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ORIGINAL ARTICLE

Effect of vermicompost and biochar application on microbial activity of soil under deficit irrigation

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ABSTRACT

Climate change is a growing global threat to biodiversity and ecosystems. In this study, we aim to find a solution to sustain soil microbial life under water shortage that occurs as a result of climate change. In this study, tomato plants were grown under full and two-stage limited irrigation conditions in soil treated with vermicompost and biochar. An insignificant effect of irrigation regime and planting application on soil respiration (BSR) value could be determined. Compared to the control, no difference could be detected with ECOF applications in unplanted soils under full irrigation conditions. While the dehydrogenase (DHG) activity of the unplanted plots was determined as 14.35 µg TPF g-1, the determination of the planted plots as 12.52 µg TPF g-1 can be considered as an expression of the fact that the microorganisms in the soil are less exposed to cultural processes in tomato cultivation and support to increase their populations. In Full irrigation and Deficit 1 application in unplanted soils, DHG activity at the level of 14.08 and 17.58 µg TPF g-1 was obtained, respectively, with the addition of biochar, followed by control plot in Full irrigation application and vermicompost application in Deficit 1 application. In Deficit 2 application, biochar application made a significant difference compared to the other two applications and caused activity of 34.91 µg TPF g-1 ($P<0.05$). With these results, it has been revealed that even at limited moisture levels, biochar applications with high porosity content can provide a lifetime opportunity to microorganisms. In conclusion, it can be stated that vermicompost and biochar applied at the level of 10 t ha-1 can support the microbial activity in the soil under limited irrigation conditions, and biochar application contributes more when the soil moisture is reduced to 15%.

Keywords: deficit irrigation, soil microbial activity, biochar, vermicompost, tomato

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1.INTRODUCTION

Tomato is the most species in the world and in our country, and Turkey ranks 3rd in world tomato production in 2020 (FAOSTAT, 2022). Therefore, is one of the most researched horticultural crops and considerable progress has been achieved in all the areas. Likewise, we preferred tomato for our research about different fertilizers and soil water keeping capacity comparison consequently.

Composting is a common practice that recycles biosolids, as well as agroindustrial organic wastes; It is considered as a simple and effective way to turn it into a non-toxic, pathogen-free and plant-nutrient-rich crop suitable for use as soil improver and fertilizer (Ros et al., 2006). There are many benefits of applying easily degradable organic wastes to agricultural soils by composting instead of dumping them into landfills or incineration. However, incorporation of organic wastes into the soil without completing their decomposition may cause phytotoxicity by immobilizing plant nutrients (Butler et al., 2001; Ros et al., 2006; Basheer, 2013). On the other hand, as a result of mixing matured compost into agricultural soils as a natural fertilizer or soil conditioner, aggregation of soil particles is encouraged and structural improvement is observed. Although composting is generally considered environmentally friendly, the most important negative aspect is the potential for oxygen (O_2) consumption and the release of carbon dioxide (CO_2), methane (CH_4), nitrogen oxide (N_2O), ammonia (NH_3) and other biogenic volatile compounds into the atmosphere in the process. For this reason, the pre-composted vermicompost product was used in the experiment, not the traditional compost product that was humified as a result of aerobic composting. In this way, it has a high potential in terms of high plant nutrition and increasing the biological activity of the soils, since it does not cause disease, weed or pathogen toxicity to the environment in which it is used, but because it has experienced the composting process very little (Bonde et al., 1988; Keeney, 1982).

