RESEARCH ARTICLE

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Evaluation of the heavy metal content of Sweetgum tree (*Liquidambar orientalis* Mill.) distributed in Mugla province

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Abstract

This study, it was aimed to investigate the nutritional status and heavy metal contents of *Liquidambar orientalis* Mill., an endemic species naturally distributed in Marmaris, Koycegiz, and Fethiye districts of Mugla province. When the soil heavy metal contents are examined, it has been determined that the Cr and Ni values are quite high in the Koycegiz and Marmaris samples. Cd, Co, Cr, Ni and Pb contents in the leaves, respectively; it was determined to be in the range of 0.04-0.09 ppm, 0.4-1.80 ppm, 2.85-6.87 ppm, 9.28-40.49 ppm and 0.52-2.15 ppm. Although some heavy metals were found to be above the limit values, no physical evidence was found that the plants in the study were adversely affected by these high values metabolically.

Keywords: Sweetgum (*Liguidambar orientalis* Mill.), Soil, Heavy Metal, Koycegiz, Mugla

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INTRODUCTION

The lands of Mugla province, which have suitable climatic conditions, are located within the borders of the Büyük Menderes Basin and the Western Mediterranean Basin, and the summers are hot and the winters are mild. In addition to having 1124 kilometers of coastline, our province is also significant in terms of agricultural practices (Anonim, 2004). Mugla province and its districts have fertile soil and a temperate climate, which support a diverse range of medicinal and aromatic plants that spread naturally. Despite the fact that the sweetgum plant (*Liquidambar orientalis* Mill.) is an endemic species, it grows in the areas between Koycegiz, Fethiye, Datca, and Cine Stream. The research, however, has determined that the only place where the sweetgum tree is seen as a forest is the Lake of Koycegiz and its surroundings (Kurt et al., 2008). Sweetgum (*Liquidambar orientalis* Mill.) tree is a member of the *Hamamelidaceae* family that can grow up to 35 meters tall and blooms in March-April (Yaltırık et al., 2000). The leaf widths range from 5-7 cm, and the number of lobes on the leaves ranges from 3 to 5. The sweetgum tree, which sheds its leaves in November and December, is a species that opens and sheds its seeds depending on its environment (Öztürk et al., 2008).

The population has grown rapidly within the limits of industrialization and urbanization, and the environment has been polluted by various pollutants. Exhaust gases emitted by vehicles used for transportation, for example, pollute the environment and release harmful substances. There are significant increases in the number of vehicles in certain periods, particularly in regions where new roads are being built or tourism is high. Exhaust gases, the subject of the study, pollute the

environment by being toxic to animals, plants, and all other living things, particularly humans (Aksoy et al., 2000). Although exhaust gases have different effects on the atmosphere, soil, plant, and animal health, they should be evaluated as a whole due to the negative effects caused by all factors such as polluting the atmosphere, deteriorating soil structure, reducing plant yield, endangering plant nutrient content, and endangering animal health (Kıl and Paksoy, 2014). It has been proposed that increased heavy metals cause stress in plants, resulting in physiological and genetic disorders, a decrease in yield, and crop losses (Munzuroğlu et al., 2004).

Toxic gases from motor vehicle exhausts cause dust on the roads as a result of the rapid movement of vehicles on highways, polluting our air, water, and soil resources (Tunçer, 2020). On the other hand, Sweetgum Tree (*Liquidambar orientalis* Mill.), which grows along highways and has a high medicinal value, has recently been used in many fields, raising the question of how reliable it is in terms of health.

