ENZYME ACTIVITY OF BIOCAR APPLIED SOIL AT DIFFERENT RATES IN IRRIGATION WITH VARYING IRRIGATION INTERVALS

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ABSTRACT
Soil enzyme activities, which indicate the quality of the soil, can be affected by the input of organic matter into the soil or the change of soil moisture stocks. Thus, the change of basic enzyme activities depending on biochar and irrigation applications was investigated in this study, which was carried out in 4-liter pots with 3 replications in greenhouse conditions for 48 days, under the conditions of irrigation of the soil applied biochar at different rates on the basis of weight (I1: irrigating at intervals of 2 days, I2: irrigating at intervals of 4 days and I3: irrigating at intervals of 6 days), with varying irrigation intervals (I1: irrigating at intervals of 2 days, I2: irrigating at intervals of 4 days, and I3: irrigating at intervals of 6 days). The results showed that urease, acid phosphatase, alkaline phosphatase and dehydrogenase enzyme activities were significantly affected ($p<0.01$) by different rates of biochar and varying irrigation intervals. As the rates of biochar applied to the soil increased, urease, acid phosphatase, alkaline phosphatase, and dehydrogenase enzyme activities increased by 11.9%-27.4%, 4.9%-16.4%, 12.7%-34.3%, and 12.6%-38.2%, respectively, compared to the control application, while with increasing irrigation intervals, the enzyme activities of the soil decreased by 4.9%-11.6%, 7.3%-14.0%, 3.0%-18.7%, and 9.7%-16.1%%, respectively, compared to the control application. The results of the study found the use of biochar in increasing irrigation intervals as recommendable considering the effectiveness of biochar to improve the decreasing soil enzyme activity in the approach of increasing the irrigation interval to protect fresh water resources in today's conditions.
Keywords: biochar, enzyme activity, irrigation interval, soil

INTRODUCTION

The main goal of agriculture is to grow plants on the soil and to obtain the highest yield and quality from these plants. In other words, the main purpose of agricultural production is to maximize the yield and quality obtained from the unit area and to obtain the highest output with the least input. Although there are many factors affecting plant development and yield, if the physical, chemical and biological properties of the soil are not suitable, it is not possible to provide high yield and quality.

Important indicators of soil health include soil carbon and nitrogen cycle, soil respiration, soil nitrogen mineralization and soil enzyme activities (Nannipieri et al., 2002). The determination of the enzyme activity of the soil, which provides important information about the cycles of carbon and plant nutrients in the soil (Arnosti et al., 2014), is accepted as a very useful approach in the evaluation of issues such as plant nutrients cycle, soil fertilization and soil pollution (Chang et al., 2007). Therefore, determination of enzyme activities is very useful in examining issues such as environmental change and soil management (Kotroczó et al., 2014).

The effects of various enzyme activities and soil microbial community on soil fertility have been proven. The main sources of enzymes active in the soil are plants and macro and micro organisms (Kiss et al., 1975). Soil enzymes play a role as the main factor in catalyzing the plant nutrient cycle, decomposition of organic matter and many other reactions in the soil (Dick et al., 1994; Dick, 1997). Various organic materials applied to the soil, chemical fertilizers or various approaches to stimulating the microbial population support the development of soil enzyme activity (Leinweber et al., 2008).

Recently, the use of highly incinerated organic materials, called biochars, to correct unfavorable soil properties has become common (Verheijen et al., 2010). Although these organic materials exhibit different characteristics because they are obtained from varying raw material contents, their robust aromatic structures and high carbon contents are expressed as important common features (Sohi et al., 2009). According to its characteristic structure, biochar ensures the retention of water and nutrients in the soil and directly affects various quality properties of the soil (Atkinson et al., 2010). The addition of biochar to the soil also has a positive effect on the activity of microorganisms living in the soil (Verheijen et al., 2010). Biochar is very effective in changes in

soil enzyme activity, as in other properties of the soil, and biochar application can be used to increase the enzyme activity of the soil (Lehman et al., 2011).

