YIELD AND YIELD CONTRIBUTING CHARACTERS OF RICE (*Oryza sativa* L.) AS AFFECTED BY BIOCHAR AND NITROGEN FERTILIZER APPLICATION

SABAL OO

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A thesis submitted to the post-graduate committee of
the Yezin Agricultural University in partial
fulfillment of the requirement for the degree of
Master of Agricultural Science
(Soil and Water Science)

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The thesis attached hereto, entitled **"Yield and Yield Contributing Characters of Rice (*Oryza sativa* L.) as Affected by Biochar and Nitrogen Fertilizer Application"** was prepared under the direction of the chairperson of the candidate supervisory committee and has been approved by all members of that committee and board of examiners as a partial fulfillment of the requirements for the degree of **Master of Agricultural Science (Soil and Water Science).**

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DECLARATION OF ORIGINALITY

This thesis represents the original work of the author, except where otherwise stated. It has not been submitted previously for a degree at any other University.

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DEDICATED TO MY BELOVED PARENTS

U MYO MYINT AND DAW KYI MYINT

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ABSTRACT

The pot experiments were conducted at the Department of Soil and Water Science, YAU during the dry and wet seasons of 2020, to study the effects of rice husk biochar and nitrogen fertilizer application on growth, yield, and yield components of rice plants and to evaluate the optimum combination of rice husk biochar and nitrogen fertilizers for rice production. Split plot design with three replications was used for these experiments in which the main plots were arranged with biochar; B_0 (0 ton ha^{-1}), B_1 (6 ton ha^{-1}) and B_2 (12 ton ha^{-1}) and sub plots were four levels of nitrogen fertilizer, N_0 (0 kg N ha^{-1}), N_1 (30 kg N ha^{-1}), N_2 (60 kg N ha^{-1}), N_3 (90 kg N ha^{-1}). Triple super phosphate and muriate of potash fertilizers were applied at the recommended dose of Department of Agricultural Research (12:31 kg PK ha^{-1}). In both seasons, there were no statistically significant effects of biochar applications on growth and yield parameters. However, in both seasons, biochar application numerically produced higher tiller number, spikelets panicle^{-1}, panicle length, filled grain and total dry matter than without biochar application. The application of nitrogen fertilizer had a highly significant effect on the number of panicles hill^{-1} and grain yield in both seasons. 90 kg N ha^{-1} gave the maximum value for growth and yield parameters such as plant height, tiller number, and SPAD reading. The maximum grain yield was observed at 90 kg N ha^{-1} in both seasons. In both seasons, there was no interaction effect on growth and yield parameters of rice, except for spikelets panicle^{-1} and panicle length in wet season. However, the combination of biochar and nitrogen application, B_2N_3 numerically produced higher grain yield than other combinations in dry season. In the wet season, the maximum grain yield was observed in B_1N_3 and B_2N_3. According to the results, 90 kg N ha^{-1} could be the optimum N dosage for the Sin Thu Kha rice variety that is grown in the sandy clay loam soil. Although different biochar rates did not clearly result in its effects on growth and yield parameters of rice, biochar should be used for long-term rice production since the rice husk ash biochar is important for the recycling of rice hush through biochar production for improving soil fertility and crop growth in soils of low fertility, particularly in smallholder farming systems where access to inputs such as inorganic fertilizers is limited.

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CHAPTER I

INTRODUCTION

Rice is the most important staple food in Asia, providing on average, 32% of total calorie uptake in which rice is typically consumed two or three times a day (Maclean, Dawe & Hettel, 2002). Therefore, over 90% of rice production globally is harvested in Asia countries. In Asia, there is still a gap between the farmer's field and potentially yield (Hayashi, 2014). By 2020, many government aspirations on food security aim to achieve self-sufficiently level, which is currently around 71.6% (Powell, 2018). By 2025, rice production must increase about 60 % more than current productivity in order to fulfill the needs of increasing global population. Nevertheless, producing more food from fixed agricultural lands requires for sustainable agricultural inputs, including natural resources (Fageria, Slaton & Baligar, 2003). Rice yield in Myanmar is very low compared to China (6.8 ton ha^{-1}), Japan (6.7 ton ha^{-1}) and Vietnam (5.7 ton ha^{-1}) (Shwe, Myint, Shwe, Tun & Ngwe, 2019). In Myanmar, rice is the staple food of about 51.7 million people. Agricultural sector is a major source of income, employment, foreign exchange earnings, and an important contributor to the economic growth of the country. To obtain high yields and sustain crop productivity, considerable fertilizer applications are necessary. The major required fertilizer types for crops are nitrogen, phosphorus and potassium fertilizers (Wu et al., 2013).

The intensive rice cultivation is readily degrading the soil quality and brings to a shortage of soil organic matter (Huang, Yang, Qin, Jiang & Zou, 2013). Intensive irrigated rice systems, with two or sometimes three rice crops produced each year in the same field, are the dominant agricultural land use in the lowland tropics and subtropics of Asia (Cassman & Pingali, 1995). Optimal productivity of these systems depends on relatively large inputs of inorganic N fertilizer, and grain yield is closely correlated with N uptake under favorable growth conditions (Witt et al., 2000). Declining soil fertility and mismanagement of plant nutrients have made this task more difficult. Balanced NPK fertilization has received considerable attention in India (Hegde & Babu, 2004). Moreover the overuse of N and P fertilizers on agricultural areas increases possibilities to threaten surrounding ecosystems through runoff and soil loss (Kim, Oh & Oh, 2006). The majority of the N that is not assimilated by the plant is lost through various mechanisms such as ammonia (NH_3) volatilization, surface runoff, nitrification, denitrification, and leaching (Dong et al., 2012).

Nitrogen (N) is the most important nutrient in irrigated rice production (Cassman et al., 1998) and current high yields of irrigated rice are associated with large applications of fertilizer N (Barker & Dawe, 2002). Rice N requirements are closely related to yield levels, which in turn are sensitive to climate, particularly solar radiation and the supply of other nutrients and crop management practices (Kropff, Cassman, Van Laar & Peng, 1993). Soil N and biological nitrogen fixation associated with microorganisms are major sources of N in the lowland rice (Bohlool, Ladha, Garrity, & George, 1992). Soil organic N is continually lost through plant removal, leaching, denitrification and ammonia volatilization (Rahman, Faruq, Sofian-Azirun & Boyce, 2012).An additional concern is that the capacity of soil to supply N may decline with continuous intensive rice cropping under wetland conditions, unless it is replenished by biological N fixation (Kundu & Ladha, 1995). The remaining N requirement is normally met with fertilizer (Mandana, Akif, Ebrahim & Azin, 2014). The main reason for the low efficiency is that much of the N applied as soluble fertilizer is lost from the plant-soil system through various pathways such as nitrification, denitrification, mineralization-immobilization, ammonia volatilization, leaching and surface runoff (Mikkelsen,1987). Crop residue from agricultural soil is vital because this resource provides readily available carbon (C) and nitrogen (N), as well as other nutrients and soil quality, soil dynamics, crop yield, and N recovery (Kumar& Goh, 2000). In addition, application of crop residue is important for improving soil fertility and for increasing organic C input of soil (Singh, Shan, Johnson-Beebout, Singh & Buresh, 2008).

Biochar (BC) is a carbon-rich product from pyrolysis of biomass such as wood, crop residues, and manure (Lehmann & Joseph, 2015). The use of BC is shapely used for sustaining soil fertility, remediating organic/inorganic contaminants, mitigating GHG emission, and facilitating environmental management (Tsang, Zhou, Zhang & Qiu, 2016; Jeffery et al., 2011). As a pyrolysis product containing high organic carbon, biochar is able to improve land quality and soil fertility also improves biological activity and reduces pollution (Maftu'ah & Nursyamsi, 2019). Biochar amendment to the soil can improve soil microorganism populations (Shen, Ashworth, Gan, & Yates, 2016). However, the effect of biochar to plants varies depending on the characteristics of biochar, soil type, and type of plant (Nguyen, Scheer, Rowlings, & Grace, 2016).

For rice-based cropping systems, the use of rice straw and rice husk has been practiced for a long time (Eagle et al., 2001). Rice husk is a major byproduct obtained from paddy. For every four tons of paddy produce one ton of husk. Rice husk contains 75-90 % organic matter such as cellulose, lignin etc. and rest mineral components such as silica, alkalis and trace elements (Wallheimer & Brian, 2010).

Burning of rice husk generates about 15–20 % of its weight as ash (Muthadhi & Kothandaraman, 2007). Rice husk biochar which is believed to contain various nutrients that enables it to serve as a source of fertilizer (Nyunt, 2014). RHA is a good source of potassium and it can be used as a potassium source for crop production Sellamuthu & Malathi, 2020). Rice husk biochar can improve not only moisture but also better aeration between soil and plant and also improves plant growth and yield (Tun, 2016). Biochar that made with rice husk can be a complementary potential fertilizer source for rice plant and it is broadly used in agricultural production (Pode, 2016).

One recently industrial alternative to conventional pyrolysis equipment is the flame curtain pyrolysis kiln, initially proposed by (Cornelissen et al., 2016). An additional advantage of this approach is the low construction and maintenance cost of the kiln, which allows for extended use at farmer level in developing countries (Owsianiak et al., 2018). The flame-curtain kiln is mobile, which practically means that it can be transferred to where the biomass is, thus saving the cost of transporting large quantities of biomass. Rice husk biochar made by flame curtain pyrolysis kiln would be the potential alternative soil amendment sources for rice production at farmer level. Another cheap alternative method for biochar production is slow partial pyrolysis method.Farmer can easily produce rice husk ash biochar with this method (Wijitkosum & Jiwnok, 2019).

As the agricultural postharvest waste management application of soil amendments as biochar would indirectly increase rice yield by maintaining soil fertility, especially enhancing soil nitrogen recovery. However, biochar rate is still needed for the rice production area in Yezin, especially in sandy loam soil with a high leaching rate of soil. Moreover, the experiment for studying the rice yield with the combined use of biochar and nitrogen fertilizer is very scare. The application of biochar and nitrogen fertilizer would enhance not only the growth but also the yield components of rice.

Therefore, the experiment was conducted with the following objectives;

- to investigate the effect of rice husk biochar and nitrogen fertilizer on yield and yield components of rice
- to evaluate the optimum combination rice husk biochar and nitrogen fertilizers for rice production

CHAPTER II
LITERATURE REVIEW

2.1 Importance of Rice

Rice is the most important food crop in the world. Rice accounts for more than 40 % of calorie intake in tropical Asia (Peng & Ismail, 2004). Furthermore, the potential for expanding irrigated rice land is limited. Irrigated rice land contributes more than 75 percent of total rice production despite accounting for about 55 percent of total rice area. As a result, the average yield of Asia's irrigated rice land must increase from 5.0 to 8.0 tons per hectare over the 30-year period from 2000 to 2030. Rice varieties with higher yield potential must be developed in order to increase average farm yields (Peng, Tang, & Zou, 2009).The majority of rice fields are placed in former natural wetlands and approximately 15 % of the world’s wetland area corresponds to rice paddies (Lawler, 2001). Rice is the most important crop in Myanmar. In conditions of rice growing area and production, Myanmar ranks seventh in the world of rice cultivation with 8.06 million ha, among which 68 % represents lowland rice cultivation areas. Most of the major lowland rice growing areas such as the Ayeyarwady, Yangon and Bago Divisions are naturally provided with fertile deltaic alluvial soil and abundant monsoon rainfall. Irrigated lowland rice is one of the major rice ecosystems in these regions, especially in semi-rainfed areas. Rice fields in Myanmar are connected as successive fields in lowland areas with a few centimeters of difference in elevation. Even though the importance of paddy rice in Myanmar, basic information of the paddy rice cultivation such as spatial variability of soil properties and yield and its related methane (CH_4) emission are still missing (Oo, Win & Bellingrath-Kimura, 2015).

2.2 Yield Fluctuation at Intensive Rice Production

Crop fertilization can be supplied with organic and inorganic fertilizers. Chemical fertilizers, because of their high nutrient concentration, easy availability, and convenient transportation and application, are very attractive and commonly used to enhance crop yields (Chen, Yuan, Liu, Ji & Hou, 2017). However, the long-term use of large amounts of chemical fertilizers only may contribute to degrade soil structure and deteriorate soil productivity (Blanco-Canqui & Schlegel, 2013; Guo et al., 2010). Application of organic fertilizers may not be able to maintain and synchronize the required supply of nutrients to the growing crops for optimum production because of relatively less quantity of plant available nutrients and more time needed for mineralization to release nutrients available for effective plant uptake (Miao, Stewart & Zhang, 2011). Organic and inorganic fertilizers in improving rice yield and paddy soil properties through long term experiments is lacking, especially in the subtropical areas with intensive cropping and excessive use of heavy tillage (Li, Lin-Zhang, Li-Zhong, Ming-Xing, Shi-Xue & Yun-Dong, 2011; Subehia, Sepehya, Rana, Negi & Sharma, 2013).

Changes in crop management practices such as irrigation, soil tillage, fertilizer application, and organic additives primarily influence CH_4 and N_2O emissions in rice fields; thus, changes in these management practices offer opportunities for mitigation (Hussain et al., 2015). Application of crop straw or green manure increases crop yield and fertilizer efficiency (Xie et al., 2016), improves soil organic C and total N storage (Nie, Zhou, Wang, Chen & Du, 2007) and enhances active pools of C and N in soil (McCarty & Meisinger, 1997; Wang, Liu, Butterly, Tang & Xu, 2013). The return of rice straw not only improves soil physical properties, but also reduces N loss by immobilization and prolongs N availability, which assists in synchronizing the release of N with crop demands (Powlson, Jenkinson, Pruden & Johnston, 1985). Soil amendment with organic additives, such as crop residue (Ma, Xu, Yagi & Cai, 2008) and green manure incorporation (Lee et al., 2010), has been shown to increase CH_4 emissions in paddy soils. The incorporation of rice straw into soil may also increase CH_4 emissions from flooded rice fields, contributing to global warming (Xu & Hosen, 2010).

Agricultural crop residue burning contributes to the GHGs – carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) – that cause global warming (Jain, Bhatia & Pathak, 2014; Fagodiya, Pathak, Kumar, Bhatia & Jain, 2017). Several solutions are available to reduce agricultural GHG emissions (Smith & Gregory, 2013). These solutions include reducing the use of fossil fuels, minimizing tillage operations and management (Gupta et al., 2016), conservational agriculture (Shyamsundar et al., 2019), alternative nitrogen management and using crop residue as mulch (Gomes, Carvalho, Almeida, Medici & Guerra, 2014).

2.3 Rice Residue Management in Rice

The harvested rice will be milled, where the majority of the rice production residue is produced. Every year, approximately 600–800 million tons of rice straw is produced in Asia, while approximately 800–1000 million tons of rice straw are produced worldwide (Singh & Arya, 2021).Furthermore, the global annual production of rice husk and rice bran is 120 tonnes and 76 million tons, respectively (Karam et al., 2021). Rice husk is used in rice mills to generate heat to dry paddy, and rice residue can be burned in the field. (Mohd Shafie, 2015; Pode, 2016).

Rice has long believed that direct application of rice husk and rice straw into paddy fields would ensure optimal nutrient cycling. Rice residue is a less expensive and more convenient way to dispose of rice waste (Ahmed, Ahmad & Ahmad, 2015). Burning rice waste for a long time pollutes the air and increases greenhouse gas emissions. As a result, not only in rice production, but also in rice residue management, a sustainable approach is required. Rice husk conversion to biochar has the potential to solve both of these problems. In addition, rice husk ash is one example of plant biomass that is widely employed in the production of products (Soltani, Bahrami, Pech-Canul & González, 2015; Bahrami, Soltani, Pech-Canul & Gutiérrez, 2016). Furthermore, due to the high Si content of rice husks, rice husk ash is a key component in the synthesis of silica nitride (Soltani, Bahrami, Pech-Canul, González & Gurlo, 2017).

