha⁻¹)

Seed yield varied significantly with the varieties. Result showed that V₂ (BWMRI Gom 3) with (4.11 t ha⁻¹) showed better result than V₁ (BWMRI Gom 2) (3.64 t ha⁻¹). Significant difference was also found with the treatments. Highest Seed yield was obtained in T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*) with (5.53 t ha⁻¹) and lowest was recorded in T₁ (control) with (0.78t ha⁻¹). T₂ (50 % CF + 2 t ha⁻¹ BC) (3.23 t ha⁻¹) and T₄ (50 % CF + 2 t ha⁻¹ RH) (4.52 t ha⁻¹) were varied non-significantly (Figure 11). Wang *et al.* (2019) also found similar types of results.

In case of interactions, we can see significant difference. Highest yield was recorded in V₂T₃ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) (5.47 t ha⁻¹) and lowest was recorded in V₃T₁(BARI Gom 32 with Control) (1.2 t ha⁻¹). In V₁T₁(BWMRI Gom 2 with Control), V₁T₂(BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ BC), V₁T₃(BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) and V₁T₄(BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ RH) seed yield were recorded 1.61 t ha⁻¹, 5.09 t ha⁻¹, 4.03 t ha⁻¹ and 3.82 t ha⁻¹ respectively. In case of V₁T₁(BWMRI Gom 2 with Control) Seed yield was recorded 1.61 t ha⁻¹ which was non-significant with V₂T₂(BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹BC) (5.32 t ha⁻¹). In V₂T₁(BWMRI Gom 3 with control), V₂T₄(BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ RH) seed yield were recorded 1.78 t ha⁻¹, 4.07 t ha⁻¹ respectively (Figure11). Again, V₃T₂ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹BC), V₃T₃ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹*Trichoderma*), V₃T₄ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹RH). Seed yield were recorded 5.27t ha⁻¹, 5.32t ha⁻¹, 4.12t ha⁻¹respectively (Figure 11). Sun *et al.* (2019) found similar result.