Soil moisture is an effective parameter on soil microbial biomass (Geissler et al., 2011). Increasing moisture conditions have an effect on the dynamics of organic matter. Thus, soil microbial activity is also affected by this situation (Li et al., 2010). Decreased soil moisture conditions cause more energy consumption of the microbial population as a result of the disintegration of the osmotic balance surrounding the microorganisms. Thus, the microbial balance is negatively affected as a result of the limitation of the population of microorganisms and their respiratory rates (Bian et al., 2022). This results in a decrease in soil enzyme activities, which affects soil fertility, management and sustainability (Bååth and Söderström, 1982). Sardans and Penvelas (2005) and Baldarionetal et al. (2010) stated that the decrease in moisture content in the soil also reduces the microbial biomass and thus the soil enzyme activities.

Current studies in the literature have extensively investigated the effects of biochar on soil quality, plant characteristics and soil enzyme activity. In addition, although few in number, studies examining the relationship between soil moisture and soil enzyme activity have been found in the literature. However, the fact that a study examining soil enzyme activity under irrigated conditions with varying irrigation intervals of soil applied with different amounts of biochar has not been found in the literature, thus aiming to fill the gap in the literature by revealing this study, which hypothesizes that soil enzyme activity would decrease with increasing irrigation intervals, but that the decrease in soil enzyme activity could be improved with biochar application.

MATERIAL AND METHODS

During the study carried out under greenhouse conditions in a completely random factorial design, the average daily temperature and humidity values of the greenhouse were 25±6°C and 42±7%, respectively. The study was carried out under the conditions of irrigation of soil applied with biochar at different rates on a weight basis (B0: no-biochar as control, B1: 1% biochar, B2: 2% biochar and B3: 3% biochar), with varying irrigation intervals (I1: irrigating at intervals of 2 days, I2: irrigating at intervals of 4 days and I3: irrigating at intervals of 6 days). The study, which was carried out in three replications in a total of 36 pots of 4-liters (diameter: 19 cm, height: 18 cm), was finished at the end of the 48th day of the study.

Before the establishment of the study, analyzes were carried out to determine the reaction (pH) and electrical conductivity (EC) values and organic matter content of soil with clay loam texture (sand: 27%, clay: 30%, silt: 43%) in USDA classification, determined according to the Bouyoucos hydrometer method (Gee and Bauder, 1986) and biochar obtained as a result of pyrolysis at 400°C. While pH and EC were determined by pH meter and conductimeter, organic matter was obtained according to Smith Weldon method (Nelson and Sommers, 1982). As a result of the analysis, pH, EC and organic matter values of soil and biochar were 7.29 and 9.65, 0.45 and 4.26 dS m^{-1} and 2.02% and 56.1%, respectively.

The air-dried soil was mixed with the sieved biochar in the mentioned ratios (B0, B1, B2 and B3), transferred to the pots and sand-gravel material was placed on the bottom layer of each pot to improve drainage. Afterwards, all pots were irrigated according to the field (pot) capacity determined in the control application and completed to the pot capacity level. After this stage, irrigations were started with varying irrigation intervals (I1, I2 and I3). The pot capacity of the control application was determined by placing the pots in a container filled with water and waiting until the soil surface was completely wet with capillarity, then covered and after the water level above the pot capacity was drained, the pot weight was determined. In determining the amount of water applied to the pots for each irrigation interval, the weights of the pots were weighed and the current moisture was provided to the field capacity.

After the study period was completed, soil samples were taken from the pots and the enzyme activities (urease, acid phosphatase, alkaline phosphatase, dehydrogenase) of the soil were determined according to Tabatabai (1982). As a result of hydrolysis by adding urea, KCl-Ag_2SO_4 and MgO to the soil sample, urease enzyme activity was obtained by distillation of NH_4^+-N. Acid and alkaline phosphatase enzyme activities were determined spectrophotometrically as a result of incubation by adding toluene, MUB and ρ-nitrophenyl to the soil sample. To determine the dehydrogenase enzyme activity, the sample was incubated with 3% TTC and read spectrophotometrically after adding methanol.

