

BIOCHAR EFFECT ON SEED GERMINATION AND GROWTH OF MONOCOTS IN SPENT-OIL-CONTAMINATED SOIL

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ABSTRACT. *Plant health and growth are adversely affected by soil pollutants released from indiscriminate anthropogenic activities. Biochar application amends and fertilizes polluted soils for improved crop productivity. A pot experiment was conducted to investigate the effect of biochars derived from rice and sorghum straws applied at different rates (1, 2, and 3 % w/w) on the germination and early growth of Zea mays and Pennisetum glaucum in spent-oil contaminated soil. Biochars significantly increased the seed germination percentages and chlorophyll contents of Zea mays and Pennisetum glaucum. Seeds planted in soil amended with rice straw-derived biochar (RB) had the highest seed germination. Morphometric parameters, including height and leaf area, were higher for Zea mays on biochar-amended soil when compared to untreated soil. In conclusion, the 3% rate of rice biochar recorded the highest values for seed germination, chlorophyll content, growth parameters, and biomass of the studied plants. Hence, this rate is considered a suitable application rate for the growth of Zea mays and Pennisetum glaucum.*

KEYWORDS: *biochar, Pennisetum glaucum, seed germination, seedling growth, Zea mays*

INTRODUCTION

Plants are continuously exposed to environmental pollutants that harmfully

alter their physiological and metabolic processes and ultimately limit their yield (Kalaivanan & Ganeshamurthy 2016). One of the sources of pollutants responsible for the negative impact on crop production is spent lubricating oil, which is being let out into soils without a curb. This has a deleterious effect on crops, inhibiting seed germination and causing water loss and chlorosis of foliage (Guo et al. 2008, Mohanpuria et al. 2007). Ubuoh et al. (2016) confirmed the adverse impact of oil on the growth and biomass yield of *Panicum maximum*. Nwite and Alu (2015) also confirmed the negative effect of spent oil on maize. Adu et al. (2015) reported that soil contamination with used and unused engine oil could negatively influence the vascular network of the *Vigna unguiculata* growing in such an environment due to the harmful content of the oil.

Pennisetum glaucum (L.) R. Br. (Pearl millet) is a cross-bred monocot belonging to the family *Poaceae* (Satankar et al. 2020), and *Zea mays* L., a versatile, annual, and fast-growing cereal that belongs to the tribe *Maydeae* of the family *Poaceae* (Gul et al. 2021). Humans consume these crops as food due to their high nutritional qualities (Tian et al. 2019, Yadav et al. 2016), and their grains are served as feed for animals (Ahamefule et al. 2014). They can grow well in a wide range of climatic and extreme conditions (Gheith et al. 2022, Satankar et al. 2020). Early seedling growth is necessary for the plant's survival and production (Carvalho et al. 2016) to achieve increased yield to meet the high demand for food crops. This can be enhanced by integrating biochar into the soil, which has gained attention worldwide for soil improvement and boosting crop production (Das et al. 2020). Biochar is a carbon-rich substance formed from the pyrolysis of organic materials with little or no oxygen (Lehmann & Joseph 2009). Biochar application enhances seedling growth due to its porosity and presence of soluble nutrients, which helps in the soil water-holding capacity and nutrient availability (Bu et al. 2020). Biochar as an amendment agent for soil boosts crop growth and yield by improving the physico-chemical and biological properties of the soil (Shaaban et al. 2018) and wheat growth (Bu et al. 2019) exposed to toxic substances. Uslu et al. (2020) regarded biochar as an effective sorbent that can adsorb phytotoxic substances such as heavy metals that threaten plant health and seed germination. Most studies revealed that biochar application improved the early growth of seedlings and crop growth (Anyanwu et al. 2018, Das & Avasthe 2018) under acidic conditions than alkaline or saline soil (Das et al. 2020). In addition, studies have been conducted to determine the effect of biochar on the germination and seedling growth of various

plants. Generally, positive (Das et al. 2020, Oh et al. 2012, Saxena et al. 2013) and neutral (Free et al. 2010, Gascó et al. 2016, Sun et al. 2014) and negative (Das et al. 2017, Uslu et al. 2020) effects of biochars were observed. Solaiman et al. (2012) reported a dose-dependent negative effect on germination and seedling growth. The differences in the biochar result in plant growth depend on factors like biochar quality, application rates, soil type, and crop type (Kanwal et al. 2018, Rawat et al. 2019).

