Impact of Rice Husk Biochar for Improvement of Nutrient Availability on Soil and Maize Crop

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Abstract

Maize is important crop due to its high nutritional value and multiple uses. It is grown as fodder and cereal crop in Pakistan. The population of pakistan is increasing at fast rate therefore; production of maize needs to be increased. One of the biggest challenges to agricultural production in pakistan is soil-related problems. Biochar is proved to be increase the production of several crops due to its improved soil water-holding capacity. It increases the availability of plants nutrient and increases growth and biomass of plant. Therefore, the experiment was conducted to evaluate the efficiency of rice husk biochar to improve soil property and growth of maize plant. The biochar was applied at different dose rate such as 9%, 7%, 4%, 3% and 1%. The impact of biochar on soil properties and plant growth was checked. The results showed that biochar amended soil performed better as compared to control. Maximum plant height, plant fresh weight, plant dry weight, root fresh weight and root dry weight was recorded in case of 9% rice husk biochar which was 120 cm, 100 g, 80 g, 16.23 g and 9.34 g respectively. Maximum EC, pH, organic matter was recorded in case of 9% rice husk biochar which were 1.75 ds m-^{1}, 8.34 and 2.5% respectively. Maximum available phosphorus in soil was recorded in case of 9% rice husk biochar 24.3 mg/Kg. Highest available potassium was recorded in case of 9% rice husk biochar 170 mg/Kg. Highest total nitrogen was recorded in case of 9% rice husk biochar 0.17 g/Kg. Highest available Fe was recorded in case of 9% rice husk biochar 55 g/Kg. Highest available Zinc was recorded in case of 9% rice husk biochar 16 g/Kg. The results concluded that application of rice husk biochar at dose rate of 9% improve the soil properties and growth of maize plant. So, rice husk biochar might be used as a soil amendment and to enhance the yield of maize and other crops as well.

Keywords: Maize, Biochar, soil amendment, Rice husk, Plant biomass, Lasbela District.

Introduction

Pakistan's terrain consists predominantly of dry regions, with approximately 80% of the land classified as arid or semi-arid, 12% as dry sub-humid, and the remaining 8% as humid. The total land area of Pakistan is about 79.6 million hectares, out of which 22.05 million hectares are cultivated. Additionally, 6.28 million hectares are impacted by salinity. Due to poor land management practices and growing demands on natural resources, Pakistan's arid areas are severely affected by soil erosion and desertification (Zia et al., 2004). The environment is under stress due to a number of factors, including the degradation of dry land habitats, a decline in soil fertility, flash flooding, biodiversity loss, declining crop yields, soil depletion, inadequate drainage, salinity, and a number of other problems associated with high birth rates. Poor land resource management raises the dangers, resulting in desertification and reduced productivity. Some dangers of land loss are more serious than others in terms of manifestation. Water logging and salinity are the results of inadequate drainage efforts (GOP, 2014).

Maize (Zea mays L.) is recognized as the world's most important cereal and food crop. The entire maize crop is versatile, being used for both food and non-food products. In developed countries, it is widely used as industrial raw material and animal feed, whereas in developing countries, its primary use is for feed. Recently, there has been growing interest in producing ethanol from maize as an alternative to petroleum-based fuels. In Pakistan, maize covers an area of 1.0873 million hectares, with an average yield of 3990 kg per hectare, contributing to an annual production of 4.3383 million tons (Khan et al., 2016). Due to its short growing season, high yield potential, adaptability to various environments, and high value as forage, food, and feed for poultry and livestock, maize is an integral part of Pakistan's cropping system. It is also a valuable raw material for many agro-based industries and offers a high net economic return. Every year, synthetic fertilizers are applied to the soil to enhance maize yields (Ju et al., 2009). Maize serves as an important cash and food crop in Pakistan, with additional use in silage production. It is among the highest-yielding cereal crops globally, ranking as the fourth most important crop in Pakistan after rice, wheat, and cotton. It is typically planted in two seasons: spring and fall, with sowing periods from February to March in the spring and from July to August in the fall. Water stress during any phonological stage, including maturity and reproductive phases, significantly affects grain yields. Previous studies have shown that drought stress during the reproductive stage reduces grain yield. Maize is nutritionally rich, consisting of 72% carbohydrates, 10% protein, 8.5% fiber, 4.8% oil, 3% sugar, and 1% ash content (Chaudhary, 1983).

Biochar can help plants access nutrients and prevent them from just being lost by leaching, which promotes plant growth in a wide range of soil types. This suggests that using biochar in acidic soil might help to increase soil pH and lessen Al's toxicity using the techniques indicated above. The effects of applying lime to biochar may be further improved because liming allows the acidic functional units in the biochar to be separated. These functionally separated groupings might nonetheless hold on to cations. However, right after applying biochar, the pH of the soil in the rhizosphere may drastically rise, causing nitrification and the volatilization of nitrogen. Additionally, past studies have shown that adding lime to acidic soil improves soil pH while also increasing soil CO_2 emission. The rates of lime and biochar application must be established for large-scale field biochar application. Some other limiting element that prevents crop growth in acidic soils is phosphorus fixation. According to (Zhang et al., 2014) due to phosphorus' lower availability in the soil, about 30% of the world's arable croplands is affected by the phosphorus insufficiency. There are two basic ways to introduce the stable phosphate to the soil solutions. First an increase in soil pH would neutralize proton binding sites on mineral surfaces, which might decrease the positive soil surface areas. Second, enhancing the interactions of fixed phosphate with other soil components that compete with it (such as organic matter, nutrients with negative charges, etc.) may also aid in the addition of immovable phosphate to the soil solution. Applications of biochar may boost phosphorus bioavailability and plant phosphorus absorption by assisting both processes.

The effect of biochar soil acidity and plant performance has been investigated in the past. These research discovered that the productivity of maize was significantly impacted by lime and biochar. Though, these studies was conducted in pots and only a slight number of plants and soil were used. Because of the connections of biochar and plants with a wide volume of soil, variations in nutrient outputs, inputs and environmental factors, the situation crucial to consider the simultaneous application of biochars under field circumstances. These interactions might be very different from those of biochar and lime with soils in pot culture. The study's objective was to evaluate how well maize performed following the application of charcoal with lime and various P fertilizer rates. Additionally, we provide information on changes in soil characteristics and CO_2 emissions.

Biochar enhances microbial activity and abundance when added to soil (Lehmann et al., 2011; Chan et al., 2008; Ameloot et al., 2013a). Soil microbial communities exhibit a response to biochar application (McCormack et al., 2013; Ameloot et al., 2013b). The physicochemical properties of the soil, including humus formation, decomposition of organic matter, transformation of soil substances, and nutrient cycling, are closely linked to soil microorganisms (Fierer, 2017). Moreover, since soil microorganisms are sensitive to changes in the environment, the community composition, diversity, and dynamics of soil microbes can serve as key indicators for evaluating soil quality and fertility (Jeffries et al., 2003; Luo et al., 2016).