Soil enzyme activity data (urease, acid phosphatase, alkaline phosphatase, dehydrogenase) with three replications, four biochar at different rates and three irrigation intervals were evaluated with the General Linear Model in the SPSS statistical program, and the significant averages were separated by Duncan multiple range test at 5% probability level.

RESULTS AND DISCUSSION

The enzyme activities (urease, acid phosphatase, alkaline phosphatase and dehydrogenase) of biocar applied soil at different rates in irrigation with varying irrigation intervals are given in Figures 1-4. The effects of biochar applications at different rates and varying irrigation intervals on urease, acid phosphatase, alkaline phosphatase and dehydrogenase enzyme activities were significant at the $p<0.01$ level. While urease, acid phosphatase, alkaline phosphatase and dehydrogenase enzyme activities increased with increasing biochar rates applied to the soil, enzyme activities of the soil decreased with increasing irrigation intervals.

Urease, acid phosphatase, alkaline phosphatase and dehydrogenase enzymes are extracellular enzymes that are highly sensitive to environmental factors and precursors to other enzymes. Although they are closely related to soil properties such as soil organic matter and nutrient availability and soil electrical conductivity and soil reaction, they are severely affected by possible changes and stress factors (Tabatabai, 1982). There is an important relationship between these enzymes, which are effective in mineralization and oxidation processes, and the soil microbial community (Dick and Tabatabai, 1992). Therefore, soil biological activity is frequently mentioned in the evaluation of urease, acid phosphatase, alkaline phosphatase and dehydrogenase enzymes and in establishing the relationship with soil quality (Frankenberger and Tabatabai, 1991). Because, with a general approach, the presence and amount of extracellular enzymes depend on the activity of microorganisms.

The increase in the enzyme activity of the soil with the increasing rate of biochar can be evaluated depending on the organic matter and nutrient content of the biochar to the soil. Kookana et al. (2011) stated that adding biochar to the soil enriches the soil nutrient content. Ozdemir et al. (2000) reported that the increase in the microbial population as a result of the enrichment of the organic matter content of the soil by the organic wastes applied to the soil supports the development of soil enzyme activity. Similarly, Yerli (2023) drew attention to the increase in soil enzyme activity as a result of the biochar applied to the soil biologically improving the soil.