Several studies have been conducted on the integration of biochar into soil concerning its functions in plant health and soil (Alburquerque et al. 2013, Oh et al. 2012), and few research has been conducted on the effect of biochar on seed germination and early growth of plants in soil (Uslu et al. 2020). However, little or no study has been conducted on the impact of biochar on seed and early growth of monocots exposed to contaminated sites, spent oil in particular. Therefore, the study's objective is to assess the effect of the different concentrations of biochar from different feedstocks on the germination and early growth of *Pennisetum glaucum* and *Zea mays* L grown in spent oil-contaminated soil.

MATERIAL AND METHODS

Experimental design

The pot experiment was set up in a greenhouse in the Botanical Garden of the University of Ilorin, Ilorin, Kwara State, Nigeria. The soil was spiked with spent engine oil with a fraction of 50 ml/kg (5% v/w) and was left for two weeks for integration. Each polyethylene pot (diameter- 19cm and height- 23cm) filled with polluted soil was mixed with fractions of 30g/3kg (1% w/w), 60g/3kg (2% w/w), and 90g/3kg (3% w/w) of different biochars (Standard biochar, rice straw biochar, and sorghum straw biochar) following the International Biochar Initiative (IBI) guideline (application rate of 2.5% equivalent to 50 t/ha) (IBI, 2015) and irrigated with tap water to make 60% water holding capacity (i.e., the field water capacity of the soil) according to Jien and Wang (2013). The seeds of *Zea mays* and *Pennisetum glaucum* were collected. The choice of these plants was based on their availability and tolerance to unfavorable conditions, according to Gheith et al. (2022) and Satyavathi et al. (2021). A viability test was conducted on the seeds using the floatation method (Anoliefo & Vwioko 1995). Ten (10) viable seeds of *Zea mays* and *Pennisetum glaucum* were sown per pot. The number of germinated plants was thinned to two plants per pot. Watering was done daily with 180 ml of tap water, and regular weeding was done by hand-picking. The experiment was arranged in a completely randomized design for a

discrete and perfect result. Each treatment was triplicate.

Data collection

The seed germination rate was calculated for day 7 after sowing. Germination percentage was calculated using the formula of Close and Wilson (2002):

$$\text{Germination percentage} = \frac{\text{Number of germinated seeds}}{\text{Number of seeds sown}} \times 100 \quad \text{Equ. (A 1.)}$$

The plants were harvested six (6) weeks after planting, and plant height was determined by measuring the length of the plant from the soil level to the collar of the uppermost leaf using the thread and meter rule (Okonokhua et al. 2007). The number of leaves was determined by counting the leaves per plant in each pot. Leaf area was determined by measuring a leaf's length and width (at the widest point) per plant. The products of the length and width were multiplied by a correction factor of 0.75 (Watt 1973). Stem girth was measured using Vanier Caliper. The shoot biomass was collected by cutting from the base of the plant stalks. The root biomass was manually and carefully separated from the potted soil and washed off soil and biochar particles with water (Rajkovich et al. 2012). Root length was measured with thread, which was later extrapolated on the ruler. The fresh weights of shoot and root biomass were measured on an electronic weighing balance (Mettler Toledo PL203) immediately after harvest. The dry weights of shoot and root biomass were air-dried to constant weight and weighed on an electronic weighing balance (Mettler Toledo PL203). Chlorophyll content was determined using the acetone incubation method (Makeen et al. 2007). Leaf tissue of plants (50 mg) was placed in a sample bottle containing 5 ml of 80% buffered acetone (80 ml of acetone made up to 100 ml with 20 ml of 2.5 ml sodium phosphate buffer, pH 7.8), and the sample bottle was placed under refrigeration for three days. The extracted liquid was filtered through glass wool to remove leaf pieces and transferred to another graduated tube. Absorbance was read using a UV/VIS spectrophotometer (Thermos scientific-Genesys10S) at a wavelength of 645 nm and 663 nm and was converted in mg g^{-1} using the formula of Arnon (1949):

