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Effects of Different Biochars and the Impact of Heavy Metals on Growth and Yield of Amaranthus at Zagyuri Irrigation Field Tamale, Ghana

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ABSTRACT

Background and Objective: Vegetables are essential for human health, but in Northern, Ghana limited due to scarcity of water for irrigation. The study aims to determine the effects of different biochar wastewater filtrates on chlorophyll content, growth, yield parameters and heavy metal remediation of Amaranthus under pot cultivation in both rainy and dry seasons. **Materials and Methods:** The study employed a randomized complete block design with three replications. The treatment combinations consist of eight levels of treated wastewater, groundnut husk biochar produced in open field conditions, wastewater and pipe borne water, rice husk biochar and groundnut husk biochar both pyrolyzed at 400 and 600°C. The wastewater was prefiltered by corn cob biochar to reduce suspended solids and turbidity. The wastewater and pipe water were added as controls. Amaranthus (*Amaranthus cruentus*) was used as a test crop. **Results:** The studies revealed that high levels of contamination in the WW (wastewater) and soil reduced the vegetative growth parameters (leaf number, leaf area and chlorophyll content) of Amaranthus for both seasons even though the nutritional composition of the WW was observed to be higher than what was observed in the other irrigated source. Generally, filtrate from groundnut husk biochar pyrolyzed at 600°C resulted in the highest growth and yield parameters as well as reducing cadmium and lead in Amaranthus leaves for both rainy and dry seasons. **Conclusion:** This study recommended that the use of groundnut husk biochar(s) should be adopted in remediating wastewater to minimize the adverse effects of cadmium and lead on Amaranthus.

KEYWORDS

Amaranthus, irrigation, wastewater, heavy metals, biochar, filtrate

INTRODUCTION

Vegetables are essential parts of the human diet for populations across the country due to their significant sources of antibacterial, anti-inflammatory, anti-carcinogenic, prophylactic and therapeutic properties[1], as well as a variety of nutritional sources, such as potassium, protein, vitamins, minerals, iron, calcium, folate (folic acid) and phytochemical compounds content that help to boost human immunity[2] which prevent many infections such as COVID-19.

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Despite these unique benefits of vegetables to the human system, their cultivation at a certain period of the year is limited due to scarcity of water for irrigation[3].

Studies revealed that approximately forty percent of the earth's surface area is semi-arid or arid[4-6]. In addition, the geographical region of desert and semi-arid districts will gradually increase as the extent of global warming increases, owing primarily to a steady rise in the fluctuation of yearly precipitation. Moreover, the increasingly greater levels of dryness can have a major adverse impact on vegetable production making it imperative for wastewater (WW) usage in crop production[7,8].

According to available statistics, 550,000 ha in 17 cities and 350,000 ha in 75 cities are, respectively directly and indirectly watered by effluent[7]. And in urban regions like Accra, Kumasi and Tamale in Ghana and other parts of Africa, WW is used to irrigate vegetables[8]. In Ghana, WW is used to irrigate around 17% of the country's arable land, producing about 34% of the crops that are consumed in urban areas[9]. Wastewater is known to contain a significant amount of pollutants including heavy metals (HM) such as Cadmium (Cd) and Lead (Pb)[10-12]. Zeeshanur Rahman and Singh[13] proposed that Cd and Pb can be harmful even in small doses. High levels of Cd, Cu, Co and Pb in dietary products are the main cause of diseases such as bone cancer, upper intestine cancer, reproductive issues, hypertension and renal failure[14].

Plants in nature are constantly faced with abiotic and biotic stresses[15]. According to Feng *et al.*[16], metals that are toxic are extremely susceptible to plants and any quantity of metallic material with toxic stress may trigger a variety of physiological manifestations in plants. Excessive HMs can harm protective enzymes and the membrane systems, prevent the development of seeds and seedling growth, cause chromosomal aberrations and, kill plants[16].

Heavy metals negatively impact plant growth, genetic diversity and soil quality, requiring defense mechanisms and reducing agricultural productivity[17]. Seasonal variations in water and soil contribute to HM concentration[18-20].

Amaranths are widely known for their nutritional value and their easy-growing habit. Many scientists[21,22] reported that the protein content of *Amaranthus* species based on 100 g fresh edible weight can go as high as 4.6. depending on the species. Despite the importance of Amaranthus in the human diet and the hazardous effects of metals in crops, there are few studies on the effects of HM stress on Amaranthus in the Tamale municipality. This study, therefore, seeks to identify the effects of different biochar-treated wastewater on chlorophyll content, growth and yield parameters on Amaranthus cultivation in both rainy and dry seasons.

MATERIALS AND METHODS

The experiments were conducted at Zagyuri, near Kamina Military Barracks in Tamale Metropolis, Ghana, from April to November, 2020 and January to March, 2021 (rainy and dry seasons, respectively) under a controlled environment.

Description of the experimental site: Zagyuri, the experimental site was described as indicated by researchers[23-25].

Experimental design and treatment: The study was arranged in a Randomized Complete Block Design (RCBD) with three replications. The WW was prefiltered by corn cob biochar to reduce suspended solids and turbidity to a favorable level before passing it through the remediation chamber. After the primary treatment, the WW is then channeled to each remediation chamber (biochar treatment filters) by downstream gravity (Fig. 1).

