The effect of biochar and extract of organic fertilizer on the readiness of certain elements in the soil

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Abstract

A field experiment was conducted at the second research station of the College of Agriculture, Al-Muthanna University, using a mixed soil. The objective of the study was to investigate the impact of varying quantities of biochar and organic fertilizer extract on the availability of nitrogen (N), phosphorus (P), potassium (K), iron (Fe), and zinc (Zn) elements in the soil.The experimental design encompassed the incorporation of four distinct biochar levels (A0, 0%), (A1, 1.5%), (A2, 2%), and (A3, 2.5%), which were applied proportionally to the soil volume. Additionally, four levels of organic fertilizer extract (0, 20, 40, and 80) liters per hectare (B0, B1, B2, and B3) were implemented. A factorial experiment was employed inside a randomized complete block design (RCBD) framework, consisting of three replications.The means were subjected to a Least substantial Difference (LSD) test at a significance threshold of 0.05. The findings indicated substantial disparities between the application of biochar and organic fertilizer extract, as well as their interaction, in relation to the levels of accessible nitrogen in the soil.Moreover, notable disparities were observed regarding the incorporation of biochar and organic fertilizer extract in relation to the accessibility of phosphorus within the soil. Furthermore, the introduction of biochar and organic fertilizer extract, as well as the interplay between these two factors, exhibited a substantial impact on the availability of potassium within the soil. Furthermore, the use of charcoal and organic fertilizer extract had a notable impact on the accessibility of iron and zinc within the soil.

Keywords: Biochar, Nitrogen, Phosphorus, Potassium.

Introduction

Biochar is an organic material characterized by its porous nature and high carbon content, resulting from the pyrolysis of organic molecules in the absence of oxygen [1]. Agricultural scientists have undertaken efforts to mitigate greenhouse gas emissions and enhance agricultural soil fertility and quality through the utilization of organic resources [2, 3, and 4]. The incorporation of biochar into agricultural soil through the conversion of plant leftovers, which are classified as organic waste, is a contemporary environmentally sustainable technology that is being implemented worldwide [5]. The regular incorporation of biochar into the soil results in an augmentation of the soil's elemental composition, specifically nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg), while concurrently causing a reduction in soil pH [6].

The utilization of biochar has been found to have a positive impact on crop biomass and growth due to its potential to enhance nutrient availability. Biochar has been identified as a viable and cost-effective substitute for commercially produced mineral chemical fertilizers due to its rich content of essential nutrients including as phosphorus, potassium, and nitrogen [7]. A study [8] revealed that the use of biochar in soil has the potential to enhance phosphorus availability. This effect is attributed to the reduction of calcium-phosphorus bonding, hence rendering phosphorus more accessible in the soil. The introduction of biochar into the soil enhances nutrient availability, leading to improved nutrient release to plants. This is achieved through the enhancement of soil properties, including physical, chemical, and biological aspects. Biochar effectively traps nutrients such as phosphorus inside its fine pores, contributing to their increased availability for plant uptake [9], Biochar has the potential to be engineered in a manner that enables the controlled release of nutrients stored within its pores, thereby mitigating the risk of nutrient loss through leaching and aligning with the specific nutrient needs of the plant. The storage capacity of different nutrients can be facilitated by the extensive surface area and porous structure exhibited by biochar [10].

The most optimal definition of compost tea is presented in [11]; the term "compost infusion" is frequently used in commercial settings to refer to the process of soaking compost in water for a specific duration. The objective of this process is to transfer soluble organic matter, beneficial microorganisms, and nutrients from the compost into the solution.

The augmented concentration of soluble mineral nutrients inside the organic extract has the potential to promote the absorption of nutrients from the soil [12]. Nevertheless, it seems that this phenomenon is interconnected with additional chemical and potentially biological constituents present in the compost extract [13].

Materials and Methods

A field experiment was conducted during the winter agricultural season of 2022-2023 in Muthanna Governorate. The experiment took place at the second agricultural research station, which is affiliated with the College of Agriculture at Muthanna University. The research station is located in the Bandar area, approximately 3 km away from the city center. The objective of the experiment was to investigate the impact of biochar and organic fertilizer extract on the availability of nitrogen (N), phosphorus (P), potassium (K), iron (Fe), and zinc (Zn) in the soil.