2.4 Cheap Biochar Production Method

Biochar is a carbonaceous material made from biomass like agricultural waste and crop processing by-products. Biochar's physicochemical qualities are influenced by the biomass type and pyrolysis conditions. Biochar is widely used in a variety of applications thanks to the quantity of suitable biomasses and the development of cost-effective pyrolysis techniques. The majority of biochar production over the last 15 years has gone toward improving the physical, chemical, and biological aspects of nutrient-depleted soils in order to boost crop output (Ahmad, Mosa, Zhan & Gao 2021; Waqas et al., 2021). Agricultural wastes like olive husk, corncob, and tea waste (Demirbas, 2004; Ioannidou & Zabaniotou, 2007), green waste (Chan, Dorahy & Tyler, 2007) , animal manures, and other waste items can all be used to make biochar (Downie, Munroe, Klatt & Downie, 2007; Lima, McAloon & Boateng, 2008; Chan, Van Zwieten, Meszaros, Downie & Joseph, 2007). Biochar is a mixture of char and ash with the major part (70-95 %) carbon (C) (Brandstaka et al., 2010; Luostarinen, Vakkilainen & Bergamov, 2010). Biochar has been demonstrated to increase soil quality and plant growth (Chan, Van Zwieten, Meszaros, Downie & Joseph, 2008), as well as reduce greenhouse gas emissions from soil (Van Zwieten et al., 2014). Furthermore, pyrolysed products are protected from rapid microbial degradation, so are able to securely sequester carbon, offering substantial potential for mitigation of greenhouse gas emissions (Lehmann, Gaunt & Rondon, 2006).

Biochar is now being researched for usage in more complex applications. Biochars have showed promise as adsorbents for wastewater treatment and as substrates for the creation of nanocatalysts for improved oxidation processes due to structural similarities with activated carbons and customizable surface chemistry (Qiu et al., 2021; Zhou et al., 2021). Activated carbon preparation also necessitates specialized equipment, significant technical expertise, and is frequently pricey. However, if biochar can be employed as a precursor to high-performance functional materials using simple, inexpensive pyrolysis equipment and a sustainable source of biomass, it could be a viable and cost-effective replacement to activated carbon.

Cheap flame curtain pyrolysis method is a simple, low-cost, high-yield method for making porous carbons with a large surface area from rice straw, one of the most common and commonly available biomasses (Zhang, Wang, Li & Chen, 2009). Despite the fact that burning crop wastes is convenient, rapid, and cost-effective, and allows for speedy field preparation for the following rotation, some farmers prefer to incorporate crop residues into the soil to maintain long-term soil fertility. Nevertheless, farmers can use slow pyrolysis to convert vast amounts of crop leftovers into biochar rather of burning them (Sirijanusorn, Sriprateep & Pattiya, 2013). Pyrolysis has proven to be a successful method for turning waste into biochar, a very stable material (Kambo & Dutta, 2015). Biochar is also beneficial as a soil ameliorant, according to various studies, and can even enhance crop yields (Zhang et al., 2012; Wijitkosum & Kallayasiri, 2015).

Slow partial pyrolysis method of biomass can be used to produce biochar, whose properties depend on feedstock properties as well as the reaction temperature and duration .The utility of biochar has been demonstrated in reducing the need for agrochemicals, increases in productivity, long-term improvement in soil conditions and reduction in greenhouse gas emissions through soil sequestration as well as indirectly through increasing the efficiency of fertilizer use (Wijitkosum & Sriburi, 2018). The chemical and physical properties of biochar can be fine-tuned by modification of these reaction conditions (Mašek, 2016). Biochar is highly stable, comprising more than 65% carbon. Chemical composition is highly dependent on feedstock and pyrolysis conditions (Kim et al., 2013). Biomass subjected to pyrolysis is converted to biochar with high fixed carbon content and high stability. Biochar’s stability in soil is crucial to its long-term environmental benefits. Because of its long-term stability, biochar can be used for carbon sequestration, mitigating climate change by locking carbon in the soil. The stability of biochar ensures longevity of expected benefits for soil, crops, water resources and climate change mitigation (Lehmann, Gaunt & Rondon, 2006). Biochar also regulates and increases availability of cationic plant nutrients such as P, K, Na, and Mg (Li & Delvaux, 2019). In addition to its direct agronomic benefits (enhanced fertilizer use efficiency, higher yields and improvement in soil fertility), biochar delivers three primary environmental benefits: sequestrating carbon in soils, reducing greenhouse gas emissions (Stewart, Zheng, Botte & Cotrufo, 2013) and reducing pollution via runoff fertilizers and pesticides into waterways and groundwater.

2.5 Role of Biochar in Agriculture

Soil fertility depletion and declining agricultural productivity due to a reduction of soil organic matter (SOM) and nutrient imbalances are major constraints in most tropical agricultural soils (Agegnehu, Srivastava & Bird, 2017). Soil nutrient depletion is an important concern, directly linked to food insecurity due to unsustainable intensified land use (Henao & Baanante, 1999). In most tropical environments, sustainable agriculture faces significant constraints due to low nutrient status and rapid mineralization of SOM (Zech et al., 1997). Decline in SOM content leads to decreased cation exchange capacity (CEC). Under such conditions, the efficiency of applied mineral fertilizers is low (Agegnehu, Nelson & Bird, 2016). Biochar has progressed considerably with important on agronomic benefits, carbon sequestration, gas emissions, soil quality, soil acidity, soil fertility, soil salinity, etc. (Van Zwieten et al., 2014). Biochar is a carbonaceous material obtained from pyrolysis of biomass residues in the absence of oxygen (Palanivelu, Ramachandran & Raghavan, 2021). It contains more than 60 % carbon, and is rich in various nutrients and trace elements essential for crop. Biochar can be an efficient, beneficial, and environmentally friendly option for the remaining, unutilized fractions of waste biomass and can be used in composting to reduce nitrogen loss, increase the porosity, and increase the water holding capacity (Awasthi et al., 2016).However, the effects of biochar on crop yield are influenced by various factors, such as the properties and amount of biochar, soil type, and environmental conditions (McLauglin & Taylor, 2010).

Farmers would need to produce their own biochar on a small scale from residues such as straw, husks, left-over animal feed, shrubs, cuttings, and prunings using low-cost but high-quality biochar kilns with clean combustion to improve biochar related cost-benefits for agricultural uses (at least for small and subsistence farmers). Biochar production can thus be combined with on-farm waste management, biomass heat generation, and on-site organic fertilizer production (Schmidt et al., 2015) lowering greenhouse gas emissions from uncontrolled decomposition and open burning.

2.6 Importance of Nitrogen in Rice

Nitrogen is one of the most important plant nutrients and plays a vital role in plant photosynthesis and biomass production. In the plant, it combines with compounds produced by carbohydrate metabolism to form amino acids and proteins. Being the essential constituent of proteins, it is involved in all the major process of plant development and yields formation (Kahsay, 2019). Rice plants require N during vegetative stage to promote growth and tillering, which in turn, determines potential number of panicles. Nitrogen contributes to spikelet production during early panicle formation stage, and contributes to sink size during the late panicle formation stage. Nitrogen also plays a role in grain filling, improving the photo-synthetic capacity, and promoting carbohydrate accumulation in culms and leaf sheaths (Mandana, Akif, Ebrahim & Azin, 2014). Moreover nitrogen (N) acts as the motor of plant growth. High yield requires correct amount of fertilizers to be applied. The choice of fertilizers and amount to be applied for raising crop production is usually predicted on the fertility status of a soil (Pessarakli, 2014).

Nitrogen occupies a unique position as a plant nutrient because rather high amounts are required compared to the other essential nutrients. It stimulates root growth and crop development as well as uptake of the other nutrients. With regard to the soil-plant compartment, there can be N gains (such as deposition, microbial fixation, animal manures and inorganic fertilizer inputs) as well as N losses (such as leaching, volatilization and denitrification) and N removal via harvested products. The relative importance of these parameters determines the need for fertilizers to sustain crop production. As the importance of nitrogen fertilization on the rice grain yield, it is necessary to know what the best dose is for each variety as well as its influence on components of yield and other agronomic parameters such as the cycle, plant height, lodging and moisture content of the grain (Chaturvedi, 2005). Increased rates of nitrogen fertilizer may increase the yield but reduce the quality of the grain. The average amount of nitrogen (N) fertilizer applied to paddy rice in China is 300 kg N ha^{-1} (Qian et al., 2018).

Nitrogen (N) is the most important nutrient in irrigated rice production (Cassman et al., 1998). Current high yields of irrigated rice are associated with large applications of fertilizer N (Barker & Dawe, 2001). Soil N and biological nitrogen fixation by associated organisms are major sources of N for lowland. The major part of N in soil is lost through volatilization, leaching, denitrification, and soil erosion (Fageria & Baligar, 2005). An additional concern is that the capacity of soil to supply N may decline with continuous intensive rice cropping under wetland condition. More than 50 % of the N used by flooded rice receiving fertilizer N is derived from the combination of soil organic N and biological nitrogen fixation by free-living and rice plant-associated bacteria. The remaining N requirement is normally met with fertilizer (Rahman, Amano & Shiraiwa, 2009). Nitrogen (N) is also one of the most yield limiting nutrients for upland rice production. The N deficiency in upland rice is related to low organic matter content of rice growing soils, soil acidity, soil erosion, use of low level of N fertilizers by farmers due to high cost of these fertilizers. Nitrogen deficiency is also related to low N use efficiency by the crop due to loss by leaching, volatilization, denitrification and erosion (Fageria & Baligar, 2005). Hence, use of N efficient genotypes in conjugation with use of chemical fertilizers is an important complementary strategy in improving rice yield and reducing cost of production. Upland rice genotypes differ significantly in N uptake and utilization efficiency (Fageria, 2007).

2.7 Nitrogen Deficiency and Excess in Rice

Nitrogen plays significant role in many physiological and biochemical processes in the plants. It improved tillering in rice and consequently panicle density. Nitrogen also increases panicle length and grain weight and reduces spikelet sterility (Fageria & Baligar 2001; Fageria, 2007). Adequate rate of nitrogen improves root growth in rice which is very important for the absorption of water and nutrients (Fageria, 2012). In rice N deficiency symptoms are characterized by yellowing of the leaves. Since nitrogen is mobile nutrient in the plants, deficiency symptoms first start in the older leaves. If deficiency persists longer, all the leaves become yellow. Nitrogen deficiency symptoms are very clear at low level of N.

Nitrogen is the most important nutrient for crop production, and its deficiency occurs in most rice growing regions of the world. The main reasons for N deficiency are (i) loss of N by leaching, volatilization, and denitrification; (ii) lower rates of N applied compared to rates of N removed in the harvested portion of the crop; (iii) low N use efficiency by the crops; (iv) use of high yielding and N responsive cultivars; and (v) soil degradation with successive crop cultivation. The loss of N in lowland rice culture depends on soil properties, timing of N application and water management during crop growth cycle. Losses of N are minimum in heavy textured soils with high cation exchange capacity, N applied during maximum absorption or requirements of the crop and once rice is established, the flood is maintained until physiological maturity. If water is drained during crop growth cycle, NH_4^+ is oxided to NO_3 and NO_2 and upon flooding N is lost through leaching and denitrification or both depending on soil properties, crop root system development and level of demand for N.

Excessive use of synthetic N fertilizer result in significant challenges regarding N use efficiency and mitigating N fertilizer-induced N_2O emissions, particularly when water-saving management is used, which decreases NH_3 volatilization (Tan, Liu, Wu, Lal & Meng, 2017). Excessive use of N fertilizer in agriculture caused numerous environmental problems (Xia et al., 2017), such as ammonia (NH_3) volatilization, leaching losses, and denitrification. The N use efficiency of agricultural systems therefore, has both economic and environmental consequences (Chien, Prochnow & Cantarella, 2009). In rice systems, based on global estimates, fertilizer N recovery by the crop averages 46% (Ladha et al., 2016).Too much N can lead to lodging at maturity (especially in direct-seeded rice), high levels of sterility and reduced yield (Joshi et al., 2013).

2.8 Nitrogen Management for Rice Production

Nitrogen fertilizer management may contribute to differences in crop performance under different crop establishment methods. Nitrogen is the most limiting nutrient for rice growth, and almost every farmer has to apply N fertilizer to get a desirable grain yield. However, N fertilizer is susceptible to losses when timing and rate of application do not match with crop demand. Efficient management of N fertilizer is important for both economic and environmental (Ibrahim, Peng, Tang, Huang, Jiang & Zou, 2013).

In double rice-cropping systems in China, the second crop is usually established within 1 week after harvest of the first crop. Because of limited time between rice crops and a lack of alternative uses for crop residues, farmers often burn residue of the first rice crop in the open field instead of returning residue to the soil during land preparation of the second rice crop. Because of the negative effects of incorporated straw on growth and grain yield of the next rice crop during short time decomposition period, farmers have to burn residues as a method of disposal (Singh, Thind & Sidhu, 2014).

One of the major problems of open-field straw burning is atmospheric pollution. One ton of crop residue after burning releases 1515 kg CO_2, 92 kg CO, 3.83 kg NO_2, 0.4 kg SO_2, 2.7 kg CH_4, and 15.7 kg non-methane volatile organic compounds (Andreae & Merlet, 2001). Straw burning also releases particulate matter to the atmosphere, which can cause reduced air quality and human respiratory ailments. Recycling of crop residues has been suggested to improve overall soil fertility and to support sustainable rice production. The benefits of incorporating undecomposed straw have also been recognized in tropical environments (Xu et al., 2010). Saurabh et al. (2020) reported that incorporation of crop residues is essential for sustaining rice soil productivity through replenishing soil organic matter (SOM). However, the drawback of this crop residue incorporation is taking long time for residue decomposition.

In agricultural systems, extensive use of inorganic nitrogen (N) fertilizers has significantly improved crop yields, but also along with caused environmental problems. Biochar, as a carbonaceous material obtained after thermal treatment of biomass residues (Alburquerque et al., 2013), represents a potential sustainable option for decreasing N fertilizer application without yield penalty (Yang et al., 2019). Biochar application may enhance sustainability of the agricultural systems (Xia et al., 2020), suitable to: increasing soil porosity and decreasing soil bulk density; high content of recalcitrant carbon favoring soil carbon sequestration; high cation exchange capacity (CEC) that may contribute to decreased N leaching and nitrous oxide (N_2O) emissions; as well as the improvements in soil fertility and crop yields (Hossain et al., 2020).

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental site and Growing Season

The pot experiment was conducted at the Department of Soil and Water Science, Yezin Agricultural University, Zeyarthiri Township, Nay Pyi Taw. This area is located at 19° 50' N latitude, 96° 16' E longitude with the elevation of 132 m above sea level. Experiment I was conducted from February to June 2020 (Dry season) and Experiment II was performed from July to November 2020 (Rainy season). Rice plant cultivar (Sin Thu Kha) was used as a test variety in the pot experiment and the seedlings were planted in pots (26 height, 23 wide, and 30 cm diameter) which were filled with 13 kg soil. The monthly range of rainfall and temperature recorded at the meteorological station of Yezin are given in Figure (3.1 and 3.2). The details of materials used, methods and experimental techniques adopted during the course of experimental are described in this chapter.

3.2 Soil Sampling

A composite surface soil sample were collected from 0-15 cm depth from different location in rice growing field of Mon Tae Kwin, Zeyarthiri Township, Nay Pyi Taw. The composite soil sample was air-dried, crushed and ground to pass through a 2 mm sieve. Some physiochemical properties of initial soils were analyzed, such as soil texture, soil pH, electrical conductivity (EC), total N, available P, available K, organic carbon, and cation exchange capacity (CEC) at the Department of Soil and Water Science, Yezin Agricultural University before growing the plant.

3.3 Experimental Design and Treatments

Both experiments were laid out in split-plot design with three replications. Thirty-six pots were used comprising 12 treatments and 3 replications. Pots were arranged in rows that were 30 cm apart and pots within each row were 26 cm apart.