There are many studies in the international literature on vermicompost. However, most of these studies generally focused on the effects of vermicompost on plant growth and yield, its ability to suppress pathogens and vermicompost production mechanisms. Although relatively few, there are also studies investigating the effects of vermicompost on soil microorganisms (Pilli, 2019). However, there are no studies showing the adaptation abilities of soil microorganisms to arid conditions where the soil surface is covered with and without plants. In our country, studies on vermicompost in terms of soil and plant nutrition are at the initial stage. Although, there are some studies on vermicompost production (Kızılkaya and Türkay 2012) examining the effects of different applications on earthworms, earthworm excrement and its environment (Ekberli and Kızılkaya 2006; Kızılkaya and Hepsen 2007; Kızılkaya 2008). There are very few studies on the effects of vermicompost on soil as an organic fertilizer. Most of the existing studies are related to the effects of seedling and plant growth, yield, quality and nutrient status in the soil (Çıtak et al., 2011; Tavalı et al., 2013; Atik 2013; Kızılkaya et al., 2012; Atmaca et al., 2014; Küçükyumuk et al., 2014).

Biochar has attracted increasing attention in recent years, with the increasing need for soil conditioners at the global level, as well as the idea of using soils as a carbon sink (Lehmann et al., 2006; Saifullah et al., 2018). Biochar has a much more stable structure than any fresh or composted organic soil conditioner or additive; demonstrating that it can remain in soils for a long time without decomposition (Lehmann et al., 2011). Researches showed that biochar applications increased the organic material and the availability of macro contents including nitrogen (N), phosphor (P) and potassium (K) (Yilmaz and Ergun, 2019). The data showing that it increases the availability of plant nutrients constitute the basis of interest (Lehmann, 2009). These characteristic features of biochar are due to its high charge density (Liang et al., 2006), as well as specific physical and chemical properties that can provide more effective plant nutrient retention, low solubility and unique chemical structure (Skjemstad et al., 1996; Baldock and Smernick, 2002). is supported by the fact that it is more resistant to microbial decomposition

than other organic substances in the soil (Shindo, 1991; Cheng et al., 2008). While trying to increase the amount of organic matter in the soil by applying fresh organic fertilizer to the soil, a significant amount of CO_2 is released into the atmosphere due to the rapid organic carbon movement. The important sources of carbon released into the atmosphere are the decomposition of hydrocarbon compounds and organic compounds of agricultural-soil origin. As one of the causes of global warming, the increase in the amount of CO_2 in the atmosphere is of great importance. For this reason, the use of biochar has gained importance in recent years, especially in Europe, as one of the applications that will increase the amount of organic matter in the soil as a sustainable physical and chemical regulator and cause a minimum amount of CO_2 release into the atmosphere (Kimetu et al. 2008; Steiner et al., 2007). As a result, the application of biochar to soils is seen as one of the ways of atmospheric CO_2 sequestration. In this process, carbon leaves its fast ecological cycle and joins the slower and more stable biochar cycle (Lehmann, 2007). In the light of similar studies and publications, the idea that biochar can be an important tool in environmental management has gained its current persuasiveness.

It is generally known that, the soil ecosystem of Mediterranean Basin where arid and semi-arid climatic conditions are dominate, adversely affected not only by drought but also by biodegradable conditions due to the high temperatures, as is known, the untimely and extreme precipitation regimes which are called global climate change. In terrestrial ecosystems, natural processes of C transformation occur mainly in the soil, where biogeochemical activities and abiotic factors, such as climate, regulate the internal cycles and flows of the organic and inorganic forms of these elements (Monreal et al., 1997). A series of strategies to increase long term pools of agricultural and degraded soils, such as the dissemination of zero-soil treatment, the use of cover plants, and the adoption of low-density grazing systems, are proposed (Lal, 2004). Land use (LU), land use change (LUC) and management practices alter the long-term steady-state level of soil organic C and N in soils. These activities, along with climatic variables, can potentially increase or decrease soil biological activity associated with heterotrophic decomposition of soil organic matter (SOM). Additionally, the most stable C in the soil are organic materials that are complex with clay minerals or biochemically protected such as biochar. Some studies were suggested that application of the mixture of vermicopost and the biochar can improve the C/N concentration in the treated soil (Yilmaz and Kurt, 2020).