Fig. 1: A multi-chamber downwards anaerobic filtration set

The treatment combinations consist of eight levels of treated wastewater filtered through the following, (1) Rice husk biochar, pyrolyzed at 400°C, (2) Rice husk biochar, pyrolyzed at 600°C, (3) Groundnut husk biochar pyrolyzed at 400°C, (4) Groundnut husk biochar pyrolyzed at 600°C, (5) Rice husk biochar produced in open field conditions, (6) Groundnut husk biochar produced in the open field, (7) Wastewater (WW) and (8) Pipe-borne water (PM) was added as a control. Amaranthus (*Amaranthus cruentus*) was used as a test crop that was irrigated during dry and wet seasons under pot cultivation.

The pot experiment was set up in an improvised plant house made of polyethylene mesh. The polyethylene mesh had holes with a diameter of less than 1.9 mm with 91.2% porosity and a linear mass density of 152 kg.

Seventy-two plastic buckets with 12 L volume and 30 cm top diameter representing the total number of treatments were used for the experiment. Holes were perforated under each bucket to allow excess water to drain during watering. The pots were filled with 13.3 kg of soil to the neck level of each pot. Pots were watered to field capacity and were made to stand for 24 hrs before transplanting. One plant was transplanted into each pot. Pots were arranged 50×50 cm apart.

Cultural practices: To avoid contamination of the crops, no insecticides were sprayed on the crops during nursery and transplanting. Weed control in the pots was by hand pulling. Watering was done to field capacity when required. As 200 kg hr^{-1} NPK was applied to each pot in a split application for 2 and 4 weeks after sowing.

Data collection: Data were taken from the individual plants in each pot. Vegetative and yield data were taken every other day until harvest. Plant height, stem girth, chlorophyll, leaf length, leaf diameter and leaf area were measured as described by Nimatu *et al.*[26].

Soil sampling, preparation and analysis: Soil samples were taken along the two diagonals of the field. Five cores were picked along each diagonal at regular intervals at a depth of 15 cm and mixed thoroughly. A composite soil sample was then taken with a sterile agar into sterile plastic bags (Stomacher (R) lab system) sealed and put into cooling boxes with ice blocks for cooling and transported to the microbiology laboratory CSRI-Water Research, Accra for analysis of HM and pathogens.

Water sampling, preparation and analysis: Zagyuri irrigation field was purposefully selected because of its accessibility of water all year round, farming activities around the site and yearly availability of vegetables to consumers. The WW was collected from the reservoir and the up-flow near the production source (homes from which the WW is a channel). These areas were selected because there are places where vegetable cultivation is practiced all year round. The WW was sampled during rainy and dry seasons, three samples were taken for analysis on the same day for each season. The WW and other filtrates for irrigation were sampled into pre-labelled 500 mL plastic bottles. The samples were kept in the ice chest with ice blocks and transported to the microbiology laboratory CSRI-Water Research, Accra for analysis. Each sampled irrigated water was used for the analysis of all the parameters (EC, pH, COD, temperature, turbidity, HM and NPK).

Analysis of physical and chemical parameters of irrigated field and WW

pH: The pH of WW was determined using a pH meter (Basic 20) of the Crison model in a 10 mL container. The pH was then identified by inserting the electrode of the pH meter into it and the value was recorded. For soil pH, 10 g of air-dried soil sampled was weighed into a 50 mL beaker. Twenty-five milliliters of distilled water was added. The suspension was vigorously stirred for 20 min to allow homogeneity and allowed to stand for about 30 min. The electrode was then inserted into the partly settled suspension and the values of the pH were taken.

Electrical conductivity of soil and wastewater (EC): A Crimson Basic EC meter ([6]CM39P model) was used to determine the EC of soil and WW. Samples were determined by inserting the electrode of the EC meter into the soil solution and in WW in the container as described by Reynolds *et al.*[6].

Concentration of NPK in wastewater: The NPK concentration in WW was done using Jenway 6405 UV/VIS Spectrophotometer at the microbiology laboratory CSRI- Water Research, Accra, Ghana. The N was identified using the Hydrazine Reduction method described by Crutchfield and Grove[27]. Phosphorus (P) was determined using the Stannous Chloride Method and the potassium (K) portion of the WW was identified using the Flame Photometer (Jenway PFP7) method[28].

Organic carbon of soil: Organic carbon was determined using the dichromate oxidation method (Walkley-Black wet oxidation procedure, Schumacher, 2002).

Concentration of NPK in soil and water: The N was determined using the micro Kheldahl method. Three processes were involved in identifying crude protein which includes digestion, distillation and titration. The digestion portion of the crude protein was done by grindings the oven-dry matter samples into powder and 1 g each was weighed into filter papers. The N content was finally determined using the standard method of the Turner *et al.*[29].

Analysis of soils (proximate): The proximate composition of the soil was analysed using a C/N analyser (Vario MAX cube, Elementar, Hanau) at the microbiology laboratory CSRI-Water Research, Accra.

Analysis of heavy metals (HM) from soil and water samples: Measurement of HM was conducted by Absorption Spectrophotometer (Model 2380, Perkin Elmer, Inc. Norwalk, CT and USA) at the microbiology laboratory of CSRI-Water research Legon, Accra.

Reference standards: Blanks and duplications were used as a positive control to analyse HM. The same approach used to analyse the HM was adopted for the blanks and duplication analysis. The equipment was calibrated to zero (blank). This allows for effective monitoring of contaminations throughout sample preparation and the efficacy of all the equipment used for the study.

To determine the concentration of HM from the solution, 2 blank digests of the same amounts of reagents (H_2SO_4 and H_2O_2) are prepared. All data against mean blank values Cd and Pb, are corrected and determined using Atomic Absorption Spectrophotometer (Model 2380, Perkin Elmer, Inc. Norwalk, CT and USA).