Treatments details are as follows

Main plot Factor (Biochar)	**Sub-plot Factor (Nitrogen)**
B_0= 0 ton ha^{-1}	**N_0=0 kg N ha^{-1}**
B_1=6 ton ha^{-1}	**N_1= 30 kg N ha^{-1}**
B_2=12 ton ha^{-1}	**N_2= 60 kg N ha^{-1}**
	N_3= 90 kg N ha^{-1}

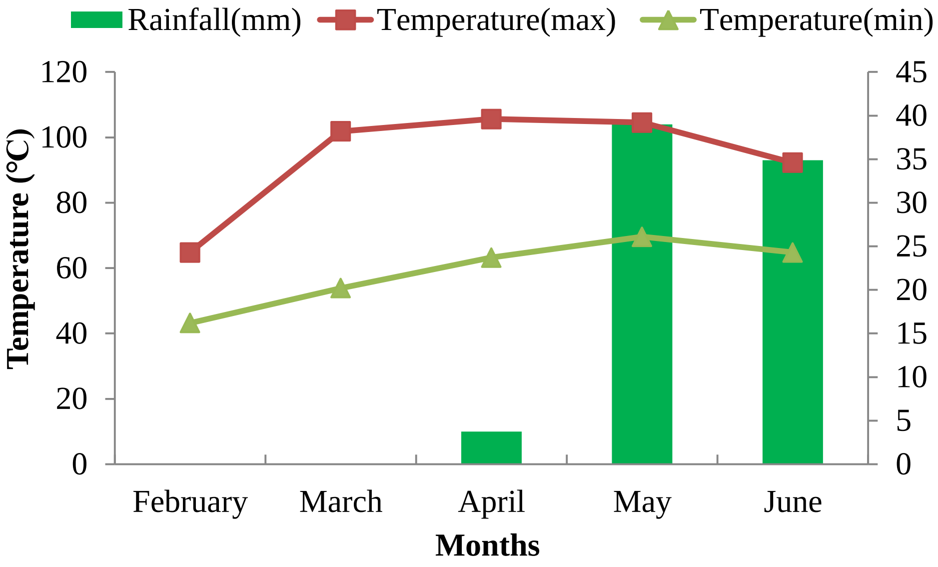


Figure 3.1 Monthly maximum and minimum temperature and monthly rainfall of Yezin during dry season, 2020

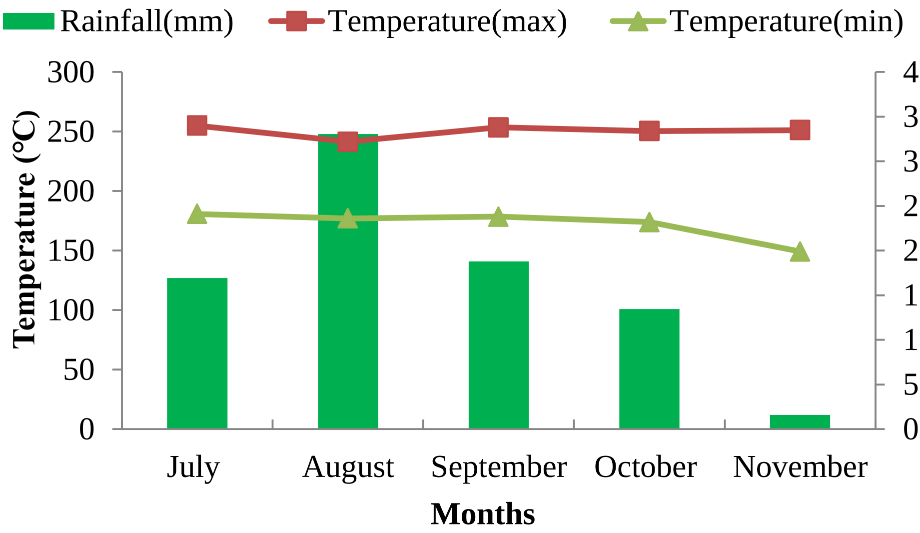


Figure 3.2 Monthly maximum and minimum temperature and monthly rainfall of Yezin during wet season, 2020

Table 3.1 Physicochemical properties of experimental soil before sowing

Characteristics	Content	Rating
Texture class		Sandy Clay loam
Sand (%)	57.69	
Silt (%)	76.92	
Clay (%)	23.08	
Bulk Density(gcm^{-3})	1.1	
pH	5.5	Moderately acidic
CEC(cmol^{+} kg^{-1})	39.96	High
EC (dSm^{-1})	0.09	Non-saline
OM (%)	4.5	Optimum
Total N (%)	0.01	Very low
Available P (mg kg^{-1})	2	Low
Available K (mg kg^{-1})	175	Medium

Table 3.2 Chemical composition of rice husk ash used in this experiment

Parameters	Amount
Organic Carbon (%)	21.99
pH	6.39
EC (dSm^{-1})	0.11
Ash (%)	62.08

3.4 Pot Preparation

Plastic pot with a diameter of 30 cm in height, 30 cm diameter at the bottom and 22 cm at the bottom. The plastic pots were filled with 13 kg of soil. Twenty days old rice seedlings were transplanted with two plants per pots. The tested variety in this experiment is Sin Thu Kha (135 days).

3.5 Rice Husk Biochar Making by Slow Partial Pyrolysis Method

Slow partial pyrolysis method is cost-efficient and can build easily by farmers themselves using locally available materials. The procedure is that 11.13 kg rice husk was placed in the biochar making can (Plate 3.1). Then, it was heated for 3 hours at around 500°C. During heating process, some CO_2 was emitted into through the flue. After 3-hour heating, the rice husk biochar was obtained. The ash percent and organic carbon content of rice husk biochar was 62.80 % and 21.99% respectively.

3.6 Fertilizer and Biochar Application

Biochar (control, 6 ton ha^{-1} and 12 ton^{-1} ha) was used in basal at two days after pot preparation. Before experiment, all fertilizers that used in this experiment were analyzed at the Department of Soil and Water Science. According to analytical results, urea (46% of N), triple superphosphate (12% P) and muriate of potash (31% K) were used in this experiment. The triple superphosphate fertilizer was applied as basal application but urea and potassium were applied at three equal splits: at recovery stage (7-10 DAT), active tillering and panicle initiation stage.

3.6 Data Collection

3.6.1 Measurement parameters for growth

Growth parameter such as plant height and number of tiller $hill^{-1}$ were collected at 14 days interval.

(a) Plant height

Plant height was measured in centimeter (cm) by recording the distance from ground level to the tip of the tallest leaf starting from 14 days after transplanting.

(b) Number of tiller per $hill^{-1}$

Numbers of tiller were collected at weekly interval from each pot from 14 days after transplanting.

(c) SPAD reading

Leaf greenness measurement used SPAD 502 on the youngest fully expanded leaf of a plant. Readings are taken on one side of the midrib of the leaf blade, midway between the leaf base and tip. In early growth stages, when leaves are too narrow to allow SPAD measurements on one side of the midrib, the leaf tip can be used for measuring SPAD values.

3.6.2 Measurement parameters for yield and yield components

Number of panicle hill^{-1}, panicle length, number of spikelets panicle^{-1}, grain percentage and 1000 grain weight were measured at harvest.

(a) Number of panicle per hill

The number of panicle hill^{-1} was collected from each pot at harvest time.

(b) Panicle length

Panicle length was measured from each pot as a linear distance from the neck-node of the panicle to the tip of the panicle.

(c) Number of spikelets per panicle

Total number of spikelets panicle^{-1} present on each panicle were collected from 10 panicles and averaged. The spikelets number included filled, partial filled and unfertilized spikelets.

(d) Filled grain percentage

The percentage of filled grains was calculated as the ratio of the number of grains to the total number of spikelets.

(e) Thousand grain weight

Fully developed grains were randomly selected from each pot and their weights were recorded.

(f) Grain yield

The grains were harvested from the pot area and hand threshed, winnowed and sum dried. The dried grain from each treatment was weight and computed to gram per plant.

(g) Total dry matter

Total dry matter of rice was recorded after complete drying from each pot and expressed in gram per plant.

3.6.3 Harvest index

The harvest index was calculated by dividing the economic yield (grain yield) by biological yield and was expressed as percentage

$$\text{Harvest Index} = \frac{\text{Economic yield (grain yield)}}{\text{Biological yield (grain + straw yield)}}$$

(Fageria, 2009)

3.6.4 Cultural management and pest and disease control

The pots were subjected with alternate wetting and drying system. Rats and birds damage were occurred in both wet and dry seasons. The rat problem was successful eliminated by sheltering the experimental plot with plastic sheets and covering with fishing net. In both dry and wet season the crop was found neither insect damage nor infection of bacterial diseases.

3.4.5 Statistical analysis

The collected data were analyzed by using statistical software Statistix (Version 8). All the data were subjected to analysis of variance and mean separation among treatments were done by Least Significant Difference (LSD) test at 5% level.

CHAPTER IV

RESULTS AND DISCUSSION

The pot experiment was conducted at the Department of Soil and Water Science, Yezin Agricultural University, to evaluate the effect of biochar and nitrogen fertilizer application on yield and yield components of rice in other parameters during the dry and wet seasons of 2020. The results detailed from this study have been discussed and presented in this chapter.

4.1 Rice Performances on Biochar and Nitrogen Fertilizer Application during Dry and Wet Season (February to June 2020)

4.1.1 Growth parameters of rice

4.1.1.1 Plant height

The plant height was measured at a two-week interval from 14 to 98 days after transplanting, as presented in Table (4.1). In dry season, plant height increased progressively from 14 days after transplanting (DAT) to 98 DAT. At 14 DAT to 98 DAT, the plant height of rice grown in various biochar treatments ranged from 23.1 cm to 109.5 cm. There were no significant differences in plant height values under different biochar treatments throughout the growth stages. The results of Pratiwi, Hanudin, Purwanto, Sulistyaningsih & Hayashi (2021) showed that the increased level of biochar showed no significant effect on plant height. In the sub plot factor of different nitrogen fertilizer applications, it did not show significant differences in plant height values among the treatments throughout the growing season except at 98 DAT. At 98 DAT, maximum plant height (110.7 cm) was significantly obtained when the highest N dose (90 kg N ha^{-1}) was applied, while minimum plant height (107.1 cm) was obtained from control (no N fertilizer treatment). Therefore, the increments in plant height with the rise in N dose indicated that plants used N during active cell division or cell elongation. Reddy, Subhani, Khan & Kumar (1985) reported that plant height increased due to increasing levels of nitrogen. The effect of biochar and nitrogen on plant height of the Sin Thu Kha rice variety throughout the growing season was almost similar in all treatment combinations (Figure 4.1). However, at 98 DAT, the highest plant height was obtained at the B_2N_3 treatment (6 ton ha^{-1} with 90 kg N ha^{-1}) (111.00 cm), whereas the shortest plant height was observed from without biochar and nitrogen application treatment (B_0N_0) (107.67 cm).

In the wet season, plant height increased progressively from 14 days after transplanting (DAT) to 98 DAT (Table 4.2) .The plant height of rice grown in different biochar treatments ranged from 53.7 cm to 108.2 cm at 14 DAT to 98 DAT. There were no significant differences of plant height values under different biochar treatments throughout growth stages except 28 DAT. At 28 DAT, maximum plant height (73.2 cm) was significantly obtained when the highest biochar (6 ton ha^{-1}) was applied, while minimum plant height (70.6 cm) was from control (no biochar treatment). However, there were significant differences in plant height on nitrogen fertilizer application at 14 DAT, 28 DAT, 70 DAT, 84 DAT, 98 DAT except at 42 DAT and 56 DAT. Therefore, nitrogen is an essential nutrient for supporting plant growth. Dobermann & Fairhurst (2000) stated that N promotes rapid growth (increased plant height and number of tillers). The increased plant height with increasing rate of N fertilizers was due to enhanced rate of translocation of nitrogen from culms to leaves and leads to the production of photosynthates, which enhance the translocation of nutrients for developing panicle. Sakakibara, Takei & Hirose (2006) reported that nitrogen promote significantly tiller. The effect of biochar and nitrogen fertilizer application was presented in Figure 4.1. Plant height expanded continuously at all growth stages in the rice plant. In wet season, there was no significant variation among all interaction treatments except 84 DAT. However, the interaction effect of biochar and nitrogen treatments in B_0N_3 (0 ton ha^{-1} with 90 kg N ha^{-1}) and B_1N_3 (6 ton ha^{-1} with 90 kg ha^{-1}) obviously showed higher plant height than other combined treatment was followed by maximum plant height (99.5 cm) and the minimum plant height was obtained in B_0N_3 (86.0 cm), respectively.

Table 4.1 Mean value of plant height of rice as affected by biochar and nitrogen fertilizer application during dry season, 2020

Treatment	Plant height (cm)						
	14DAT	**28DAT**	**42DAT**	**56DAT**	**70DAT**	**84DAT**	**98DAT**
Biochar(A)							
0 ton ha^{-1}	23.1	44.6	63.2	76.3	83.9	88.8	109.5
6 ton ha^{-1}	23.0	44.2	63.7	77.2	84.9	89.7	108.8
12 ton ha^{-1}	23.1	44.3	63.5	77.5	83.1	87.3	108.5
LSD$_{0.05}$	2.84	5.19	2.45	2.55	4.24	4.25	4.67
Nitrogen(B)							
0 kg N ha^{-1}	23.3	42.9	62.5	76.1	83.4	87.1	107.1**b**
30 kg N ha^{1}	22.8	43.9	63.7	78.1	83.9	89.6	109.6**ab**
60 kg N ha^{1}	22.8	45.2	63.6	77.2	84.7	88.9	108.4**ab**
90 kg N ha^{1}	23.3	45.4	64	76.5	83.8	88.7	110.7**a**
LSD$_{\mathbf{0.05}}$	2.50	3.20	2.80	3.20	3.30	3.30	3.20
Pr > F							
Biochar	ns	ns	ns	ns	ns	ns	ns
Nitrogen	ns	ns	ns	ns	ns	ns	ns
B x N	ns	ns	ns	ns	ns	ns	*
CV%(A)	10.87	10.33	3.41	2.92	5.09	4.23	3.78
CV%(B)	10.98	7.23	4.48	4.14	3.92	3.71	2.93

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

*=significant difference at 5% level, **=significant difference at 1% level, ns=non-significant difference

Table 4.2 Mean value of plant height of rice as affected by biochar and nitrogen fertilizer application during wet season, 2020

Treatments	**Plant height (cm)**						
	14DAT	**28DAT**	**42DAT**	**56DAT**	**70DAT**	**84DAT**	**98DAT**
Biochar(A)							
0 ton ha^{-1}	53.7	70.6 **b**	75.3	82.2	87.3	92.3	106.9
6 ton ha^{-1}	54.3	73.2 **a**	75.8	83.3	88.8	94.0	108.2
12 ton ha^{-1}	53.8	72.7 **a**	76.2	83.9	87.6	92.5	108.2
LSD$_{0.05}$	3.1	2.1	0.9	2.8	3.4	4.1	1.8
Nitrogen(B)							
0 kg N ha^{-1}	52.2 **c**	69.8 **c**	75.7	80.7	84.1 **b**	89.2 **c**	103.1 **b**
30 kg Nha^{1}	56.0 **a**	71.2 **bc**	75.0	82.9	85.3 **b**	91.3 **bc**	105.9 **b**
60 kg N ha^{1}	53.6 **b**	72.7 **ab**	75.8	83.4	90.1 **a**	93.5 **b**	110.2 **a**
90 kg N ha^{1}	55.3 **ab**	74.9 **a**	76.6	85.6	92.1 **a**	97.6 **a**	111.5 **a**
LSD$_{\mathbf{0.05}}$	2.2	2.2	2.4	3.5	4.0	3.9	3.4
Pr>F							
Biochar	ns	*	ns	ns	ns	ns	ns
Nitrogen	**	**	ns	ns	**	**	**
B x N	ns	ns	ns	ns	ns	*	ns
CV%(A)	5.15	2.58	1.03	3.01	3.42	3.86	1.51
CV%(B)	4.05	3.12	3.15	4.3	4.61	4.29	3.21

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

*=significant difference at 5% level, **=significant difference at 1% level, ns=non-significant difference