The application of organic residues has been presented as an adequate strategy against soil degradation in semi-arid environments. However, the interactions between organic amendments and drought which is a major deficit on agricultural production are not fully known. We evaluate the proposed study whether biochar and vermicompost amendment in Mediterranean soils influences the stability of the soil microbial community and microbially-mediated processes against drought. We hypothesize that a multi-level characterization of the soil microbial community provided a better understanding of the responses of amended soils to drought. We also hypothesize that vermicompost and biochar provide different services. We would also like to understand the persistence of the soil communities and associated ecosystem services after application organic amendments to the soils in the different type of drought conditions.

2. MATERIAL AND METHOD

This research was conducted in the agricultural greenhouse of Horticulture Department of Ege University, (38◦27’17.03’’N. 27◦14’17.71’’E; Bornova- İzmir) in the spring of 2021. The greenhouse, whose side and roof ventilations are covered with insect net, is 16.5x50 m in size, and is covered with a polyethylene (PE) cover. Prior to the experiment, the 0-30 cm soil layer had a mean carbonate content of 13.2 g kg^{-1}, pH (saturation paste) of 8.24, soil electrical conductivity (EC) of 0.93 dS m^{-1}, total nitrogen ($N_{KJELDAHL}$) of 0.62 g kg^{-1}, total organic carbon (C_{org}) of 10.30 g kg^{-1}, available P_{OLSEN} of 21.80 mg kg^{-1} and available K_{NH4OAc} of 217 mg kg^{-1}.

2.1. Plant material and organic soil amendments

Among the tomato genotypes sent from different countries within the framework of the PRIMA-VEGADAPT project, VC-T24 GRC-451/04 AUA (Agricultural University of Athens-Greece) genotype was used as a planted medium in the study. Vermicompost (pH, 6.92; EC, 5.56 dS m^{-1}; organic-C, 32.52%; total N, 2.61%; total P, 1.62%; total K, 1.28%) was obtained by processing by *Eisenia foetida* type worms in a 1-year period from dairy manure using the box method. The manure obtained after the harvest was rested in a cool and dry environment for 1-year. Biochar (pH, 6.71; EC, 2.16 dS m^{-1}; organic-C, 31.09%; total N, 3.78%; total P, 2.12%; total K, 0.15%) was obtained by slow pyrolysis at 550°C, using olive pomace, a waste of 3-phase olive oil plant.

2.1.1. Seed planting medium

The seeds used in the experiments were sown with imported peats (Klasmann TS1, Germany). The peat clods in the package were crushed, moistened and filled into the seed sowing container (viol). 128 foam trays (66.5 x 33.5 x 4.9 cm) were used to grow tomato seedlings.

2.1.2. Growing site (pots)

Cultivation was carried out in brown plastic horizontal pots (Model: S334, Ceren Plastic, Yenisehir-Izmir) measuring 75x23x16 cm. In the research, super coarse "Perlite" (İzper Perlite Enterprises, cigli, Izmir) for agricultural purposes was used as the growing medium.

21.3. Seed planting

After the peat used in seed sowing was blended and moistened, it was filled into 128 foam viols. The seeds of the selected genotypes used in the experiment were sown on February 19, 2021, with 1 seed in each cell compartment, then the medium was moistened again and the viols were placed in the germination chamber after they were covered with cling film. The viols were kept under dark conditions for 3 days at 22-24 °C day and night temperatures and 80% humidity, then continued to be grown in the same cabin under light for 16 hours at 20-22 °C day and 16-18 °C night temperatures. During seedling cultivation, 300 g/da Agroleaf Power 20-20-20+TE foliar fertilizer was given along with irrigation and irrigation when necessary. Irrigation and foliar fertilization were done with a back pump in the form of micro particles.