Soil related issues are one of the most significant obstacles to agricultural production in Pakistan. Poor land resource management raises the threat, resulting in desertification and decreased output. Certain consequences of land loss are more drastic in term of manifestation. To boost soil productivity and sustainability, several method and approaches have been used, with biochar being the most successful. The level of decomposition of organic materials in soil is far too high. As a result, biochar is better soil management option. Because of its considerable recalcitrance, biochar can last for several years in the soil.

Biochar have the capacity to increase soil fertility and offer protection against several soil borne diseases and foliar biochar has the potential to increase agricultural production by restoring degraded soils. In the agriculture industry, biochar is utilized as a supplemental organic fertilizer to chemical fertilizer for sustainable crop cultivation because of its exceptional agronomic qualities and yield potential in degraded, poor soils. The water-holding capability, nutrient availability and biomass of crops are all said to be enhanced by biochar.

Matarial and Methods

Outline of study area

The research was carried out in Uthal, located in the Lasbela district of Balochistan Province, along the southern coast of the Arabian Sea. Lasbela is bordered by Khuzdar District to the north, Sindh Province to the east, the Arabian Sea to the south, Gwadar District to the west, and Awaran District to the northwest. The district’s landscape mainly consists of expansive sandy plains, interspersed with hilly areas. The coastal region is marked by numerous shallow-water bays and creeks. Lasbela is also known for its small towns and villages, which are predominantly fishing communities. The climate in Lasbela reflects the characteristics of a tropical hot and dry environment. Winters, lasting about three months (December to February), are mild due to the district’s coastal location. Summers are hot and dry, but continuous winds help to keep the temperatures moderate and relatively comfortable.

The study area in Lasbela district, Balochistan, lies at an elevation ranging from 0 to 1494 meters above mean sea level (MSL). The district generally experiences hot summers and mild winters. However, the coastal areas, which include towns like Somiani, Hub, and Gaddani, are more temperate and humid compared to the inland regions. Summer spans from April to October, with June being the hottest month. The winter season lasts from November to March, with January being the coldest month, while February and March have milder weather. The northwestern wind, locally known as “Gorich,” blows from October to February, growing stronger as the cold season ends. This wind turns extremely hot during April and May, known then as “Liwar.” Annual rainfall is irregular, with most precipitation occurring in the summer months. In January, the average maximum and minimum temperatures are about 17°C and 3°C, respectively, while in June, these rise to above 38°C and 24°C.

Biochar Production

Rice straw was sourced from various locations and used to produce biochar. The material was air-dried and ground prior to biochar production. After grinding, the material was placed in a biochar production tank and heated for a duration of three hours. Once the rice husk biochar was produced, it was collected from the tank and stored in plastic bags. This experiment was carried out in the Department of Soil Science at Lasbela University of Agriculture, Water and Marine Sciences in Uthal, Lasbela, Balochistan.

Pot Preparation

The experiment took place in the Department of Soil Science at Lasbela University of Agriculture, Water and Marine Sciences in Uthal, using a Completely Randomized Design (CRD). Six treatments, each in triplicate, were included in the study. Soil samples were collected, air-dried, and then ground. The samples were further dried at 65ºC until a constant weight was achieved. One type of biochar, derived from rice straw, was applied to the soil at different rates of 1%, 3%, 5%, 7%, and 9%. No biochar was added to the control treatment. The experiment involved three replications. The effects of biochar on various soil properties including pH, electrical conductivity, organic matter content, total nitrogen, available potassium, available phosphorus, available zinc, and available iron were analyzed after the first, second, and third months following the application.

Soil sampling and Soil analysis

After crop harvesting, soil samples were collected from each pot using a soil auger and stored in plastic bags, which were then labeled appropriately. The samples were subsequently transferred to the Soil Science Department at Lasbela University of Agriculture, Water, and Marine Sciences, Uthal, Baluchistan, for nutrient availability analysis. Prior to testing, the soil samples were air-dried at room temperature and sieved through a 2mm sieve. The following properties were analyzed: soil pH, electrical conductivity (EC), soil organic matter (OM), available phosphorus, potassium, total nitrogen, zinc, and iron. Soil pH was measured using a calibrated glass electrode pH meter in a 1:5 soil-to-water suspension after shaking for 30 minutes. Electrical conductivity was assessed using a calibrated EC meter in the same soil-water ratio. The Walkley-Black method, as outlined by Jackson (1967), was employed for soil organic matter determination, where chromic acid (sulfuric acid and potassium dichromate) was used for oxidation, followed by back titration with ferrous sulfate or ferrous ammonium sulfate. Available phosphorus was determined using Olsen’s method (1954), which involved extracting 2.5 g of soil with 0.5 M sodium bicarbonate at pH 8.5. Phosphate in the extract was measured by reacting it with ammonium molybdate in an acid medium to form a blue-colored complex with ascorbic acid, and absorbance was detected at 882 nm using a spectrophotometer. The concentration of potassium was measured using the ammonium acetate extraction method, with potassium extracted by shaking, filtration, or centrifugation of 5 g of soil, followed by quantification with a flame photometer, as per Jackson (1967). Total nitrogen content was measured using the Kjeldahl digestion method, followed by distillation and titration, with organic materials oxidized in concentrated sulfuric acid (0.1 N H_2SO_4), as described by Black (1965).

Soil Micronutrient Analysis

Soil available micronutrients, specifically zinc (Zn) and iron (Fe), were extracted using a DTPA solution. This solution consisted of 1.97 g of diethylene triamine pentaacetic acid (DTPA), 1.10 g of calcium chloride ($CaCl_2$), and 14.92 g of triethanolamine (TEA) in 1,000 mL of water. The pH of the solution was adjusted to 7.3 using 6 N hydrochloric acid, following the method outlined by Lindsay and Norvell (1987). The concentrations of micronutrients in the extracts were then measured using Atomic Absorption Spectroscopy (AAS).

Calculation and Statistics

A one-way analysis of variance (ANOVA) was conducted to compare the treatment and control means, utilizing the IBM Statistical Package for Social Sciences (SPSS 20.0). Duncan’s Multiple Range Test was used to separate the means, with the level of significance set at $P<0.05$.

Results and Discussion

Maize is the important cereal and fodder crop of Pakistan. It is cultivated all over the country due to its nutritional contents and multiple uses. Biochar has to be proven to increase the productivity and yield of several crops. Therefore, the research was conducted to evaluate the effected of rice husk biochar on nutrient availability of soil along with crop growth and fodder yield.