The field experiment was done on a plot of land with dimensions of 9 units by 36 units. The plowing procedure was executed twice, following a perpendicular orientation, with adjustments made to ensure proper leveling. The area was partitioned into three sectors, with each sector comprising 16 experimental units. Based on the experimental design, the planting procedure was conducted on November 23rd subsequent to the addition of coal in accordance with transaction levels.

In each experimental unit, a total of ten lines were sown, with each unit having an area of 4 m^2. The quantity of seed used per unit was 120 kg ha^{-1}.

Uniform application of chemical fertilizers was carried out throughout all experimental units in accordance with the prescribed fertilizer recommendations. Prior to planting, biochar was incorporated into the soil at a depth ranging from 0 to 30 cm, and it was designated as symbol A. The research encompassed four distinct concentration levels (2.5%, 2%, 1.5%, and 0% by volume), referred to as A0, A1, A2, and A3. The extract, symbolized as B, was introduced into the soil as a supplement for plant growth. The investigation incorporated four distinct levels (0, 8, 16, 32 mL) denoted as B0, B1, B2, and B3, respectively. The recommended application rate for this experiment was 40 liters per hectare. Consequently, I employed half of the recommended rate, twice the recommended rate, and the recommended rate itself.

Table 1 displays the soil samples that were randomly collected for analysis within the graduate laboratory of the College of Agriculture.

Table (1): Soil sample chemical and physical parameters before planting

Chemical properties	**PH**	**ECe (ds m-1)**	**O.G**	**N(mg kg-1)**	**P(mg kg-1)**	**K(mg kg-1)**	**I(ppm)**	**Zn (ppm)**
	7.68	8.13	0.4	18.9	10	195	1.005	0.025
physical properties	**Sand**	**Silt**	**clay**	**Soil texture**				
	48.2	32.7	19.1	sandy loam				

Studied traits

Available nitrogen: The quantification of nitrogen availability in the soil was conducted using the extraction technique involving a 2M potassium chloride solution, as outlined in the methodology described by reference[14]

Available Potassium: The measurement of potassium was conducted through the process of extraction using ammonium (1N NH4OAS). Subsequently, the determination of potassium was performed utilizing a flame photometer, namely the PFP7 model [14]

Available Phosphorus: The concentration of phosphorus in a solution of 0.5M $NaHCO_3$ is analyzed using the color development method with a spectrophotometer set at a wavelength of 882 nm[15]

Iron: A quantity of 10 grams of soil that has been dried in ambient air is introduced into the experimental setup. The iron content of the soil is subsequently assessed by employing an extraction solution consisting of DTPA, $CaCl_2.2H_2O$, and TEA. The resulting solution is then filtered using Whatman NO 42 paper. The measurement of Fe is conducted through direct utilization of an atomic absorption spectroscopy instrument[15]

Zinc: A quantity of 10 grams of desiccated soil is introduced into a conical flask, followed by the addition of 20 milliliters of an extraction solution consisting of DTPA and TEA. The resulting mixture is then subjected to filtration using filter paper, after which the concentration of zinc (Zn) is directly determined using an atomic absorption spectroscopy equipment, as described in previously [15].

Results and Discussion

Levels of biochar and compost extract affect Available nitrogen

The findings shown in Table (2) demonstrate that the incorporation of biochar and organic fertilizer extract, as well as their combined effect, resulted in statistically significant variations when compared to the control treatment. There were notable variations seen in the quantities of biochar applied to the soil and their impact on the concentration of available nitrogen in the soil. The A3 and A2 treatments exhibited superior performance, with recorded values of 32.29 and 31.76 mg kg-1 soil N, respectively. The A1 treatment followed closely with a recorded value of 30.10 mg kg-1 soil N, which aligns with previous findings. According to [16], the inclusion of Biochar in soil has been found to have several positive effects. These include enhancing moisture levels, reducing bulk density, and improving nutrient availability .

Additionally, charcoal particles play a significant role in capturing and preserving nitrogen, preventing its loss through leaching. The findings shown in Table 2 indicate that there are statistically significant variations in the levels of organic fertilizer extract in relation to the nitrogen values. Specifically, the B3 treatment exhibited the highest performance with a recorded value of 32.29 mg kg-1, followed by B2 and B1 with values of 27.71 and 28.73 mg kg-1, respectively. One possible explanation for this phenomenon is that the organic extract facilitates the availability of nutrients in the soil, rendering them readily accessible for plant uptake. Additionally, the organic extract may function to safeguard these nutrients, preventing their loss or depletion.