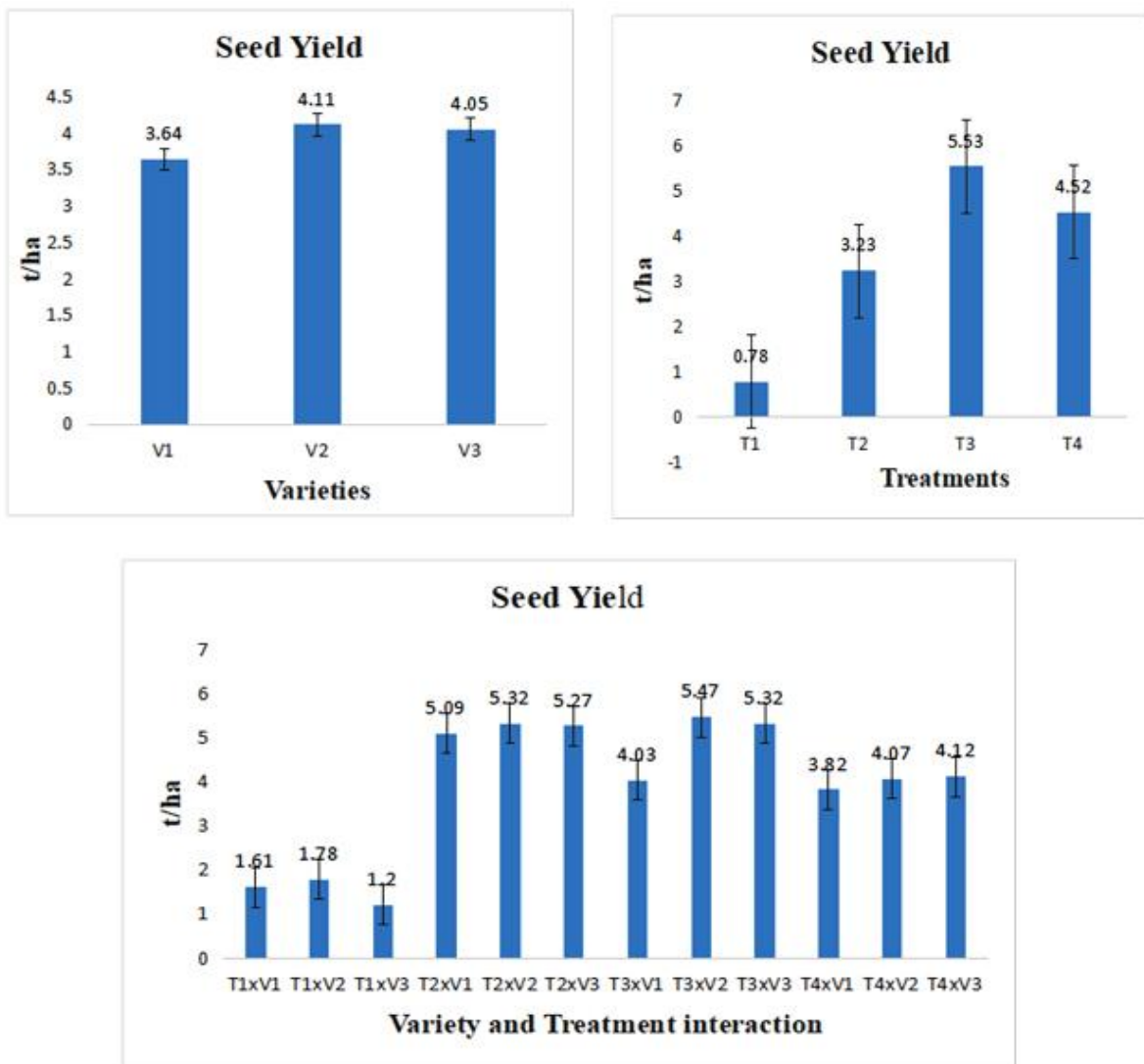


Figure 11: Effect different variety and treatments on seed yield of wheat

V₁= BWMRI Gom 2

V₂=BWMRI Gom 3

V₃= BARI Gom 32

T₁

Control

T₂

50% Chemical fertilizer + 2 t/ha biochar

T₃

50% chemical fertilizer + 2 t/ha *Trichoderma*

T₄

50 % chemical fertilizer + 2 t/ha rice husk

4.11. Biological yield (t ha⁻¹)

Result showed that V₂ (BWMRI Gom 3) with (8.35 t ha⁻¹) showed better performance over V₁ (BWMRI Gom 2) with (7.42 t ha⁻¹) which were significantly different with each other (Table12). Significant differences were experienced with treatments. Highest value was recorded in T₂ (50 % CF + 2 t ha⁻¹ Biochar) with (8.84 t ha⁻¹) and lowest was recorded in T₁ (control) (3.26 t ha⁻¹). Again T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*) And T₄ (50 % CF + 2 t ha⁻¹ rice husk) with treatments were recorded (8.42 t ha⁻¹) and (7.35 t ha⁻¹) shown in (Table13). Ullah *et al.* (2022) also found close conformity with these results.

Table 12 : Effect of varieties on straw yield and biological yield of wheat

| Variety | Straw yield (t/ha) | Biological yield (t/ha) |
|----------------|--------------------|-------------------------|
| V ₁ | 3.78b | 7.42b |
| V ₂ | 4.32a | 8.35a |
| V ₃ | 4.24a | 8.14a |
| LS | * | * |
| LSD | 0.28 | 0.49 |
| CV | 8.09 | 7.26 |

In a column, bearing NS do not differ significantly at 5% level of significance

**= Significant at 1% level of probability

LS=Level of significance

LSD= Least Significant Difference

V₂=BWMRI Gom 3

*= Significant at 5% level of probability

CV=Co-efficient of variance

V₁=BWMRI Gom 2

V₃= BARI Gom-32

In case of interaction highest biological yield was obtained in V₃T₃ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) (9.28 t ha⁻¹) and lowest was obtained in V₁T₁ (BWMRI Gom 2 with Control) (6.59 t ha⁻¹). In case of V₁T₂ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ BC), V₁T₃ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) and V₁T₄ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ RH) biological yield were recorded 8.90 t ha⁻¹, 7.40 t ha⁻¹ and 6.77 t ha⁻¹ respectively. Again, in case of V₂T₁ (BWMRI Gom 3 with control), V₂T₃ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*), V₂T₄ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ RH) and V₂T₂ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ BC) biological yield were recorded 7.66 t ha⁻¹, 8.58 t ha⁻¹, 7.35 t ha⁻¹ and 8.95 t ha⁻¹ respectively And also again V₃T₁ (BARI Gom 32 with Control), V₃T₂ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ BC), and V₃T₄ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ RH) biological yield were recorded 7.54 t ha⁻¹, 8.66 t ha⁻¹, and 7.92 t ha⁻¹ (Table14). Similar result was found in an experiment conducted by Ali *et al.* (2019).

Table 13: Effect of treatments on straw yield and biological yield of wheat

| Treatments | Straw yield (t/ha) | Biological yield (t/ha) |
|----------------|--------------------|-------------------------|
| T ₁ | 1.33c | 3.26c |
| T ₂ | 3.61b | 8.84a |
| T ₃ | 4.89a | 8.42a |
| T ₄ | 4.35a | 7.35b |
| LS | * | ** |
| LSD | 0.32 | 7.26 |
| CV | 8.09 | 0.56 |

In a column, bearing NS do not differ significantly at 5% level of significance

**= Significant at 1% level of probability

*= Significant at 5% level of probability

LS=Level of significance

CV=Co-efficient of variance

LSD= Least Significant Difference

V₁=BWMRI Gom 2

V₂=BWMRI Gom 3

V₃= BARI Gom-32

Table 14: Effect of interactions on straw yield and biological yield of wheat

| Interactions | Straw yield (t/ha) | Biological yield (t/ha) |
|-------------------------------|--------------------|-------------------------|
| V ₁ T ₁ | 3.37f | 6.59f |
| V ₁ T ₂ | 3.98cde | 8.90a |
| V ₁ T ₃ | 4.20bcd | 7.40def |
| V ₁ T ₄ | 4.13bcde | 6.77ef |
| V ₂ T ₁ | 3.63ef | 7.66cde |
| V ₂ T ₂ | 4.45abc | 8.95a |
| V ₂ T ₃ | 4.79a | 8.58abc |
| V ₂ T ₄ | 4.56ab | 7.35def |
| V ₃ T ₁ | 3.38f | 7.54def |
| V ₃ T ₂ | 4.29abcd | 8.66ab |

