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Original Article

Evaluation of the fertility status of agricultural lands in Aydın province, Türkiye

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Abstract:

Soil health is vital for the sustainability of agriculture. Therefore, samples were collected from agricultural lands of 5 different districts of Aydın province. In this context, it was determined that the pH values of 61 soil samples collected were between 7.08 and 9.37. When the variation analysis of electrical conductivity (EC) values was analyzed, it was seen that the soils showed a high degree of variability. When the soil samples were analyzed in terms of microbial loads, it was observed that 14.75% of the soil samples were below the healthy soil reference values (6-8 log CFU/g), 3.27% had microbial loads close to the lower limit and 81.98% were microbially healthy. The number of halotolerant bacteria was found to be in the range of 4.3-6.89 log CFU/g in the soil samples. Halotolerant bacteria are important microorganisms in Aydın agriculture because they are stress-resistant bacteria that can promote plant growth under extreme conditions.

Key words:
agricultural lands, microbial load, soil health, soil sample

Apstrakt:

Procena plodnosti poljoprivrednog zemljišta u provinciji Ajdin, Turska

Zdravlje zemljišta je od suštinskog značaja za održivost poljoprivrede. Zbog toga su uzorkovani uzorci sa poljoprivrednih površina u 5 različitih okruga provincije Ajdin. U tom kontekstu, utvrđeno je da su pH vrednosti 61 prikupljenog uzorka zemljišta bile u rasponu od 7.08 do 9.37. Varijacionom analizom vrednosti električne provodljivosti (EC) utvrđeno je da zemljište pokazuje visok stepen varijabilnosti. Kada su uzorci zemljišta analizirani sa aspekta mikrobnog opterećenja, primećeno je da se 14,75% uzoraka nalazi ispod referentnih vrednosti za zdravo zemljište (6-8 log CFU/g), 3,27% ima mikrobno opterećenje blizu donje granice, dok je 81,98% uzoraka mikrobiološki zdravo. Broj halotolerantnih bakterija u uzorcima zemljišta bio je u rasponu od 4.3-6.89 log CFU/g. Halotolerantne bakterije predstavljaju važne mikroorganizme u poljoprivredi provincije Ajdin jer su to bakterije otporne na stres koje mogu podsticati rast biljaka u ekstremnim uslovima.

Ključne reči:
poljoprivredno zemljište, mikrobno opterećenje, zdravlje zemljišta, uzorak zemljišta

Introduction

While it takes thousands of years for bedrock to turn into soil, it only takes a few decades for our agricultural land to degrade (Hillel, 2003). It is a matter of concern that the productivity of agricultural land is decreasing day by day despite the rapid increase in the world population. Although alternative crop cultivation methods such as cellular agriculture are being developed, soils will be an indispensable resource for many years to come. For this reason, determining the current status of our indispensable soil, improving it and ensuring sustainability are very important issues.

The unconscious pollution of agricultural land by human beings has unfortunately led to irreversible disasters. Salinity and alkalinity problems cause salinization and soil loss. Salinity and erosion are the main constraints on the productivity of Turkish soils (Dinç et al., 1991, 2001). Eighty percent of Türkiye's salt-affected soils are saline or mildly salty. Soil salinity is measured by a soil's electrical conductivity (EC), which has a direct impact on plant growth and development. The EC of the solution rises in the presence of ions, or salts. The low EC in the absence of salts suggests that the soil solution has poor electrical conductivity. The quantity and timing of rainfall, internal soil drainage, and irrigation techniques are some of the variables that determine salts. Rainfall generally has a tendency to dilute the salts in the soil. During drought, water is lost from the soil through evaporation and salts are effectively concentrated.