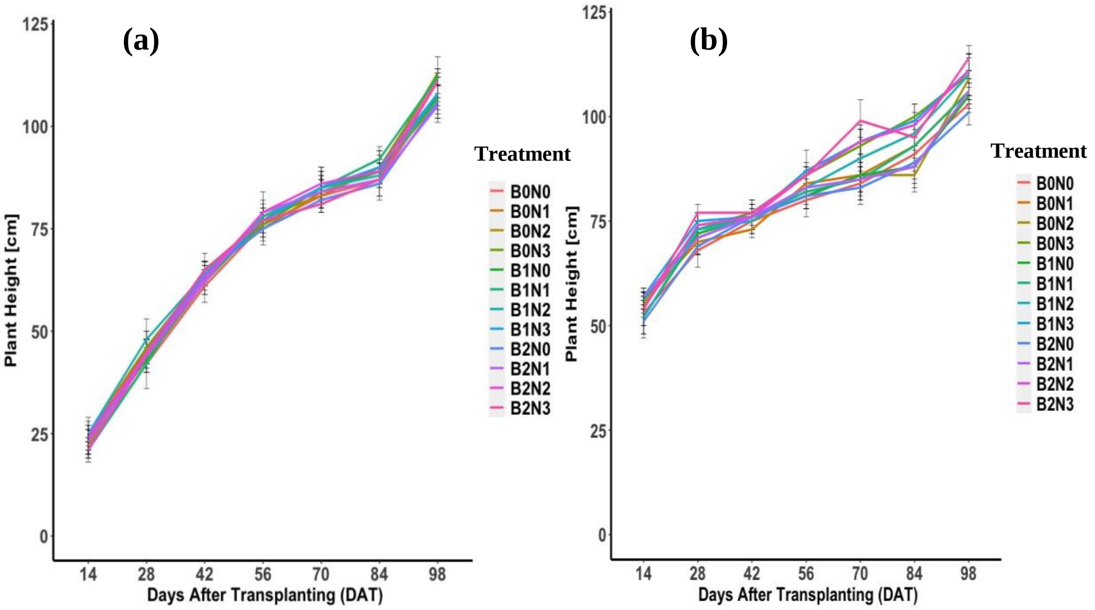


Figure 4.1 Mean value of plant height of rice as affected by the interaction effect of biochar and nitrogen fertilizer application in (a) dry and (b) wet seasons, 2022

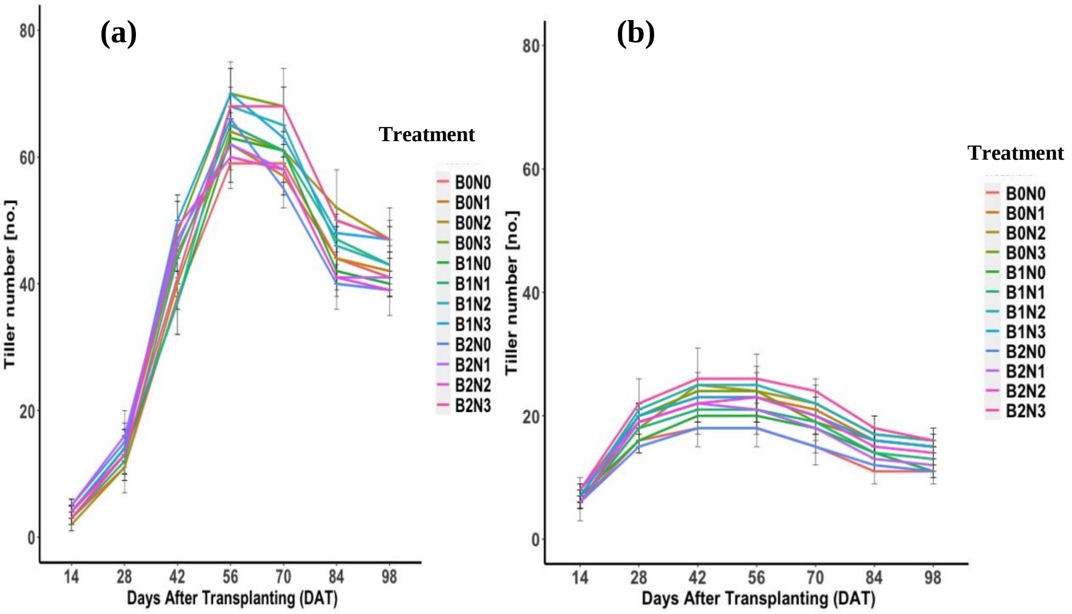


Figure 4.2 Mean value of number of tiller hill^{-1} as affected by the interaction effect of biochar and nitrogen fertilizer application in (a) dry and (b) wet season, 2020

4.1.1.2 Number of tillers per hill

In both experiments, the effect of biochar and nitrogen fertilizer on the number of tiller hills during the dry season in 2020 was shown in Table 4.3. In the dry season, there was no significant difference in tiller number in biochar at all growth stages except at 56 DAT and 84 DAT. The number of tillers increased progressively at all growth stages and declined after the maximum tillering stage. The higher number of tillers per hill was observed at 56 DAT. At both 56 and 84 DAT, the maximum tiller number was observed in 6 ton ha^{-1} of biochar application. Therefore, it can be interpreted that 6 ton can give optimum growth development for tiller. Lakitan et al. (2018) reported that biochar application significantly increased yield components, including number of tillers, percentage of productive tiller. The experiment result of Kaderi (2004) showed that tiller number per clump on compound NPK fertilizer application more than control plant. This condition showed that compound NPK fertilizer can give more nutrients to plant. Growth of productive tiller number connected with nitrogen available and successful of primordial formation. Ahmed et al. (2005) found higher number of tillers with higher dose of N application. After 56 DAT, tiller number declined progressively throughout the growing seasons. According to Yoshida (1981), tillers are branches that develop from the leaf axils at each unelongated node of the main shoot or from other tillers during vegetative growth. At 98 DAT, there were no significant difference, control numerically produce higher effective tiller number than biochar treatments. Low tillering varieties particularly short duration ones gave low number of panicles m^{-2}, while high tillering cultivars caused competition and more shading consequently low yield. In dry season, the different rate of nitrogen fertilizer application, tiller numbers were statistically significant among the nitrogen treatment in all growth stages except 14 DAT and 28 DAT. 90 kg N ha^{-1} produce the highest tiller number compare to other treatment throughout the growing season. The lowest tiller number was observed at control. Hossain, Islam and Hasanuzzaman (2008) described that the amount of nitrogen at the tiller stage is important for optimum tiller number in rice because nitrogen has a positive effect on the production of tiller number per plant, yield and yield attributes. Tun (2016) reported that rice husk ash contains over 60% silica and application of biochar significantly increased the number of reproductive tillers.

There was no interaction of biochar and nitrogen fertilizer application on tiller number per hill except 42 DAT (Figure 4.2). At 42 DAT, biochar treatment and nitrogen fertilizer application were related to the number of tillers per hill was a significant difference in interaction effect. At 42 DAT, the maximum number of tillers per hill (41) was obtained from the interaction of B_2N_2 (12 ton ha^{-1} with 90 kg N ha^{-1}) and the minimum number of tillers per hill (38) was observed from the interaction of B_0N_0 (0 ton ha^{-1} with 0 kg N ha^{-1}). However, at 98 DAT, B_0N_3 and B_2N_3 produced slightly higher tiller number than other treatments. This result showed that biochar was not influenced on number of tiller responded to nitrogen fertilizer application.

In wet season, the effect of biochar and nitrogen fertilizer on the number of tiller per hill during the wet season in 2020 was shown in Table 4.4. In the wet season, there was no significant difference in tiller number among different biochar rates at all growth stages. The number of tillers increased progressively at all growth stages and declined after the maximum tillering stage. The higher tiller number was obtained from 12 ton ha^{-1} (22.3) and the lower tiller number resulted from 0 ton ha^{-1} (6.5). In the different rate of nitrogen fertilizer application, tiller numbers were statistically significant among the nitrogen treatment in all growth stages except 14 DAT. 90 kg N ha^{-1} and 60 kg N ha^{-1} produce the highest tiller number compare to other treatments 30 kg N ha^{-1} and control throughout the growing season. The lowest tiller number was observed at control. In this experiment, the number of tiller was enhanced with the rising nitrogen doses.

There was no interaction of biochar and nitrogen fertilizer application on tiller number per hill except 70 DAT and 98 DAT (Figure 4.2). At 70 DAT, the combination of biochar and nitrogen fertilizer application related to the number of tillers per hill was significantly different in their interaction effect. The highest number of tillers per hill (24) was obtained from the interaction of B_2N_2 (12 ton ha^{-1} with 90 kg N ha^{-1}) and the lowest number of tillers per hill (15) was observed from the interaction of B_0N_0 (0 ton ha^{-1} with 0 kg N ha^{-1}). At 98 DAT, the maximum number of tiller per hill (16) was resulted from the interaction of B_2N_3 (12 ton ha^{-1} with 90 kg N ha^{-1}) and the minimum number of tiller per hill (11) was obtained from the interaction of B_0N_0 (control). However, at 98 DAT, B_0N_2 and B_2N_3 slightly higher tiller number than other treatments. This result showed that biochar was not influenced on number of tiller responded to nitrogen fertilizer application.

Table 4.3 Mean value of number of tiller as affected by biochar and nitrogen fertilizer application during dry season, 2020

Treatments	**Number of tillers hill^{-1}**						
	14DAT	**28DAT**	**42DAT**	**56DAT**	**70DAT**	**84DAT**	**98DAT**
Biochar (A)							
0 ton ha^{-1}	4	12	43	64 **b**	63	48 **a**	44
6 ton ha^{-1}	4	13	42	67 **a**	62	46 **a**	43
12 ton ha^{-1}	4	14	46	64 **b**	60	43 **b**	42
LSD$_{0.05}$	0.95	3.27	6.65	2.48	4.2	2.04	3.16
Nitrogen(B)							
0 kg N ha^{-1}	4	13	40 **c**	62 **b**	57 **c**	42 **c**	40 **b**
30 kg Nha^{1}	4	14	45 **ab**	63 **b**	59 **bc**	44 **bc**	42 **b**
60 kg N ha^{1}	3	13	42 **bc**	64 **b**	63 **ab**	47 **ab**	43 **b**
90 kg N ha^{1}	4	14	46 **a**	69 **a**	66 **a**	49 **a**	47 **a**
LSD$_{\mathbf{0.05}}$	1.03	3.07	4.19	4.51	5.3	3.06	2.87
Pr>F							
Biochar	ns	ns	ns	*	ns	**	ns
Nitrogen	ns	ns	*	*	**	**	**
B x N	ns	ns	*	ns	ns	ns	ns
CV%(A)	21.49	21.60	13.53	3.39	6.04	3.95	6.49
CV%(B)	26.80	23.31	9.76	7.05	8.72	6.79	6.77

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

*=significant difference at 5% level, **=significant difference at 1% level, ns=non-significant difference

Table 4.4 Mean value of number of tiller as affected by biochar and nitrogen fertilizer application during wet season, 2020

Treatments	Number of tillers hill^{-1}						
	14DAT	**28DAT**	**42DAT**	**56DAT**	**70DAT**	**84DAT**	**98DAT**
Biochar (A)							
0 ton ha^{-1}	6.5	18.3	21.9	22.1	18.7 **a**	15.1	14.5 **a**
6 ton ha^{-1}	6.8	18.8	22.0	22.2	19.6 **a**	15.2	13.9 **a**
12 ton ha^{-1}	7.0	18.8	22.3	21.8	19.1 **a**	14.4	13.4 **a**
LSD$_{0.05}$	0.65	2.51	2.84	2.67	2.78	1.56	2.39
Nitrogen(B)							
0 kg N ha^{-1}	6.3	15.7 **b**	18.1 **c**	18.3 **c**	15.1 **b**	12.3 **c**	11.2 **c**
30 kg Nha^{1}	7.3	19.0 **a**	21.9 **b**	21.7 **b**	19.4 **a**	14.3 **b**	13.7 **b**
60 kg N ha^{1}	6.3	19.2 **a**	24.0 **ab**	23.9 **ab**	21.0 **a**	16.0 **a**	15.3 **a**
90 kg N ha^{1}	7.0	20.7 **a**	24.2 **a**	24.2 **a**	20.9 **a**	16.9 **a**	15.6 **a**
LSD$_{\mathbf{0.05}}$	1.27	2.61	2.24	2.43	1.99	1.57	1.23
Pr>F							
Biochar	ns	ns	ns	ns	ns	ns	ns
Nitrogen	ns	**	**	**	**	**	**
B x N	ns	ns	ns	ns	**	ns	*
CV%(A)	8.55	11.88	11.36	10.71	12.85	9.26	15.12
CV%(B)	18.97	14.16	10.28	11.17	10.49	10.62	8.97

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

*=significant difference at 5% level, **=significant difference at 1% level, ns=non-significant difference

The growth and development pattern of tiller number were significantly different between two growing seasons. In dry season, it produced from 2 to 40 tiller numbers in all treatments but the tiller number started from 2 to only 19 tiller numbers in all treatment at the end of growth stages of wet season. Overall, tiller numbers of all treatments in the dry season are significantly higher than those in the wet season. The tiller number of rice in summer is normally higher than that in rainy season since high sunlight, and long day duration in this season.

4.1.1.3 SPAD reading

In dry season, the SPAD value of rice was not significantly different between biochar and nitrogen fertilizer application throughout the growing season (Table 4.5). Moreover, overall SPAD values in all treatment slightly changed from the higher value (40) to the lower value (34) from 14 DAT to 98 DAT, respectively. Basnet (2018) reported that chlorophyll content tends to increase initially in all treatments but most the treatment decreased when the crop is attaining the maturing. In the nitrogen treatment, the SPAD readings were significantly different among different nitrogen rate applications at 56 DAT. 90 kg N ha^{-1} produced significantly higher tiller number than other N application rates. The initial increase in SPAD reading was in spite of decreasing nitrogen fertilizer application. Madakadze et al. (1999) suggested that as the plant grows more tissue nitrogen is found in the top leaves because SPAD meter reading were taken on the top most fully expanded leaf.

In the wet season, the SPAD value of rice was not significantly different biochar treatments throughout the growing season (Table 4.6). However, nitrogen fertilizer treatments overall SPAD values in all treatment slightly change from the higher value (36) to the lower value (28) from 14 DAT to 98 DAT, respectively. This result is similar to Shwe, Myint et al. (2019) who reported 90 kg N ha^{-1} fertilizer application had the highest SPAD values than other treatments of fertilizer. Numerically, nitrogen fertilizer produced greater SPAD than biochar treatment. This result agrees with the finding of Rodriquez & Miller (2000) who reported that SPAD-502 chlorophyll meter readings were affected by applications of N fertilizer sources. Varvel, Wilhelm, Shanahan and Schepers (2007) demonstrated that N fertilizer significantly increased SPAD reading. The mean SPAD value of biochar was not significantly different at all growth stages of rice. The higher rate of biochar application increased SPAD values during the early vegetative growth stage but sharply declined during the late vegetative growth stage. Asai et al. (2009) who also described a decrease in plant N uptake and attributed the effect to N immobilization caused by the high C/N ratio of the applied biochar.

In comparing SPAD values of total nine treatments in both seasons, it was interestingly observed that SPAD value flow throughout the growing seasons were totally different in both seasons. The SPAD value flow in dry season was dramatically decreased, however, the SPAD values were around (35) SPAD value in all growth stages in wet season. SPAD reading above (35) means that there is enough content in the plant sample and did not need to apply additional nitrogen during growth stage of crop. Loh, Grabosky and Bassuk (2002) presented that SPAD reading was correlated with chlorophyll content and N concentration in plants. Evans and Poorter (2001) described that higher SPAD reading means higher chlorophyll content as a result of better N uptake which will increase the photosynthesis rate, subsequently improving plant growth, and also increases the amount of N per unit leaf area, as well as the amount of soluble protein.

Although different SPAD values were observed, 90 kg N ha^{-1} produces the highest SPAD values in both seasons. However, the result did not clearly point out the effect of biochar on SPAD reading throughout the growing season. In the comparison of biochar application and without biochar application, the biochar application treatment produced high preserved optimum chlorophyll content at 84 DAT to 98 DAT chlorophyll meters, which could lead to optimum yield through maintenance of optimum nitrogen levels in the soil during these periods.

No interaction was found in SPAD value between the effects of biochar and nitrogen fertilizers. The combination of biochar and nitrogen fertilizer application did not significantly increase the growth stages of rice SPAD value.

The interaction between the biochar level and the N level was non-significant ($P \leq 0.05$) for the assessment of the chlorophyll (SPAD values) in all growth stages in both seasons (Figure 4.3). Nevertheless the results showed that the B_2N_3 treatment resulted in an average increase in the SPAD values of 33.73, 36.40 and 35.80 compared to B_0N_0 in the tillering, heading, and maturity stages, respectively. N fertilization at the rate of 90 kg N ha^{-1} resulted in higher SPAD values.