$$\text{Chl } a \text{ (mg g}^{-1}\text{)} = [(12.7 \times A_{663}) - (2.6 \times A_{645})] \times \text{ml acetone/mg leaf tissue} \quad \text{Equ. (A 2.)}$$

$$\text{Chl } b \text{ (mg g}^{-1}\text{)} = [(22.9 \times A_{645}) - (4.68 \times A_{663})] \times \text{ml acetone/mg leaf tissue} \quad \text{Equ. (A 3.)}$$

Statistical analyses

One-way Analysis of Variance (ANOVA) was used to assess the significant

differences of the biochar treatments and Duncan's Multiple Range Tests ((DMRT) was used to check the level of the significant differences of biochar treatments based on growth parameters ($p \leq 0.05$). All statistical analyses were performed using the SPSS 21.0 Statistical Package.

RESULTS

Figure 1 shows the percentage rate of *Pennisetum glaucum* and *Zea mays* germination in soils treated with different rice and sorghum biochar concentrations. It was observed that the biochars improved the germination rate of *Pennisetum glaucum* and *Zea mays* compared to the control. There was an increasing germination rate of *Pennisetum glaucum* and *Zea mays* with increasing rice and sorghum biochars. However, the current study revealed that the germination rate of *Pennisetum glaucum* decreased with the increased application rate of standard biochar and vice versa for *Zea mays*. Rice and sorghum biochars increased the chlorophyll a and b content of *Pennisetum glaucum* and *Zea mays* (Table 1) compared to the control, and the studied plants treated with RB3% had the highest chlorophyll contents. Concerning plant height, the results from the present study (Table 2) revealed increased height in *Zea mays* and *Pennisetum glaucum*. It was observed that there was no significant impact of biochars on the number of leaves of *Zea mays* and *Pennisetum glaucum*. There was an increase in the leaf area of *Zea mays* grown on biochars compared to the control, while the leaf area of *Pennisetum glaucum* increased at 3% of all the biochars. Compared with the control, the stem girth of *Zea mays* was raised in the presence of rice and sorghum biochar, especially at a 3% rate of rice biochar. However, the control stem girth of *Pennisetum glaucum* was higher than the treated ones (Table 2)

Table 3 revealed that biochars improved the shoot biomass of *Zea mays* except StB1% compared to the control. However, the fresh root weight of *Zea mays* was not enhanced at 1% rates of standard and sorghum biochar. Also, the biochar treatments did not favor the root dry weight of *Zea mays* except SB2%. For *Pennisetum glaucum*, the shoot biomass was improved by 3% rates of the biochars, and root biomass was enhanced by all the biochars treatments (Table 4). Concerning root length, the studied plants responded positively to biochar application.

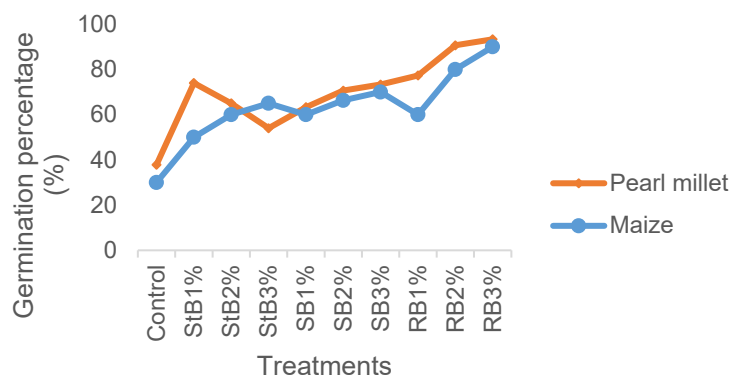


Figure 1 Germination rate of *Pennisetum glaucum* and *Zea mays* in control and soils treated with different concentrations of rice and sorghum biochars