In addition to soil salinity, soil pH is also important for plant health. Soil pH affects plant growth primarily through nutrient availability. Plant-essential nutrients are most available at neutral pH. In addition, soil pH affects nutrient toxicity and microbial activity and has a direct effect on the protoplasm of plant root cells (Larcher, 1980; Marschner, 1986). A soil pH between 5.5 and 8 is ideal for most plants (Brady & Weil, 1996). In acidic soils, plants cannot utilize some elements such as potassium, magnesium, calcium and phosphorus, while in basic soils, elements such as copper, zinc, boron, manganese and iron are not easily absorbed by plants (Neina, 2019).

Healthy soil is the basis for productive and sustainable agriculture. In healthy soil, parameters such as salinity and pH, as well as the number and diversity of soil microorganisms are vital. Soil microorganisms support soil structure, water infiltration and plant root growth. They also contribute significantly to plant growth by fixing atmospheric nitrogen (Datta et al., 2015), increasing the amount of soluble phosphorus in the soil (Etesami & Maheshwari, 2018), activating plant hormones (Ahmad et al., 2008) and producing siderophores (Mia et al., 2012; Baber et al., 2018). However, overuse of synthetic fertilizers, pesticides and herbicides can damage soil pH and EC as well as beneficial soil organisms. Today, pesticides account for nearly one-third of the global chemical input market, which is approximately USD 1.7 trillion. These chemicals negatively affect the diversity and number of soil microorganisms that are effective in soil health. The deterioration in soil quality means much more than a reduction in food production. This represents a broken link in the complex web of life in which every organism, regardless of size, plays a role. A healthy soil ecosystem is filled with billions of microorganisms, including rhizosphere bacteria, all contributing to the soil's nutrient cycling. When this system is disrupted, a domino effect is triggered, jeopardizing the entire ecosystem. It is therefore clear that this issue is vital.

Maintaining healthy soils is essential to halt desertification and land degradation and even for the balance of the entire ecosystem. In order to monitor the productivity of agricultural lands, it is necessary to monitor the current salinity, alkalinity status and determine the soil microbial load in shorter periods. For these reasons, pH, EC, total number of microorganisms and the number of bacteria that can survive at 6% salt content were determined in soil samples taken from agricultural areas of 5 different districts of Aydın province. With these results, it was aimed to have information about the current status of agricultural soils in Aydın province.

Materials and Methods

Collection of soil samples

In June and July 2024, 61 soil samples were collected from agricultural lands in 5 different districts [Söke (Akçakonak, Güllübahçe and Argavlı neighborhoods), Koçarlı, İncirliova, Nazilli, Bozdoğan] of Aydın province in the Aegean Region (**Fig. 1**). Soil samples were taken from the surface to a depth of 25 cm. While sampling from agricultural lands, care was taken to represent the entire area by zigzagging. The collected samples were first placed in paper bags and then in plastic bags and transferred to the laboratory in cold chain.

Determination of microorganism counts in soil samples

Microorganism counts in soil samples collected from agricultural fields were carried out according to Atlas Ronald (1984). Each of the collected soil samples was passed through a soil sieve with a hole size of 0.2 mm. From the homogeneously mixed and sieved soil samples, 10 g of soil samples were shaken in 90 mL physiological saline (FTS-0.85% NaCl) for two hours at room temperature. Dilution series were prepared in tubes containing 9 mL FTS by taking 1 ml of the suspension and 100 μL of -3 -4, -5 and -6 dilutions were taken and sown on Nutrient Agar (NA) (Merck, Germany) in 3 replicates. After incubation at 28 °C for 48 hours, colony forming units per gram of soil (CFU/g) were calculated.

Determination of the number of microorganisms resistant to 6% salt in soil samples

Each of the collected soil samples was passed through a soil sieve with a hole size of 0.2 mm. Homogenously mixed, 10 g of the sieved soil samples were shaken in 90 mL FTS for two hours at room temperature. Taking 1 mL of the prepared suspension, dilution series were prepared in tubes containing 9 mL FTS and 100 μL of the -3 -4, -5 and -6 dilutions were transferred to NA containing 6% NaCl (Merck, Germany) in 3 replicates and the sample was spread on the petri surface by smear inoculation method. Petri dishes were incubated at 28 °C for 48 hours. After the incubation period, colony forming units per gram of soil (CFU/g) were calculated.