Table 4.5 Mean value of SPAD reading of rice as affected by biochar and nitrogen fertilizer application during dry season, 2020

Treatments	SPAD reading						
	14DAT	**28DAT**	**42DAT**	**56DAT**	**70DAT**	**84DAT**	**98DAT**
Biochar (A)							
0 ton ha^{-1}	40.1	42.8	40.9	36.8	34.2	33.4	34.7
6 ton ha^{-1}	40.3	41.5	39.4	35.3	33.8	32.6	34.0
12 ton ha^{-1}	40.0	42.0	38.8	36.6	34.5	33.2	34.7
LSD$_{0.05}$	5.1	3.5	2.4	1.8	1.7	4.2	1.0
Nitrogen(B)							
0 kg N ha^{-1}	38.3	41.8	40.0	34.6 **c**	34.1	32.7	34.3
30 kg N ha^{1}	40.6	42.6	38.7	35.6 **bc**	34.2	32.5	34.7
60 kg N ha^{1}	42.0	41.7	40.1	36.9 **ab**	34.3	33.4	34.4
90 kg N ha^{1}	40.3	42.4	40.1	37.8 **a**	33.9	33.6	34.5
LSD$_{\mathbf{0.05}}$	3.2	1.9	2.5	2.0	1.5	2.1	1.7
Pr>F							
Biochar	ns	ns	ns	ns	ns	ns	ns
Nitrogen	ns	ns	ns	*	ns	ns	ns
B x N	ns	ns	ns	ns	ns	ns	ns
CV%(A)	11.13	7.38	5.42	4.39	4.42	11.13	2.63
CV%(B)	7.93	4.44	6.43	5.67	4.57	6.31	5.09

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

*=significant difference at 5% level, **=significant difference at 1% level, ns=non-significant difference

Table 4.6 Mean value of SPAD reading of rice as affected by biochar and nitrogen fertilizer application during wet season, 2020

Treatments	**SPAD reading**						
	14DAT	**28DAT**	**42DAT**	**56DAT**	**70DAT**	**84DAT**	**98DAT**
Biochar (A)							
0 ton ha^{-1}	33.9	32.2	33.5	30.9	31.0	33.3	31.9
6 ton ha^{-1}	32.2	32.2	33.7	31.1	31.1	33.3	32.8
12 ton ha^{-1}	32.2	32.1	32.9	30.2	32.6	33.0	32.8
LSD$_{0.05}$	1.3	1.1	1.3	1.3	2.3	1.7	0.9
Nitrogen(B)							
0 kg N ha^{-1}	31.8 **b**	29.5 **d**	29.8 **c**	28.1 **b**	29.7 **c**	31.6 **b**	31.8
30 kg N ha^{1}	32.1 **b**	31.0 **c**	32.0 **b**	30.7 **a**	30.6 **b**	32.5**ab**	31.6
60 kg N ha^{1}	32.9**ab**	32.8 **b**	35.2 **a**	32.1 **a**	32.8 **a**	33.9 **a**	33.9
90 kg N ha^{1}	34.3 **a**	35.2 **a**	36.3 **a**	31.9 **a**	33.0 **a**	34.6 **a**	32.8
LSD$_{\mathbf{0.05}}$	1.8	1.4	1.6	2.1	1.6	1.8	2.2
Pr>F							
Biochar	ns	ns	ns	ns	ns	ns	ns
Nitrogen	*	**	**	**	**	*	ns
B x N	ns	ns	ns	ns	ns	ns	ns
CV%(A)	3.49	3.10	3.52	3.81	7.80	5.32	2.38
CV%(B)	5.63	4.53	4.72	6.84	6.54	7.66	6.98

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

*=significant difference at 5% level, **=significant difference at 1% level, ns=non-significant difference

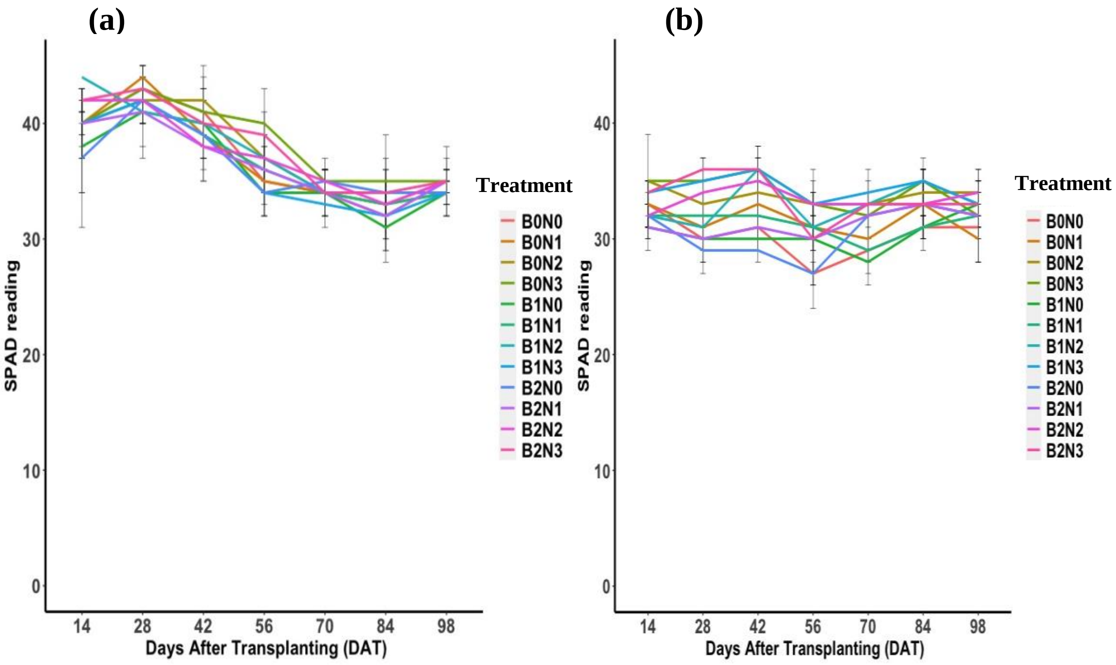


Figure 4.3 Mean value of SPAD reading as affected by the interaction effect of biochar and nitrogen fertilizer application in (a) dry and (b) wet season, 2020

4.1.2 Yield and yield components of rice

4.1.2.1 Number of panicles per hill

The number of panicles per hill was not significantly different among biochar treatments in the dry season (Table 4.7). In the dry season, nitrogen fertilizer application rates were significantly different based on the number of panicles hill^{-1} at the 1% level. The maximum number of panicle hill^{-1} was recorded from 12 kg N ha^{-1} (47), then 60 kg N ha^{-1} (43), following by 30 kg N ha^{-1} (40) and the minimum number of panicles per hill^{-1} was obtained from 0 kg N ha^{-1} (39) of nitrogen fertilizer application. Cobo, Barrios, Kass and Thomas (2002) found that the decomposition rates of plant residues vary in relation to soil conditions, such as temperature regime, moisture regime, the recalcitrance of the specific plant residues involved and the carbon/ nitrogen (C/N) ratios of the residues.

In the wet season, the number of panicles per hill was not significantly influenced by biochar treatment (Table 4.7). Among the nitrogen fertilizer levels, the effect of nitrogen fertilizer application on the number of tillers hill^{-1} was significantly different at 1 % level in rice yield. In this result, the higher number of panicles hill^{-1} was recorded at 90 kg N ha^{-1}(15), 60 kg N ha^{-1}(14), the optimum number of panicles hill^{-1} was gained at 30 kg N ha^{-1}(12), and the lower number of panicles hill^{-1} was obtained at 0 kg N ha^{-1}(10).Ghoneim, Gewaily and Osman (2018) also mentioned that the high rate of N showed maximum counts of panicles per hill while the control showed minimum counts of panicles per hill^{-1}. This is consistent with the findings of Metwally, Gabr and Hashem (2017) who found that increased nitrogen application improved panicle counts hill^{-1}.

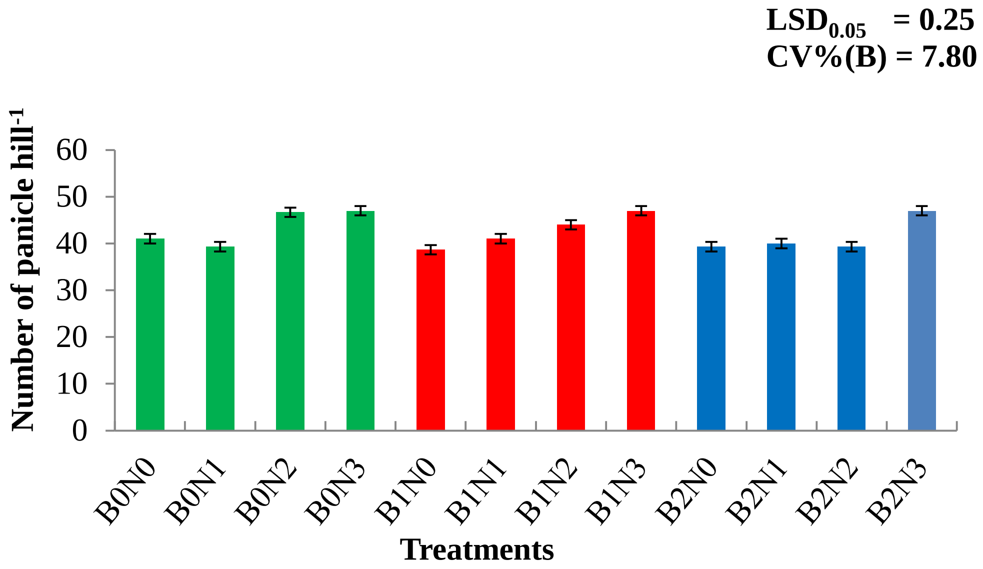
The interaction between biochar and nitrogen fertilizer application on the number of panicles per hill did not significantly differ in either of the two seasons (Figure 4.4 and 4.5).The mean number of panicle hill^{-1} ranged from (39) to (47) in all combined treatments in dry season. The maximum number of panicles hill^{-1} (47) resulted from B_1N_3 (6 ton ha^{-1} biochar with 90 kg N ha^{-1}) and the minimum number of panicles hill^{-1} (39) was obtained from the combined effect of B_1N_0 (6 ton ha^{-1} biochar with control). In wet season, the maximum number of panicles hill^{-1} (16) resulted from B_2N_3 (12 ton ha^{-1} biochar with 90 kg N ha^{-1}) and the minimum number of panicles hill^{-1} (11) was obtained from the combined effect of B_0N_0 (0 ton ha^{-1} biochar with control).

Table 4.7 Number of panicle per hill as affected by biochar and nitrogen fertilizer application during dry and wet season, 2020

Treatments	No. of panicle hill^{-1}	
	Dry	**Wet**
Biochar(A)		
B_0 (0 ton ha^{-1})	43	13
B_1 (6 ton ha^{-1})	42	12
B_2 (12 ton ha^{-1})	41	12
$LSD_{0.05}$	2.98	2.91
Nitrogen(B)		
N_0 (0 kg N ha^{-1})	39 **c**	10 **c**
N_1 (30 kg N ha^{-1})	40 **bc**	12 **b**
N_2 (60 kg N ha^{-1})	43 **b**	14 **a**
N_3 (90 kg N ha^{-1})	47 **a**	14 **a**
$LSD_{0.05}$	3.29	1.6
Pr>F		
Biochar	ns	ns
Nitrogen	**	**
B×N	ns	ns
CV%(A)	6.17	19.8
CV%(B)	7.8	12.37

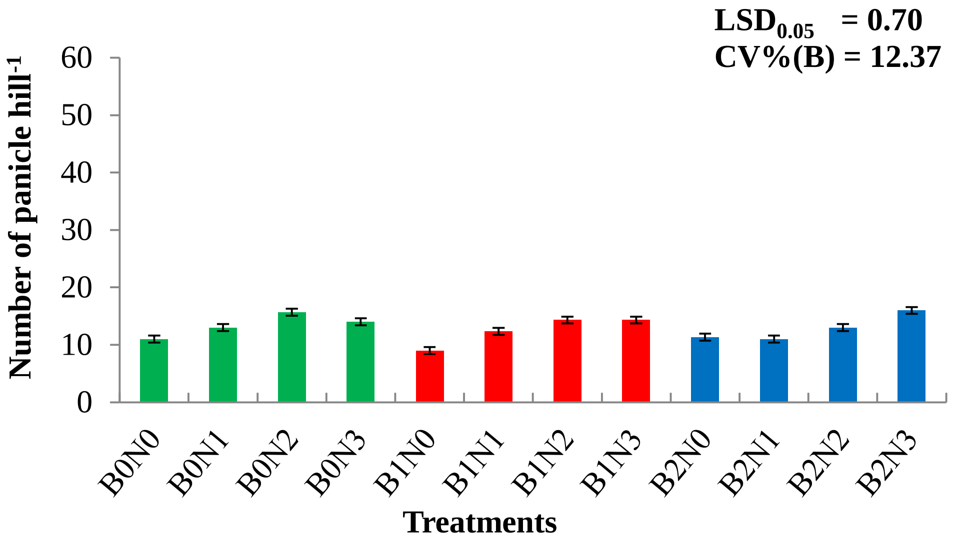
In each column, means followed by a same letters are not significantly different at LSD test 5% level.

*=significant difference at 5% level, **=significant difference at 1% level, ns=non-significant difference



$LSD_{0.05}$ = 0.25
CV%(B) = 7.80

Figure 4.4 Mean value of number of panicles hill^{-1} as affected by the interaction effect of biochar and nitrogen fertilizer application in dry season, 202



$LSD_{0.05}$ = 0.70
CV%(B) = 12.37

Figure 4.5 Mean value of number of panicles hill^{-1} as affected by the interaction effect of biochar and nitrogen fertilizer application in wet season, 2020

4.1.2.2 Number of spikelets per panicle

In the dry season, the number of spikelets panicle^{-1} was not significantly different between biochar and nitrogen fertilizer applications (Table 4.8). However, the higher number of spikelets per panicle ranged from (144) was observed in 12 ton ha^{-1}, and the lowest number of spikelets panicle^{-1} (143) was obtained in 0 ton ha^{-1}. The number of spikelets panicle^{-1} was not significantly different from nitrogen fertilizer in the dry season. The highest number of spikelets panicle^{-1} (146) was obtained in 90 kg N ha^{-1} , and then (147) was observed in 60 kg N ha^{-1}, followed by (142) was gained in 30 kg N ha^{-1}, and the lowest number of spikelets panicle^{-1} (138) was recorded in 0 kg ha^{-1}. Nitrogen fertilizer application had no significant difference effect on number of spikelets panicle^{-1}. Rogers et. (2014) reported that nitrogen promotes increased leaf size, spikelet number per panicle, percentage of filled spikelets in each panicle and grain protein content.

In the wet season, the number of spikelets per panicle was not significantly affected by biochar (Table 4.8). But, biochar treatment was not significantly different in the number of spikelets per panicle. At that moment, biochar 12 ton ha^{-1} and 6 ton ha^{-1} gave the highest number of spikelets panicle^{-1} of 90 kg N ha^{-1} (164), while at 6 ton ha^{-1} (165) and the lowest number of spikelets panicle^{-1} of 0 ton ha^{-1} was obtained from (160). While the nitrogen fertilizer application increased by the number of spikelets panicle^{-1}, significance was obtained at a 1 % level. The maximum number of spikelets panicle^{-1} (177) was achieved from the application of 90 kg N ha^{-1} followed by the application of 60 kg N ha^{-1} and 30 kg N ha^{-1}. The lowest number of spikelets panicle^{-1} of 0 kg N ha^{-1} (160) resulted in no nitrogen fertilizer treatment.

The effect of biochar and nitrogen fertilizer application was not significantly different from the number of spikelets panicle^{-1} in both seasons (Figure 4.6 and Figure 4.7). The highest number of spikelets panicle^{-1} (184.26) was resulted from B_1N_3 (6 ton ha^{-1} with 90 kg N ha^{-1}) and the lowest number of spikelets panicle^{-1} (135.11) was obtained from B_0N_1 (0 ton ha^{-1} with 30 kg N ha^{-1}).