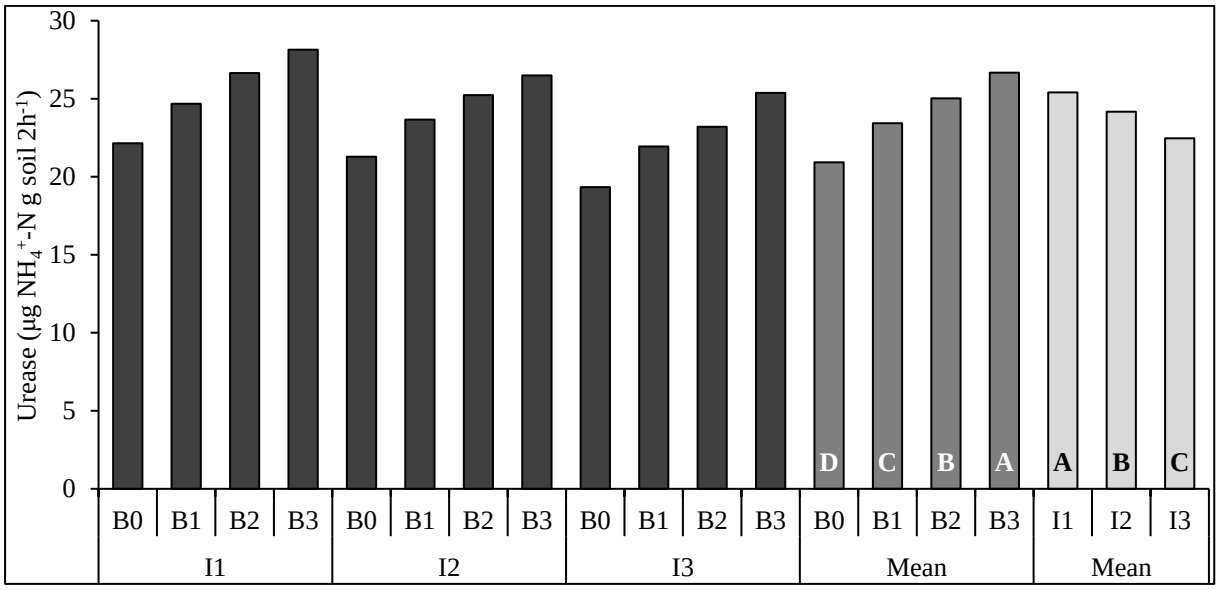


Figure 1. Urease enzyme activity of biocar applied soil at different rates in irrigation with varying irrigation intervals (B0: no-biochar as control, B1: 1% biochar, B2: 2% biochar and B3: 3% biochar, and I1: irrigating at intervals of 2 days, I2: irrigating at intervals of 4 days and I3: irrigating at intervals of 6 days).

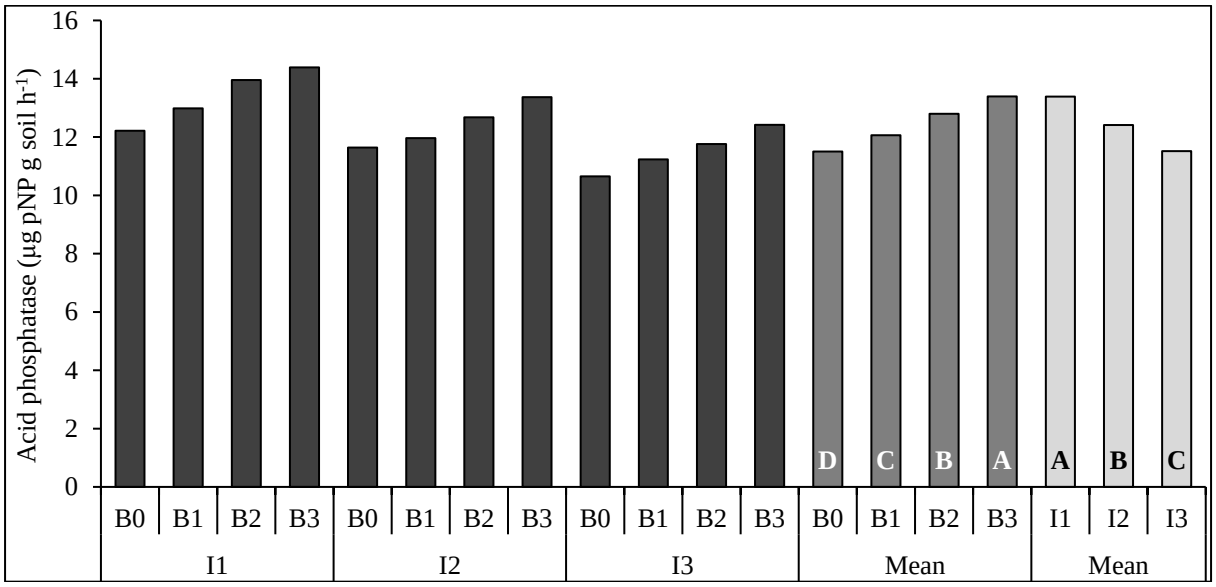


Figure 2. Acid phosphatase enzyme activity of biocar applied soil at different rates in irrigation with varying irrigation intervals (B0: no-biochar as control, B1: 1% biochar, B2: 2% biochar and B3: 3% biochar, and I1: irrigating at intervals of 2 days, I2: irrigating at intervals of 4 days and I3: irrigating at intervals of 6 days).

