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Changes in Some Properties of Soil in Irrigation of Soil Containing Biochar at Different Rates with Varying Irrigation Levels

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Abstract – Although it is a good practice to use deficit water in irrigation for the protection of freshwater resources, decreasing plant yield is an important problem. It has been proven by many studies that the use of biochar in deficit irrigation to improve this problem tolerates reduced yields, but it has been observed in the literature that the number of studies examining the effects of biochar on soil properties in the use of biochar against water stress is limited. Thus, in this study, it was aimed to increase the limited number of studies in the literature on this subject by examining the changes in some properties of the soil under irrigation of lettuce-grown soil containing biochar at different rates on a weight basis (B0: 0% biochar, B1: 1% biochar, B2: 2% biochar, B3: 3% biochar) with varying irrigation levels (100%: full irrigation at 100% level, 67%: deficit irrigation at 33% level, 33%: deficit irrigation at 67% level). As a result of the study, organic matter/carbon, total nitrogen and pH were 12% and 20%, 11% and 16% and 1% and 3% higher, respectively, at decreasing irrigation levels compared to full irrigation, while electrical conductivity was 6% and 12% lower, and organic matter/carbon, total nitrogen and electrical conductivity were higher in the range of 57% to 193%, 38% to 127% and 28% to 117%, respectively, at increasing biochar rates compared to the control treatment, while pH was lower in the range of 1% to 4%. As a result, by evaluating the improving effect of biochar on soil properties under deficit irrigation conditions, it was found that it can be recommended to use biochar at a rate of 3% on a weight basis, but considering electrical conductivity-increasing and pH-reducing effects of biochar and carrying out alternative studies to examine the effects of the application of different rates of biochar on field conditions under deficit irrigation conditions, including in this regard, are among the findings that can be suggested as a result of this study.

Keywords – Biochar, Deficit Irrigation, Electrical Conductivity, Organic Carbon, Organic Matter, Ph, Total Nitrogen

I. INTRODUCTION

Pollution and reduction of freshwater resources have led to the search for alternatives in the agricultural sector, where water is used the most. Among these alternative searches, deficit irrigation has been accepted as a practical action [1]. Deficit irrigation can be defined as providing a certain amount of water to the soil instead of meeting the entire amount of water needed by the plant. Deficit irrigation aims to irrigate more agricultural areas with the existing water source, provided that sufficient product is provided in irrigation, especially in regions where water resources are insufficient [2]. Although plants show a decrease in yield due to stress in the deficit irrigation approach, it is a strategic irrigation technique that reduces costs and increases income, especially in regions where water costs are high and water resources are scarce [3].

Biochar, a material that occurs as a result of the pyrolysis of biomass at high temperatures through thermochemical processes [4], supports better plant growth by regulating many properties of the soil [5]. Among the properties of the soil regulated by the biochar, the soil's water holding capacity and organic matter content [6] support the development of plant yield and quality characteristics that decrease under deficit irrigation conditions [7]. The special porous and spongy structure of the biochar contributes to more water retention in the soil and more effective management of irrigation [8]. In addition, biochar, which reduces the emission of gases caused by global warming, is evaluated as an environmentally friendly application [9] and is considered an important material in agricultural production by improving many important properties of the soil [10].

When these positive reflections for biochar are evaluated, these unique abilities of biochar have enabled it to be evaluated as a soil conditioner that brings it to the fore, especially in arid conditions, thus, in recent years, studies on the use of biochar against various biotic and abiotic stress conditions, especially drought, have accelerated. While many studies have been found in the existing literature on the use of biochar against drought in various plants, the number of studies examining soil properties in the use of biochar against water stress conditions has been limited. Thus, this study, it is aimed to increase the limited number of studies in the literature by examining the organic matter, organic carbon, total nitrogen, electrical conductivity and pH of the lettuce soil containing biochar at different rates under irrigation conditions with varying irrigation levels.