Statistical analysis: The data gathered on physico-chemical properties, HM concentrations in both soil and WW for both seasons, physiological development and yield parameters were analysed using Analysis of Variance (ANOVA) using the GenStat Statistical package, 12th Edition. Means were separated using Least Significant Differences (LSD) at a 5% confidence level and data was presented on tables and graphs.

RESULTS

Physico-chemical properties of soil: The initial laboratory analysis conducted on the irrigated soil indicates that the Zagyuri irrigation field contains mean values of 1.28 organic carbon (OC), 23.80 ppm EC and slightly acidic soil with a pH of 6.52. The soil has a particle size/surface area of (loam = 44.2%, clay = 24.56% and a silt proposition of 31.25%) with a porosity of 43.00% (Table 1).

Physicochemical properties of different irrigation sources used for the study: The physico-chemical properties conducted on WW revealed that the EC, pH, chemical oxidation demand (COD), temperature and turbidity were 517 μS cm^{-1}, 7.43, 108 mg L^{-1}, 29.4°C and 45.9 NTU during the rainy season and 1250 μS cm^{-1}, 7.0, 168 mg L^{-1}, 36. 1°C and 7.11 NTU for the dry season respectively. Generally, WW for both seasons had higher pH and COD than the biochar filtrates. And higher rates of NPK in the WW than in the other irrigated waters (Table 2).

Heavy metal concentration in cultivated soil and irrigation water sources at Zagyuri (Tamale, Ghana).

Table 1: physical and chemical properties of soil/initial soil analysis

Parameter	Soil
Level (ppm) wet season	
pH (1:2.5 HO)	6.52
Temperature (°C)	27.3
EC (Us/cm)	23.8
Organic carbon (OC) (%)	1.28
Porosity (%)	43
Surface area	
(Loamy soil) (%)	44.2
Clay (%)	24.56
Silt (%)	31.25
Nitrogen (mg kg^{-1})	0.49
Phosphorus (mg kg^{-1})	2.4
Calcium (mg kg^{-1})	0.89
Potassium (mg kg^{-1})	4.9

Source: Field data (2021)

Table 2: Physico-chemical properties of different water sources used for irrigation

Irrigated source	pH	EC (μS cm^{-1})	Turbidity (NTU)	COD (mg L^{-1})	Nitrate (NO_3) (mg L^{-1})	Phosphate (PO_4) (mg L^{-1})	Potassium (K_2O) (mg L^{-1})
Wet season WW	7.43	517	45.90	108	4.10-19.14	3.1-6.7	0.10-0.45
Dry season WW	7.00	1250	7.11	168	0.14-6.31	0.14-0.21	1.31-30.2
RHB 400	6.40	778	1.66	101	0.04-0.074	0.07-0.18	0.09-4.8
RHB 600	6.00	965	2.14	105	0.01-0.081	0.05-0.19	0.10-7.2
GHB 400	6.20	780	1.99	104	0.03-0.049	0.04-0.13	0.02-3.9
GHB 600	6.40	749	2.33	107	0.03-0.077	0.01-0.16	0.05-4.0
RHBOF	6.50	798	2.16	101	0.02-0.060	0.02-0.12	0.3-3.8
GHBOF	6.50	725	2.35	137	0.02-0.079	0.05-0.15	0.02-4.5
W.H.O limits	6.5-8	100	5.00	-	10	0.005	-
EPA Ghana limits	6.5-8	100	5.00	-	50.0	2.0	2.0

Source field data (2020-2021), GHB 600: Groundnut husk biochar pyrolyzed at 600°C, GHB 400: Groundnut husk biochar at 400°C, RHB600: Rice husk biochar at 600°C, RHB 400: Rice husk biochar at 400°C, GHBOFJ: Groundnut husk biochar open field, RHBOF: Rice husk biochar open field, WW: Wastewater, pH: Potential of hydrogen, EC: Electrical conductivity, chemical oxygen demand COD, NTU: Nephelometric turbidity units and COD: Chemical oxidation demand