Table (2): Illustrates notable disparities in the levels of available nitrogen between

Treatment	Organic fertilizer extracts				Average	L.S.D. 0.05
biochar	B0	B1	B2	B3		
A0	18.55	20.77	21.58	22.05	20.74	A= 1.375
A1	24.85	30.80	28.70	36.05	30.10	
A2	30.45	30.10	30.45	36.05	31.76	
A3	30.80	33.25	30.10	35.00	32.29	
Average	26.16	28.73	27.71	32.29		
L.S.D. 0.05	B= 1.375			A*B=2.750		

biochar and organic fertilizer extract. Specifically, treatments A1B3 and A2B3 yielded a nitrogen value of 36.05 mg kg-1, while treatment A3B3 exhibited a slightly lower value of 35.00 mg kg-1. These findings indicate statistically significant distinctions when compared to the control treatment.

Levels of biochar and compost extract affect Available Phosphorus

The findings presented in Table 3 indicate that the inclusion of charcoal and organic fertilizer extract has a notable impact on the levels of available phosphorus in the soil. The A2 treatment exhibited the highest average value of 30.48 mg kg-1, which was significantly different from the control treatment. The A3 and A1 treatments followed closely with average values of 27.53 mg kg-1 and 27.41 mg kg-1, respectively. The obtained results align with the findings reported by [17], who verified that the incorporation of biochar into the soil effectively enhances its fertility. The presence of organic carbon serves to increase the metabolic activities of fungal microorganisms, hence augmenting the overall efficiency of biological processes. This is mostly attributed to the microbial-mediated dissolution of phosphorus and the subsequent mineralization of organic matter.

The findings presented in Table 3 demonstrate statistically significant variations in the levels of organic fertilizer extract addition in relation to the phosphorous values. Specifically, the B3 treatment exhibited the highest performance with a recorded value of 30.43 mg kg-1, surpassing all other treatments. Following closely, the B2 treatment showed a phosphorous value of 26.59 mg kg-1. The observed differences in performance may be attributed to various factors. The organic fertilizer extract functions by facilitating the accessibility of essential nutrients to plants in the soil through the reduction of soil pH and the solubility of minerals present in the soil.

Table (3): Biochar and organic fertilizer extract levels and their interaction on soil phosphorus concentration

Treatment	**Organic fertilizer extracts**				**Average**	**L.S.D. 0.05**
biochar	B0	B1	B2	B3		
A0	17.00	16.50	18.05	29.35	20.23	A= 2.501
A1	25.40	24.70	29.40	30.15	27.41	
A2	28.40	29.00	31.00	33.50	30.48	
A3	26.50	27.00	27.90	28.70	27.53	
Average	24.33	24.30	26.59	30.43		
L.S.D. 0.05	B= 2.501			A*B=N.S		

Levels of biochar and compost extract affect Available potassium

The findings presented in Table (4) demonstrate a statistically significant impact of biochar levels and organic fertilizer extract on the addition of biochar to soil, specifically in relation to the levels of available potassium in the soil. The A2 treatment exhibited the highest performance among all treatments, with a recorded

Value of 281.1 mg kg-1. This was followed by the A1 and A3 treatments, which recorded values of 247.4 and 272.1 mg kg-1, respectively. These results align with previous research [18] that highlights the efficacy of biochar as a cost-effective alternative to manufactured mineral chemical fertilizers, as it serves as a valuable source of phosphorus, potassium, and nitrogen.

The data shown in the table indicate that there are statistically significant variations in the amounts of organic fertilizer extract with respect to the values of available potassium in the soil. The B3 treatment had superior performance compared to all other treatments, with a measured value of 273.1 mg kg-1. The B2 treatment followed closely behind, with a value of 255.6 mg kg-1.

The table (4) presented also indicates notable disparities in the levels of biochar and organic fertilizer extract in terms of available potassium values within the soil. This discrepancy may be attributed to the organic extract's ability to counterbalance the deficiency of essential nutrients, thereby preserving soil pH and enhancing the presence of mineral-rich nutrients. Conversely, biochar serves to sustain the aforementioned conditions. The element is prepared for uptake by the plant.