Measurement of pH and electrical conductivity

20 g of each soil sample was weighed and mixed with 50 mL of deionized water and stirred for

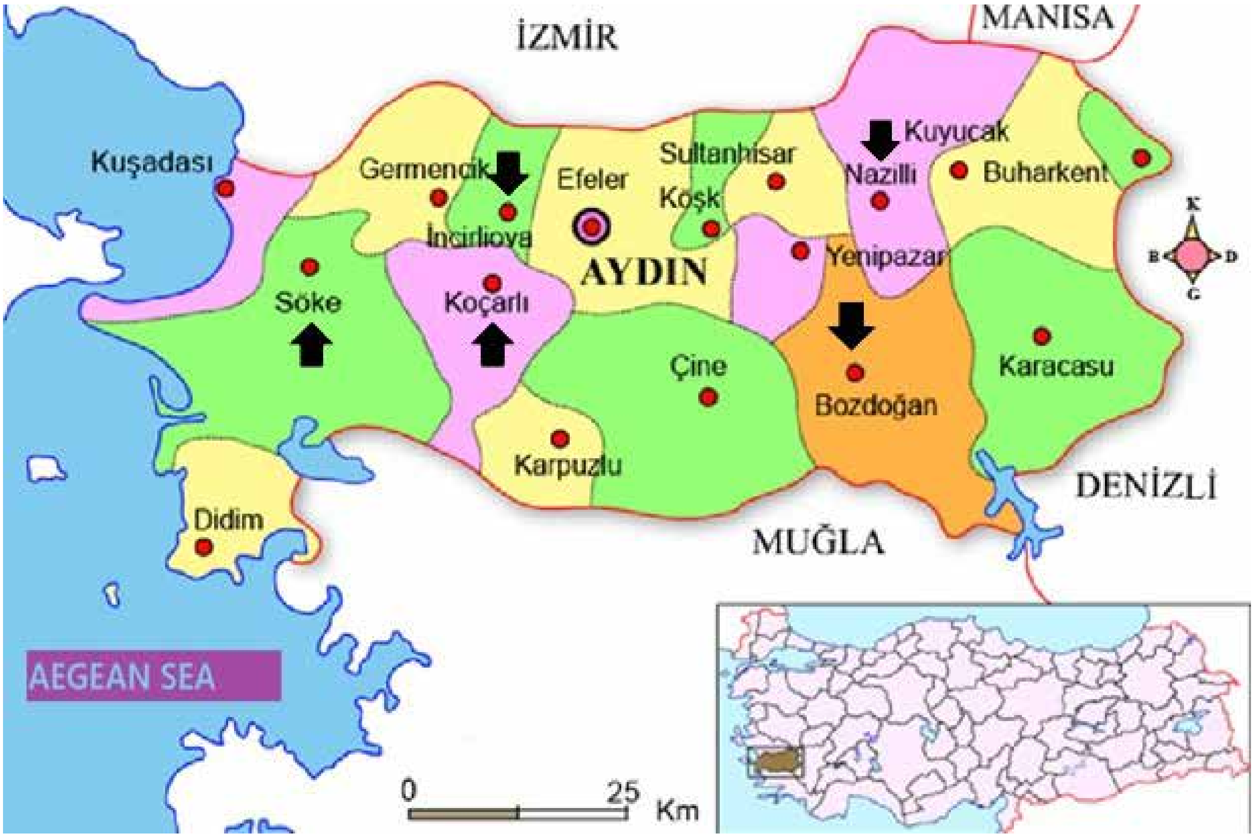

Fig. 1. Districts (indicated by arrows) where the soil samples used in the study were collected

120 minutes. The soil solutions were then filtered through filter paper. The resulting liquid was used to determine pH and electrical conductivity (EC). The pH and EC of the samples were measured using an AD8000 pH/mV/EC/TDS & Temperature meter.