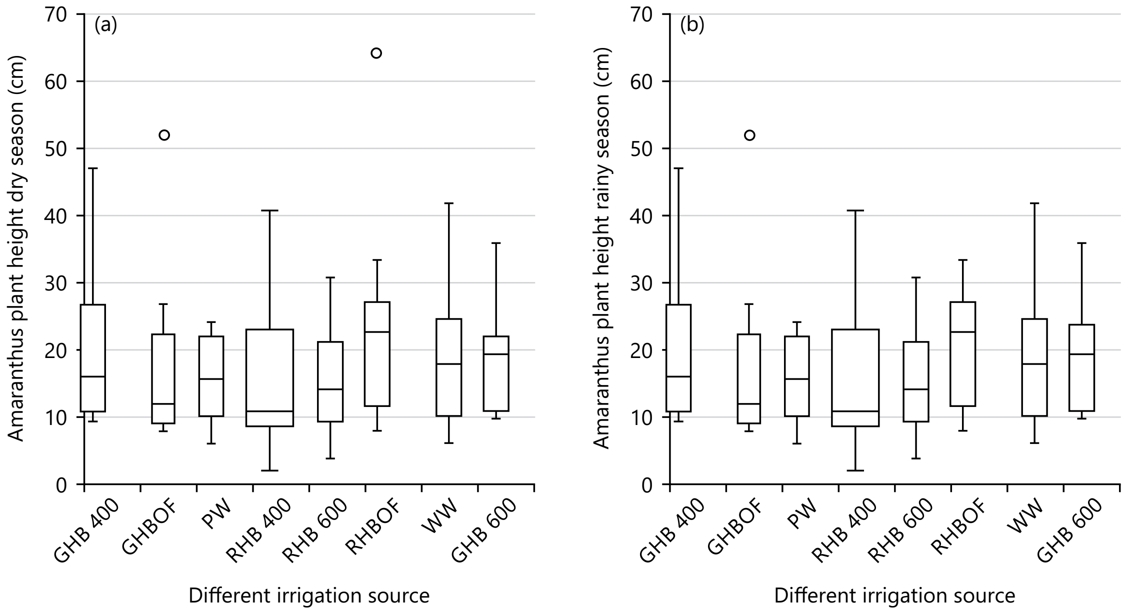

Fig. 2(a-b): Effects of different irrigation water on the plant height of Amaranthus (a) Rainy season (b) Dry season

Source field data (2020-2021), GHB 600: Groundnut husk biochar pyrolyzed at 600°C, GHB 400: Groundnut husk biochar at 400°C, GHBOF: Groundnut husk biochar open field, WW: Wastewater and PW: Pipe water

Table 3: Concentration of heavy metal (Cd and Pd) in wastewater and irrigated soil at Zagyuri field for both rainy and dry season

	Waste water		Soil	
Heavy metals	Cd (mg L^{-1})	Pd (mg L^{-1})	Cd (mg L^{-1})	Pd (mg L^{-1})
Rainy season	0.144	0.001	0.023-0.043	0.63-0.95
Dry season	0.23	0.026	-	-
W.H.O limit	0.003	0.001	≤0.02	≤0.1

Source field data (2020-2021)

The initial analysis to determine the level of HM (Cd and Pd) before the cultivation of crops revealed a higher concentration of HM in the soils and WW than the environmental protection agency (EPA) Ghana and WHO recommended detection rates for soil and WW. The results indicated that the concentration of HM in the soil was higher than those in the WW. The concentration ranged from 0.04-668.76 mg kg^{-1} in the soil and 0.01-2.05 mg L^{-1} in the WW (Table 3). The soil, Cd (0.023-0.043) and Pd (0.63-0.95) and Cd (0.144-0.23) and Pd (0.001-0.026) in WW, respectively.

Growth parameters

Plant height Amaranthus: The treatment for the study significantly affected ($p<0.05$) plant height of Amaranthus. The application of GHB filtrate on amaranthus gave the highest plant height for both seasons, however, there were no significant differences between the three groundnut husk treatments (GHB 400, GHB 600 and GHBOF). Pipe water (PW) irrigation had the least plant height. Generally, GHB 400 led to a higher plant height however, there were no significant differences among GHB 400, WW and RHB 400 filtrate irrigation sources for both seasons (Fig. 2a-b).

Number of leaves Amaranthus: The treatment for irrigation significantly affects ($p<0.05$) the number of leaves of Amaranthus. Among the different filtrates, groundnut husks' pyrolysis temperature of 600°C (GHB 600°C) irrigation led to the highest number of leaves for both dry and rainy seasons (Fig. 3a-b). However, there were no significant differences among WW, RHBOF, GHBs and PW-irrigated Amaranthus for both seasons.

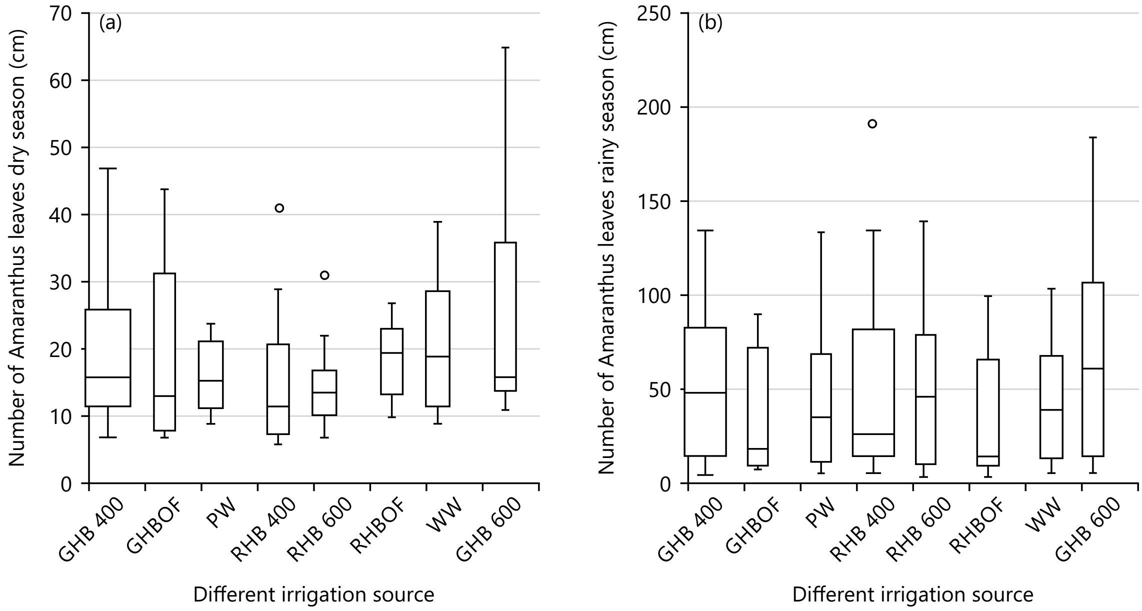

Fig. 3(a-b): Effects of irrigation sources on number of leaves of Amaranthus for (a) Dry and (b) Rainy seasons