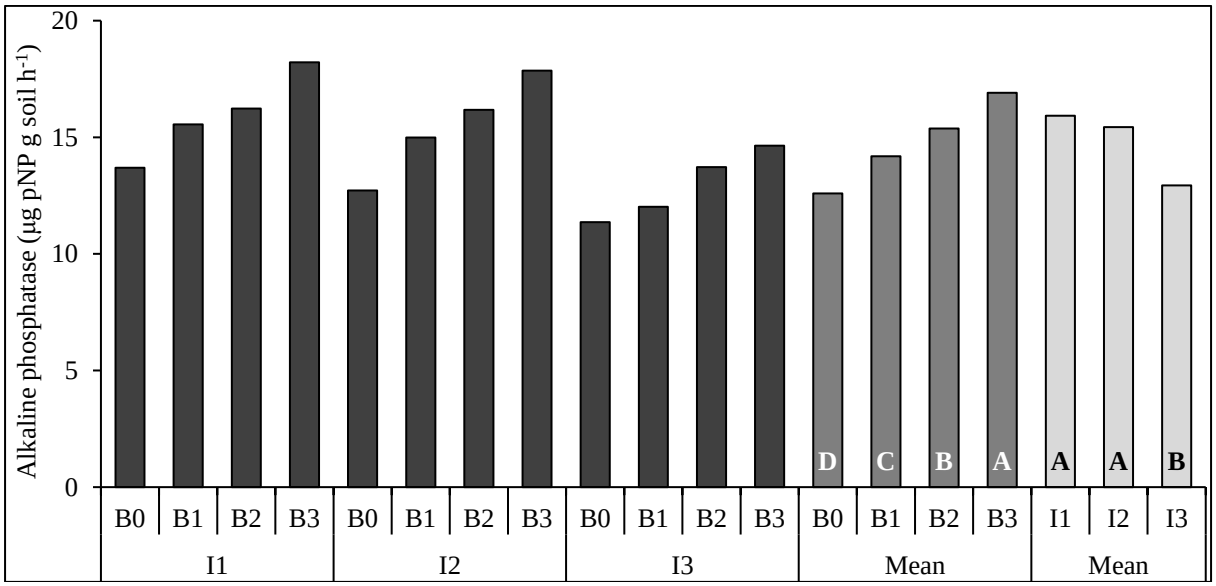


Figure 3. Alkaline phosphatase enzyme activity of biocar applied soil at different rates in irrigation with varying irrigation intervals (B0: no-biochar as control, B1: 1% biochar, B2: 2% biochar and B3: 3% biochar, and I1: irrigating at intervals of 2 days, I2: irrigating at intervals of 4 days and I3: irrigating at intervals of 6 days).