Results and discussion

In the study, 5 different districts of Aydın were visited (**Fig. 1**). Sixty-one soil samples were collected from agricultural lands. The pH, electrical conductivity (EC), total number of microorganisms in 1 gram of soil and the number of microorganisms that can survive in 6% salt were determined for each sample. The minimum and maximum values, arithmetic mean, standard deviation and coefficient of variation values of pH and EC values of soil samples are given in **Tab.1** The pH values of soil samples collected from agricultural lands were found to vary between 7.08 and 9.37. In the same samples, EC values were found to vary between 71-3450 µs/cm. While the coefficient of variation between the pH values of the soil samples collected from agricultural lands was below 10%, the coefficient of variation in EC values was above 50% (**Tab.1**).

Total mesophilic aerophilic bacteria counts of agricultural soils collected from 5 different districts of Aydın were 5.27 - 8.89 log CFU/g (**Tab. 2**).

In 9 of 61 soil samples, the number of bacteria was below 6 log CFU/g (**Fig. 2**). In the same samples, the number of bacteria that can survive in 6% saline environment was 4.3 - 6.89 log CFU/g (**Tab. 2**).

In 31.15% of these soil samples, the number of bacteria that can survive in 6% saline environment was above 6 log CFU/g (**Fig. 3**).

Coefficient of variation (CV) is the most discriminating factor compared to other parameters to describe the variability of soil properties (Zhang et al., 2007). Wilding (1985) and Mulla & Mc Bratney (2000) classified the coefficient of variation, which is accepted as an important indicator in explaining the changes in soil properties, according to its values, those less than 15% are classified as less variable, those between 15-35% as moderately variable and those greater than 35% as highly variable. **Tab. 1** shows that the coefficient of variation of soil pH values is less than 15%. Although soil samples did not show variability in terms of pH values, they were found to be highly variable in terms of EC values. According to Moasheri & Foroughifar (2013), the low coefficient of variation of pH is due to the composition of the main substance in the soil. The high coefficient of variability may be due to land management factors such as fertilization and land use type.

Richards (1954) reported that the electrical

Table 1. EC and pH values of the collected soil samples

Soil sampling site	Parameter	Min.	Max.	AO	S.S.	V.K.
Söke	EC (µs/cm)	519	3450	1661.82	905.97	54.52
	pH	7.15	8.08	7.51	0.38	5
İncirliova	EC (µs/cm)	174	1220	562.13	322.36	57.35
	pH	7.5	9.37	8.26	0.57	6.84
Koçarlı	EC (µs/cm)	71	580	204.78	150.54	73.51
	pH	7.44	8.32	8.03	0.28	3.53
Nazilli	EC (µs/cm)	109	2100	521.85	638.83	122.42
	pH	7.66	8.9	8.22	0.27	3.34
Bozdoğan	EC (µs/cm)	560	1625	828	597.42	72.15
	pH	7.08	7.37	7.34	0.27	3.62

Min: Minimum value, **Max**: Maximum value, **AO**: Arithmetic mean, **S.S**: Standard deviation, **VK**: Coefficient of variation (%), **EC**: Electrical conductivity

Table 2. Total numbers of mesophilic aerophilic bacteria and bacteria viable at 6% NaCl in soil samples

Soil sampling site	Bacteria counts (log CFU/g)			
	Parameter	Min.	Max.	AO
Söke	MAB	5.27	8.48	6.61
	%6 NaCl MAB	4.3	6.89	5.24
İncirliova	MAB	6.93	7.59	7.27
	%6 NaCl MAB	5.48	6.35	5.92
Koçarlı	MAB	5.66	7.57	6.65
	%6 NaCl MAB	4.6	6.07	5.48
Nazilli	MAB	6.18	8.89	7.31
	%6 NaCl MAB	5.02	6.2	5.89
Bozdoğan	MAB	7.06	7.24	7.15
	%6 NaCl MAB	6.18	6.44	6.35