Source field data (2020-2021), GHB 600: Groundnut husk biochar pyrolyzed at 600°C, GHB 400: Groundnut husk biochar at 400°C, GHBOF: Groundnut husk biochar open field, WW: Wastewater and PW: Pipe water

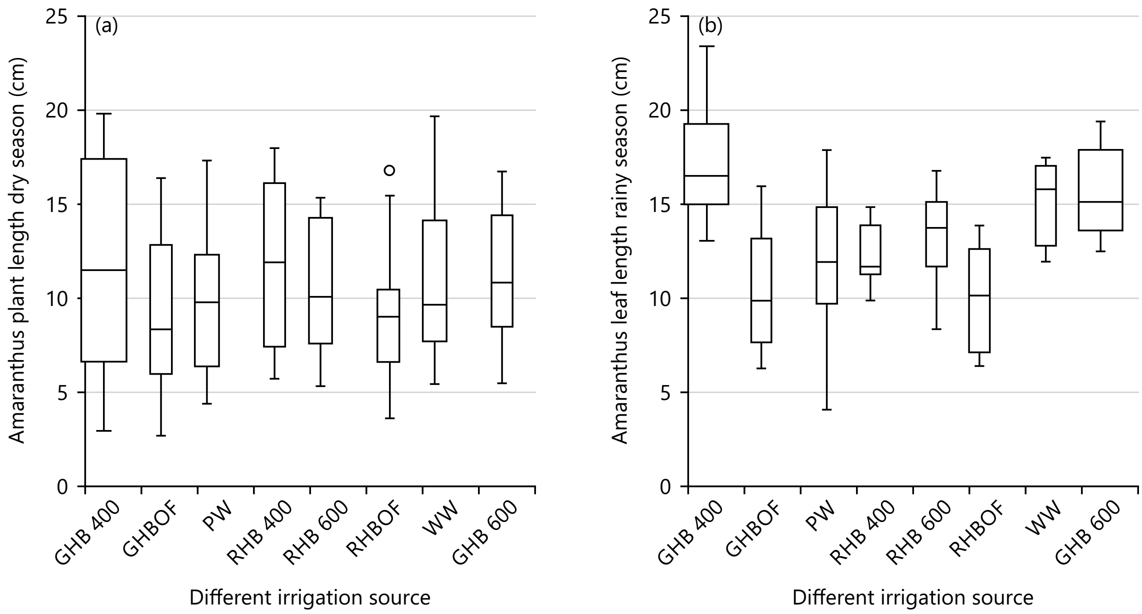

Fig. 4(a-b): Effects of different irrigation sources on leaf length of Amaranthus (a) Dry season and (b) Rainy season

Source field data (2020-2021), GHB 600: Groundnut husk biochar pyrolyzed at 600°C, GHB 400: Groundnut husk biochar at 400°C, GHBOF: Groundnut husk biochar open field, WW: Wastewater and PW: Pipe water

Leaves length Amaranthus: Leaf length was significantly influenced by the different irrigation water sources ($p<0.05$). Again, the application of GHB filtrate on Amaranthus gave the highest leaf length for both seasons but was not different from the performance of RHB 400. The WW, however, had a shorter leaf length but there was not much difference among the yield of other irrigated sources (Fig. 4a-b).

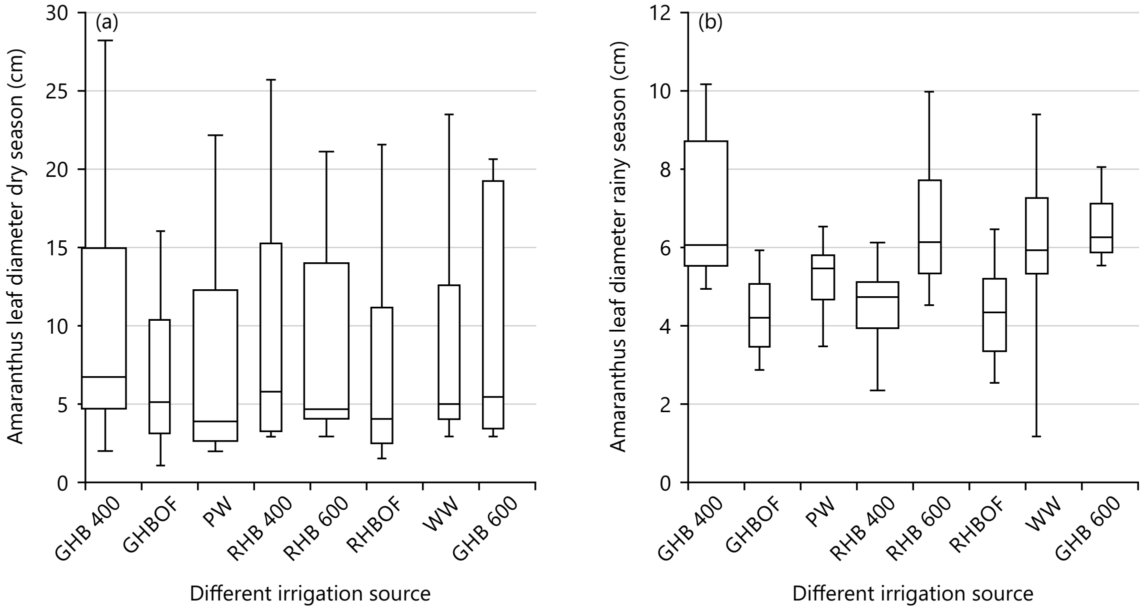

Fig. 5(a-b): Effects of different filtrates for irrigation on leaf diameter of Amaranthus
Source field data (2020-2021), GHB 600: Groundnut husk biochar pyrolyzed at 600°C, GHB 400: Groundnut husk biochar at 400°C, GHBOF: Groundnut husk biochar open field, WW: Wastewater and PW: Pipe water