II. Materials and Method

The study, which was designed in 3 replications under the conditions of irrigation of lettuce soil containing 4 different rates of biochar (B0: 0% biochar by weight, B1: 1% biochar by weight, B2: 2% biochar by weight, B3: 3% biochar by weight) with varying irrigation levels (100%: full irrigation at 100% level, 67%: deficit irrigation at 33% level, 33%: deficit irrigation at 67% level), was carried out in a total of 36 pots with a volume of 4 liters, a diameter of 0.19 m and a height of 0.18 m in the greenhouse. The lettuce [*Lactuca sativa* L. var. *Crispa* (cv. Campania)] was used as plant material in the study, and oak biochar material pyrolyzed at 400^{o}C was commercially obtained and used in this study. Before the experiment, analyzes and calculations were made to determine some properties of the study soil and the biochar used in the study, and these are presented in Table 1.

Table 1. The some properties of the study soil and the biochar used in the study

Properties	Soil	Biochar
Organic matter (%)	0.81	56.1
Organic carbon (%)	0.47	32.5
Total nitrogen (%)	0.040	1.80
EC (dS m^{-1})	0.62	4.26
pH	7.17	9.65

According to the USDA classification, the study soil with sandy loam texture (sand: 66%, silt: 16%, clay: 18%) was sieved through a 4 mm sieve in air-dry form and mixed homogeneously with different rates (B0, B1, B2, B3) of biochar sieved through a 2 mm sieve to minimize wind losses and particle transfer from the soil [11], and filled in pots. Following the planting of the lettuce seedlings in the pots, all pots were irrigated with an equal irrigation level under full irrigation conditions (100%) with the approach of completing the current pot weight determined in the B0 treatment to the pot weight in the field capacity. To ensure the adaptation process of the plants to the soil and to prevent the plants from being directly exposed to drought stress, the first three irrigations were continued with this approach, then irrigation practices with varying irrigation levels (100%, 67%, 33%) were carried on until the harvesting period of the lettuce plants at three-day irrigation intervals. The pot weight in the field capacity was determined based on weight by weighing after the B0 treatment was saturated with water, covered to prevent evaporation, and the water level above the pot weight in the field capacity was drained. While plant weight was neglected in irrigation, weed control was provided by manually plucking the weeds seen on the pot surface.

At the end of the study period, after the lettuce plants were harvested, soil samples were taken to represent each pot and the organic matter, organic carbon, total nitrogen, electrical conductivity (EC) and pH contents of the soil samples were determined by analysis and calculations. While the organic matter content in soil samples was determined according to the Walkley-Black method [12], the organic carbon content was calculated from the organic matter amount with a standard coefficient [13]. While the total nitrogen content of the soil samples was determined based on the Kjeldahl method [14], the EC and pH content of the soil were obtained by reading the EC meter [15] and pH meter [16] in a 1:2.5 extracts of soil to water.

The statistical analysis of the data in the study, which was carried out according to a completely randomized factorial design, was made in the SPSS program. The data were evaluated with the General Linear Model by considering the variables as fixed factors (irrigation and biochar treatments) and the significant means were classified with the Duncan multiple comparison test at the 5% probability level [17].

III. RESULTS AND DISCUSSION

The changes in some properties of the soil under irrigation with varying irrigation levels of lettuce soil containing biochar at different rates are presented in Table 2. Accordingly, the effects of varying irrigation levels and biochar treatments at different rates on organic matter, organic carbon, total nitrogen, electrical conductivity and pH contents of lettuce soil were found to be significant at $P < 0.01$ (Table 3). Organic matter, organic carbon, total nitrogen contents and soil pH were higher at decreasing irrigation levels, while electrical conductivity was lower, and soil organic matter, organic carbon, total nitrogen contents and electrical conductivity increased with increasing biochar rates, while soil pH decreased.

The higher organic matter, organic carbon and total nitrogen contents of the soil at decreasing irrigation levels can be explained by the decrease in water uptake from the soil, and thus in organic matter, organic carbon and nitrogen uptake also, due to the effect of deficit irrigation. Since the plant cannot overcome the osmotic pressure in drought conditions, it cannot benefit from the water and nutrients in the soil [18]. In addition, the higher organic matter, organic carbon and total nitrogen contents of the soil at decreasing irrigation levels can also be evaluated by the decrease in mineralization under insufficient soil moisture conditions. Appropriate soil moisture is needed for oxidation of organic matter, organic carbon and total nitrogen in the soil by the soil microbial community [19]. Appropriate soil moisture increases the mineralization of organic matter, organic carbon and total nitrogen by enabling soil microorganisms to work more actively [20]. Thus, the supply of organic matter, organic carbon and total nitrogen in the soil decreases and its use by plants increases. In addition to all these, the increase in the total nitrogen content of the soil at decreasing irrigation levels can also be considered due to the decrease in the nitrogen uptake of the plant due to the change in the activities of enzymes that absorb nitrate and ammonium [21].