Electrical conductivity (EC) of soil (ds/m^{-1})

The electrical conductivity, (EC) of soil is a measurement of its salts content. It is a good determinant of accessible water capacity, soil texture, and nutrient availability and loss**.** The results showed the significant impact of biochars treatments on EC of soil. The influence of different doses of rice husk biochar on EC of soil is represented in Figure 4.1. Maximum EC of soil was observed in case of 9% rice husk biochars (1.75 ds m^{-1}), followed by 7% rice husk biochars (1.65 ds m^{-1}), 5% rice husk biochar (1.41 ds m-^{1}), 3% rice husk biochars (1.39 ds m^{-1}) and 1% rice husk biochar (1.36 ds m^{-1}). The lowest EC of soil was observed in case of control (1.29 ds m^{-1}). Soil EC is positivity affected by rice husk biochar application in dose dependent manner. This might be due to increases in ash content of soil after application of biochar (Abrishamkesh *et al.*, 2015). The increase in soil EC might be due to addition of soluble slats and release of soluble elements by biochar (Ghorbani & Amirahmadi, 2018).

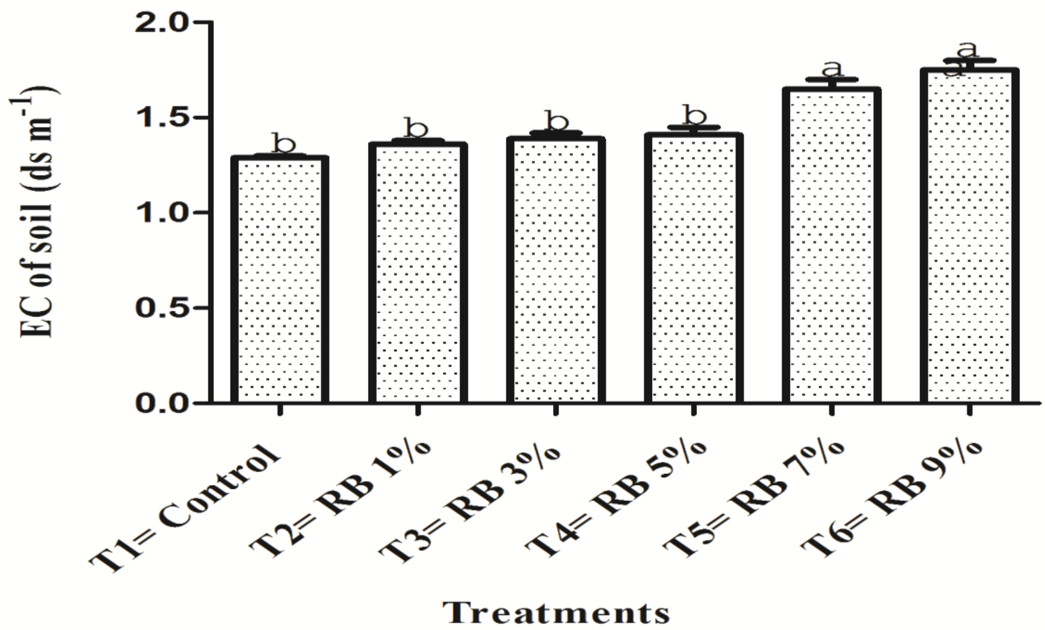

Figure 4.1: Effects of different doses of rice husk biochar on EC of soil

pH

The pH of soil is important factor that affects the plant health. The availability of nutrients and other soluble materials in soil water, which can be absorbed by plants, is influenced by the soil's pH. Certain nutrients become more accessible in acidic conditions, while others are more readily available in alkaline environments. The results showed the significant impact of biochar treatments on pH of soil. The influence of different doses of rice husks biochar on pH of soil is represented in Figure 4.2. Maximum pH of soil was observed in case of 9% rice husk biochar (8.34) whereas lowest pH of soil was observed in case of control (7.4). Soil pH was positively affected by biochar application. The increase in soil pH was noted after the application of biochars as compared to control. This might be due to inherent alkalinity property of rice husk biochar. Our results were supported by findings of Ducey *et al.* (2013) who observed the increase in soil pH after biochar application. Li *et al.* (2016) also reported that the major cause of increase in pH of soil is due to ash content of rice husk biochars which are dominated by alkali earth metals, alkaline carbonates, and organic anions. Moreover, high CEC of biochar amended soil results in increase of soil pH (Masulili *et al.*, 2010). According to Lehmann *et al*. (2012), the increases in soil pH caused by the application of biochars was typically related to ash accretion because ash residues are typically predominately composed of silica and alkaline earth metals and carbonates of alkali. Accordingly, Arocena & Opio, (2003) reported that ashes have the ability to neutralize acidic soil. According to Utomo *et al*. (2011), the alkaline character of biochar may be the cause of the rise in soil pH following biochar applications. Another explanation for the rise in soil pH following application of biochar may be its porous nature and large surface area which increase the CEC of soil (Nigussie *et al.,* 2012).