Table 1. Effect of different concentrations of biochars on the chlorophyll content ($mg\ g^{-1}$) of *Zea mays* and *Pennisetum glaucum* (Values are presented as means \pm S.D of triplicate values. Values with different superscripts in the same column differ significantly at $p \leq 0.05$. Trts – Treatments; StB – Standard Biochar; SB – Sorghum Biochar; RB - Rice Biochar, Nd- Not determined)

Trts	Biochar rates (%)	<i>Zea mays</i>		<i>Pennisetum glaucum</i>	
		Chlorophyll a	Chlorophyll b	Chlorophyll a	Chlorophyll b
Control	0	0.27 \pm 0.06 ^{cd}	0.10 \pm 0.01 ^{cd}	0.33 \pm 0.02 ^{bc}	0.04 \pm 0.02 ^e
	1	0.28 \pm 0.04 ^{cd}	0.11 \pm 0.03 ^c	0.41 \pm 0.00 ^b	0.11 \pm 0.00 ^d
StB	2	0.48 \pm 0.22 ^{bc}	0.10 \pm 0.04 ^{cd}	0.41 \pm 0.00 ^b	0.31 \pm 0.00 ^{ab}
	3	0.68 \pm 0.09 ^{ab}	0.16 \pm 0.02 ^c	0.65 \pm 0.04 ^{ab}	0.16 \pm 0.06 ^{cd}
SB	1	0.73 \pm 0.51 ^{ab}	0.20 \pm 0.30 ^{bc}	Nd	Nd
	2	0.59 \pm 0.23 ^{bc}	0.34 \pm 0.29 ^b	0.18 \pm 0.02 ^d	0.20 \pm 0.02 ^c
	3	0.37 \pm 0.19 ^{cd}	0.25 \pm 0.15 ^{bc}	0.76 \pm 0.18 ^a	0.21 \pm 0.17 ^c
RB	1	Nd	Nd	0.43 \pm 0.21 ^b	0.21 \pm 0.01 ^c
	2	Nd	Nd	0.63 \pm 0.19 ^{ab}	0.26 \pm 0.09 ^b
	3	1.01 \pm 0.09 ^a	0.42 \pm 0.09 ^a	0.80 \pm 0.05 ^a	0.33 \pm 0.15 ^a

Table 2. Effects of different concentrations of standard, sorghum and rice biochars on the growth parameters of *Zea mays* and *Pennisetum glaucum*. (Values are presented as means \pm S.D of triplicate values. Values with different superscripts in the same column differ significantly at $p \leq 0.05$. Trts – Treatments; StB – Standard Biochar; SB – Sorghum Biochar; RB - Rice Biochar. Units: height (cm), leaf area (m²), stem girth (cm))