MAB: Mesophilic aerophilic bacteria, **%6 NaCl MAB**: 6% Salt viable mesophilic aerophilic bacteria

conductivity value of soil is unsaline when it is less than 2 dS/m, very slightly saline when it is between 2-4 dS/m, moderately saline when it is between 4-8 dS/m, very saline when it is between 8-16 dS/m and extremely saline when it is more than 16 dS/m. The EC values of the soil samples taken from the agricultural lands in Akçakonak neighborhood of Söke district were lower than Güllübahçe and Argavlı neighborhoods. It was determined that the soil samples taken from Argavlı neighborhood of Söke district had the highest EC value (3450 µs/cm). Among 61 soil samples, the highest number of bacteria that can survive at 6% salt (6.89 log CFU/g) was observed in Argavlı samples. This suggested that microorganisms adapted to soil salinity (**Tab. 1 and 2**). Nazilli soil samples were generally unsaline, but only one sample contained salts in the range of 2-4 dS/m and one sample was close to this range. Soil samples from İncirliova, Koçarlı and Bozdoğan districts were generally classified as saline soils (**Tab. 1**).

According to Kadam (2016), soil can be classified into three main categories based on pH: acidic soil: pH<6.5 (low pH), normal soil: pH 6.5-7.8 (medium pH) and alkaline soil: pH>7.8 (high pH). According to these criteria, the pH values of the soil samples taken from Incirliova were found to be very strongly alkaline (pH:9.37) compared to other districts. When the soils of Söke district were analyzed in terms of pH, it was observed that the pH values shifted from normal pH values to alkaline soil (highest pH: 8.08), while similar situations were found in other districts except Bozdoğan (**Tab. 1**). Başar (2001) reported that the pH values of soil samples obtained