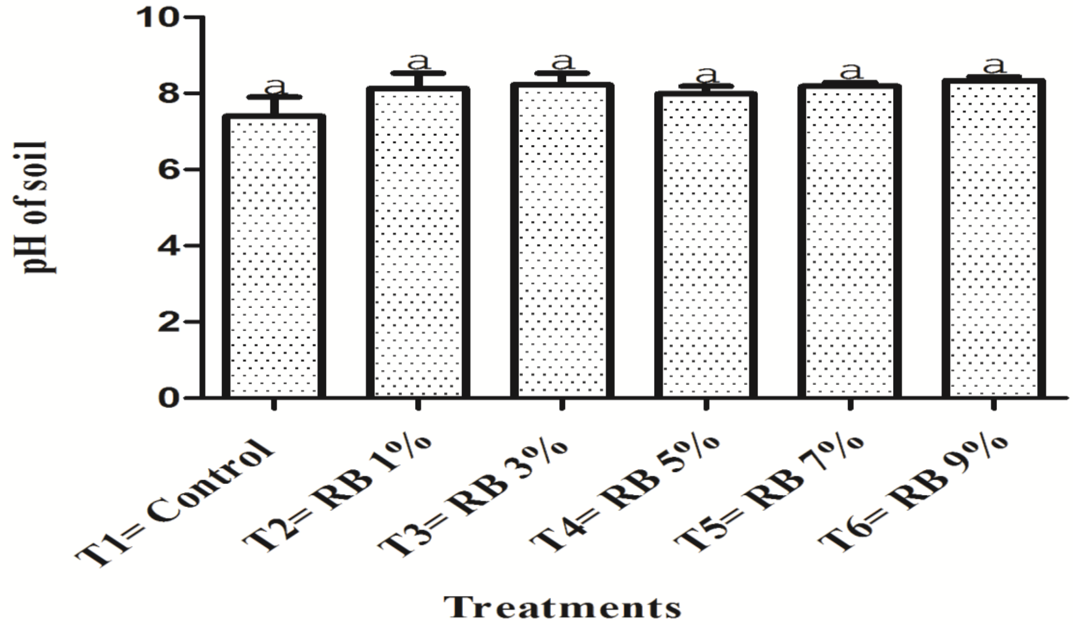

Figure 4.2: Effects of different doses of rice husk biochar on pH of soil

Organic matter of soil

The ability of soil to retain harmful substances and supply essential nutrients such as nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), and calcium (Ca) is greatly enhanced by soil organic matter. It accelerates the breakdown of soil minerals and allows the soil to better adapt to changes in acidity. The results demonstrated a significant effect of biochar treatments on soil organic matter. Figure 4.3 illustrates the impact of various rice husk biochar doses on the organic content of the soil. The highest organic matter content was observed with the 9% rice husk biochar treatment (2.5%), followed by 7% (2.3%), 5% (2%), 3% (1.4%), and 1% rice husk biochar (1.35%). The lowest organic matter content was found in the control (0.93%). Rice husk biochar application increased the organic content of the soil compared to the control. The higher organic matter content in the soil is attributed to the decomposition process facilitated by bacteria present in the biochar. Several studies have shown that hybrid maize cob biochar can also be added to soil to improve organic matter levels, which is beneficial for plant growth (Rodriguez et al., 2019; Rahayu et al., 2021).

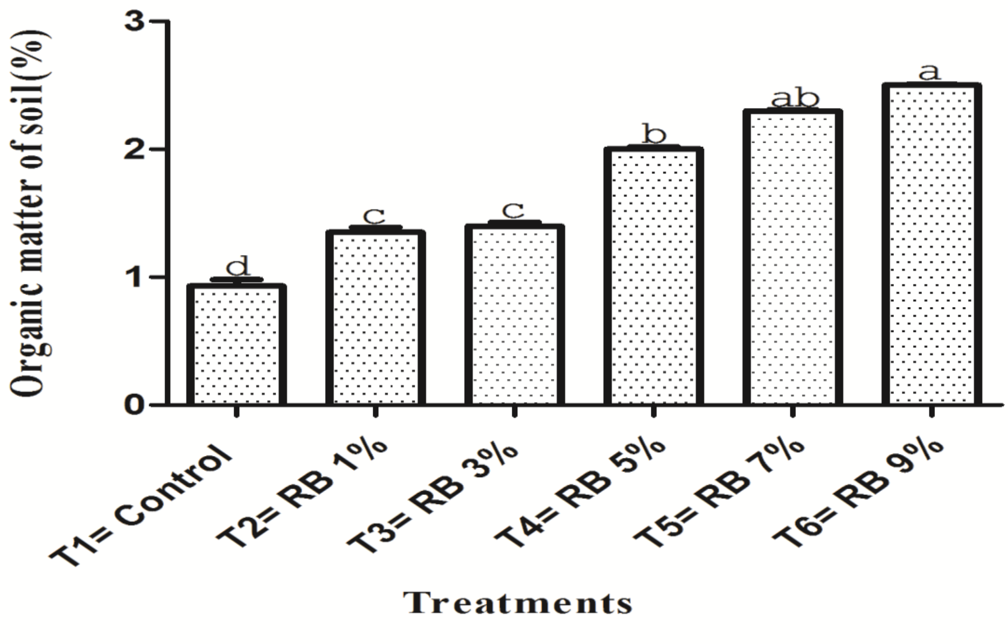

Figure 4.3: Effects of different doses of rice husk biochar on organic matter

Available Phosphorus (mg/Kg)

Phosphorus plays a key role in plants by transporting and storing energy derived from photosynthesis, which is then used for growth and reproduction. Sufficient phosphorus levels promote tillering, enhance root development, improve winter hardiness, and speed up the plant's maturity. The results showed the significant impact of biochar treatments on available phosphorus of soil. The result of different doses of rice husk biochar on available phosphorus is represented in Figure 4.4. Maximum available phosphorus in soil was observed in case of 9% rice husk biochars (24.3 mg/Kg), followed by 7% rice husk biochar (20.3 mg/Kg), 5% rice husk biochar (16.4 mg/Kg), 3% rice husk biochar (14.56 mg/Kg) and 1% rice husk biochar (12.76 mg/Kg). The lowest available phosphorus was observed in case of control (7.41 mg/Kg). The amount of soil available phosphorus determines the degree of soil phosphorus nutrient supply, and its composition affects the soil's ability to store and provide phosphorus. This study demonstrated that biochar can increase soil available phosphorus, most likely because straw biochar improves soil phosphorus retention. Additionally, Romdhane *et al.* (2019) also reported the biochar increased soluble phosphorus. Prendergast-Miller *et al.* (2011) also observed the increase in soil available phosphorus after straw biochar application. The increase in soil available phosphorus was might be due to high phosphorus contents of biochar. Moreover, the biochar treated soil high phosphorus contents as compared to control. This could be because biochar stimulates the conversion of organic phosphorus into available phosphorus which is released into the soil. Related results were reported by Jing *et al.*, (2020) who observed the increases in phosphorus in biochar amended soils.

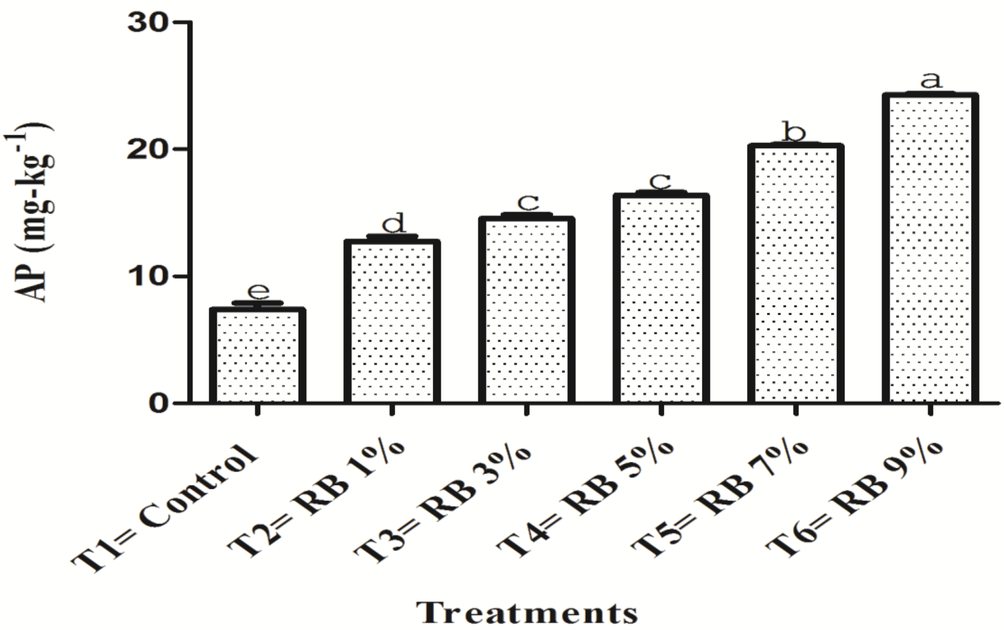

Figure 4.4: Effects of different doses of rice husk biochar on available phosphorus