The increase in organic matter, organic carbon and total nitrogen contents in the soil with increasing biochar rates can be evaluated depending on the organic matter, organic carbon and total nitrogen content of the biochar (Table 1). Liu et al. defined biochar as a good fertilizer material that enriches soil organic matter, organic carbon and total nitrogen content [22]. In a different study, attention was drawn to the effect of biochar, which acts as an organic fertilizer that improves soil organic matter and carbon reserves and provides nitrogen increase in the soil, and it is stated that biochar supports plant growth with this effect [8]. In addition, many researchers have reported that biochar increases soil organic matter or organic carbon and total nitrogen content [5, 23, 24, 25, 26].

It is thought that the electrical conductivity of the soil is higher in full irrigation compared to the deficit irrigation treatments, due to the increase in the solubility of soluble salts in the soil with the water entering the soil. Although the increase in soil salinity is related to the quality of irrigation water, considering that all irrigation water contains dissolved salts in varying amounts and can increase the solubility of salts in the soil, the amount of irrigation can also increase soil salinity [27]. Haj-Amor et al. drew attention to the effects of irrigation frequency and amount of irrigation on soil salinity [28]. Similarly, Hou et al. reported that the soil salinity increased and its distribution in the soil profile expanded in conditions where the amount of irrigation increased [29].

The increase in the electrical conductivity of the soil at increasing rates of biochar mixed into the soil can be explained by the salt content of the biochar (Table 1). Biochar materials applied to the soil can directly affect soil salinity depending on their raw material content [8]. Similarly, Taiwo et al. stated that the soil salinity increased depending on the salt concentration of the compost material mixed with the soil [30], while Karimi et al. pointed out that the soil salinity increased between 17% and 49% in biochar-treated soils compared to the control treatment [5]. However, on the contrary, the reducing effects of biochar on soil sali-

Table 2. The some properties of soil in irrigation of soil containing biochar at different rates with varying irrigation levels

Treatments		Organic matter (%)	Organic carbon (%)	Total nitrogen (%)	EC (dS m^{-1})	pH
100%	B0	0.66±0.03	0.38±0.02	0.034±0.002	0.68±0.01	7.01±0.02
	B1	0.98±0.09	0.57±0.05	0.046±0.001	0.87±0.05	6.91±0.04
	B2	1.52±0.03	0.88±0.02	0.060±0.003	1.24±0.03	6.81±0.09
	B3	1.93±0.04	1.12±0.03	0.078±0.002	1.53±0.06	6.70±0.01
	Mean	1.28±0.15 C	0.74±0.09 C	0.055±0.005 C	1.08±0.10 A	6.86±0.04 C
67%	B0	0.72±0.03	0.42±0.02	0.037±0.001	0.65±0.02	7.08±0.04
	B1	1.16±0.06	0.67±0.03	0.052±0.004	0.83±0.04	7.01±0.01
	B2	1.71±0.06	0.99±0.03	0.070±0.005	1.17±0.04	6.91±0.12
	B3	2.11±0.12	1.22±0.07	0.083±0.003	1.42±0.02	6.79±0.12
	Mean	1.43±0.16 B	0.83±0.09 B	0.061±0.006 B	1.02±0.09 B	6.95±0.05 B
33%	B0	0.76±0.02	0.44±0.01	0.039±0.001	0.63±0.04	7.15±0.02
	B1	1.26±0.06	0.73±0.03	0.055±0.002	0.78±0.01	7.11±0.02
	B2	1.82±0.07	1.05±0.04	0.073±0.003	1.10±0.04	7.01±0.03
	B3	2.30±0.09	1.33±0.05	0.090±0.001	1.29±0.03	6.93±0.04
	Mean	1.53±0.18 A	0.89±0.10 A	0.064±0.006 A	0.95±0.08 C	7.05±0.03 A
Mean	B0	0.72±0.02 D	0.42±0.01 D	0.037±0.001 D	0.65±0.02 D	7.08±0.02 A
	B1	1.13±0.03 C	0.66±0.02 C	0.051±0.001 C	0.83±0.01 C	7.01±0.01 A
	B2	1.68±0.04 B	0.98±0.02 B	0.068±0.001 B	1.17±0.03 B	6.91±0.02 B
	B3	2.11±0.05 A	1.23±0.03 A	0.084±0.001 A	1.41±0.02 A	6.81±0.02 C