In a column, bearing NS do not differ significantly at 5% level of significance

4.12. Straw Yield (t ha⁻¹)

Straw yield was significantly different with the varieties. Highest straw yield was recorded in V₂ (BWMRI Gom 3) with (4.32 t ha⁻¹) and lowest was obtained in V₁ (BWMRI Gom 2) with (3.78t ha⁻¹) (Table12). In case of treatments, it varies significantly. Highest straw yield was obtained in T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*) with (4.89t ha⁻¹) and lowest was obtained in

T₁ (control) (1.33 t ha⁻¹). In case of T₂ (50 % CF + 2 t ha⁻¹ Biochar) and T₄ (50 % CF + 2 t ha⁻¹ rice husk) straw yield were recorded 3.61 t ha⁻¹ and 4.35 t ha⁻¹ (6.249 t ha⁻¹) respectively (Table 13). Close conformity with these results also found by Majeed *et al.* (2021).

In case of interactions straw yield varied significantly. Highest straw yield was obtained in V₂T₃ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) (4.79 t ha⁻¹) and lowest was recorded in V₁T₁ (BWMRI Gom 2 with Control) (3.37t ha⁻¹). In case of V₁T₂ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ BC), V₁T₃ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ *Trichoderma*), and V₁T₄ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ RH) straw yield were recorded 3.98 t ha⁻¹, 4.20 t ha⁻¹, and 4.13 t ha⁻¹ respectively. Again, in case of V₂T₁ (BWMRI Gom 3 with Control), V₂T₂ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ BC), and V₂T₄ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ RH) straw yield were recorded 3.63 t ha⁻¹, 4.45 t ha⁻¹ and 4.56 t ha⁻¹ respectively (Table 14). And again V₃T₁ (BARI Gom 32 with control), V₃T₂ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ BC), V₃T₃ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ *Trichoderma*), V₃T₄ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ RH) straw yield were recorded 3.38 t ha⁻¹, 4.29t ha⁻¹, 4.20t ha⁻¹, 4.11 t ha⁻¹ respectively (Table 14) Similar result was found by Zhao *et al.* (2014).

4.13. Harvest Index (%)

In case of variety maximum harvest index were recorded in V₂ (BWMRI Gom 3) with (48.77 %) and the lowest was recorded in V₁ (BWMRI Gom 2) with (47.23 %) (Figure 12). Harvest index varied significantly with the treatments. Maximum value was obtained from T₄ (50 % CF + 2 t ha⁻¹ Rice husk) with (53.70%) and the lowest value was obtained from T₁ (control) with (28.15%). In T₂ (50 % CF + 2 t ha⁻¹ Biochar) and T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*) harvest index recorded 49.20% and 42.90 % respectively (Figure 12). Sun *et al.* (2019) also found similar results.

Significant difference was observed in interaction. Maximum harvest index was recorded from V₂T₃ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) (60.72 %) and lowest was recorded from V₁T₁ (BWMRI Gom 2 with Control) (36.41 %). Value of harvest index from V₁T₂ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ BC), V₁T₃ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ *Trichoderma*), V₁T₄ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ RH), V₂T₁ (BWMRI Gom 3 with Control), V₂T₂ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ BC), V₂T₄ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ RH), V₃T₁ (BARI Gom 32 with control), V₃T₃ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) and V₃T₄ (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ RH)

were recorded 41.54 %, 54.35 %, 41.66 %, 41.54 %, 59.217 %, 53.75 %, 54.35 % and 54.24 %, 53.06% respectively (Figure 12). Smaller results were found in the experiment conducted by Huang *et al.* (2019).