Available Potassium (mg/Kg)

Potassium is the most abundant inorganic cation and is vital for supporting healthy plant growth. It activates several important enzymes involved in processes such as sugar transport, protein synthesis, nitrogen and carbon metabolism, as well as photosynthesis. The results showed the significant impact of biochar treatments on available potassium of soil. The influence of different doses of rice husk biochar on available potassium is represented in Figure 4.5. Highest available potassium was observed in case of 9% rice husk biochar (170 mg Kg), followed by 7% rice husk biochar (150 mg Kg), 5% rice husk biochar (135 mg Kg), 3% rice husk biochar (120 mg Kg) and 1% rice husk biochar (105 mg Kg). The lowest phosphorus was observed in case of control (73.82 mg Kg). The soil available potassium contents were high in biochar added soil as compared to control. The high ash concentration of biochar may be responsible for the increased availability of potassium in the biochar-amended soils. Higher potassium availability in the biochar-amended soils might result from the rapid release of potassium from the ash. Abrishamkesh *et al.* (2015) also observed the increase in soil potassium after the application of rice husks biochar.

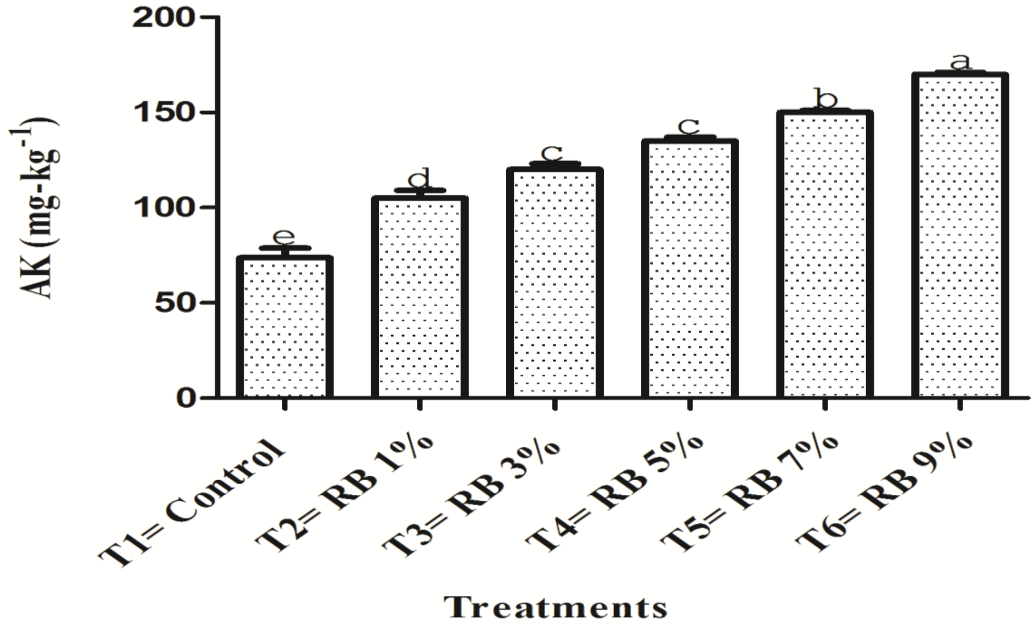

Figure 4.5: Effects of different doses of rice husk biochar on available potassium

Total Nitrogen (g/Kg)

Nitrogen is the important component for boosting crop yields in all crops. It is crucial for plant development, food processing, and chlorophyll production. The plants cannot create enough food or grow taller without enough nitrogen in it. The results showed the significant impact of biochar treatments on total nitrogen. The result of different doses of rice husk biochar on total nitrogen is represented in Figure 4.6. Highest total nitrogen was observed in case of 9% rice husk biochar (0.17 g/Kg), followed by 7% rice husk biochar (0.15 g/Kg), 5% rice husk biochar (0.13 g/Kg), 3% rice husk biochar (0.11 g/Kg) and 1% rice husk biochar (0.07 g/Kg). The lowest was observed in case of control (0.03 g/Kg). The results indicated that the biochar applications improved the soil total nitrogen. The application of soil biochar change the pH, oxygen content, soil moisture, and microbes of soils which affects and alter the nitrogen contents of soil. In the present study, adding biochar to the soil enhanced nitrogen contents which may be connected to the properties of the straw-based biochar (Wang *et al.,* 2015). Rice biochar is an allogeneic substance which elevated the nitrogen level of soil. Similar results were reported by Jing *et al.* (2020) because biochar may have an indirect impact on the concentration of soil nitrogen by bolstering the microbial communities. El-Naggar *et al.* (2018) observed that the applications of rice biochar raised the concentration of total nitrogen in soil.

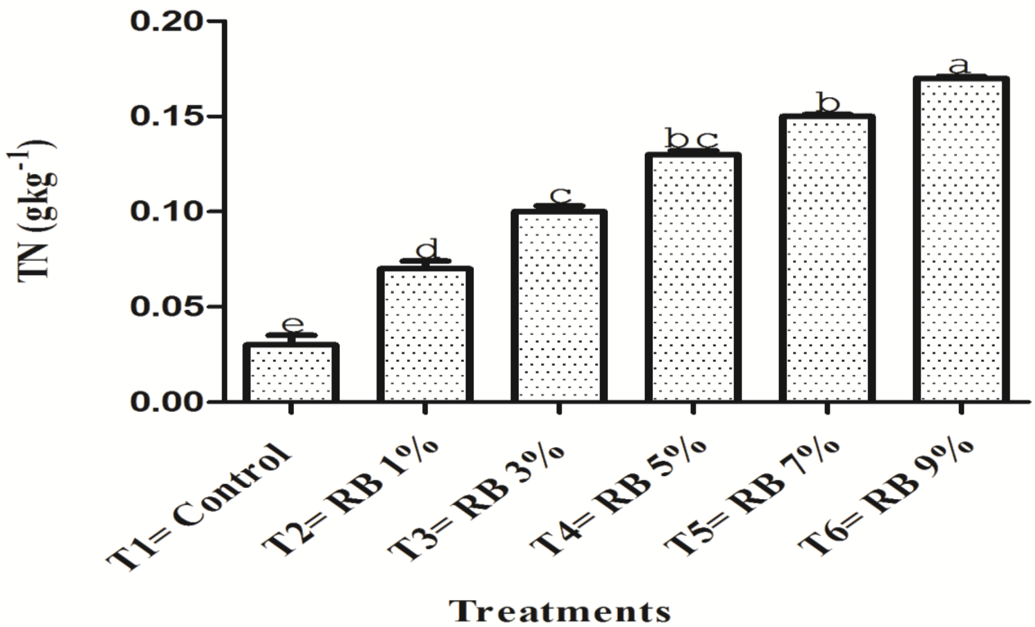

Figure 4.6: Effects of different doses of rice husk biochar on total nitrogen

Available Fe (mg/ kg)