2.1.4. Cultivation System and Planting

In the research, open system media culture was used in soilless cultivation. Before planting, the greenhouse was prepared for production, the pots left over from the previous production were disinfected, filled with perlite (18 liters/pot), and the perlites in the pots in the greenhouse were washed with plenty of water. After the water drained from the media, on March 29, 2021, 2

Figure 1. General view of the greenhouse after planting seedlings

plants (100 x 37.5 cm) were planted in each pot (Figure 1). The plant density was 2.66 plants/m2. For each genotype used in the experiment, a total of 24 seedlings were planted with 3 replications and 8 plants in each replication under the relevant irrigation topic. Only for VC-T14 (Seccagno PSC1-1) genotype 12 seedlings were planted at 4 plants per replication because there were not enough seeds.

2.1.4. Nutrient Solution Recipe and Used fertilizers

Day's (1991) recipe was used for plant nutrition. According to the recipe, a nutrient solution was prepared by using fertilizers that are easily available in the market and easily dissolved in water. The nutrient solution recipe and the fertilizers used are given in Table 1. Nutrient applied to the seedlings the day after planting.

2.1.5. Irrigation System and Trial Topics

In the study, drip irrigation system was used in the application of nutrient solution and water to the root zone. The fertilizers in Table 1 were prepared as a stock solution (stock A, B and C) and a 10 liter volume micro element solution (stock MESS) in 3 separate tanks with a volume of 150 liters, according to their miscibility, then added to the water in the main tank and added nutrients to made the solution. The solution, taken from the main tank with the help of centrifugal pump, was conveyed into the greenhouse through a PVC main pipeline with 50 mm outer diameter after passing through a disc filter, and was used to fill the feeding tanks. The solution, which comes out of the feeding tanks with 20 mm main pipes, was delivered to the plants by black coloured PE lateral pipes with 16 mm outer diameter. In the study, the amount of nutrient solution applied for each subject was measured with the help of the calibrated counters. Pipes with a length of 5 cm and a diameter of 16 mm were attached to the ends of the pot drainage outlets to collect the drained nutrient solutions. Drainage outlets were combined with pipes with a diameter of 25 mm and conveyed in the drainage tank. In the greenhouse experiment, irrigation issues were included in the main plots and plant situations as planted and unplanted were included in the subplot. Irrigation topics consisted of S0: full irrigation (control) and S1: Deficit and S2: Deficit 2. The experiment was carried out in randomized blocks according to the split plot design with 3 replications. In the programming of irrigation, the value of the accumulated solar radiation value in the greenhouse was taken as a basis, and approximately 25-30% drainage was allowed for full irrigation (S0). The amount of irrigation water applied in S1 and S2 subjects was reduced by 35% and 50%, respectively. Irrigation issues were started 3 weeks after planting. The amount of irrigation water applied during the trial was automatically measured and recorded with digital meters.

2.1.6. Experiment, Soil Sampling and Analysis

In the greenhouse experiment, on March 24, 2021, organic soil conditioners, vermicompost and biochar, were applied at 10 t ha^{-1}. Tomato seedlings were planted on March 29, 2021 and the first soil sample for microbiological purposes (dehydrogenase-DHG and basal soil respiration-

Table 1. Nutrient solution recipe used in plant nutrition

Element	mg/L	Chemical source used	
N	210 (240) *	Ammonium nitrate	NH_4NO_3 (%33)
P	40	Phosphoric acid	H_3PO_4 (%85)
K	250 (300) *	Potassium nitrate	KNO_3 (%13 N, %46 K)
Ca	150 **	Calcium nitrate	$5Ca(NO_3)_2.NH_4NO_3.10H_2O$ (%15.5 N, %19 Ca)
Mg	50	Magnesium sulfate	$MgSO_4.7H_2O$ (%10Mg)
Fe	2	Iron chelate	Na_2.Fe-EDTA (%1.5 Fe)
Zn	0.50	Zinc sulfate	$ZnSO_4.7H_2O$
Mn	0.75	Manganese sulfate	$MnSO_4.H_2O$
B	0.4	Boric acid	H_3BO_3
Cu	0.10	Copper sulfate	$CuSO_4.5H_2O$
Mo	0.05	Ammonium molybdate	$(NH_4)6Mo_7O_{24}.4H_2O$

*Doses in parentheses were applied after the 3rd cluster.