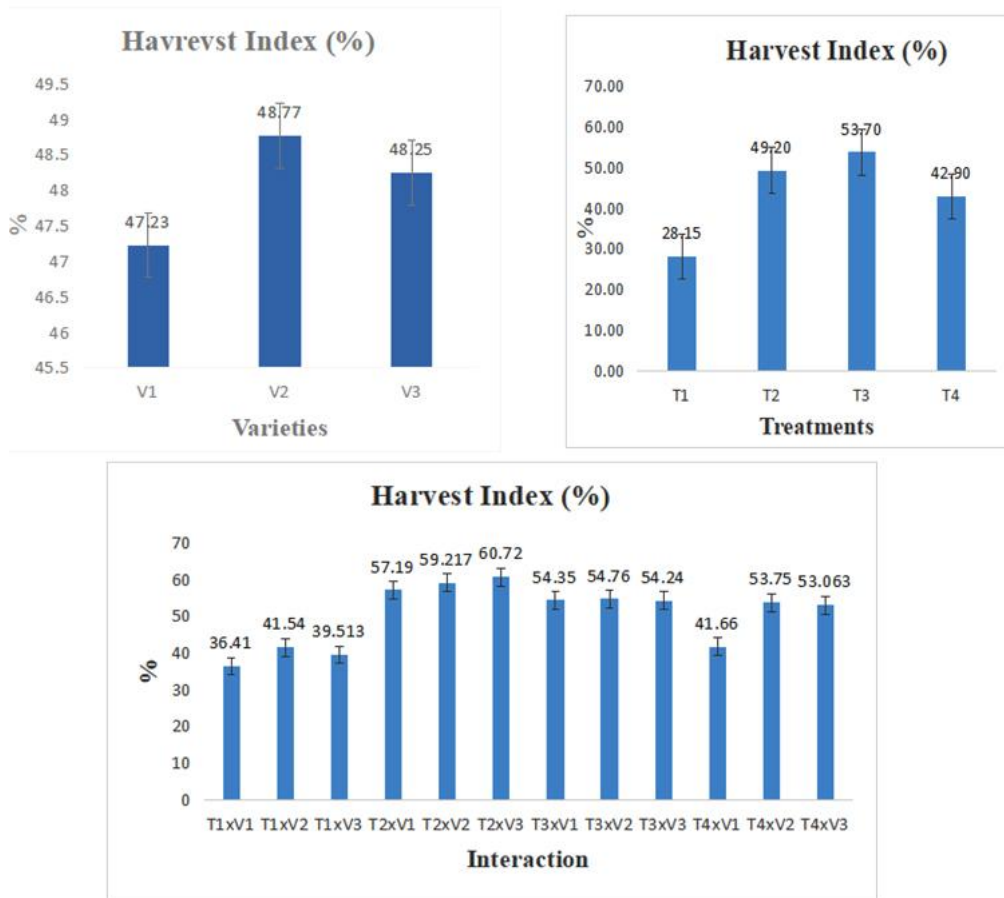


Figure 12 : Effect of different treatments on harvest index of wheat

V₁= BWMRI Gom 2

V₂=BWMRI Gom 3

V₃= BARI Gom 32

T₁

Control

T₂

50% Chemical fertilizer + 2 t /ha biochar

T₃

50% chemical fertilizer + 2 t/ha *Trichoderma*

T₄

50 % chemical fertilizer + 2 t/ha rice husk

Pearson correlation among the yield contributing characters:

Correlation result showed that a strong correlation among the yield contributing traits. Plant height at 30DAS showed a positive correlation with harvest index (0.73), grain yield (0.72), fresh weight plant⁻¹ (0.49), dry weight plant⁻¹ (0.48), 1000 seed weight (0.35), leaf number (0.42), spike length (0.3). While negative correlation showed with only one parameter straw yield (-0.66). A very low positive correlation showed with biological yield (0.3).

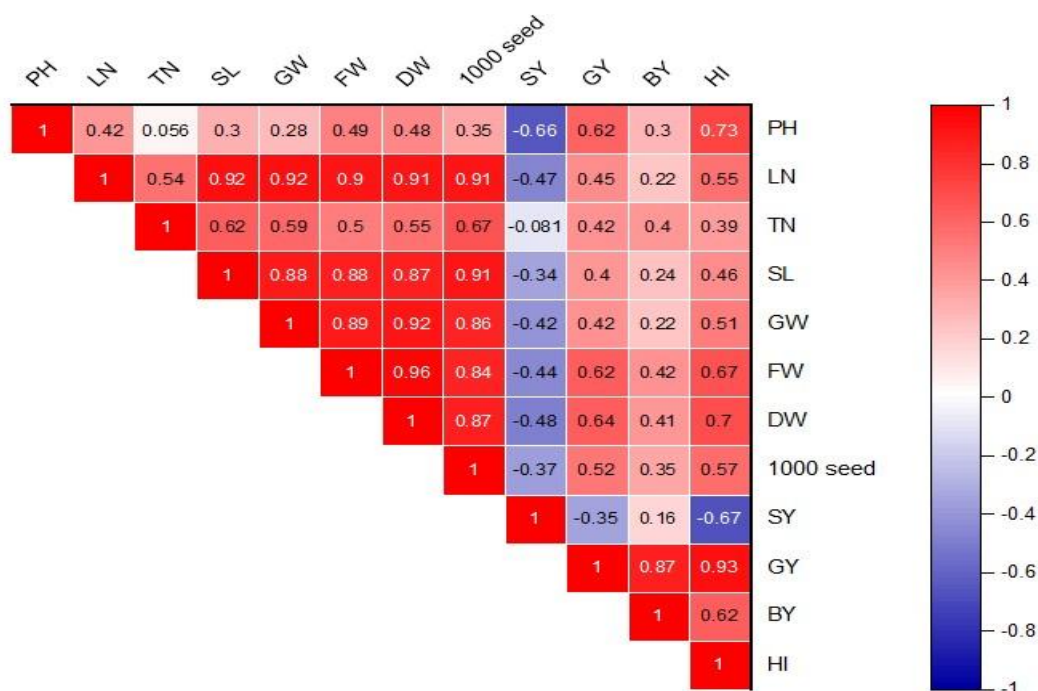


Fig 13: Pearson correlation among the yield contributing characters of wheat. Here, PH= Plant Height, LN= Leaf Number, TN= Tiller Number, Sl = Spike Length, GW = Grain Weight, FW =Fresh Weight of Seed, DW= Dry weight of Seed, 1000 SW= 1000 Seed Weight, GY= GrainYield, SY= Straw Yield , BY= Biological Yield, HI=Harvest Index