Trts	Biochar rates (%)	<i>Zea mays</i>				<i>Pennisetum glaucum</i>			
		Height	No of leaves	Leaf area	Stem girth	Height	No of leaves	Leaf area	Stem girth
Control	0	29.96 \pm 1.96 ^b	4.00 \pm 0.00 ^a	14.22 \pm 3.17 ^c	2.29 \pm 0.09 ^e	28.33 \pm 2.58 ^{cd}	6.00 \pm 0.00 ^a	8.82 \pm 1.46 ^{cd}	2.57 \pm 0.09 ^a
	1	32.72 \pm 4.06 ^b	3.00 \pm 0.00 ^a	14.81 \pm 0.96 ^c	2.51 \pm 0.16 ^{de}	27.10 \pm 5.05 ^{cd}	4.00 \pm 0.00 ^c	5.91 \pm 1.23 ^{cde}	1.71 \pm 0.00 ^c
	2	36.36 \pm 11.06 ^b	3.00 \pm 0.00 ^a	23.33 \pm 11.7 ^{bc}	2.35 \pm 0.31 ^{de}	23.50 \pm 0.00 ^d	6.00 \pm 0.00 ^a	2.95 \pm 0.00 ^{de}	1.77 \pm 0.10 ^c
StB	3	38.38 \pm 1.96 ^b	3.00 \pm 0.00 ^a	19.61 \pm 1.02 ^c	2.88 \pm 0.32 ^c	35.60 \pm 0.00 ^{bc}	6.00 \pm 0.00 ^a	8.88 \pm 0.00 ^{cd}	1.77 \pm 0.09 ^c
	1	35.93 \pm 3.85 ^b	4.00 \pm 0.00 ^a	19.27 \pm 3.14 ^c	2.67 \pm 0.41 ^{cd}	Nd	Nd	Nd	Nd
	2	48.76 \pm 8.61 ^a	4.00 \pm 0.00 ^a	33.32 \pm 16.03 ^b	3.30 \pm 0.00 ^b	34.17 \pm 1.50 ^{bc}	4.00 \pm 0.00 ^c	6.81 \pm 2.11 ^{cde}	1.77 \pm 0.10 ^c
SB	3	35.07 \pm 1.46 ^b	4.00 \pm 0.00 ^a	18.11 \pm 1.63 ^c	1.88 \pm 0.00 ^f	42.85 \pm 9.45 ^{ab}	4.00 \pm 0.00 ^c	11.47 \pm 4.96 ^{bc}	1.82 \pm 0.10 ^c
	1	Nd	Nd	Nd	Nd	43.47 \pm 1.08 ^{ab}	6.00 \pm 0.00 ^a	17.27 \pm 8.68 ^{ab}	2.19 \pm 0.00 ^b
	2	Nd	Nd	Nd	Nd	35.93 \pm 4.20 ^{bc}	5.00 \pm 0.00 ^b	7.35 \pm 4.51 ^{cde}	1.88 \pm 0.17 ^c
RB	3	54.38 \pm 0.00 ^a	4.00 \pm 0.00 ^a	51.89 \pm 0.00 ^a	6.60 \pm 0.00 ^a	49.87 \pm 6.53 ^a	5.00 \pm 0.00 ^b	20.41 \pm 7.69 ^a	1.93 \pm 0.24 ^c

Table 3. Effects of different concentrations of standard, sorghum, and rice on root length, fresh and dry weight of root and shoot of *Zea mays*. (Values are presented as means \pm S.D of triplicate values. Values with different superscripts in the same column differ significantly at $p \leq 0.05$. Trts – Treatments; StB – Standard Biochar; SB – Sorghum Biochar; RB - Rice Biochar, RL- Root length, SFW- Shoot Fresh Weight, RFW- Root Fresh Weight, SDW- Shoot Dry Weight, RDW- Root Dry Weight)

Trts	Biochar rates (%)	RL (cm)	SFW (g/kg)	RFW (g/kg)	SDW (g/kg)	RDW (g/kg)
Control	0	13.93 \pm 7.52 ^b	0.98 \pm 0.33 ^{bc}	0.28 \pm 0.07 ^{bc}	0.14 \pm 0.01 ^{bc}	0.06 \pm 0.02 ^{ab}
	1	23.77 \pm 0.85 ^a	0.92 \pm 0.21 ^{bc}	0.28 \pm 0.05 ^{bc}	0.11 \pm 0.03 ^c	0.03 \pm 0.02 ^{cde}
StB	2	22.47 \pm 4.72 ^{ab}	1.91 \pm 1.03 ^{ab}	0.41 \pm 0.22 ^{ab}	0.30 \pm 0.17 ^{ab}	0.05 \pm 0.01 ^{bcd}
	3	23.43 \pm 8.57 ^a	1.34 \pm 0.13 ^{abc}	0.29 \pm 0.14 ^{bc}	0.16 \pm 0.02 ^{bc}	0.03 \pm 0.03 ^{dde}
SB	1	15.77 \pm 0.95 ^{ab}	1.61 \pm 0.27 ^{ab}	0.20 \pm 0.01 ^{bc}	0.15 \pm 0.04 ^{bc}	0.04 \pm 0.01 ^{bcd}
	2	14.63 \pm 5.62 ^{ab}	2.50 \pm 1.10 ^a	0.48 \pm 0.25 ^{ab}	0.36 \pm 0.09 ^a	0.09 \pm 0.03 ^a
	3	17.93 \pm 7.33 ^{ab}	1.28 \pm 0.43 ^{abc}	0.30 \pm 0.03 ^{bc}	0.17 \pm 0.09 ^{bc}	0.05 \pm 0.01 ^{bcd}
RB	1	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^f
	2	0.00 \pm 0.00 ^c	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^f
	3	19.27 \pm 1.35 ^{ab}	2.54 \pm 1.63 ^a	0.61 \pm 0.38 ^a	0.34 \pm 0.21 ^a	0.06 \pm 0.02 ^{ab}