Table 4. 8 Number of spikelets per panicle as affected by biochar and nitrogen fertilizer application during dry and wet season, 2020

Treatments	No. of spikelets panicle^{-1}	
	Dry	Wet
Biochar(A)		
B_0 (0 ton ha^{-1})	143	160
B_1 (6 ton ha^{-1})	142	165
B_2 (12 ton ha^{-1})	144	164
$LSD_{0.05}$	10.4	17.1
Nitrogen(B)		
N_0 (0 kg N ha^{-1})	138	160 **b**
N_1 (30 kg N ha^{-1})	142	153 **b**
N_2 (60 kg N ha^{-1})	147	164 **b**
N_3 (90 kg N ha^{-1})	146	177 **a**
$LSD_{0.05}$	8.58	11.4
Pr>F		
Biochar	ns	ns
Nitrogen	ns	**
B×N	ns	**
CV%(A)	6.47	9.32
CV%(B)	6.04	7.08

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

*=significant difference at 5% level, **=significant difference at 1% level, ns=non-significant difference

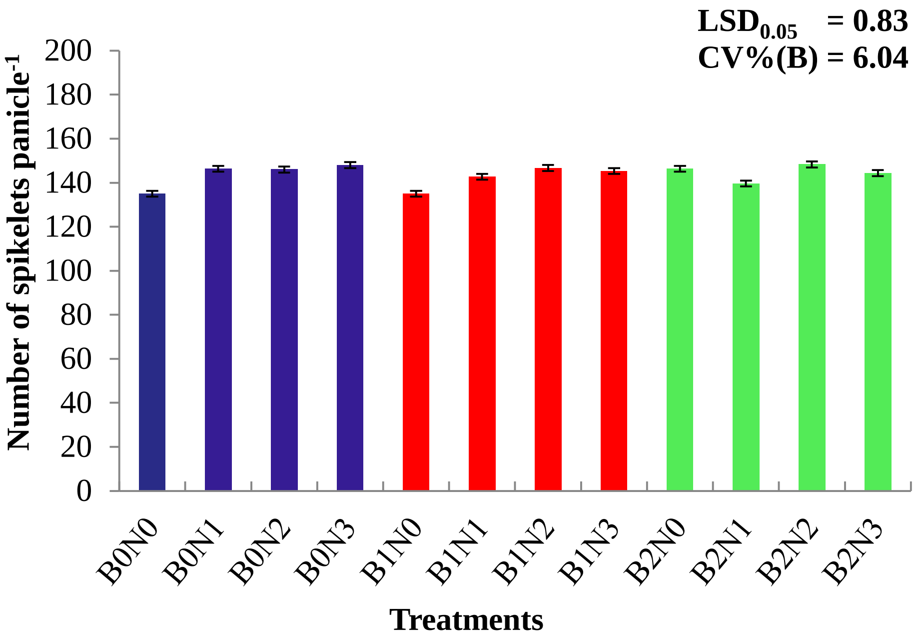


Figure 4.6 Mean value of number of spikelets panicle^{-1} as affected by the interaction effect of biochar and nitrogen fertilizer application in dry season, 2020

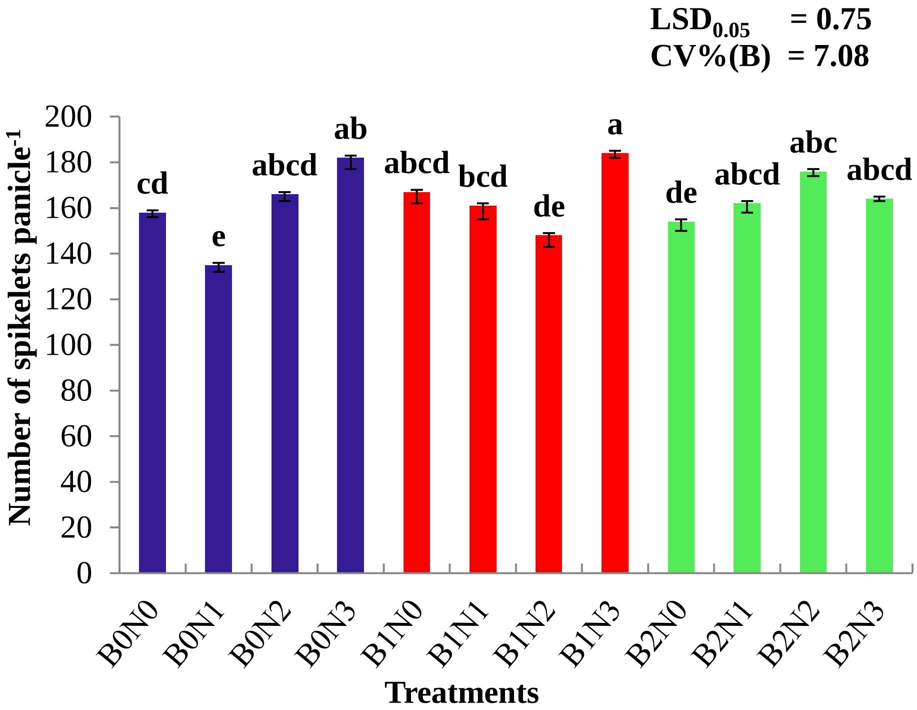


Figure 4.7 Mean value of number of spikelets panicle^{-1} as affected by the interaction effect of biochar and nitrogen fertilizer application in wet season, 2020

4.1.2.3 Panicle length

In the dry season, the panicle length of rice varietie was not affected by biochar and nitrogen fertilizer application (Table 4.9). Biochar rate did not significantly affect panicle length. The highest panicle length was 12 ton ha^{-1} (21.3 cm), followed by 6 ton ha^{-1} (21.0cm) and the lowest panicle length was 0 ton ha^{-1} (21.1cm). Panicle length was not significantly influenced by nitrogen fertilizer application. Among them, nitrogen fertilizer application produced a longer panicle length than without nitrogen fertilizer. Although there was a statistical difference, the longest panicle length (21.00 cm) was observed from 90 kg N ha^{-1}, and then 60 kg N ha^{-1} and 30 kg N ha^{-1} had the same panicle length (21.3 cm), and the shortest panicle length was obtained from 0 kg N ha^{-1} (20.8 cm) control. Metwally, Eladawy and Feilat (2017) and Yoseftabar (2013) also reported that the maximum panicle length was obtained at highest level of nitrogen fertilizer application.

The interaction of biochar and nitrogen fertilizer application was not significantly different in panicle length (Figure 4.8). The longest panicle length (21.3 cm) resulted from B_2N_3 (12 ton ha^{-1} with 90 kg N ha^{-1}) and the shortest panicle length (20.3cm) was observed from B_0N_0 (0 ton ha^{-1} with 0 kg N ha^{-1}).

In the wet season, the panicle length was not significantly different between biochar and nitrogen fertilizer application (Table 4.9). Panicle length is a very important parameter because it is associated with other important things such as the number of grains and 1000 grain weight. There was no significant difference in the panicle lengths. The highest panicle length (22.7 cm) was obtained at 12 tons ha^{-1}, (22.4 cm) at 6 tons ha^{-1}, and the lowest panicle length (22.2 cm) was gained at control. The nitrogen fertilizer application produced greater panicle length than without nitrogen fertilizer. The maximum panicle length (22.9 cm) was observed from 90 kg N ha^{-1}, and then (22.3 cm) was resulted from 60 kg N ha^{-1}, (22.3 cm) was obtained from (22.0 cm) 30 kg N ha^{-1} and the minimum panicle length was obtained from 0 kg N ha^{-1} (22.4 cm) control.

The interaction effect of biochar and nitrogen fertilizer application was significant different on panicle length in (Figure 4.9). The longest panicle length (21.3 cm) resulted from the interaction of B_2N_3 (90 kg N ha^{-1} with 6 ton ha^{-1}) and the shortest panicle length (20.3 cm) was obtained from B_0N_0 (0 kg N ha^{-1} and 0 ton ha^{-1}).

Table 4.9 Panicle length as affected by biochar and nitrogen fertilizer application during dry and wet season, 2020

Treatments	Panicle length (cm)	
	Dry	Wet
Biochar(A)		
B_0 (0 ton ha^{-1})	21.1	22.2
B_1 (6 ton ha^{-1})	21.0	22.4
B_2 (12 ton ha^{-1})	21.3	22.7
$LSD_{0.05}$	0.71	0.51
Nitrogen(B)		
N_0 (0 kg N ha^{-1})	20.8	22.4 **ab**
N_1 (30 kg N ha^{-1})	21.3	22.0 **b**
N_2 (60 kg N ha^{-1})	21.3	22.3 **ab**
N_3 (90 kg N ha^{-1})	21.0	22.9 **a**
$LSD_{0.05}$	0.76	0.70
Pr>F		
Biochar	ns	ns
Nitrogen	ns	ns
B×N	ns	*
CV%(A)	3.01	2.04
CV%(B)	3.65	3.15

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

*=significant difference at 5% level, **=significant difference at 1% level, ns=non-significant difference

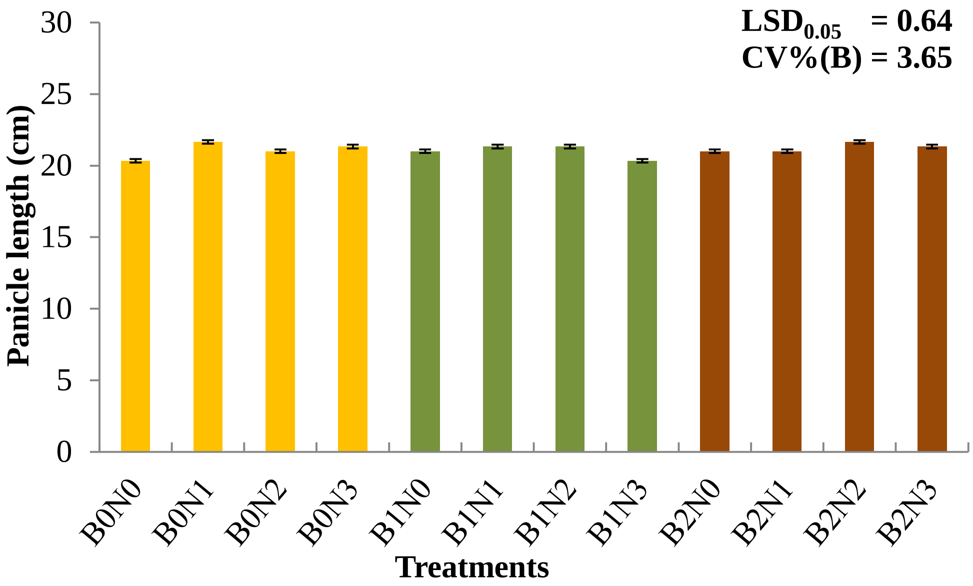


Figure 4.8 Mean value of panicle length as affected by the interaction effect of biochar and nitrogen fertilizer application in dry season, 2020

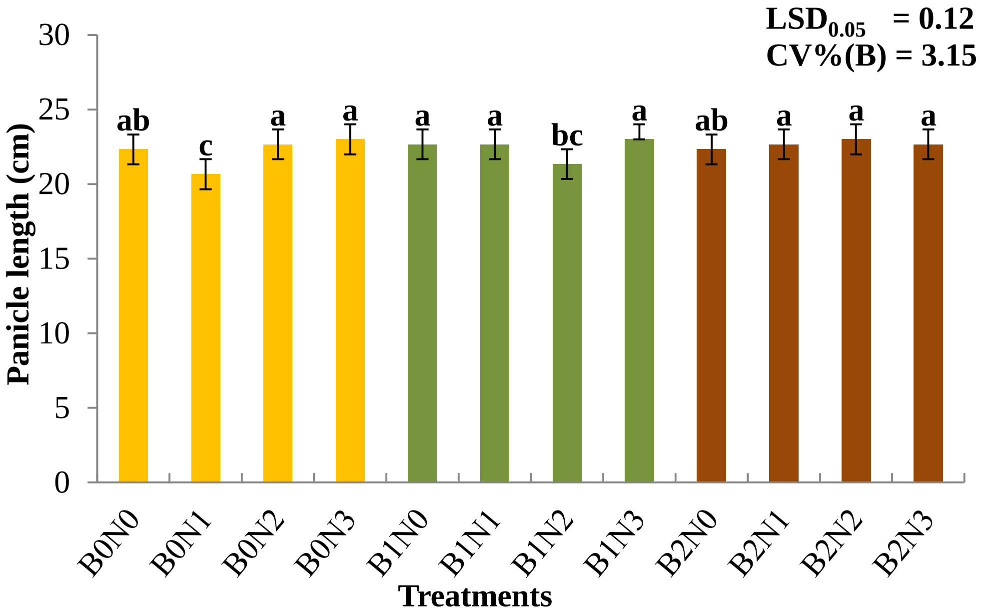


Figure 4.9 Mean value of panicle length as affected by the interaction effect of biochar and nitrogen fertilizer application in wet season, 2020

4.1.2.4 Filled grain percent

The mean values of biochar, nitrogen fertilizers and their combined effects on the filled grain percent in the dry season were described in (Table 4.10 and Figure 4.10) .The percentage of filled grain did not differ significantly among biochar treatments. Among all the biochar treatments, the highest filled grain percentage (66.17) was obtained from 6 ton ha^{-1}, followed by 0 ton ha^{-1} (65.25), and the lowest filled grain percentage was obtained 12 tons ha^{-1} (64.58). There was no significant difference observed in nitrogen fertilizer application. Although the percent of filled grain did not differ significantly across all nitrogen fertilizer applications, the highest percent of filled grain was obtained at 0 kg N ha^{-1}(67.22%) and the lowest percent of filled grain was resulted from 90 kg N ha^{-1} (62.11%). However, the differences between highest and lowest filled grain percent were around 4 %. Moreover the effect of biochar and nitrogen fertilizer application did not significantly differ in terms of filled grain percent in dry season.

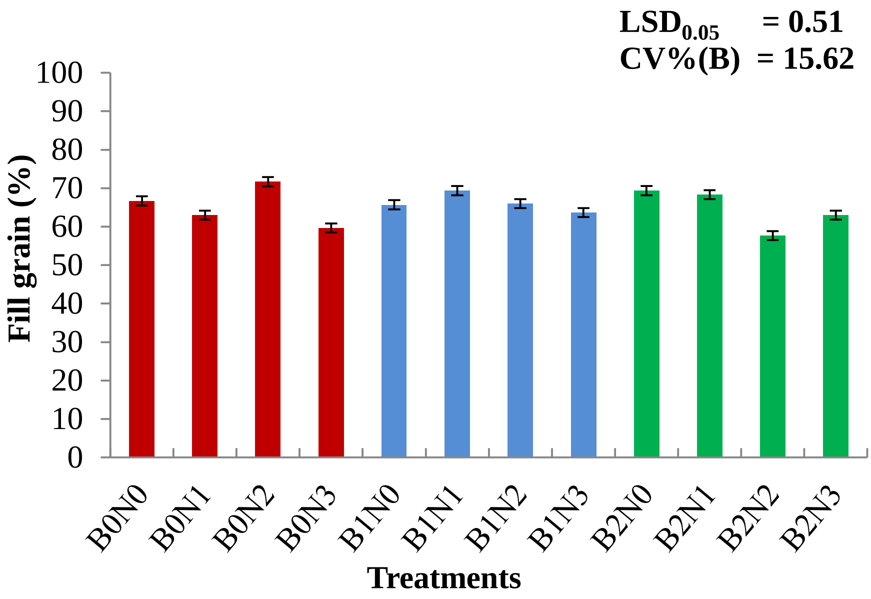
In the wet season, there was no significant effect on biochar, nitrogen fertilizer application and their combined effect on the percentage of fill grain percent (Table 4.10 and Figure 4.11). The higher percentage of fill grain was observed at 89.87% and the lowest fill grain percentage was achieved at 89.82%. Talashilkar and Chavan (1996) stated that using rice husk causes the production of more grain and straw in paddy and that yields increase too. Nitrogen fertilizer application was not significantly different from the percentage of fill grain. The maximum fill grain percentage was achieved at (91.59) 60 kg N ha^{-1} whereas the minimum fill grain percentage was recorded at (88.88) 90 kg N ha^{-1}.The interaction of biochar and nitrogen fertilizer application was not significant on fill grain percentage.