Leaf number showed a positive correlation with spike length (0.92), grain weight (0.92), fresh weight (0.90), dry weight plant⁻¹ (0.91), 1000 seed weight (0.91) and harvest index (0.55). A very low positive correlation showed with tiller number¹, and biological yield (0.54, and 0.22). Tiller number showed a highly positive correlation with 1000 seed weight (0.67), spike length (0.62), grain weight (0.59), fresh weight (0.50), dry weight (0.55) A very low positive correlation showed with biological yield (0.4). While negative correlation showed with straw yield (-0.081). Spike length showed highly positive correlation with 1000 seed weight (0.91), grain weight (0.88), fresh weight (0.88) and dry weight (0.87). A very low positive

correlation showed with biological yield (0.24) and grain yield (0.40). While negative correlation showed with straw yield (-0.34). Grain weight showed highly positive correlation with 1000 seed weight (0.86), fresh weight (0.89) and dry weight (0.92). A very low positive correlation showed with biological yield (0.22) and grain yield (0.42). While negative correlation showed with straw yield (-0.42).

Fresh weight of seed showed highly positive correlation with 1000 seed weight (0.84), and dry weight (0.96). A very low positive correlation showed with biological yield (0.42) and grain yield (0.62). While negative correlation showed with straw yield (-0.44). Dry weight of seed showed highly positive correlation with 1000 seed weight (0.87), and dry weight (1.00). A very low positive correlation showed with biological yield (0.41) and grain yield (0.62). While negative correlation showed with straw yield (-0.48). 1000 seed weight showed highly negative correlation with biological yield (0.35) and grain yield (0.52). Grain yield showed highly negative correlation with biological yield (0.87). Therefore, it could be concluded that plant height, leaf number, spike length, grain fresh weight and dry weight, had a positive and strong correlation for higher yield of different wheat variety.

CHAPTER V

SUMMARY AND CONCLUSIONS

The experiment was conducted at the Agronomy research field, HSTU, Dinajpur during November 2022 to April 2023 to assess the effect of Biochar, *Trichoderma* and Rice Husk on the growth and yield performance of wheat. The experiment consisted of two factors namely one was variety and another one treatment. The planting material of the experiment were wheat ($V_1 = \text{BWMRI Gom 2}$, $V_2 = \text{BWMRI Gom 3}$ and $V_3 = \text{BARI Gom 32}$). The treatments were, T_1 (Control), T_2 (50 % chemical fertilizer + 2 t ha⁻¹ biochar), T_3 (50 % chemical fertilizer + 2 t ha⁻¹ *Trichoderma*) and T_4 (50 % chemical fertilizer + 2 t ha⁻¹ Rice Husk). The experiment was laid out in a Randomized Complete Block Design (RCBD). There were 4 treatment combinations where each treatment replicated three times. The treatments were randomly distributed to the plots within a block. Thus, the number of plots was $3 \times 9 = 27$. The unit plot size was (4 m \times 2.5 m) *i.e.*, 10 m². Irrigation and drainage channel were made by maintaining 50 cm width and 30 cm between the blocks and 25 cm wide and 25 cm depth between plots.

In the research field, the seeds were sown on November 2022. The crop was harvested at maturity about 108 days after sowing. The growth, yield and yield components were recorded for each plot from randomly selected 15 plants. Parameters like plant height, number of tillers plant⁻¹, number of leaves plant⁻¹, spike length, fresh weight plant⁻¹, dry weight plant⁻¹, thousand seed weight, grain yield, straw yield, biological yield, harvest index were influenced by Biochar, *Trichoderma* and Rice Husk and inorganic fertilizers. The results revealed that at 25 DAS, 50 DAS and 75 DAS as a variety, the longest plant was recorded from V_2 (BWMRI Gom 3) with (25.68 cm), V_2 (BWMRI Gom 3) with (58.41 cm) and V_1 (BWMRI Gom 2) with (100.21 cm) respectively and the shortest plants were obtained from V_3 (BARI Gom 32) (24 cm), V_1 (BWMRI Gom 2) (55.24 cm) and V_1 (BWMRI Gom 2) (97.86 cm) respectively. . As a treatment, the longest plant was recorded from T_3 (50 % chemical fertilizer + 2 t ha⁻¹ *Trichoderma*)(27.15 cm), T_3 (50 % chemical fertilizer + 2 t ha⁻¹ *Trichoderma*) (62.52cm) and T_3 (50 % chemical fertilizer + 2 t ha⁻¹ *Trichoderma*) (103.79cm) respectively and the shortest plant obtained from T_1 (Control) (8.92 cm, 28.71 cm and 57.59 cm) respectively. Variety treatment interaction showed the lowest plant height at T_1V_1 (BWMRI Gom 2 with control) (13.67 cm), T_1V_1 (BWMRI Gom 2 with control) (51.45 cm) and T_1V_1 (BWMRI Gom 2 with