Table (4): Effects of biochar, organic fertilizer extract, and their interaction on soil potassium content

Treatment	Organic fertilizer extracts				Average	L.S.D. 0.05
biochar	B0	B1	B2	B3		
A0	185.5	206.5	217.0	223.5	208.1	A= 14.07
A1	220.5	247.0	260.0	262.0	247.4	
A2	263.0	249.5	286.0	326.0	281.1	
A3	285.5	262.5	259.5	281.0	272.1	
Average	238.6	241.4	255.6	273.1		
L.S.D. 0.05	B= 14.07			A*B=28.13		

Levels of biochar and compost extract affect Iron

The findings shown in Table 5 indicate statistically significant variations in the amounts of biochar and organic fertilizer extract, as well as their interaction, with respect to the soil's iron availability. Table 5 demonstrates notable variations in the impact of biochar addition, specifically highlighting an observed enhancement in the soil's iron availability as the quantities of biochar grow. In terms of soil enrichment, the A3 treatment exhibited superior performance compared to all other treatments. Specifically, the A3 treatment demonstrated a significant increase in concentration, measuring 1.774 parts per million (PPM). This represents a substantial 60.98% increase when compared to the comparison treatment, which recorded a concentration of 1.102 PPM. Following the A3 treatment, the A2 and A1 treatments recorded concentrations of 1,528 and 1,401 PPM, respectively, also surpassing the comparison treatment's concentration of 1.102 PPM. The data given in this study align with the conclusions drawn by [18], which provide evidence supporting the presence of several cations, including Al+3, Fe+3, Ca+2, and Mg+2, in biochar .

The findings presented in Table 5 demonstrate that the application of organic fertilizer extract to the soil had a notable impact on the levels of available iron. Specifically, treatment B3 exhibited the highest concentration of iron at 1.689 parts per million (PPM), representing a substantial increase of 46.86% compared to the control. This was followed by treatments B2 and B1, which recorded iron concentrations of 1.531 and 1.435 PPM, respectively. In contrast to the comparison treatment, which yielded a measurement of 1.150 parts per million (PPM), it is plausible that the incorporation of organic fertilizer extract resulted in enhanced nutrient accessibility and preparedness for the plant, as suggested by [19].

Table (5): Biochar and organic fertilizer extract levels and harvest soil ready-made iron (ppm)

Treatment	**Organic fertilizer extracts**				**Average**	**L.S.D. 0.05**
biochar	**B0**	**B1**	**B2**	**B3**		
A0	1.003	1.098	1.195	1.111	1.102	A= 0.2810
A1	1.132	1.331	1.461	1.680	1.401	
A2	1.075	1.475	1.538	2.026	1.528	
A3	1.388	1.837	1.932	1.939	1.774	
Average	1.150	1.435	1.531	1.689		
L.S.D. 0.05	B= 0.2810				A*B=N.S	

Levels of biochar and compost extract affect zinc

The findings shown in Table 6 indicate the presence of statistically significant disparities in the readiness values of zinc in the soil when biochar and organic fertilizer extract are introduced, as well as when there is an interaction between these two factors. It is observed that the inclusion of biochar in soil has a notable impact on the availability of zinc, as shown by large variations in readiness values. It is shown from Table 6 that the concentration of zinc exhibits an upward trend with increasing degrees of biochar addition. Specifically, the A3 treatment has the highest availability of zinc, with a recorded concentration of 0.904 parts per million (PPM). In comparison, the comparison treatment records a concentration of 0.218 PPM. The A1 and A2 treatments follow with concentrations of 0.474 and 0.863 PPM, respectively. The potential cause for this phenomenon may be ascribed to the presence of nutritional components within biochar, which can be related to its plant-derived origin and varying amounts of elements[20] .

The findings shown in Table 6 demonstrate statistically significant variations in the quantities of organic fertilizer extract and their impact on the zinc content in the soil. Specifically, the B3 treatment exhibited a notably higher zinc concentration of 0.789 parts per million (PPM) compared to the comparator treatment, which recorded a lower value of 0.513 PPM. The rationale behind this phenomenon can be related to the efficacy of using organic fertilizer extract. In order to enhance the soil composition with the essential nutrients required for plant growth, it is imperative to implement the findings previously [21].

Table (6): Effect of biochar, organic fertilizer extract, and their interaction on soil zinc content at harvest.

Treatment	Organic fertilizer extracts				Average	L.S.D. 0.05
biochar	B0	B1	B2	B3		
A0	0.026	0.122	0.350	0.372	0.218	A= 0.1942
A1	0.277	0.358	0.542	0.719	0.474	
A2	0.830	0.830	0.867	0.926	0.863	
A3	0.918	0.999	0.560	1.139	0.904	
Average	0.513	0.577	0.580	0.789		
L.S.D. 0.05	B= 0.1942			A*B=N.S		

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