Iron is essential for chlorophyll production and photosynthesis in plants. Soil iron availability influences the distribution of plant species in natural ecosystems and also limits crop productivity and nutrient quality. The results showed the significant impact of biochar treatments on available Fe. The influence of different doses of rice husk biochar on available Fe is represented in Figure 4.7. Highest available Fe was observed in case of 9% rice husk biochar (55 g/Kg), followed by 7% rice husk biochar (50 g/Kg), 5% rice husk biochar (48 g/Kg), 3% rice husk biochar (46 g/Kg) and 1% rice husk biochar (43 g/Kg). The lowest was observed in case of control (40g/Kg). The increases in soil Fe after biochar application was might be due to decomposition of biochar which released micronutrients and chelating soluble organic compounds. Our results are similar to finding of Rasuli *et al.* (2022) who noted the increase in Fe after biochar application.

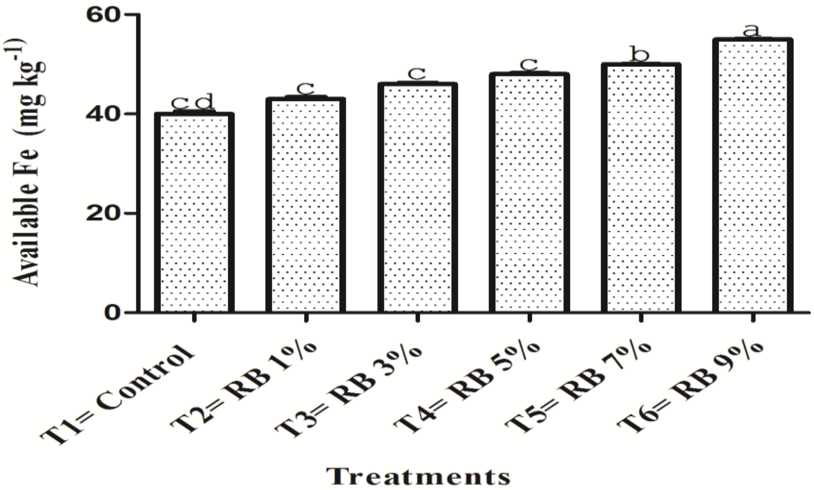

Figure 4.7: Effects of different doses of rice husk biochar on available Fe

Available Zinc (mg/Kg)

The results showed the significant impact of biochar treatments on available Zinc. The influence of different doses of rice husk biochar on available Zinc is represented in Figure 4.8. Highest available Zinc was observed in case of 9% rice husk biochar (16 g/Kg), followed by 7% rice husk biochar (13 g/Kg), 5% rice husk biochar (11 g/Kg), 3% rice husk biochar (10 g/Kg) and 1% rice husk biochar (9 g/Kg). The lowest was observed in case of control (8g/Kg). Applications of rice husk biochar increased the available Fe and Zn in soil. Vahedi *et al.* (2022) reported the increase in phosphorus, Fe and Zn in the soil when compared to non-biochar treatments. Karimi *et al.* (2020) also observed the increases in soil available Zn after biochar application.

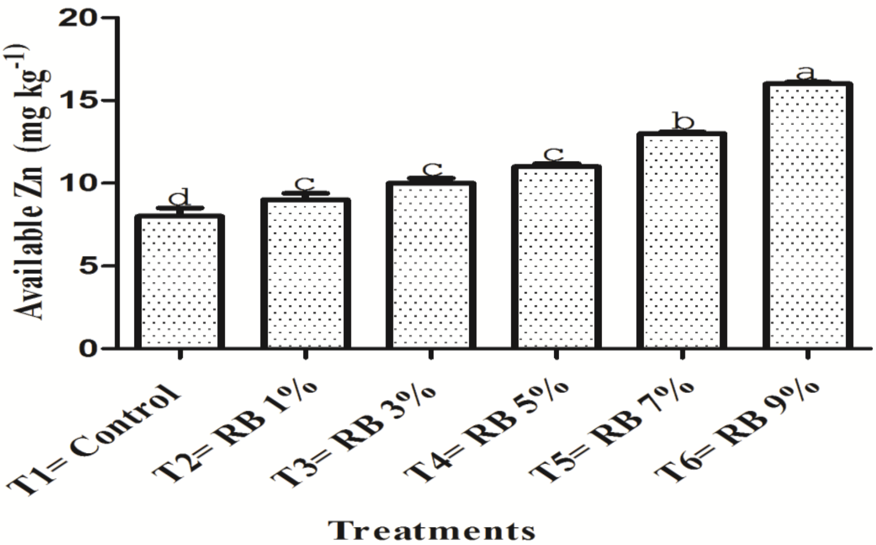

Figure 4.8: Effects of different doses of rice husk biochar on available Zinc

Plant Height (cm)

Plant height is one of the most important vegetative character which affects the yield of crop. The effect of different doses of rice husk biochar on crop height of maize is represented in Figure 4.9. The results showed the significant impact of different doses of rice husk biochar on height of maize crops. Maximum plant height ware observed in case of 9% rice husk biochar (120 cm), followed by 7% rice husk biochar (114 cm), 5% rice husk biochar (104 cm), 3% rice husk biochar (94 cm) and 1% rice husk biochar (84 cm). The lowest plant height was observed in case of control (45.6 cm). Plant height is important character in determination of growth and development. The application of Rice husk bio char enhanced the growth of plant. This might be due to that the application of biochar enhances the nutrient availability in soil which improves the plant height. Related effects were reported by Rahayu *et al.* (2022) who reported that applications of rice husks biochar enhance the height of maize as compared to control. The applications of biochar alter the soil composition and enhance the growth of plant. The uses of biochar promote plant development and retain nutrients in the soil, both of which have an impact on plant growth (Kurniawan *et al.* 2016). The higher dose of rice husk biochars proved to be effective in increasing plant growth. Githinji, (2014) reported that the elevation in soil Organic carbon content and subsequent increase in plant development are directly correlated with biochar dose.