control) (68.66cm) respectively and the highest plant at T_3V_3 (BARI Gom 32 and 50% chemical fertilizer + 2 t ha⁻¹ *Trichoderma*) (25.93 cm), T_2V_3 (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ Biochar)(87.89 cm) and T_2V_3 (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ Biochar) (105.00 cm) respectively. As a variety, the results revealed that the lowest number of tillers plant⁻¹ were obtained from V_1 (BWMRI Gom 2)(4.92no.), while the highest number of tillers plant⁻¹ V_2 (BWMRI Gom 3)(6.92no.) respectively. As a treatment the lowest number of tillers plant⁻¹ was obtained from T_1 (Control) (3.66no.) and the highest number of tillers plant⁻¹ was observed from T_3 (50% chemical fertilizer + 2 t ha⁻¹*Trichoderma*) (7.22no.) and T_4 (50% chemical fertilizer + 2 t ha⁻¹ Rice Husk) (7.22no.) respectively. As a variety treatment interaction showed the highest number of tillers plant⁻¹ obtained from V_2T_3 (BWMRI Gom 3 with 50% CF + 2 t ha⁻¹*Trichoderma*) (8.2no.) and the lowest tiller plant⁻¹ obtained from T_1V_1 (BWMRI Gom 2 with control) (4.09no.) respectively. At 25 DAS, 50DAS and 75 DAS as a variety the highest number of leaves plant⁻¹ was obtained from V_1 (BWMRI Gom 2) (4.86no. , 17.69no. and 14.18no.) and the lowest number of leaves plant⁻¹ was obtained from V_2 (BWMRI Gom 3)(4.80no.), V_3 (BARI Gom 32)(17.45no.) and V_3 (BARI Gom 32) (13.22no.) respectively. As a treatment highest number of leaves plant⁻¹ was obtained from T_3 (50% chemical fertilizer + 2 t ha⁻¹*Trichoderma*) (5.93no., 21.8no. and 17.59no.) respectively and the lowest number of leaves plant⁻¹ was obtained from T_1 (Control)(3.59no., 14.36no. and 11.17no.) respectively. As a treatment and variety combination highest number of leaves plant⁻¹ was obtained from T_2V_3 (BARI Gom 32 with 50 % CF + 2 t ha⁻¹ Biochar) (8.31no.,19.00no. and 25.05no.) respectively and the lowest was obtained from T_1V_1 (BWMRI Gom 2 with control) (4.09no.), V_2T_1 (BWMRI Gom 2 with control) (8.80no.) and T_1V_3 (BARI Gom 32 with control) (14.33no.) respectively. As a variety, the lowest spike length was obtained at (14.76 cm) with V_1 (BWMRI Gom 2) and the highest (15.77cm) was found in V_2 (BWMRI Gom 3). As a treatment the lowest harvest index was obtained at (7.99 cm) at T_1 (Control) and the highest (16.81 cm) was found in T_3 (50 % CF + 2 t ha⁻¹*Trichoderma*) treatment. Finally, interaction showed the lowest spike length (7.56cm) at T_1V_2 (BWMRI Gom 3 with control) and the highest (18.95cm) at T_3V_2 (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹*Trichoderma*). The results of the experiment revealed that the maximum Fresh weight plant⁻¹ (16.84g) was produced at V_2 (BWMRI Gom 3) and the lowest Fresh weight plant⁻¹ (13.16 g) at V_1 (BWMRI Gom 2). As a treatment lowest Fresh weight plant⁻¹ was obtained (9.29g) at T_1 (Control) and the highest (14.42g) at T_3 (50 % CF + 2 t ha⁻¹ *Trichoderma*). Finally, the interaction highest Fresh weight plant⁻¹ (17.54 g) was obtained at T_3V_2 (BWMRI

Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) and the lowest was obtained (7.74 g) at T₁V₂ (BWMRI Gom 3 with control). As a variety, the lowest Dry weight plant⁻¹ obtained (9.63g) at V₁ (BWMRI Gom 2) and highest (11.74 g) at V₂ (BWMRI Gom 3). As a treatment lowest Dry weight plant⁻¹ obtained (6.79g) at T₁ (Control) treatment and the highest at (11.20 g) T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*). Finally, interaction showed the lowest Dry weight plant⁻¹ at T₁V₃ (BARI Gom 32 withc Control) (9.14 g) and highest at T₃V₂ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) (12.06 g). Fertilizer management had significant effect on the thousand seed weight of wheat. The highest thousand seed weight (35.06 g) was obtained from V₂ (BWMRI Gom 3) and the lowest at (32.98 g) V₁ (BWMRI Gom 2). As a treatment highest (38.46 g) was obtained at T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*) and while the lowest thousand seed weight (20.47 g) was obtained at T₁ (Control) and interaction showed the highest thousand seed weight (48.73g) at T₃V₂ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) and lowest (20.2 g) at T₄V₁ (BWMRI Gom 2 with 50 % CF + 2 t ha⁻¹ Rice Husk). The results of the experiment revealed that the maximum seed fresh weight plant⁻¹ (12.30g) was produced at V₂ (BWMRI Gom 3) and the minimum seed fresh weight plant⁻¹ (9.82 g) at V₁ (BWMRI Gom 2) .As a treatment lowest seed fresh weight plant⁻¹ was obtained at (6.11 g) at T₁ (Control) and the highest seed fresh weight plant⁻¹ (13.76g) at T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*). Finally, at interaction highest seed fresh weight plant⁻¹ (17.54 g) was obtained at T₃V₂ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) and the lowest was obtained (8.78 g) at V₁T₁ (BWMRI Gom 2 with Control). The results of the experiment revealed that the maximum Seed dry weight plant⁻¹ (7.97 g) was produced at V₂ (BWMRI Gom 3) and the lowest Seed dry weight plant⁻¹ (6.71g) at V₁ (BWMRI Gom 2) . As a treatment lowest Seed dry weight was obtained at (4.25g) at T₁ (Control) and the highest (10.28g) at T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*). Finally, at interaction highest seed dry weight plant⁻¹ (10.87 g) was obtained at T₃V₂ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) and the lowest was obtained (4.21g) at V₃T₁ (BARI Gom 32 with control). The results of the experiment revealed that the maximum seed yield (4.11 t ha⁻¹) was produced at V₂ (BWMRI Gom 3) and the lowest seed yield (3.64t ha⁻¹) at V₁ (BWMRI Gom 2) . As a treatment lowest seed yield was obtained at (0.78 t ha⁻¹) at T₁ (control) and the highest (5.53 t ha⁻¹) at T₃ (50 % CF + 2 t ha⁻¹ *Trichoderma*). Finally, at interaction highest seed yield (5.47 t ha⁻¹) was obtained at T₃V₂ (BWMRI Gom 3 with 50 % CF + 2 t ha⁻¹ *Trichoderma*) and the lowest was obtained (1.2t ha⁻¹) at V₃T₁ (BARI Gom 32 with control). Straw yield varied significantly with the different levels of fertilizer. As a variety, the lowest straw yield

obtained (3.78 t ha^{-1}) at V_1 (BWMRI Gom 2) and highest at (6.59 t ha^{-1}) V_2 (BWMRI Gom 3). As a treatment lowest Straw yield obtained (4.72 t ha^{-1}) at T_1 (control) treatment and highest at (4.89 t ha^{-1}) T_3 (50 % CF + 2 t ha^{-1} *Trichoderma*). Finally, interaction showed lowest straw yield at T_1V_1 (BWMRI Gom 2 with control) (1.33 t ha^{-1}) and highest at T_3V_2 (BWMRI Gom 3 with 50 % CF + 2 t ha^{-1} *Trichoderma*) (6.49 t ha^{-1}). Biological yield varied significantly with the different levels of fertilizer. As a variety the lowest biological yield (7.42 t ha^{-1}) at V_1 (BWMRI Gom 2) and highest at (8.35 t ha^{-1}) was found in V_2 (BWMRI Gom 3). As a treatment the lowest biological yield (3.26 t ha^{-1}) at T_1 (control) and highest (8.84 t ha^{-1}) at was found in T_2 (50 % CF + 2 t ha^{-1} Biochar) treatment. Finally, interaction showed lowest biological yield at V_1T_1 (BWMRI Gom 2 with control) (6.59 t ha^{-1}) and highest at T_3V_3 (BARI Gom 32 with 50 % CF + 2 t ha^{-1} *Trichoderma*) (9.28 t ha^{-1}). As a variety the lowest harvest index (47.23%) at V_1 (BWMRI Gom 2) and highest at (60.72 %) was found in V_2 (BWMRI Gom 3). As a treatment the lowest harvest index was obtained at (28.15 %) at T_1 (control) and the highest (53.70%) was found in T_4 (50 % CF + 2 t ha^{-1} Rice Husk) treatment. Finally, interaction showed the lowest harvest index at (36.41%) at V_1T_1 (BWMRI Gom 2 with control) and highest at (48.97 %) T_3V_2 (BWMRI Gom 3 with 50 % CF + 2 t ha^{-1} *Trichoderma*). From the experimental results, the highest seed yield was observed from T_3V_2 combination. Cultivation of BWMRI Gom 3 along with 50% chemical fertilizer + 2 t ha^{-1} *Trichoderma* came out very important for obtaining higher yield of wheat in the Old Himalayan Piedmont Plain (AEZ -1) soils.

RECOMMENDATIONS

Considering the above results of this experiment, further studies in the following areas may be recommended:

1. Such study is needed in different Agro-Ecological Zones (AEZ) of Bangladesh for regional compliance and other performances for soil improvement.
2. It might be recommended that, appropriate treatment i.e., 50 % chemical fertilizer with BWMRI Gom 3 should be applied for the farmer's field that does not use recommended biofertilizer in their fields for wheat production.
3. Farmers should be motivated to adopt wheat variety BWMRI Gom 3 for highest grain yield.
4. The remaining land that is not under application of adequate biofertilizer application should be practically taken under proper application of recommended biofertilizer treatment to increase and sustainable wheat production in the field.
5. Varietal trials need to be investigated.