** Calculated considering the amount in the irrigation water.

BSR) was taken from a depth of 0-15 cm on April 8, 2021, 15 days after the applications. With the last harvest, the second soil sample for microbiological purposes was taken on July 16, 2021, 114 days after the applications. To evaluate whether biochar and vermicompost amendment in Mediterranean soils influences the stability of the soil microbial community and microbially-mediated processes against drought, two organic amendments (biochar and vermicompost) and 3 irrigations treatments namely (1) Full irrigation (water is applied when 20% of soil water depletion), (2) Deficit 1 (70% of water applied at Full irrigation), (3) Deficit 2 (40% of water applied at Full irrigation) were tested. Agricultural chemical applications were carried out with pesticides and chemical fertilizers and application doses specified in the project. However, hoeing, taking a seat and etc. cultural processes, such as these, were applied only to planted areas. Thus, to declare the possible different between planted and unplanted areas, sampling carried out through planted either unplanted soil in this study. Basal soil respiration was detected using a 0.1 N NaOH solution after an incubation period of 24 h at 25° C (Isermeyer, 1952; Jäggy, 1976). Dehydrogenase activity (DHG, EC 1.1) was determined by photometric measuring at 546 nm of TPF (triphenyl formazan) formed by adding a solution of TTC (2,3,5 triphenyl tetrazolium chloride) at a concentration determined according to soil texture and the amount of organic matter, and incubating for 16 h at 25°C (Thalmann, 1968).

2.1.7. Statistical evaluation

Independent variables in the study known as; soil sampling period (PERIOD; 1-08.04.2021, 2-16.07.2021), vegetation status (PLANT; 1-Unplanted, 2-Plant), irrigation (IRRIGATION; 1-Full Irrigation, 2-Deficit1, 3-Deficit2) and organic soil amendments (TREATMENT; 1-Vermicompost, 2-Biochar, 3-Control). There were also three replications (REPLICATION; 1-2-3) in the study. Basal soil respiration (BSR) and dehydrogenase activity (DHG) were the dependent variables. The data obtained in the study; factorial multivariate ANOVA (MANOVA) was evaluated according to the variance analysis technique using the "SPSS 25.0" statistical package program, and Duncan's test, one of the multiple comparison methods, was used to detect different groups as a result of the variance analysis.