DISCUSSION

In relation to the current study, the soil of the study site was sandy loam. The biochars used had pH values that ranged between 8.15-8.54, high porosity, increased minerals, and lower heavy metal content (Ogunremi et al. 2023). The improved germination rate of *Pennisetum glaucum* and *Zea mays* in this study was on a similar note to Hilioti et al. (2017), who revealed high germination of castor seeds in the presence of 1% and 5% castor stalk biochar as compared with the control soil. In addition, the increasing germination rate of *Pennisetum glaucum* and *Zea mays* with increasing rice and sorghum biochars corresponds with the result of Kanwal et al. (2018),

who reported an increase in seed germination of wheat after the introduction of 1% and 2% biochar derived from dried leaf material and sawdust. The enhanced seed germination observed in *Zea mays* and *Pearl millet* in this research could result from the high porosity of rice biochar and sorghum biochar, as suggested by Das et al. (2020) and Bu et al. (2020) that integration of porous biochar to soil could result to improved water-holding capacity and soil aeration thus enhancing seed germination. Moreover, Das et al. (2020) further pointed out that the presence of minerals (Ca, P, K, Zn, Cu, Fe, and B) may be a key factor influencing seed germination and early seedling growth. This factor can be connected with the result of this study that showed biochar to have increased the minerals in the soil, which in turn enhanced the seed germination and early growth of *Zea mays* and *Pearl millet*.

Table 4. Effect of different concentrations of standard, sorghum, and rice on root length, fresh and dry weight of root and shoot of *Pennisetum glaucum* (Values are presented as means \pm SD of triplicate values. Values with different superscripts in the same column differ significantly at $p \leq 0.05$. Trts – Treatments; StB – Standard Biochar; SB – Sorghum Biochar; RB - Rice Biochar, RL- Root length, SFW- Shoot Fresh Weight, RFW- Root Fresh Weight, SDW- Shoot Dry Weight, RDW- Root Dry Weight)

Trts	Biochar rates (%)	RL (cm)	SFW (g/kg)	RFW (g/kg)	SDW (g/kg)	RDW (g/kg)
Control	0	6.97 \pm 0.85 ^c	0.67 \pm 0.14 ^b	0.06 \pm 0.01 ^{bc}	0.10 \pm 0.03 ^{bc}	0.001 \pm 0.00 ^c
	1	11.80 \pm 1.30 ^{ab}	0.28 \pm 0.13 ^{cd}	0.06 \pm 0.01 ^{bc}	0.11 \pm 0.05 ^{bc}	0.002 \pm 0.001 ^c
StB	2	15.90 \pm 5.80 ^a	0.13 \pm 0.15 ^d	0.09 \pm 0.01 ^b	0.02 \pm 0.02 ^d	0.002 \pm 0.001 ^c
	3	13.10 \pm 3.30 ^{ab}	0.38 \pm 0.19 ^c	0.10 \pm 0.04 ^{ab}	0.11 \pm 0.05 ^{bc}	0.01 \pm 0.01 ^{bc}
SB	1	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^e	0.00 \pm 0.00 ^d	0.00 \pm 0.00 ^e	0.00 \pm 0.00 ^d
	2	9.93 \pm 1.11 ^c	0.35 \pm 0.09 ^c	0.06 \pm 0.04 ^{bc}	0.10 \pm 0.02 ^{bc}	0.01 \pm 0.02 ^{bc}
	3	12.53 \pm 4.13 ^{ab}	1.12 \pm 0.87 ^a	0.14 \pm 0.10 ^a	0.14 \pm 0.05 ^b	0.05 \pm 0.02 ^a
RB	1	16.67 \pm 4.85 ^a	0.48 \pm 0.36 ^c	0.12 \pm 0.03 ^{ab}	0.16 \pm 0.01 ^b	0.02 \pm 0.01 ^b
	2	17.23 \pm 9.29 ^a	0.64 \pm 0.39 ^b	0.09 \pm 0.06 ^b	0.09 \pm 0.03 ^c	0.01 \pm 0.01 ^{bc}
	3	15.03 \pm 3.12 ^a	1.88 \pm 1.07 ^a	0.15 \pm 0.07 ^a	0.24 \pm 0.12 ^a	0.03 \pm 0.02 ^b