Table 4.10 Filled grain percent of rice as affected by biochar and nitrogen fertilizer application during dry and wet season, 2020

Treatments	Filled grain %	
	Dry	Wet
Biochar(A)		
B_0 (0 ton ha^{-1})	65.25	89.87
B_1 (6 ton ha^{-1})	66.17	90.59
B_2 (12 ton ha^{-1})	64.58	89.82
$LSD_{0.05}$	3.52	1.14
Nitrogen(B)		
N_0 (0 kg N ha^{-1})	67.22	91.14
N_1 (30 kg N ha^{-1})	66.88	89.77
N_2 (60 kg N ha^{-1})	65.11	91.59
N_3 (90 kg N ha^{-1})	62.11	88.88
$LSD_{0.05}$	10.1	3.66
Pr>F		
Biochar	ns	ns
Nitrogen	ns	ns
B×N	ns	ns
CV%(A)	4.76	1.12
CV%(B)	15.62	4.1

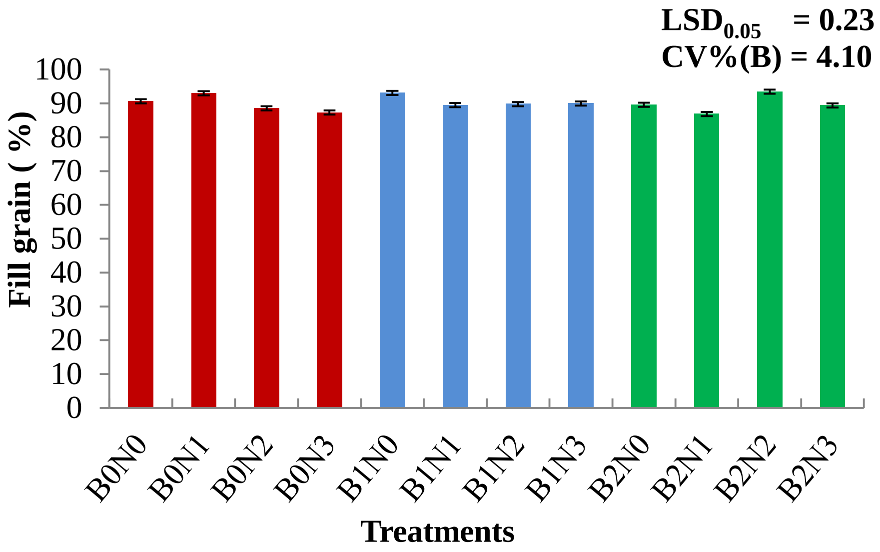
In each column, means followed by a same letters are not significantly different at LSD test 5% level.

*=significant difference at 5% level, **=significant difference at 1% level, ns=non-significant difference



$LSD_{0.05}$ = 0.51
CV%(B) = 15.62

Figure 4.10 Mean value of filled grain percent as affected by the interaction effect of biochar and nitrogen fertilizer application in dry season, 2020



$LSD_{0.05}$ = 0.23
CV%(B) = 4.10

Figure 4.11 Mean value of filled grain percent as affected by the interaction effect of biochar and nitrogen fertilizer application in wet season, 2020

4.1.2.5 Thousand grain weight

The mean value of biochar and nitrogen fertilizer application and their combined effects on 1000 grain weight in dry season were shown in Table 4.11. There was no significant difference in thousand grain weight due to the effect of biochar treatments. In the dry season, biochar 12 tons ha^{-1} ranged from (18.06), and then 0 ton ha^{-1} was obtained from (18.33) and 6 tons ha^{-1} (17.76). Nitrogen fertilizer applications were not significantly different on 1000 grain weight. Alam, Baki, Sultana, Ali and Islam (2012) stated that different nitrogen fertilizer did not have any significant effect on 1000 grain weight since 1000 grain weight is variety character. The application of 90 kg Nha^{-1} resulted in the highest 1000 grain weight (17.96) and the lowest 1000 grain weight was found by the treatment of 0 kg N ha^{-1}. There was no interaction between biochar and nitrogen fertilizer application (Figure 4.12). There were no significant changes in 1000 grian weight in biochar treatment that responded to different nitrogen fertilizer applications.

In wet season, 1000 grain weight that was affected by biochar, different rates of nitrogen fertilizer application and their interaction effects were followed in (Table 4.11 and Figure 4.13). There was no significant difference at 1000 grain weight of biochar treatment. Biochar 0 ton ha^{-1} resulted from a numerically higher percentage of 1000 grain weight was obtained from (19.12 g), followed by 6 ton ha^{-1} (18.9 g) and then 12 ton ha^{-1} (19.01 g), respectively. Nitrogen fertilizer application was not significant different at 1000 grain weight. The maximum 1000 grain weight was given (18.81 g) with 90 kg N ha^{-1} and the minimum 1000 grain weight gained (18.30 g) was obtained with 0 kg N ha^{-1}. Among the yield components, 1000 grain weight was less influenced by the treatment combinations because it is more or less a genetically controlled characteristic. It usually has a stable varietal character, and management has little effect on its variation (Yoshida, 1981).

The interaction between biochar and nitrogen fertilizer application was not significantly different at 1000 grain weight. Hakim et al. (2013) stated that nitrogen plays an important role in formation of organs and physiological processes for rice production as well as becoming a major component in tillers and grains production which explains the higher 1000-grain weight of rice with better N uptake.

Table 4.11 Thousands grain weight of rice as affected by biochar and nitrogen fertilizer application during dry and wet season, 2020

Treatments	1000 grain weight (g)	
	Dry	Wet
Biochar(A)		
B_0 (0 ton ha^{-1})	18.33	19.12
B_1 (6 ton ha^{-1})	17.76	18.9
B_2 (12 ton ha^{-1})	18.06	19.01
$LSD_{0.05}$	0.63	0.48
Nitrogen(B)		
N_0 (0 kg N ha^{-1})	17.95	18.3
N_1 (30 kg N ha^{-1})	18.05	18.59
N_2 (60 kg N ha^{-1})	18.30	18.32
N_3 (90 kg N ha^{-1})	17.96	18.81
$LSD_{0.05}$	0.39	0.52
Pr>F		
Biochar	ns	ns
Nitrogen	ns	ns
B×N	ns	ns
CV%(A)	3.07	2.22
CV%(B)	2.21	1.63

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

*=significant difference at 5% level, **=significant difference at 1% level, ns=non-significant difference

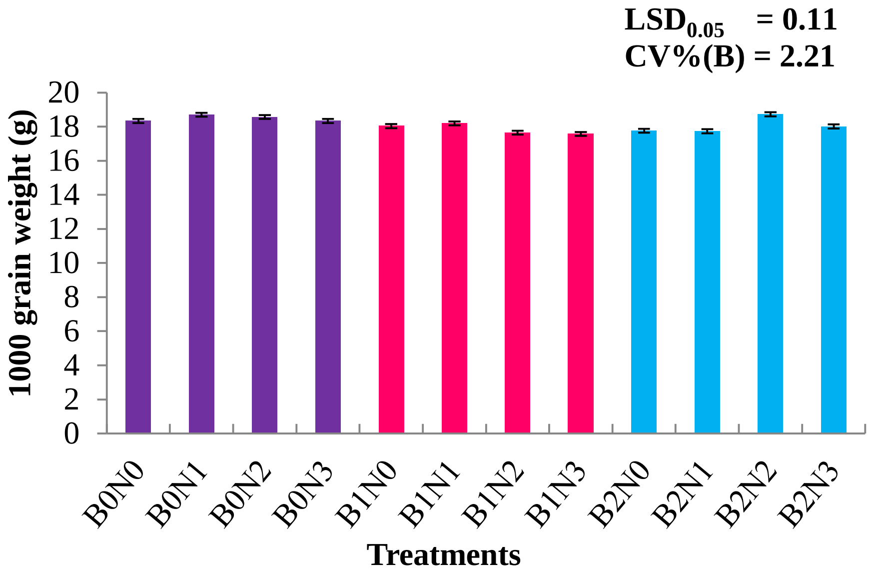


Figure 4.12 Mean value of 1000 grain weight as affected by the interaction effect of biochar and nitrogen fertilizer application in dry season, 2020

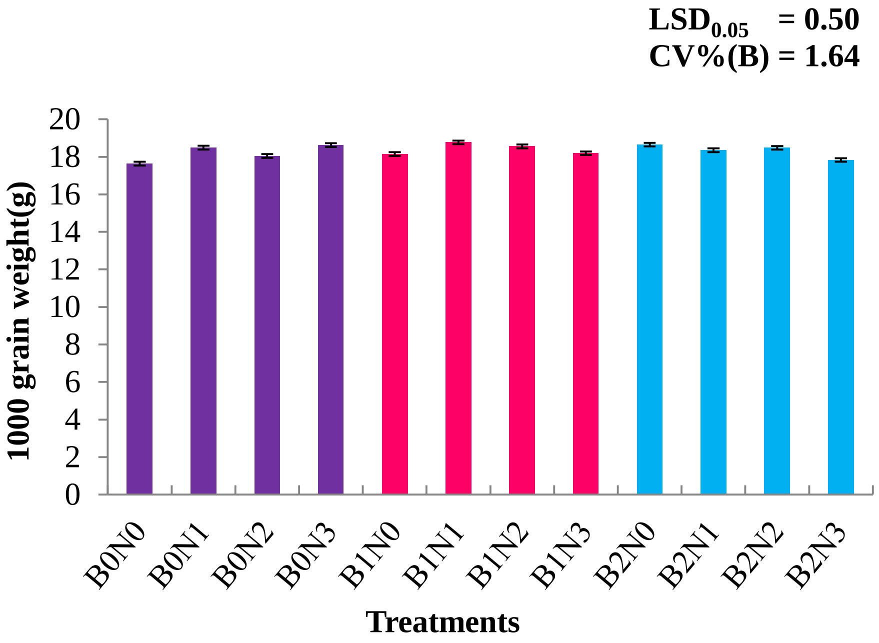


Figure 4.13 Mean value of 1000 grain weight as affected by the interaction effect of biochar and nitrogen fertilizer application in wet season, 2020

4.1.2.6 Grain yield (g pot^{-1})

The mean values of biochar and nitrogen fertilizer application on grain yield were shown in Table 4.12. In dry season, the mean value of grain yield was not significantly different among biochar. However grain yield was numerically different among different rate of biochar. The highest grain yield (74.91) was gained from 12 tons ha^{-1}, the lowest grain yield (69.83) from 0 tons ha^{-1} and the grain yield (72.41) from 6 tons ha^{-1}, respectively. It can be said that biochar application indirectly promoted the increase growth yield by increasing yield components parameter such as number panicle hill^{-1}. However, nitrogen fertilizer application had a significant effect on grain yield at the 5% level. The maximum grain yield of rice per hill (76.33 g) was obtained from 90 kg N ha^{-1}, and the minimum grain yield of rice hill^{-1} (72.44 g) was resulted from 30 kg N ha^{-1}, respectively. Ebaid & Ghanem (2000) supported that the increase in grain yield might be due to nitrogen application enhancing the dry matter production, improving rice growth rate, promoting elongation of internodes and activity of growth. The interaction between biochar and nitrogen fertilizer application did not result in a significant difference in rice grain yield (Figure 4.14). The maximum grain yield (80.67) was resulted from the combined effect of B_2N_3 (12 ton ha^{-1} with 90 kg N ha^{-1}) and the minimum grain yield B_0N_0 (66.33) was obtained from the combined effect of (0 ton ha^{-1} with control).

In wet season, the effect of biochar and nitrogen fertilizer application was shown in Table 4.12 and their combined effects on grain yield were shown in figure 4.15. There was no significant difference in biochar, treatments in grain yield were highly significant different at 1% level by different nitrogen fertilizer application rates. This result the highest grain yield (44.9 g pot^{-1}) was obtained at the application of 90 kg N ha^{-1} and it was not statistically different with the yield (40.3 g pot^{-1}) at the application of 30 kg N ha^{-1}.The lowest grain yield was resulted in 0 kg N ha^{-1} (28.2 g pot^{-1}). The effect of nitrogen fertilizer application was significantly on rice grain yield. Uddin et al. (2013) who reported that grain yield increased significantly with an increased dose of nitrogen. The effect of biochar and nitrogen fertilizer application was not significantly different in grain yield. The maximum grain yield (46.53.) was obtained from the combined effect of B_2N_3 (12 ton ha^{-1} with 90 kg N ha^{-1}) and the minimum grain yield B_1N_0 (25.67) was obtained from the combined effect of (6 ton ha^{-1} with control).

Table 4.12 Grain yield of rice as affected by biochar and nitrogen fertilizer application during dry and wet season, 2020

Treatments	**Grain yield (g pot^{-1})**	
	Dry	**Wet**
Biochar (A)		
B_0 (0 ton ha^{-1})	69.83	36.8
B_1 (6 ton ha^{-1})	72.41	35.3
B_2 (12 ton ha^{-1})	74.91	36.3
$LSD_{0.05}$	6.99	7.01
Nitrogen (B)		
N_0 (0 kg N ha^{-1})	69.11 **b**	28.2 **c**
N_1 (30 kg N ha^{-1})	71.67 **b**	31.2 **c**
N_2 (60 kg N ha^{-1})	72.44 **ab**	40.3 **b**
N_3 (90 kg N ha^{-1})	76.33 **a**	44.9 **a**
$LSD_{0.05}$	4.5	3.33
Pr>F		
Biochar	ns	ns
Nitrogen	*	**
B×N	ns	ns
CV%(A)	8.53	17.12
CV%(B)	6.28	9.3

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

*=significant difference at 5% level, **=significant difference at 1% level, ns=non-significant difference

$LSD_{0.05}$ = 0.24
CV%(B) = 6.28

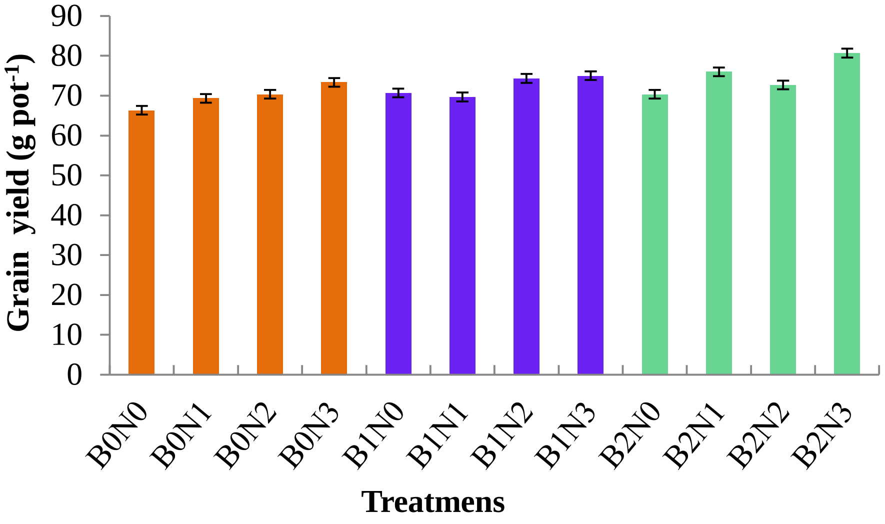


Figure 4.14 Mean value of grain yield as affected by the interaction effect of biochar and nitrogen fertilizer application in dry season, 2020

$LSD_{0.05}$ = 0.81
CV%(B) = 9.44

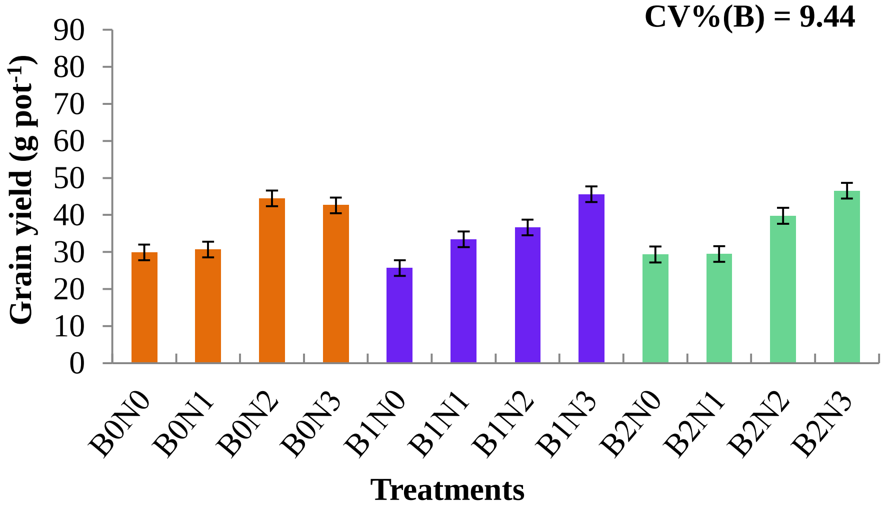


Figure 4.15 Mean value of grain yield as affected by the interaction effect of biochar and nitrogen fertilizer application in wet season, 2020

4.1.2.7 Harvest index

During the dry season, there was no significant difference in harvest index between biochar, nitrogen fertilizer application, and the combined effect (Table 4.13 and Figure 4.16). The highest value of biochar was observed at 12 ton ha^{-1}(0.36) and the lowest value of biochar resulted from 0 ton ha^{-1} (0.35) in the harvest index. There was no significant difference in nitrogen fertilizer application on the harvest index, but the maximum value was obtained from nitrogen at 90 kg N ha^{-1} (0.35), following by 60 kg N ha^{-1} was produced from (0.36) and then 30 kg N ha^{-1} (0.34) and the minimum value was gained from (0.35).