Table 2. Microbial parameters determined in soil samples

Dependent variables				BSR[f] ($\mu g\ CO_2\text{-}C\ g^{-1}\ h^{-1}$)	DHG[g] ($\mu g\ TPF\ g^{-1}$)	Dependent variables				BSR ($\mu g\ CO_2\text{-}C\ g^{-1}\ h^{-1}$)	DHG ($\mu g\ TPF\ g^{-1}$)
1st Period (8 April 2021)	Unplanted	Full irrigation	V[a]	4.96[d] (±2.70)[e]	9.52 (±2.62)	2nd Period (16 July 2021)	Unplanted	Full irrigation	V	4.62 (±1.26)	7.57 (±0.57)
			B[b]	6.64 (±1.53)	17.83 (±2.01)				B	3.66 (±1.22)	10.32 (±0.44)
			C[c]	7.18 (±2.03)	11.51 (±3.64)				C	4.21 (±1.16)	10.75 (±1.30)
		Deficit 1	V	4.34 (±91)	11.82 (±6.63)			Deficit 1	V	5.45 (±0.52)	13.03 (±2.16)
			B	7.48 (±1.47)	14.56 (±6.39)				B	5.38 (±0.51)	20.61 (±4.57)
			C	8.63 (±0.11)	5.52 (±0.54)				C	5.79(±0.45)	11.14 (±5.02)
		Deficit 2	V	7.33 (±1.25)	17.17 (±1.99)			Deficit 2	V	3.80 (±0.35)	10.62 (±0.75)
			B	8.51 (±0.57)	38.90 (±4.68)				B	5.30 (±0.22)	30.93 (±1.90)
			C	10.76 (±2.53)	12.52 (±1.29)				C	7.83 (±1.91)	3.89 (±2.33)
	Planted	Full irrigation	V	7.02 (±0.88)	11.66 (±2.40)		Planted	Full irrigation	V	5.68 (±0.82)	16.78 (±0.65)
			B	6.65 (±3.26)	12.74 (±3.21)				B	7.30 (±0.95)	10.44 (±0.63)
			C	8.19 (±1.07)	19.30 (±7.06)				C	6.44 (±1.28)	5.98 (±1.23)
		Deficit 1	V	7.32 (±1.40)	13.73 (±2.29)			Deficit 1	V	5.73 (±0.96)	6.89 (±2.46)
			B	7.80 (±0.82)	16.63 (±0.80)				B	5.92 (±0.70)	10.92 (±3.34)
			C	7.93 (±0.76)	11.60 (±2.80)				C	5.37 (±1.37)	2.75 (±1.18)
		Deficit 2	V	6.47 (±2.14)	15.98 (±2.06)			Deficit 2	V	6.01 (±0.31)	9.95 (±2.21)
			B	7.00 (±2.24)	40.74 (±20.4)				B	4.62 (±1.26)	7.57 (±0.57)
			C	5.44 (±1.65)	4.93 (±1.67)				C	3.66 (±1.22)	10.32 (±0.44)

[a]: V, Vermicompost; [b]: B, Biochar; [c]: Control; [d]: All values are given on a dry matter basis as the average of six values; [e] : Standard deviation; [f] : Basal soil respiration; [g]: Dehydrogenase activity.

* Averages shown with the same letter are not statistically different from each other according to the Duncan test. (P<0.05). Lower case letters following averages show comparisons of organic soil conditioners in the same irrigation application, uppercase letters in the same planting status, and bold capital letters in the period average.

3. RESULTS

According to the statistical analysis of the data obtained from the greenhouse experiment results; the differences that the independent variables created on the biological properties of the soils individually and interactively were found to be significant in terms of the dependent variables. The fact that the replications established in the trial plan were found to be statistically insignificant indicates that the data obtained from the study can be evaluated more healthily.

3.1. Effects on soil respiration (BSR)

As can be seen from Table 2, the BSR value of the research soils varied between 3.66 and 10.76 µg CO_2-C g^{-1} h^{-1}. The amount of CO_2, which is the end product as a result of the use of organic C in the soil as a C and energy source by heterotrophic microorganisms, gives healthy and important information about the mineralization of soil organic C. CO_2-formation is also known as soil respiration (BSR). Soil microbial activity is easily affected by cultural treatments applied to soils. The fact that the unplanted area shows lower BSR activity than the planted area is the biggest evidence for this. In addition to the negative effects of cultural processes on the structure of the soil in the planted area, it is an expected result that the planted area will show higher BSR activity as a result of the increase in the amount of oxygen entering the soil through plant roots and hoeing.