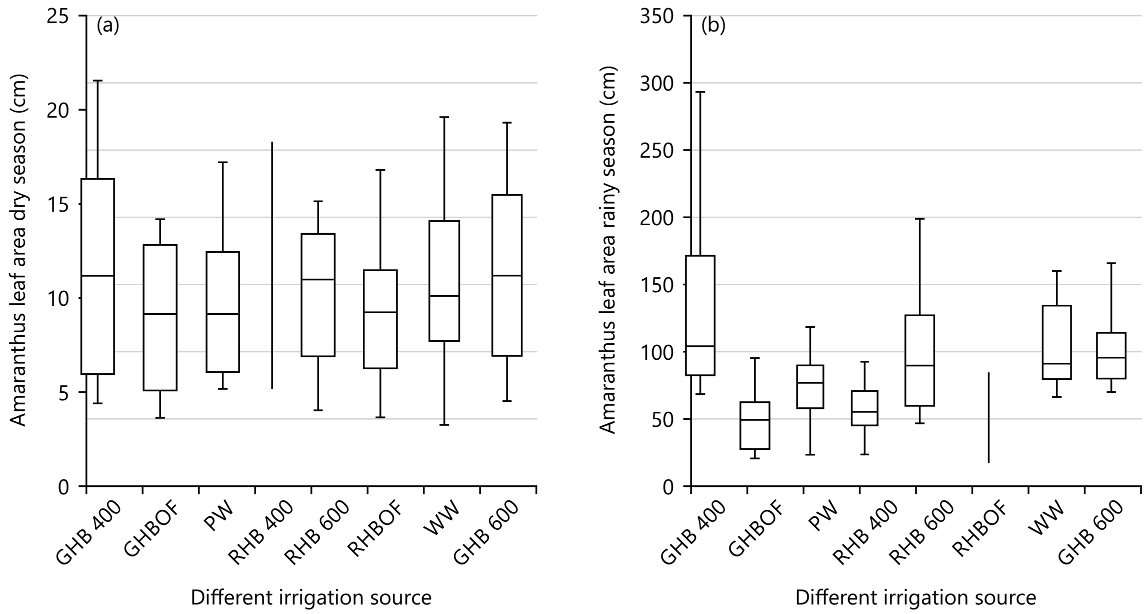

Fig. 6(a-b): Effects of different irrigation water sources on the leaf area of Amaranthus (a) Dry season and (b) Rainy season
Source field data (2020-2021), GHB600: Groundnut husk biochar pyrolyzed at 600°C, GHB 400: Groundnut husk biochar at 400°C, GHBOF: Groundnut husk biochar open field, WW: Wastewater and PW: Pipe water

Leaf diameter Amaranthus: The different irrigation sources significantly influenced ($p<0.05$) the performance of leaf diameter of Amaranthus differently during both seasons (Fig. 5a-b). Groundnuts husk filtrate stood out tall with GHB 600 resulting in a drastic performance in leaf diameter in the dry seasons while GHB 400 led to an increased in leaf diameter for the rainy season.

Leaves area Amaranthus: Leaf area was significantly influenced ($p>0.05$) by the different irrigation sources. Again, for leaf area, GHB 400 filtrate led to an increase in leaf area for both rainy and dry seasons (Fig. 5a-b). However, there were no significant differences in the performance of other irrigated sources (Fig. 6a-b).

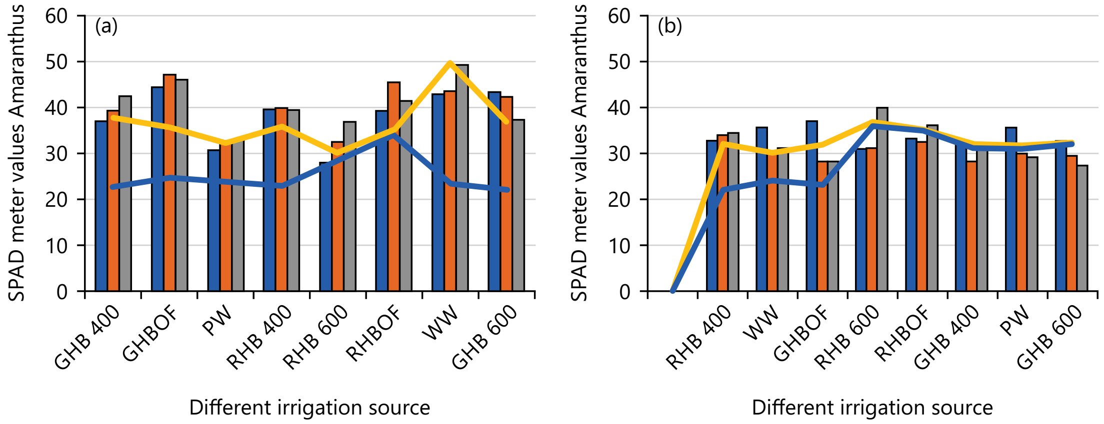

Fig. 7(a-b): Effects of various irrigation sources on SPAD meter value of Amaranthus (a) Dry season and (b) Rainy season