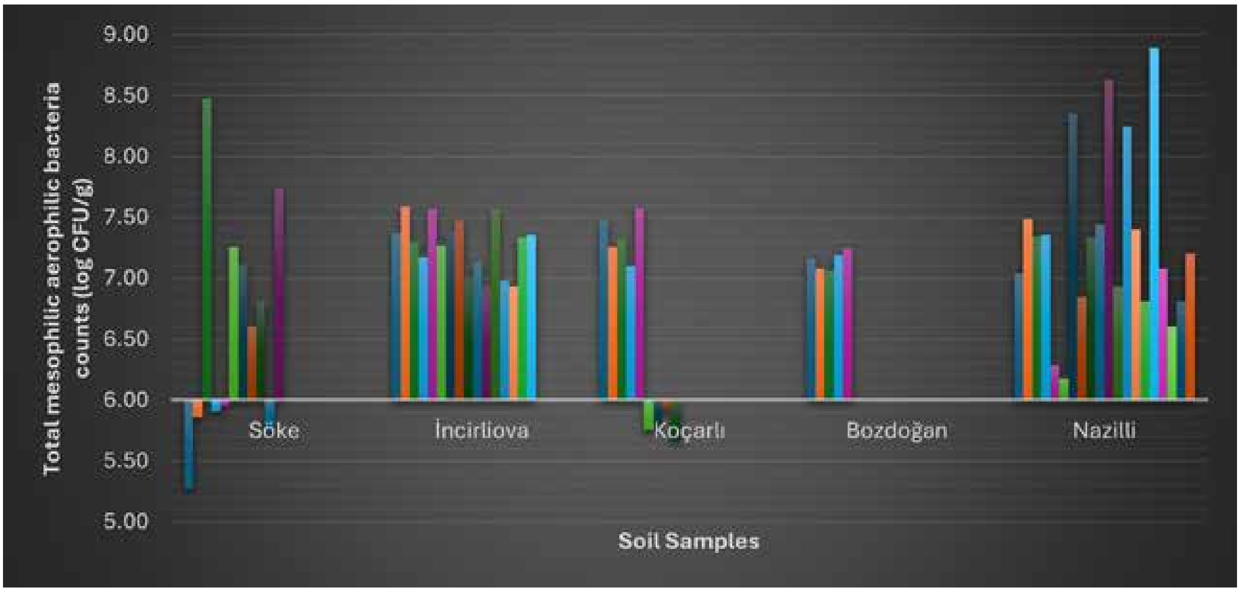

Fig. 2. Total number of mesophilic aerophilic bacteria in soil samples

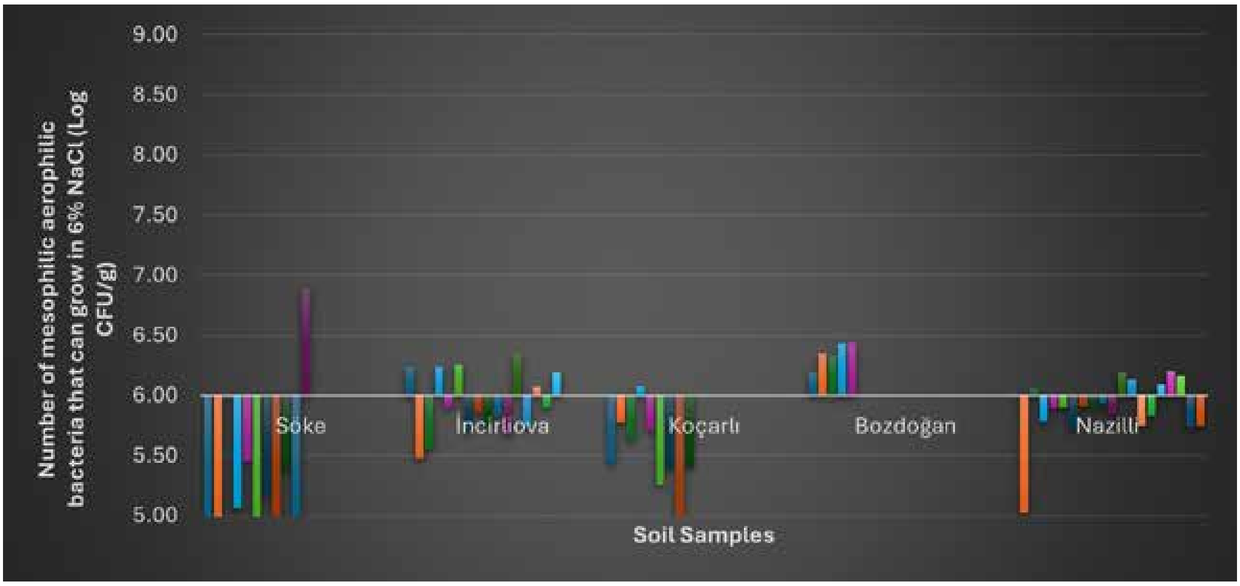

Fig. 3. Number of mesophilic aerophilic bacteria viable in the presence of 6% NaCl in soil samples

from soils where different crops were grown in Bursa region were slightly and strongly alkaline, Taşova & Akın (2013) reported that the soils of the Marmara Region were slightly alkaline. Demirekin & Erdal (2015) reported that the agricultural soils of Hakkâri-Çukurca region were slightly alkaline, while Yorulmaz et al. (2020) reported that the pH value of Söke plain soils was 8.32 on average. It is noticeable that the alkalinity problem seen in soils is general. Increasing soil pH negatively impacts its physical properties by disrupting structure and thereby reducing water permeability.

Integrating microbiological indicators into soil investigations offers a more comprehensive approach to soil health assessment, enabling better monitoring and management of soil ecosystems in the context of changing agricultural practices and land use (Semenov et al., 2025).