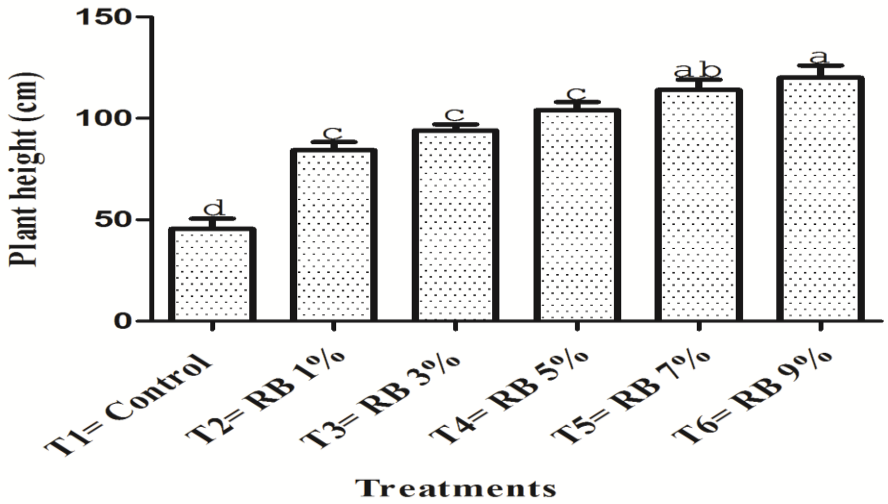

Figure 4.9: Effects of different doses of rice husk biochar on height of maize plant

Fresh Plant Weight (g)

The fresh weight is the gross weight of a substance including the water content. Plant weight is an important characteristic to determine and evaluate the growth. The effects of different doses of rice husk biochars on fresh plant weight is represented in Figure 4.10. The results showed the significant impact of different doses of rice husk biochars on fresh plant weight. Maximum plant fresh weight was observed in case of 9% rice husk biochars (100 g), followed by 7% rice husk biochar (95 g), 5% rice husk biochar (81 g), 3% rice husk biochar (76 g) and 1% rice husk biochar (64 g). The lowest plant fresh weight was observed in case of control (33 g). One of the metrics used to describe the mechanism of photosynthesis is the fresh weight of plants. High fresh weights show that the photosynthetic process is working effectively and that assimilate is accumulating. The rise in fresh weight of plants will depend on the degree of asymptotic hoarding (Zhang *et al.*, 2014). Comparable results were reported by Major *et al.* (2010). The maximum fresh weight was produced by the higher biochar dosage. This shows that adding organic matter to the soil may improve its ability to absorb water and may facilitate the uptake of additional chemical fertilizers. Optimal nutrient uptake will boost the plant's last stage of photosynthesis, which will then be transferred to all of its organs to produce moist biomass (Zhang *et al.,* 2014).

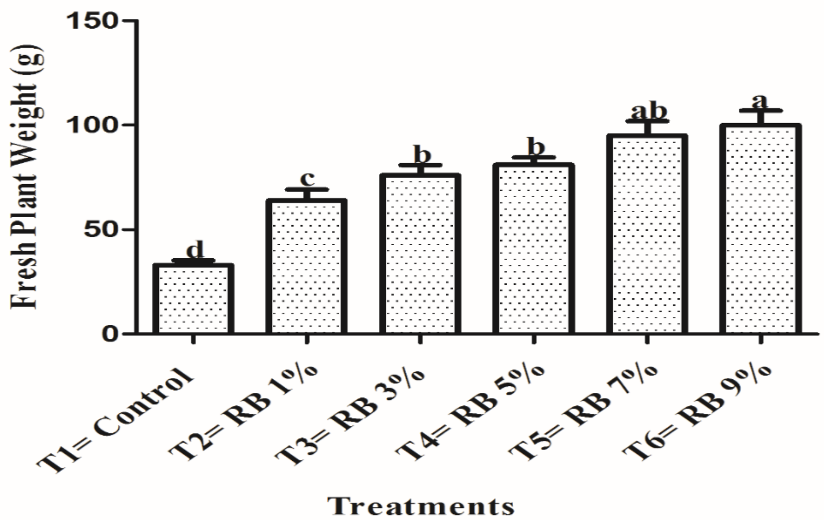

Figure 4.10: Effects of different doses of rice husk biochar on fresh plant weight

Dry Plant Weight (g)

Measurement of dry plant weight is highly helpful and accurate technique when trying to assess crop performance, especially following the application of any treatments intended to increase yield or quality. It helps to measure the growth and bio mass by eliminating the water content. The results showed the significant impact of biochar treatments of dry plant weight. The influence of different doses of rice husk biochar on dry plant weight is represented in Figure 4.11. Maximum plant dry weight was observed in case of 9% rice husk biochars (80 g), followed by 7% rice husk biochar (74 g), 5% rice husk biochar (65 g), 3% rice husk biochar (51 g) and 1% rice husk biochar (41 g). The lowest plant dry weight was observed in case of control (15.66 g). The efficacy of the photosynthetic process is evaluated by the dry weight of plants as it impacts the growth of maize. Dry weight of the plant has an impact on the growth of maize crops because it reveals the nutrients and moisture content utilized in plant metabolism (Rahayu *et al.*, 2022). The applications of biochar with the appropriate dose in plants enhances d the plant biomass. This might be due to increases in microbial activities in soil (Warnock *et al.*, 2017).

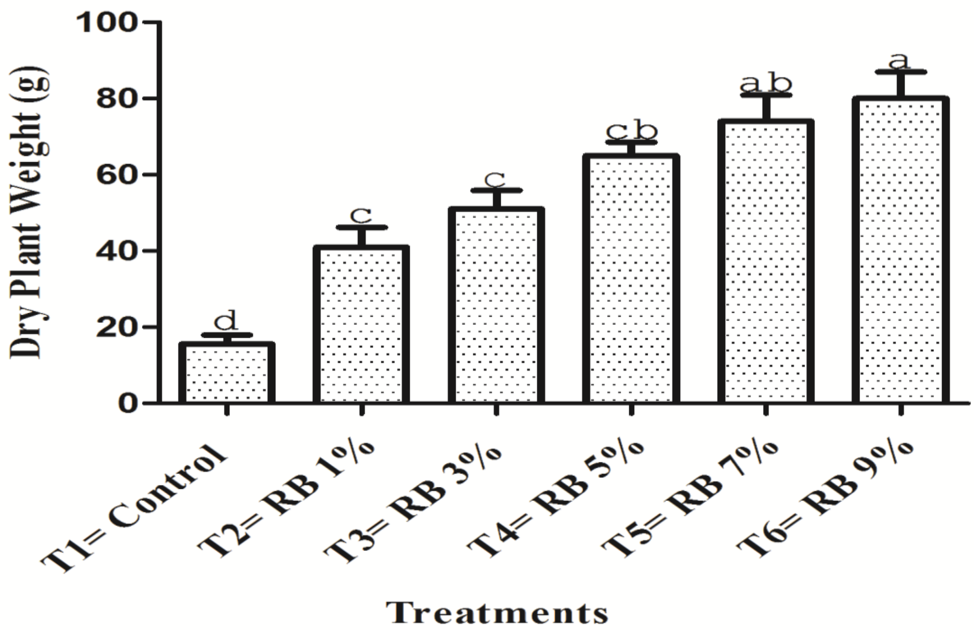

Figure 4.11: Effects of different dosses of rice husk biochar on dry plant weight