Source field data (2020-2021), GHB 600: Groundnut husk biochar pyrolyzed at 600°C, GHB 400: Groundnut husk biochar at 400°C, GHBOF: Groundnut husk biochar open field, WW: Wastewater and PW: Pipe water

Chlorophyll (SPAD meter value) Amaranthus for (A) dry and (B) rainy season: The soil plant analysis development (SPAD) meter values were significantly influenced by the different irrigation sources over 42 days (6 weeks) and presented (Fig. 7a-b). The GHBs significantly led to a drastic increase in chlorophyll in Amaranthus than the other irrigation sources in the dry season except for GHB 600. While in the rainy season there were not many differences observed in the performance of WW, GHBs and RHBs. Generally, the chlorophyll content of Amaranthus reduces as the crop matures over the weeks (Fig. 7a-b).

DISCUSSION

The levels of nutrients in the soil could be a result of the bioaccumulation of ions from WW irrigation in the soil. The soil particle is the best for plant absorption of NPK. The higher levels of EC also contribute to the nutritional retention of soil as Ding *et al.*[30] noted that EC reflects the capacity of soil to retain nutrients against leaching.

According to Baligar *et al.*[31], crops need aerated soils for the uptake and utilization of nutrients. Abdul Qadir *et al.*[32] also identified that WW used for irrigation can contribute a significant amount of NPK to the irrigated soil.

The irrigated soil had a pH within the FAO limit (6.5) which is suitable for the cultivation of vegetables. However, some vegetables perform normally at lower pH as long as larger amounts of micronutrients were not present in the soil. The studies of Abdul Qadir *et al.*[32] and Hao *et al.*[33] are in line with these findings.

The level of organic carbon (OC) in the soil is a key factor in the determination of the productivity of the soil. Glaser *et al.*[34] stated that OC in the soil is a key to productivity where the soil has low fertility. This can increase food production by 17.6 Mt/year[35,36]. An additional one-ton increase in the OC in the soil can increase wheat yield by 20-40 kg ha^{-1}, maize by 10-20 kg ha^{-1} and cowpea by 0.5 kg ha^{-1}. Additionally, soil with optimal OC can absorb and store rainwater which in turn may be released for crop use under drought. Such soil provides proper aeration and an efficient supply of oxygen which can impede carbon emission as a result of methanogenesis. Also, soil irrigated with WW can increase the physico-chemical properties of the soil[37]. The high content of HM in soil was in line with study of Gyampo *et al.*[24] which indicated higher HM in the irrigated soil than WW. Long-term usage of WW for irrigation can lead to HM accumulation in the soil which in turn cause degradation of soil productivity and plant toxicity.

According to researchers[38-42] also added that physic-chemical properties in the soil can build metals accumulation in groundwater. Again, plants are generally highly sensitive to toxic metals and can reduce different physiological symptoms in plants[16]. Overpowering HMs may impede the development of seeds and seedling growth, harm the antioxidant enzymes and the membrane systems, induce chromosomal aberrations and, in severe cases, cause plant death[43]. Further, too much HM in the soil prevents root and shoot growth, which lowers yield[11].

The EC obtained for the WW during the dry season was double that of the wet season data. In both seasons the EC obtained exceeded the WHO recommended limits of 100 μS cm^{-1} [44] and a range limit of <0.7 μS m^{-1}. The high EC in both seasons could be a result of dissolved salts, substances, chemicals and mineral particles in the WW which indicates higher risks of salinity in the irrigated water which led to a lower performance of Amaranthus[45]. Gyampo *et al.*[24] also identified high EC in the irrigated WW at the study site.

The Hydrogen-ion concentration (pH) in WW for both seasons ranges from neutral to alkaline/base and falls within the WHO recommended limits[44]. Hydrogen-ion concentration (pH) is an important quality parameter for both natural and WWs[46,47]. The alkalinity in WW helps to resist changes in pH caused by the addition of acids. It can, however, be mentioned that the pH of WW is said to be an inverse proportion to H^+ ion since a higher ion concentration leads to less concentration of pH[47]. The higher rates of NPK in the WW as observed for this study (Table 1) for the dry and rainy seasons interacting with heavy metals are the reasons for the differences in performance of Amaranthus under the different irrigation sources for the different seasons. The biochar filtrates also have NPK composition as follows: GHB 600 (0.077, 0.16 and 4.0), GHB 400 (0.49, 0.13 and 3.9), RHB 600 (0.081, 0.19 and 7.2), RHB 400 (0.074, 0.18 and 4.8), RHBOF (0.060, 0.12 and 3.8) and GHBOF (0.079, 0.15 and 4.5, Table 2).

Table 2 shows the chemical oxidation demand (COD) in the WW used for irrigation during dry (168 mg L^{-1}) and rainy (108 mg L^{-1}) seasons. COD of the WW in the dry season was higher than in the rainy season. Venkatesharaju *et al.*[46] equally experience high COD in their experiments. The results of the COD of WW are consistent with the findings of Abagale *et al.*[23], who identified a higher COD in the dry (132.78 mg L^{-1}) season as compared to the rainy (102.5 mg L^{-1}) season. Again, the findings of Kaetzl *et al.*[9] recorded a higher COD value of (202 mg L^{-1}) at the study site during the dry season. Knowing the constituents of COD in the WW helps to identify the organic pollution in WW and how much oxygen is required to oxidize all organic and inorganic matter in the WW[48,49]. The differences in COD in the WW could be a result of the nutritional composition in the WW and the anthropogenic activities as well as the variation in WW flow during the dry and wet seasons[50].