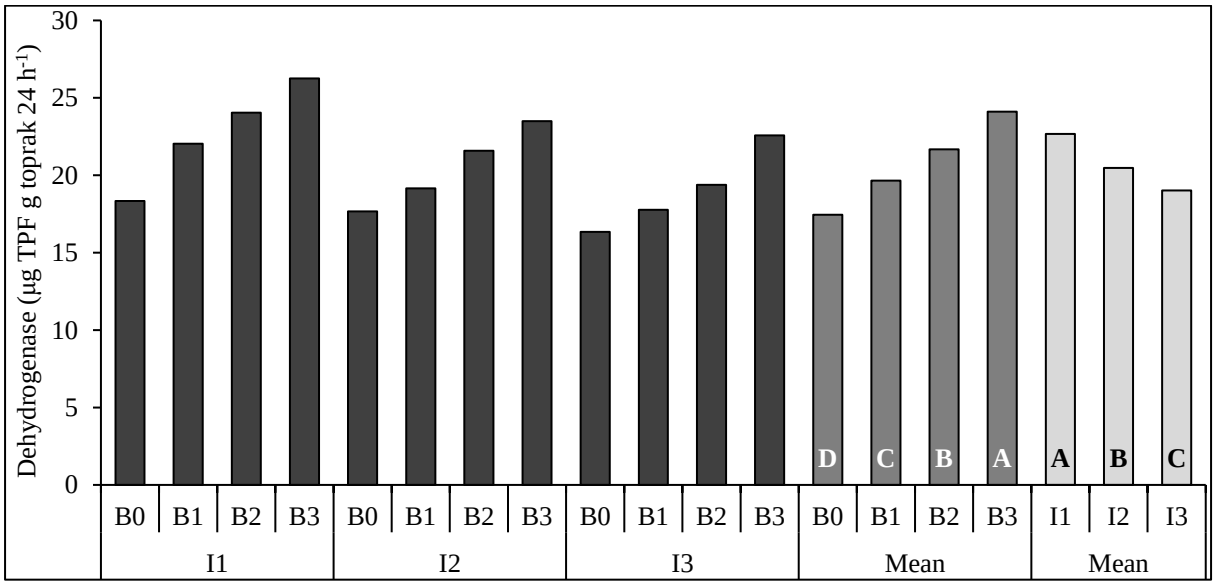


Figure 4. Dehydrogenase enzyme activity of biocar applied soil at different rates in irrigation with varying irrigation intervals (B0: no-biochar as control, B1: 1% biochar, B2: 2% biochar and B3: 3% biochar, and I1: irrigating at intervals of 2 days, I2: irrigating at intervals of 4 days and I3: irrigating at intervals of 6 days).

When organic matter, which is expressed as a source of life for microorganisms (Joergensen and Potthoff, 2005), increases in the soil, it increases the extent of microbial growth and results in an

increase in the enzyme activity of the soil (Ozdemir et al., 2000). Increasing organic matter and various nutrients in the soil increase soil enzyme activity by providing a more suitable environment for soil biology. Extracellular enzymes responsible for the decomposition of organic matter improve their activation as a result of adding organic matter to the soil (Cardelli et al., 2019). In addition, the application of biochar to the soil and the structural feature of biochar to provide a more suitable living environment for microorganisms can be evaluated as a different explanation of the increase in enzyme activity. Farrel et al. (2013) reported that the spongy and porous structure of biochar in soil increases the development and population of soil biological agents and various soil organisms. Masto et al. (2013) pointed out that the microbial community of the soil increased threefold in soil applied with biochar compared to conditions without biochar. As a result of different studies, it was determined that biochar improved the enzyme activity of the soil, in accordance with this study (Paz-Ferreiro et al., 2014; Paz-Ferreiro et al. 2015; Wang et al., 2015; Das et al., 2021; Li et al., 2022).

Soil moisture has a special importance in the microbial activities of the soil (Kucuk and Cevheri, 2018). Increasing moisture conditions of the soil provide a more suitable environment for soil microorganisms (Akbolat and Coskan, 2021). Especially in semi-arid and arid regions, soil moisture is lost rapidly in hot seasons, and accordingly, microbial activity decreases in insufficient soil moisture conditions (Sakin et al., 2021). Thus, this may explain the decrease in soil enzyme activity with increasing irrigation intervals. In addition, the decrease in the frequency of irrigation may cause the soil to dry out, its structure to deteriorate, and the nutrient availability to decrease, thus decreasing the microorganism activity and subsequently the enzyme activity.

Yerli and Sahin (2021) stated that frequent irrigation provides a more suitable environment for microorganism activities. The decrease in microbial activity directly leads to a decrease in enzyme activities in the soil (Ozdemir et al., 2000). Paz-Ferreiro et al. (2015) reported that possible changes in soil structure depending on the irrigation water source directly affect the microbial biomass and soil enzymes. In addition, considering the variations in soil temperature in irrigation with varying irrigation intervals (Yerli and Sahin, 2021), a different explanation for the changes in enzyme activity depending on irrigation practices may be soil temperature. Kunito et al. (2018) reported that soil temperature changes due to soil moisture directly affect soil enzymes. Steinweg et al.

(2012) pointed out that soil enzyme activity increases due to the improvement in microbial activity under increasing temperature conditions in the soil, but this is limited after a certain temperature.

CONCLUSION

In this study, in which the changes in soil enzymes as urease, acid phosphatase, alkaline phosphatase and dehydrogenase were investigated in the irrigation of soil applied with different rates of biochar with varying irrigation intervals, it was determined that all enzyme activities of the soil increased with increasing biochar ratios, but a decrease was observed in the enzyme activities of the soil with the increase of irrigation intervals. In today's conditions, where the sustainability of fresh water resources is a necessity, the use of biochar to improve the decreasing enzyme activity in the approach of increasing the irrigation interval to protect fresh water resources was found to be recommendable as a result of the results of this study. However, conducting more comprehensive field studies on this subject and examining alternative biochar and different organic materials were among the findings obtained from the results of the study as a recommendable strategy for obtaining clearer results.

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