Root Fresh weight (g)

The results showed the significant impact of biochars treatments of root fresh weight. The influence of different doses of rice husk biochars on root fresh weight is represented in Figure 4.12. Maximum root weight was observed in case of 9% rice husk biochars (16.23 g), followed by 7% rice husk biochar (12.33g), 5% rice husk biochar (10.66 g), 3% rice husk biochars (9 g) and 1% rice husk biochars (8 g). The lowest root weight was recorded in case of control (3g). The root biomass is important factor in determination of biochar efficiency. Most important plant organ which is crucial in sustaining the vitality of the plant is the root. Rice husks that have been converted to biochar can help in boosting the topsoil water-holding capacity. This positively affects the growth of fresh and dried root weight (Islam *et al*., 2018). The nutrient components in biochar are essential for plant development. Nitrogen content encourages plant development especially that of roots, branches, and leaves (Bahri *et al.,* 2018).

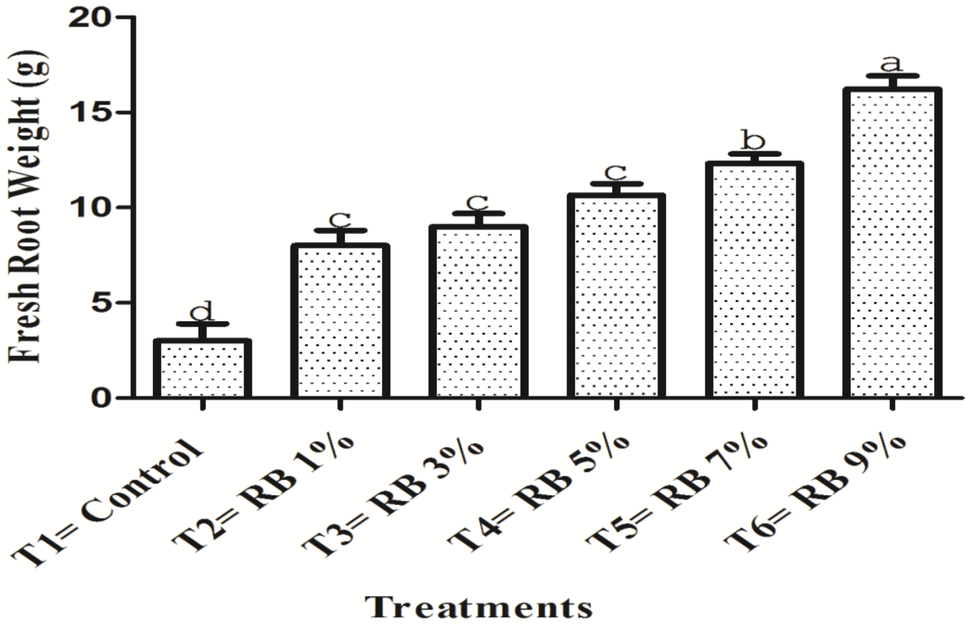

Figure 4.12: Effects of different doses of rice husk biochar on root fresh weight

Root Dry weight (g)

The results showed the significant impact of biochar treatments of dry root weight. The effect of different doses of rice husk biochars on dry root weight is represented in Figure 4.13. Maximum root weight was observed in case of the 9% rice husk biochar (9.34 g), followed by 7% rice husk biochar (5.3 g), 5% rice husk biochar (4.5 g), 3% rice husk biochar (3g) and 1% rice husk biochar (3 g). The lowest root weight was recorded in case of control (1 g). Adding biochar to the soil has resulted in an increase in root biomass (Yamato *et al.*, 2006). Biochar has been shown to alter physico chemical characteristics of the soil which may have an impact on root biomass (Lehmann *et al.*, 2011). Our study results was in agreement with finding of Abrishamkesh *et al.* (2015) who stated that the application of rice husk biochar enhanced the root growth of lentils.

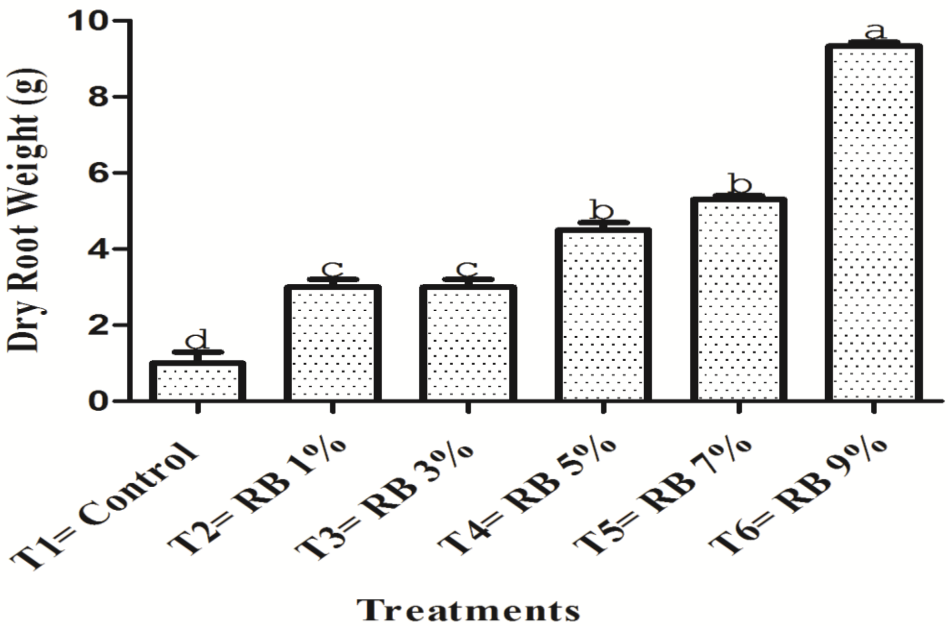

Figure 4.13: Effects of different doses of rice husk biochar on root dry weight

Conclusion

The results of study indicated that the biochar applications improved the soil properties (pH, Ec, organic matter, available potassium, available phosphorus, total nitrogen, available Zn and available Fe) as well as plant growth (Height, fresh plant weight, dry plant weight, fresh root weight and dry root weight) as compared to control. Among different doses rice husk biochar, 9% dose proved to be most effective.

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