The NPK level in the WW exceeded the WHO recommended rate of nutrient discharge into water bodies (N 10 mg L^{-1}, P 0.005 mg L^{-1} and K 4.9 mg L^{-1}). Table 1 and 2 showed the physicochemical properties of soil and WW at Zagyuri irrigation field. These findings support, Kaetzl *et al.*[51] studies that indicated that WW at the Zanyuri irrigated field contains more nitrate (about 4.10-19.14 and 0.14-6.31 mg L^{-1}) for both rainy and dry season, respectively. With the rainy season exceeding the WHO rate. Abagale *et al.*[23], however identified very low N levels in the WW during both rainy and dry seasons with the respective values as 0.433 and 4.84 mg L^{-1} for the dry and wet seasons at the same study site. Many types of research confirm that when nitrogen exceeds its critical limits in the WW, it could result to toxicity to aquatic and terrestrial organisms including man[52,53]. It is estimated that 1000 M^3 of municipal WW used for irrigating vegetables can contribute 16-62 kg nitrogen, 4-24 kg phosphorus, 2-69 kg potassium, 18-208 kg calcium, 9-100 kg magnesium and 27-182 kg sodium[54].

Wastewater even though contained a higher amount of NPK (Table 2) generally gave the least number of leaves except the control (PW). However, there were no significantly different in the performance of WW and all the filtrates of the rice husk biochar (Fig. 2). The lower yield (number of leaves, leaves diameter, leaves length, leaves aera) and chlorophyll content observed by WW-irrigated Amaranthus confirm the fact that plants are highly sensitive to toxic metals in WW which inhibit growth and yield[11,16]. Kaetzl *et al.*[51] also observed lower output of vegetables with irrigated WW and a corresponding increase in output with irrigated biochar filtrate.

Many research revealed that the presence of HM in irrigated water has drastic effects on plant development[55-57] was with the view that Pd induces chlorosis, necrosis, stunted root/shoot growth and a decrease in crop productivity by obstructing several biological reactions in plants, including seed germination, the accumulation and recovery of seeds that remain when sprouting, plant development and the processes of photosynthesis. By generating reactive oxygen species, upsetting redox balance and inducing oxidative stress, heavy metal toxicity lowers the yields of crops at levels within cells[56]. The lower performance (of leaves number, leave length and area) WW irrigated Amaranthus is a result of the metal concentration effects in WW, hence reducing the physiological development of Amaranthus as against the treated water[11,15,16]. The higher concentration of nutrients in the WW did not reflect on the irrigated Amaranthus[58-61].

Studies show that biochar is a filter material for remediating HMs[3,62-64]. And may also improve the nutritional qualities of the filtrates which may aid crop growth[65].

The higher performance of GHB filtrate in terms of physiological development and other growth parameters for Amaranthus (plants height, number of leaves, leave length and diameter, leaf area, including chlorophyll) is a result of the absents of HM stress and its associated effects on the crop[11,15,16]. Also, it may be a result of leached nutrients (minerals and other characteristics) from the GHB into the filtrate which stimulate the growth of rhizosphere microorganisms and mycorrhizal fungi[61] in the soil hence improving the vegetative growth and chlorophyll content in plants as compared to rice husk biochar and WW.

Biochar is a charcoal-like substance with numerous advantages for plant growth, soil health and environmental protection. This study looks into the effects of different biochar filtrates as well as the effects of heavy metals on Amaranthus growth and yield. The findings will assist policymakers in guiding consumers and farmers on the effective use of wastewater for irrigation. Biochar can be used as a soil amendment, a feed additive for livestock or a water treatment agent. Though biochar has numerous applications, its production could result in forest loss and polluting the environment if not properly controlled. The investigation indicates biochar might be an efficient long-term solution for reducing the toxic impact of heavy metals in Amaranthus and improving soil health. It is however recommending that, awareness and public sensitization on environmental sanitation by district assemblies in communities on the effects of consuming unwholesome vegetables. Again, groundnut husk biochars should be used to reduce the impact of heavy metals and increased the growth and yield of Amaranthus.

CONCLUSION

This study confirmed that different irrigation sources influence the amount of chlorophyll content, vegetative growth and yield parameters of Amaranthus. There were higher levels of cadmium and lead in the soil than in the wastewater. Wastewater-irrigated Amaranthus reduced the growth and yield of Amaranthus in the study area. The use of biochar, especially groundnut husk filtrates for irrigation increased the chlorophyll content, growth and yield parameters of Amaranthus. The study, therefore, recommends that for Amaranthus cultivation in the WW irrigation field, groundnut husk biochar should be used to reduce heavy metal stress and increase the growth and yield parameters of Amaranthus.

SIGNIFICANCE STATEMENT

The purpose of this study is to evaluate different biochars as potential adsorbents to reduce the concentration of heavy metals in wastewater for irrigation. Using low-cost and highly efficient treating materials. And to reduce the heavy metal concentration in wastewater and its effects on consumers in Amaranthus. The studies revealed that high levels of contamination in the WW and soil reduced the vegetative growth parameters of Amaranthus. The GHB filtrates generally led to an increase in vegetative growth parameters and chlorophyll in Amaranthus than the other irrigation sources.

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