100%: full irrigation at 100% level, 67%: deficit irrigation at 33% level, 33%: deficit irrigation at 67% level, B0: no biochar, B1: 1% biochar on a weight basis, B2: 2% biochar on a weight basis, B3: 3% biochar on a weight basis, ±: standard error

Table 3. The variance analysis results of some properties of soil in irrigation of soil containing biochar at different rates with varying irrigation levels

Parameters	Varyans sources	df	Mean square	F	P
Organic matter	Irrigation treatments	2	0.202	16.884	0.000
	Biochar treatments	3	3.383	282.413	0.000
	Irrigation × Biochar	6	0.010	0.856	0.541
	Error	24	0.012		
Organic carbon	Irrigation treatments	2	0.067	16.884	0.000
	Biochar treatments	3	1.147	290.983	0.000
	Irrigation × Biochar	6	0.004	0.893	0.516
	Error	24	0.004		
Total nitrogen	Irrigation treatments	2	0.000	14.335	0.000
	Biochar treatments	3	0.004	197.818	0.000
	Irrigation × Biochar	6	1.516E-005	0.791	0.586
	Error	24	1.917E-005		
EC	Irrigation treatments	2	0.052	12.636	0.000
	Biochar treatments	3	1.046	254.000	0.000
	Irrigation × Biochar	6	0.005	1.252	0.316
	Error	24	0.004		
pH	Irrigation treatments	2	0.107	10.213	0.001
	Biochar treatments	3	0.129	12.226	0.000
	Irrigation × Biochar	6	0.001	0.104	0.995
	Error	24	0.011		

nity were also stated by Kong et al. and this effect was explained by the biochar's ability to absorb soil salinity [31]. This situation can be considered depending on the characteristics of the biochar that changes depending on raw material, pyrolysis method and pyrolysis temperature conditions [26, 32].

The change in pH content of the soil in varying irrigation levels and biochar treatments at different rates can be evaluated in relation to the nitrogen content of the soil. Soil pH decreases as a result of the release of three H ions for each mole of NO2 that occurs during the nitrification stage [33]. Thus, this situation better explains the decrease in soil pH with increasing biochar rates. In addition, a significant ($P < 0.01$) negative correlation relationship of soil pH with total nitrogen supports this situation (Figure 1). Similarly, Karimi et al. and Khadem et al. also reported that biochar applied to soil reduces soil pH [5, 34]. In addition, the enrichment of the soil with organic matter by biochar treatment (Table 2) may have increased the acidification aspect of the soil. Because the organic acids that emerge with the oxidation of the increasing organic matter in the soil increase the acidification of the soil [35]. However, on the contrary, the total nitrogen content of the soil increased with decreasing irrigation levels, and the pH also increased. This situation can be explained by the limitation of pH decrease depending on the limitation of nitrification due to insufficient soil moisture at decreasing irrigation levels. Stark and Firestone stated that nitrification is controlled by soil moisture [36]. Similarly, Breuer et al. also drew attention to the relationship of nitrification with soil moisture and stated that appropriate soil moisture should be provided for nitrification to occur [37].

IV. CONCLUSION

In this study, in which the changes in some properties of the soil were investigated in the irrigation of lettuce soil containing biochar at different rates with varying irrigation levels, organic matter, organic carbon, total nitrogen contents and soil pH were higher at decreasing irrigation levels, while electrical conductivity was lower, and soil organic matter, organic carbon, total nitrogen contents and electrical conductivity increased with increasing biochar rates, while soil pH decreased. As a result, by evaluating the improving effect of biochar on soil properties under deficit irrigation conditions, it was found that it can be recommended to use biochar at a rate of 3% on a weight basis, but considering electrical conductivity-increasing and pH-reducing effects of biochar and carrying out alternative studies to examine the effects of the application of different rates of biochar on field conditions under deficit irrigation conditions, including in this regard, are among the findings that can be suggested as a result of this study.

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