However, the current study revealed that the germination rate of *Pennisetum glaucum* decreased with an increased application rate of standard biochar and vice versa for *Zea mays*. In conjunction with the reduced germination rate of *Pennisetum glaucum* observed in the current study, Bu et al. (2020) reported that the application rate of poplar woodchip biochar at 1% and 2% decreased the seed germination rate. It was also observed in the report made by Li et al. (2017) that lower dosages of oak biochar (between 1% and 4 %) did not influence tomato germination when compared to the control. Biomass-derived biochars that contain harmful substances could also be responsible for plants' negative response to seed germination and early seedling growth (Thomas & Gale 2015). Since pH could influence the germination rate of plants, Bu et al. (2020) further opined that the increase in soil pH (7.8 - 8.3) could be responsible for the decrease in seed germination. Contrary to Bu et al. (2020), Ebrahimi and Eslami (2012) reported that at pH 8, there was an improvement in the seed germination of *Ceratocarpus arenarius*, which supported the result of this study where RB3% recorded the highest germination rate for both plants as a result of improved soil pH from 6.76 to 8.04. According to Kanwal et al. (2018) and Rawat et al. (2019), the effect of biochar on plants could depend on the biochar type, plant species, and application rates. In this view, plants can respond to various biochars differently, as observed in the current study, *Zea mays* had better interaction with all biochars when compared with *Pennisetum glaucum*, which had selected interaction with rice and sorghum biochars only.

Increased chlorophyll a and b content of *Pennisetum glaucum* and *Zea mays* align with the results presented by Torabian et al. (2018) and Ran et al. (2020), who reported increased chlorophyll content after the introduction of biochar. Similar reports were made from the work of Akhtar et al. (2015), Bashir et al. (2018) and Mehmood et al. (2018). Reduction in chlorophyll content of the control could result from heavy metal stress such as Cr-VI stress, which can cause a decrease in the chlorophyll contents of plants (Arshad et al. 2017, Ran et al. (2020).

Different results have been reported as a result of relating soil characteristics, the climatic condition of the site, crop yield to type of feedstocks, pyrolysis conditions, and biochar applications (Sohi et al. 2010). Positive reports from biochar amendment suggested improvement in crop growth (Ali et al. 2017, Bashir et al. 2018). On the contrary, Xie et al. (2013) found no significant impact on rice growth in non-fertile soil amended with

biochar derived from wheat straw.

The increased height in *Zea mays* and *Pennisetum glaucum* of the present study follows the past reports concluding that there was an increase in maize height as related to the wheat straw biochar and rice husk biochar applications at various rates (Mensah and Frimpong 2018, Zhang et al. 2016). The increased height observed in the current study could be attributed to the improved soil properties and increased minerals in soil by biochars. Moreover, Similar reports were made by Ghoneim and Ebid (2013) and Kamara et al. (2015), who noted the positive response of rice to the application of rice straw biochar. According to Yang et al. (2015), rice straw and corn stalk-derived biochars increased the yield of peanut, sweet potato, and maize plants. Furthermore, Mensah and Frimpong (2018) suggested that P availability could contribute to plant growth. This work showed that RB3% recorded the highest height in the two studied plants studied, which is in line with Ghoneim and Ebid (2013) study, which explained that a 3% concentration of rice straw-derived biochar did better than other concentrations (1.5%) used. Abbas et al. (2020) also showed that adding biochar at 3% improved the height of *Zea mays*.