Table 3. Changes in mean microbial parameters

Dependent variables				BSR[f] (µg CO_2-C g^{-1} h^{-1})				DHG[g] (µg TPF g^{-1})			
Mean Results of the Periods	Unplanted	Full irrigartion	V[a]	4.79	*a*	*B*	***D***	8.55	*b*	*C*	***DE***
			B[b]	5.15	*a*	*B*	***B-D***	14.08	*a*	*BC*	***CD***
			C[c]	5.69	*a*	*B*	***B-D***	11.13	*ab*	*C*	***C-E***
		Deficit 1	V	4.90	*b*	*B*	***CD***	12.42	*ab*	*BC*	***CD***
			B	6.43	*ab*	*B*	***B-D***	17.58	*a*	*B*	***C***
			C	7.21	*a*	*AB*	***BC***	8.33	*b*	*C*	***DE***
		Deficit 2	V	5.56	*b*	*B*	***B-D***	13.90	*b*	*BC*	***CD***
			B	6.90	*ab*	*B*	***B-D***	34.91	*a*	*A*	***A***
			C	9.29	*a*	*A*	***A***	8.20	*b*	*C*	***DE***
	Planted	Full irrigation	V	6.35	*a*	*AB*	***B-D***	14.22	*a*	*B*	***CD***
			B	6.98	*a*	*AB*	***B-D***	11.59	*a*	*B*	***C-E***
			C	7.32	*a*	*A*	***B***	12.64	*a*	*B*	***CD***
		Deficit 1	V	6.53	*a*	*AB*	***B-D***	10.31	*ab*	*B*	***C-E***
			B	6.86	*a*	*AB*	***B-D***	13.77	*a*	*B*	***CD***
			C	6.65	*a*	*AB*	***B-D***	7.17	*b*	*B*	***DE***
		Deficit 2	V	6.24	*a*	*AB*	***B-D***	12.96	*ab*	*B*	***CD***
			B	6.24	*a*	*AB*	***B-D***	26.73	*a*	*A*	***B***
			C	5.14	*a*	*B*	***B-D***	3.25	*b*	*B*	***E***

Full irrigation	**6.05 A**	**12.04 B**
Deficit 1	**6.43 A**	**11.60 B**
Deficit 2	**6.56 A**	**16.66 A**

Vermicompost	**5.73 B**	**12.06 B**
Biochar	**6.43 A**	**19.78 A**
Control	**6.88 A**	**8.46 C**

[a]: V, Vermicompost; [b]: B, Biochar; [c]: Control; [d]: All values are given on a dry matter basis as the average of six values; [e] : Standart deviation; [f] : Basal soil respiration; [g]: Dehydrogenase activity.
* Averages shown with the same letter are not statistically different from each other according to the Duncan test. (P<0.05). Lower case letters following averages show comparisons of organic soil conditioners in the same irrigation application, uppercase letters in the same planting status, and bold capital letters in the period average.

No difference could be detected with organic soil conditioner applications in unplanted soils, under full irrigation conditions, compared to the control. However, due to the decrease in the amount of water, the amount of CO_2 released from the soils could be reduced with vermicompost and biochar applications with high stable carbon content. When evaluated from this point of view, the effect of vermicompost material, which was rested for 2 years after it became stable and mature, was statistically significantly different from the control group. Although a decrease was detected in the BSR value with the application of biochar compared to the control soils, it was not found to be statistically significant (Table 3). The effectiveness of the independent variables in terms of BSR value in tomato plant cultivation was not found significant.

If the effectiveness of irrigation practices on BSR is examined, the effectiveness of all three irrigation water amounts on BSR was not found significant. In addition, providing BSR activity close to or lower than the control group with organic soil conditioners can be considered as an important indicator of preventing the release of CO_2 greenhouse gas formed in the soil into the atmosphere. Increasing the stable carbon content of soils with porous organic materials ensures that the CO_2 formed in the soil is kept in the soil. It is thought that carbon dioxide, which is released as a greenhouse gas as a result of the reaction of CO_2 with the water held in the pores of organic soil conditioners, has the potential to alleviate the positive contribution of agricultural production on global climate change, especially even under limited irrigation conditions.