The interaction of biochar and nitrogen fertilizer application did not significantly change the harvest index. During grain filling and maturation stage, large portion of N required in rice come from the culm, leaves and panicles rather than directly from the soil (Jones, Olson-Rutz & Dinkins, 2011).

In the wet season, the harvest index as affected by biochar, nitrogen fertilizer application, the combined effect was shown in Table 4.13 and Figure 4.17. There was no significant difference in the harvest index of biochar treatment, although biochar 12 ton ha^{-1} produced high harvest index (0.50) and the low harvest index was obtained from 0 ton ha^{-1} (0.49). However, the effect of different nitrogen fertilizer rates application significantly influence on harvest index. The highest value of the harvest index was produced at 90 kg N ha^{-1} (0.51), 60 kg N ha^{-1} (0.50), after that the high value of the harvest index was obtained at 30 kg N ha^{-1} (0.47) and 0 kg N ha^{-1} (0.49), respectively.

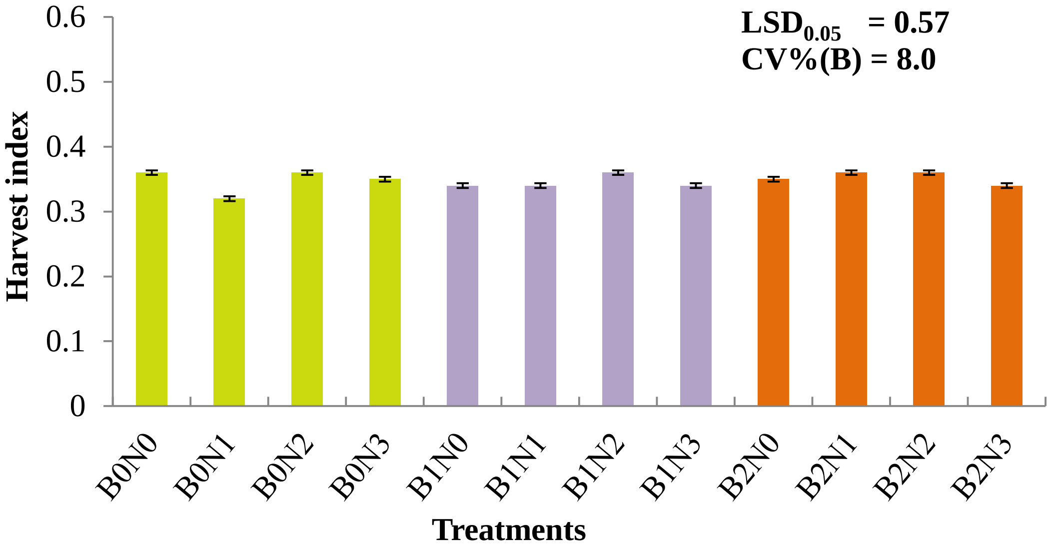
In the harvest index, there was a highly significant in the interaction of biochar and nitrogen fertilizer application. The maximum harvest index (0.52) was obtained from the interaction of B_2N_3 (12 ton ha^{-1} with 90 kg N ha^{-1}) and the minimum harvest index (0.44) was resulted from the interaction of B_1N_0 (6 ton ha^{-1} with control).

Table 4.13 Harvest index of rice as affected by biochar and nitrogen fertilizer application during dry and wet season, 2020

Treatments	Harvest index	
	Dry	Wet
Biochar(A)		
B_0 (0 ton ha^{-1})	0.35	0.49
B_1 (6 ton ha^{-1})	0.35	0.48
B_2 (12 ton ha^{-1})	0.36	0.5
$LSD_{0.05}$	0.02	0.01
Nitrogen(B)		
N_0 (0 kg N ha^{-1})	0.35	0.49 **ab**
N_1 (30 kg N ha^{-1})	0.34	0.47 **b**
N_2 (60 kg N ha^{-1})	0.36	0.50 **a**
N_3 (90 kg N ha^{-1})	0.35	0.51 **a**
$LSD_{0.05}$	0.03	0.02
Pr>F		
Biochar	ns	ns
Nitrogen	ns	**
B×N	ns	**
CV%(A)	5.72	2.91
CV%(B)	8	4.39

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

*=significant difference at 5% level, **=significant difference at 1% level, ns=non-significant difference



$\mathrm{LSD}_{0.05}$ = 0.57
CV%(B) = 8.0

Figure 4.16 Mean value of harvest index as affected by the interaction effect of biochar and nitrogen fertilizer application in dry season, 2020

$\mathrm{LSD}_{0.05}$ = 0.06
CV%(B) = 4.39

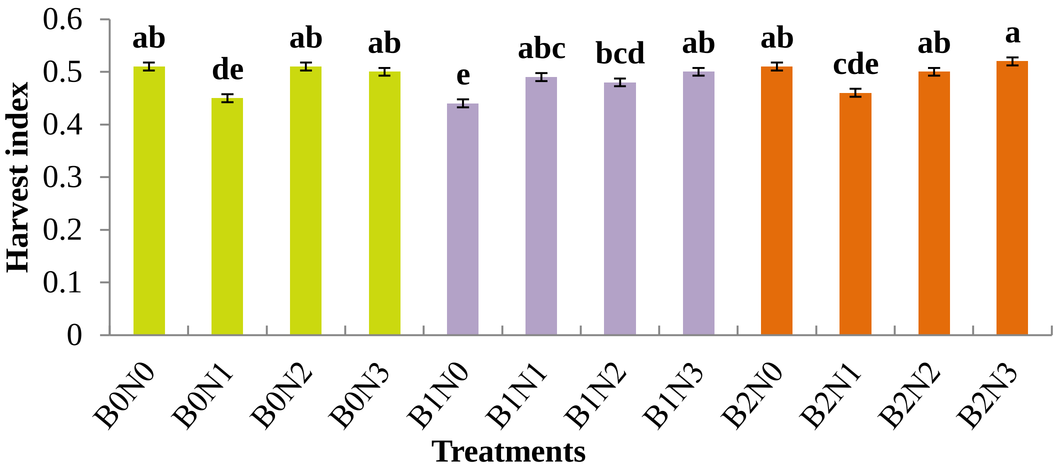


Figure 4.17 Mean value of harvest index as affected by the interaction effect of biochar and nitrogen fertilizer application in wet season, 2020

4.1.2.8 Total dry matter

In dry season, the total dry matter of rice was not significantly affected by biochar, nitrogen fertilizer application and the combined effect was shown in Table 4.14 and Figure 4.18. The total dry matter value of different biochar rates was not significantly different in the dry season. The maximum total dry matter of biochar value was obtained at 6 ton ha^{-1} (201.58 g pot^{-1}) and the minimum value of total dry matter was resulted from 0 ton ha^{-1} (182.83 g pot^{-1}). The nitrogen fertilizer application did not make a significant difference in rice yield. The highest value in total dry matter resulted from 90 kg N ha^{-1} (203.22 g pot^{-1}), and the lowest value was obtained from 0 kg N ha^{-1} (190.89 g pot^{-1}) nitrogen fertilizer application. The interaction of biochar and nitrogen fertilizer application did not result in a significant difference in total dry matter in the dry season.

In wet season, biochar did not make a significant difference in total dry matter of rice as shown in Table 4.14 and Figure 4.19. The maximum total dry matter (75.68 g pot^{-1}) was observed in control treatment and the minimum total dry matter (74.33 g pot^{-1}) was obtained from 12 ton ha^{-1} of biochar. There is a highly significant difference in total dry matter by different nitrogen fertilizer applications at 1 % level. The highest value of total dry matter (90.36 g pot^{-1}) was gained from the application of 90 kg N ha^{-1}; (82.44 g pot^{-1}) resulted from the application of 60 kg N ha^{-1}; and (68.07 g pot^{-1}) was obtained from the application of 30 kg N ha^{-1}, respectively. The lowest value of total dry matter was achieved from the application of 0 kg N ha^{-1} (59.12 g pot^{-1}).There was no significant difference in total dry matter between biochar and nitrogen fertilizer applications.

Table 4.14 Total dry matter of rice as affected by biochar and nitrogen fertilizer application during dry and wet season, 2020

Treatments	Total dry matter (TDM) (g pot^{-1})	
	Dry	Wet
Biochar(A)		
B_0 (0 ton ha^{-1})	182.83	75.68
B_1 (6 ton ha^{-1})	201.58	75
B_2 (12 ton ha^{-1})	192.92	74.33
$LSD_{0.05}$	20.48	12.82
Nitrogen(B)		
N_0 (0 kg N ha^{-1})	190.89	59.12 **d**
N_1 (30 kg N ha^{-1})	188.78	68.07 **c**
N_2 (60 kg N ha^{-1})	186.89	82.44 **b**
N_3 (90 kg N ha^{-1})	203.22	90.36 **a**
$LSD_{0.05}$	24.95	5.57
Pr>F		
Biochar	ns	ns
Nitrogen	ns	**
B×N	ns	ns
CV%(A)	9.39	15.08
CV%(B)	13.09	7.51

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

*=significant difference at 5% level, **=significant difference at 1% level, ns=non-significant difference

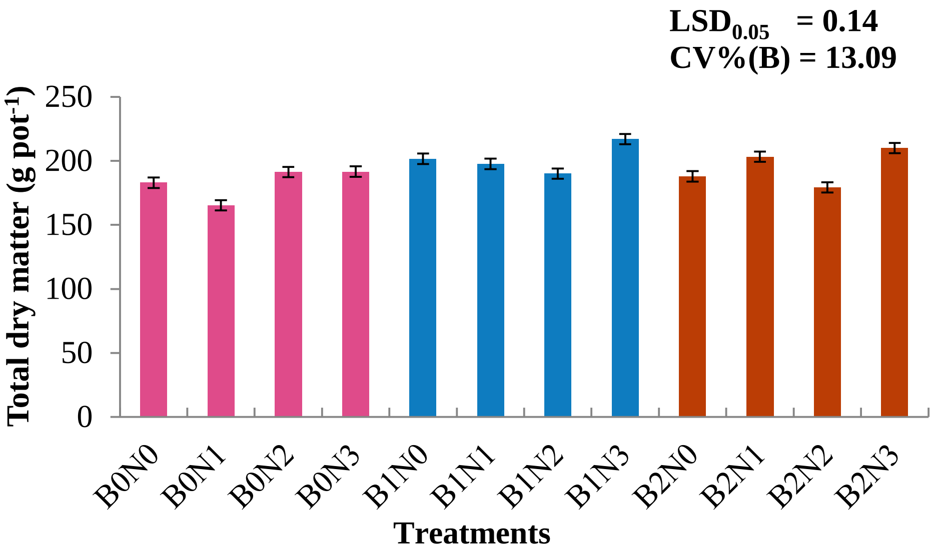


Figure 4.18 Mean value of total dry matter as affected by the interaction effect of biochar and nitrogen fertilizer application in dry season, 2020

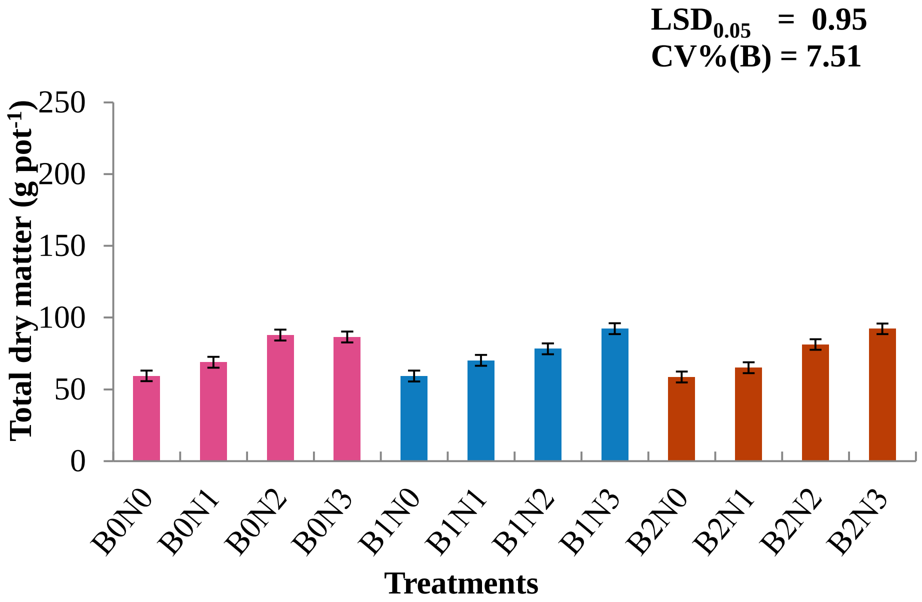


Figure 4.19 Mean value of total dry matter as affected by the interaction effect of biochar and nitrogen fertilizer application in wet season, 2020

CHAPTER V

CONCLUSION

The present study concluded that the effects of different rates of biochar and nitrogen fertilizer application on grain yield and yield components of rice in dry and wet seasons, 2020. According to the experimental results, the effect of biochar on growth and yields components parameters was not observed in both seasons. However, the beneficial effect of applying rice husk biochar on grain yield was resulted, whereas with rice husk biochar 12 ton ha^{-1} produced the higher grain yield than control in both seasons. The different rates of nitrogen fertilizer application significantly influenced on the rice growth parameters in both seasons. The significant differences of different nitrogen rates were observed on number of panicle hill^{-1} and grain yield in both seasons and number of spikelets panicle^{-1} in wet season. 90 kg N ha^{-1} significantly enhanced growth parameters and yield parameters such as number of panicle hill^{-1}, number of spikelets panicle^{-1} and 1000 grain weight compared to other nitrogen rates. Moreover, 90 kg N ha^{-1} produced highest grain yield in both seasons, it was followed by 60 kg N ha^{-1}, after that it was in 30 kg N ha^{-1}, also the minimum of grain yield was found control treatments. Therefore, high nitrogen fertilizer rates significantly gave high grain yield of Sin Thu Kha rice variety under sandy clay loam soil condition of Yezin area.

The combined use of biochar and nitrogen fertilizer application was no significant effect on some growth parameters and yield components parameters such as plant height, number of tillers hill^{-1}, SPAD reading and number of panicle per hill, filled grain percentage, total dry matter and 1000 grains weight in both seasons, however, significant effect on panicle length, number of spikelets per panicle, and harvest index especially in wet season.

Among the combined effect of biochar and nitrogen fertilizer application, the maximum grain yield was observed in B_2N_3 (12 ton ha^{-1} with 90 kg N ha^{-1}) in both seasons. Therefore, it can be concluded that 90 kg N ha^{-1} with 12 ton ha^{-1} would be the optimum N doses for Sin Thu Kha rice variety in sandy loam soil. Biochar should be used for long term rice production since the rice husk biochar is important for the recycling rice husk for improving soil fertility and crop production in soils of low fertility, particularly in small holder farming systems where access to inputs such as inorganic fertilizers is limited.

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Plate 3.1 Rice husk biochar with slow partial pyrolysis method

APPENDICES

Appendix 1 Monthly weather data during the experimental periods in 2020

Months	**Temperature** **Maximum**	**minimum**	**Rainfall (mm)**
January	32.1	15.3	1
February	24.3	16.2	
March	38.2	20.2	
April	39.6	23.7	10
May	39.2	26.1	104
June	34.6	24.3	93
July	34	24.1	127
August	32.2	23.6	248
September	33.8	23.8	141
October	33.4	23.2	101
November	33.5	19.9	12

Source: Meteorological station, Department of Agricultural Research (DAR)