It was reported by Carter et al. (2013) that the introduction of biochar increased the number of leaves of lettuce and cabbage, which is in line with the observation (increased number of leaves of *Zea mays*) made by Mensah and Frimpong (2018). In contrast to these reports, biochars had no significant impact on the number of leaves of *Zea mays* and *Pennisetum glaucum* in the present study. The improved leaf area of the studied plants corresponds with Tian et al. (2017), who revealed a positive response of the leaf area of Asian Lotus (*Nelumbo nucifera*) and Chinese sage (*Salvia miltiorrhiza*) to the application of biochar. Agegnehu (2017) also showed that biochar enhanced the leaf area of barley. The results of this study agree with the opinion made by Agegnehu (2017) that increased leaf area could result from the changes in the soil properties influenced by biochars like high water retention, increased macronutrients, soil pH and available phosphorus and possibly potassium contents in soil which was observed in the current study. The increased stem girth of *Zea mays* with the highest value at a 3% rate of rice biochar in this work concurs with Mensah and Frimpong (2018), who reported an increase in stem girth of two maize varieties in Aiyinase soil after the application of corncobs derived biochar pyrolyzed at 350°C. Also, this aligns with Carter et al. (2013), who explained that there was an increase in the

stem girth of lettuce and cabbage after introducing sorghum biochar at the rate of 50 g/kg. However, the stem girth of *Pennisetum glaucum* without treatment (Control) did better than that of *Pennisetum glaucum* grown on soils treated with biochars.

This study revealed a similar result to the previous reports on the positive response of biochars to plant biomass: biochars improved the shoot biomass of *Zea mays* compared to the control. However, the fresh root weight of *Zea mays* was enhanced. (Carter et al. 2013, Tian et al. 2017). Sigua et al. (2015) also discovered favorable effects of sorghum biochars on aboveground and belowground biomass of winter wheat. Rice straw biochar addition improved the shoot and root biomass of two varieties of rice plants (Kamara et al. 2015). The difference in the response of plant biomass in the current study could result from the differences in the rapid and stable reaction of biochars oxidized in the soil, which is determined by their physicochemical properties along with the physicochemical conditions of the soil (Sigua et al. 2015).

On a similar note to the work of Bruun et al. (2014), who revealed that biochar boosts plant biomass, the present research confirmed that the shoot biomass of *Pennisetum glaucum* was improved at 3% rates of the biochars and root biomass was enhanced by all the biochars treatments. The increased root length of the *Zea mays* and *Pennisetum glaucum* ascertained the efficacy of biochar as it was also confirmed by Farhangi-Abriz and Torabian (2018), who reported improvement of root length bean plant (*Phaseolus vulgaris*) in response to biochar application. Root growth is dependent on water-holding capacity (Crutchfield 2016) regulated by biochar (Laird et al. 2010), which was confirmed to have contributed to the increased root length of *Zea mays* and *Pennisetum glaucum* in this study, hence increasing the biomass of *Zea mays* and *Pennisetum glaucum*.

CONCLUSIONS

Generally, biochar application improved the growth of plants in spent oil-contaminated soil. From this study, rice biochar and sorghum biochar increased germination rate, and chlorophyll content improved the growth of *Zea mays* and *Pennisetum glaucum*. Considering the result obtained from the rice biochar and sorghum biochar properties in this study, it could be deduced that these properties favored the soil properties and growth of *Zea mays* and *Pennisetum glaucum*. Selecting biochars and suitable application

rates are necessary for soil fertility and crop growth.

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