3.2. Effects on DHG Enzyme activity

Soil enzyme analyses have been used as a possible holistic evaluation of soil quality to investigate biochemical processes in soils and to reflect the biological status of soils (Bandick and Dick, 1999; Ndiaye et al., 2000; Vepsäläinen et al., 2001). Enzyme assays measure the total activity of a soil sample bound to active microorganisms and stabilized enzymes in the soil. Considering that it is difficult to extract the intact enzymes in the soil from the environment, activity is measured instead of mass (Knight and Dick, 2004). Small amounts of extracellular enzymes are stabilized on soil colloids and can maintain their activity for a long time (Burns, 1982; Nannipieri et al., 1996). This may provide an ecological advantage to some soil organisms that may benefit without having to decompose and/or synthesize these enzymes or substrates that are too large to be taken up by a microbial cell. these stabilized enzymes appear to be protected against denaturation by both proteolytic enzymes and heat (Nannipieri et al. 1996; Rao et al., 2000). According to the results of the research, we determined that the DHG enzyme activity analysed within the scope of the project can be significantly manipulated by 11 different independent variables and their interactions at 1% and 5%. Soil enzymes give a very fast and clear response to cultural processes in the soil. The activity of DHG, an intracellular enzyme, is thought to reflect the total oxidative activity range of the soil microflora and may be a good indicator of microbial activity (Nannipieri et al., 1990). Considering the average values, the DHG activity of the unplanted plots was determined as 14.35 μg TPF g^{-1}, while the determination of the planted plots as 12.52 μg TPF g^{-1} can be accepted as an expression of the support of the microorganisms in the soil to increase their populations due to less exposure to cultural processes in tomato cultivation. In Full irrigation and Deficit 1 applications in unplanted soils, DHG activity at the level of 14.08 and 17.58 μg TPF g^{-1} was obtained, respectively, with the addition of biochar, followed by control plot in Full irrigation application and vermicompost application in Deficit 1 application. In Deficit 2 application, biochar application made a significant difference compared to the other two applications and caused an activity of 34.91 μg TPF g^{-1} ($P<0.05$) (Table 3). With these results, it has been demonstrated that even at limited moisture levels, biochar applications with high porosity content can provide a life opportunity to microorganisms. Changes in soil moisture levels can have a significant effect on the size of the microbial population in the soil. However, in the study, the lowest soil moisture level of 15% did not affect the DHG activity as it was not limiting for the microbial population in the soil. In particular, the soil moisture value of 5%

in the soil samples taken with the harvest was stated in previous studies as the reason for the low microbial population size of the soils (Kayikcioglu et al., 2020). It is seen that there is a similar trend in the plots where tomato plants are grown. While no statistical difference can be determined between organic soil conditioners and control in full irrigation application, it is seen that biochar application comes to the fore due to the decrease in water. Interestingly, Deficit 2 application comes to the fore when the irrigation regime is discussed ($P<0.05$). It is thought that the most important effect in this is the high DHG activity provided by biochar. This result is also seen in the average values where organic soil conditioners are taken into account. Biochar application provided the greatest difference in DHG activity ($P<0.05$), followed by vermicompost application. Both treatments made a significant difference from the control group ($P<0.05$).

4. CONCLUSION

The water deficit caused by the global climate change and which we will feel in every sector, not only in the agriculture sector in the coming period, stands before us as one of the important problems that we need to fight. In this study, the potential of mitigating the negative effects of water, which is of vital importance for living things, on soil health of the scarcity of plant production on soil health was investigated. In the study carried out under controlled conditions in greenhouse conditions, it can be said that the amount of irrigation water applied at Deficit 1 level by using soil conditioners with stable carbon content such as vermicompost and biochar is suitable for the microbial parameters examined. Moreover, Deficit 2 irrigation water amount can also support microbial activity with appropriate soil conditioners. Vermicompost and biochar applications can support soil microbial activity at different levels due to their different properties in different irrigation water conditions. While higher microbial activity could be obtained from vermicompost and biochar applications at Deficit 1 level, microbial activity could be supported only by biochar application at Deficit 2 level. The higher microbial activity of unplanted soils without cultural processes such as hoeing, spraying etc. can be considered as an indicator of the deformation of the soil structure and the negative effects of chemical pesticides on soil microorganisms. When all the results are evaluated, it can be stated that vermicompost and biochar applied at the level of 10 t ha^{-1} can support the microbial activity in the soil under limited irrigation conditions, and biochar application contributes more when the soil moisture is reduced to 15%.

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