Measuring the number of soil bacteria is an indicator of soil health, e.g. if there are 6-8 log CFU/g culturable bacteria per gram of soil, this soil is considered a healthy soil. A count of less than 6 log CFU per gram indicates poor soil health due to nutrient deficiency found in soils with low organic matter, abiotic stress from excessive soil pH values (<5 or >8), or toxicity from organic/inorganic anthropogenic pollutants (Ratnakar & Shikha, 2018). The number of culturable bacteria in soil samples collected from Söke district was between 5.27 and 8.48 log CFU/g (**Tab. 2**). While 45.4% of the soil samples contained less than 6 log CFU/g, 18.2% were close to the lower limit and 36.4% were microbially healthy (**Fig. 2**). The pH and EC values of the soils with low numbers of microorganisms were not very high, suggesting the presence of organic and inorganic pollutants in this region. A similar situation was observed in soil samples collected from Koçarlı district. In 44.4% of the soil samples collected from this district, the number of microorganisms in 1 g soil sample was less than 6 log CFU/g (**Fig. 2**). The number of microorganisms in 1 g of soil samples from other districts was within the normal range (**Fig. 2**).

Increased microbial activity enhances their contribution to soil biochemical processes, hence allowing a reduction in the use of inorganic fertilizers (Solihin & Fitriatin, 2017; Octaprama et al., 2020). Soil microorganisms fulfill various functions, including nutrient provision, organic matter decomposition, enhancement of plant growth, and regulation of plant pests and diseases. The quantity of microbial populations in soil might signify soil fertility, since a substantial microorganism population reflects the presence of suitable organic matter, sufficient water availability, optimal temperature, and good soil ecological circumstances. In this context (**Fig. 1**), the soils of İncirliova, Bozdoğan, and Nazilli districts are presumably more productive than those of Söke and Koçarlı.

In addition to determining the total number of bacteria in 1 g of the collected soil samples, the number of bacteria that can survive in the presence of 6% NaCl (halotolerant bacteria) was also determined (**Tab. 2**, **Fig. 3**). The number of halotolerant bacteria in the samples ranged from 4.3 to 6.89 log CFU/g. The highest number of halotolerant bacteria in the soil sample from Söke can be explained by the high EC value of the same sample. If we look at the other soil samples, although the EC values are not high, the number of halotolerant bacteria is close to 6 log CFU/g. Perhaps there are microenvironments within the general soils that have high salinity at certain times under certain environmental conditions. According to Howell et al. (2022), while much of the soil has little to no measurable salinity, pores in soil particles can trap moisture. Over time, salts can leach from minerals in the soil to form separate salt-enriched phases. When these evaporites are wetted by dissolution in or direct contact with water, separate brines can form within the soil particles. Since saline solutions are a restrictive growth medium, the soil can become enriched in halotolerant microorganisms. Since many soils can be quite dry during certain seasons, this competitive advantage may increase the survival of microorganisms under unfavorable conditions. From this point of view, the high number of halotolerant bacteria despite low salinity in samples collected in Aydın districts during a season without rainfall for a long time can be considered normal. Moreover, the ability of halotolerant bacteria to tolerate variable salinity concentrations, i.e. 3-30% NaCl, makes them a suitable candidate for their application in stress agriculture (Ventosa et al., 1998). Recently, Banik et al. (2018) isolated halotolerant *Bacillus* and *Halobacillus* sp. from saline media. They reported that these bacteria supported peanut growth in both saline and metal-contaminated conditions.

Conclusion

The soil food web is a complex and interconnected system of soil-dwelling organisms. Soil microorganisms perform important functions such as nutrient cycling, organic matter decomposition, disease suppression, and plant symbiosis. A thriving soil provides numerous benefits to plant nutrition, agriculture and the environment. In general, the soil samples used in the study were found to be moderately to strongly alkaline with high variability in EC values and a wide range between unhealthy and very healthy soils from the microbial point of view. Considering the climatic conditions of Aydın, the high number of halotolerant bacteria, resistant to harsh conditions such as high pH and arid climate, positively affects the yield and quality in agricultural areas. Considering these results, it can be recommended to pay attention to the organic matter ratio in order to increase the microbial activity in the soil.

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