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APPENDICES

Appendix I: Analysis of variance (mean square) of the data for plant height of wheat

| Source of variation | df | Plant height (cm) | | |
|---------------------|----|-------------------|-----------|-----------|
| | | 25 DAS | 50 DAS | 75 DAS |
| Replication | 2 | | 42.34 | 44.53 |
| Treatment | 3 | 93.375** | 1190.66** | 1091.66** |
| Variety | 2 | 424.48** | 448.20** | 469.44** |
| Treatment x Variety | 6 | 30.85** | 31.35** | 12.30** |
| Residuals | 22 | 34.05 | 30.17 | 32.16 |

Appendix II: Analysis of variance (mean square) of the data for number of tillers plant⁻¹ of wheat

| Sources of variation | d.f | Number of tillers plant ⁻¹ | | |
|----------------------|-----|---------------------------------------|-----------|---------|
| | | 25 DAS | 50 DAS | 75 DAS |
| Replication | 2 | 0.67 | 0.78 | 0.86ns |
| Treatment | 3 | 0.34481** | 1.915** | 26.52* |
| Variety | 2 | 0.01281** | 0.00012** | 15.36** |
| Treatment x Variety | 6 | 0.3394** | 0.148** | 0.54* |
| Residuals | 22 | 0.08125 | 0.032 | 1.04 |

Appendix III: Analysis of variance (mean square) for number of leaves plant⁻¹ of wheat

| Sources of variation | d.f | Number of leaves plant ⁻¹ | | |
|----------------------|-----|--------------------------------------|---------|----------|
| | | 25 DAS | 50 DAS | 75 DAS |
| Replication | 2 | 2.34ns | 2.21ns | 4.00ns |
| Treatment | 3 | 314.29** | 354.16* | 319.44** |
| Variety | 2 | 40.02* | 50.08* | 55.75 ** |
| Treatment x Variety | 6 | 1.70* | 1.13* | 5.27* |
| Residuals | 22 | 0.31 | 7.72 | 1.52 |

Appendix IV: Analysis of variance (mean square) of the data for spike length, fresh weight plant⁻¹, dry weight plant⁻¹ of wheat

| Sources of variation | d.f | Spike length plant ⁻¹ (cm) | Fresh weight plant ⁻¹ (gm) | Dry Weight plant ⁻¹ (cm) |
|----------------------|-----|---------------------------------------|---------------------------------------|-------------------------------------|
| Replication | 2 | 2.39 ^{ns} | 1.16** | 2.84** |
| Treatment | 3 | 176.18** | 102.76** | 65.75** |
| Variety | 2 | 13.58** | 18.72** | 7.38** |
| Treatment x Variety | 6 | 1.062** | 0.200** | 0.19* |
| Residuals | 22 | 1.22 | 0.22 | 0.08 |

Appendix V: Analysis of variance (mean square) of the data for seed fresh weight plant⁻¹, seed dry weight plant⁻¹ and 1000 seed weight of wheat

| Sources of variation | d.f | Seed Fresh weight plant ⁻¹ (gm) | Seed Dry Weight plant ⁻¹ (cm) | 1000 seed weight (gm) |
|----------------------|-----|--|--|-----------------------|
| Replication | 2 | 2.39 ^{ns} | 2.16** | 6.57 ^{ns} |
| Treatment | 3 | 76.18** | 92.76** | 686.68 ** |
| Variety | 2 | 23.58** | 28.72** | 39.15** |
| Treatment x Variety | 6 | 1.062** | 0.200** | 11.71* |
| Residuals | 22 | 2.13 | 2.22 | 4.18 |

Appendix VI: Analysis of variance (mean square) of the data for seed yield, biological yield, straw yield and harvest index of wheat

| Sources of variation | d.f | Seed yield (t/ha) | Biological yield (t/ha) | Straw yield (t/ha) | Harvest Index (%) |
|----------------------|-----|--------------------|-------------------------|--------------------|-------------------|
| Replication | 2 | 0.31 ^{ns} | 1.79** | 0.77** | 17.38 |
| Treatment | 3 | 11.71** | 5.52** | 1.16** | 795.32** |
| Variety | 2 | 0.76* | 2.88** | 0.67** | 0.96 |
| Treatment x Variety | 6 | 0.16* | 0.65** | 0.30* | 9.03 |
| Residuals | 22 | 0.14 | 0.33 | 0.11 | 5.72 |

Appendix VII: Location of the experimental site (map of Dinajpur Sadar Upazila showing the research plot).



Appendix VIII: Soil physical and chemical properties of the experimental location

| Parameters measured | Soil Layer between (0-40) cm |
|-----------------------|------------------------------|
| Soil textural classes | Sandy loam |
| Sand | 47.60 % |
| Silt | 36.00 % |
| clay | 16.40 % |
| Organic matter | 0.31 % |
| Organic carbon | 0.18 % |
| Total N | 0.007 % |
| Total P | 14.30 % |
| Available K | 0.05 mgkg ⁻¹ |
| Available S | 18.09 mgkg ⁻¹ |
| Field capacity | 10.50 % |
| CEC | 1.00 Meq 100g |
| Ec | 87.30 mgkg ⁻¹ |
| pH | 6.12 |

Appendix IX: Some photos of my research work