Based on these findings, we focused our research on the sweetgum tree (*Liquidamber orientalis* Mill.) plant, which grows particularly along roadsides and has high medicinal value. The plant *Liquidambar orientalis* is also known as the Anatolian sweetgum tree or the daily tree (Velioğlu et al., 2008). The Anatolian sweetgum tree (*Liquidambar orientalis* Mill.), which is found in the southwestern part of Turkey and partially in Rhodes Island, is an endemic species that is almost non-existent elsewhere in the world. It has been reported that it grows in areas with high groundwater and along streams (Kurt et al., 2008). In this study, leaf and soil samples of the sweetgum plant were collected from the districts of Marmaris, Koycegiz, and Fethiye in Mugla province, along heavily trafficked highways, and the heavy metal contents of both the plant and the soil were investigated. Sweetgum is a plant species that is used in industries such as pharmaceuticals and perfumery. The purpose of this research is to determine the heavy metal content of the sweetgum tree, which is a medicinal and aromatic plant.

MATERIALS AND METHODS

Field Studies

The sweetgum tree (*Liquidambar orientalis* Mill.) plant was used in this study, and leaf and soil samples were collected from Koycegiz, Marmaris, and Fethiye districts of Mugla province. Soil samples were collected from 0-30 cm depth at five different points along the highway and 50 meters away. Leaf samples were collected separately from healthy parts of the tree located north, south, east, and west of the road, as well as 50 meters inland from the road. Soil and leaf samples were transported to the laboratory with labels indicating the region from which they were collected and stored under proper conditions.

The sample stations and their coordinates are as follows:

Table 1. Coordinates of Sampling Areas

Location	Road distance (m)	Latitude	Longitude
FETHIYE	0	36°71′54.90″N	29°02′09.40″E
	50		
KOYCEGIZ	0	36°99′20.70″N	28°64′69.60″E
	50		
MARMARIS	0	36°85′09.90″N	28°28′48.90″E
	50		

Analysis Studies

The soil samples were sent to Mulga Sıtkı Koçman University Research Laboratory after the preliminary stages were completed in our laboratory in exchange for service procurement. At the analysis stage of soil samples; texture (sand, clay, spindle ratio) by hydrometer method, lime; calcimetrically, the amount of organic matter according to the wet burning method (the soil samples taken are dried in an oven at 105 °C, weighed during the process, 0.5 g is weighed in microwave tubes and 2 ml of nitric acid and 6 ml of hydrochloric acid are added) (Walkley and Black, 1934), pH and EC were determined with a combined pH-EC meter. The total heavy metal values determined in the soil samples were read in the HNO_3-HCl mixture (1:3 v/v ratio) by wet burning and ICP-OES (Inductively Coupled Plasma-Optical Emission Spectrometer) device (Kacar, 1995).

After the preliminary stages were completed in the laboratory, samples were collected from healthy leaves from all over the tree by measuring 50 meters from the highway and road from the sweetgum (*Liquidambar orientalis* Mill.) plant and placed in 1.5-2.0 kg bags and taken to Muğla Sıtkı Koçman University Research Laboratory. The ash obtained from the burning of the leaves was extracted using 2 N warm HCl and distilled water. Total heavy metal values were determined in plant samples by wet burning in an HNO3-HCl mixture (1:3 v/v ratio) and reading in an ICP-OES (Inductively Coupled Plasma-Optical Emission Spectrometer) device (Kacar, 1995).

RESULTS AND DISCUSSION

Analysis Results of Soils

The soils where sweetgum plants grow are generally clay textured, and samples taken from the roadsides of Fethiye and Marmaris were determined to be in the clay-loam structure class (Table 2). In general, sweetgum trees grow well in moist, alluvial, clay, and loam soils and river beds (Acar et al., 1993). According to a 2016 study, the Oak (*Quercus robur* L.) tree grows well in deep, sandy, and clay textured soils (Bektaş et al., 2016).

The pH values of the soil of the sweetgum plant were determined to be the lowest in the area 50 meters away from the roadside of Marmaris (7.46), and the highest in the sample taken from the far area of the Fethiye district

Table 2. Soil Properties in the Study Area

Location	Road distance (m)	EC (dS/m)	pH	Kireç (%)	Organic matter (%)
FETHIYE	0	0,44	8.00	6.20	1.74
	50	1.05	8.82	15.42	0.80
KOYCEGIZ	0	0.58	7.78	0.45	2.93
	50	0.50	7.75	0.49	6.41
MARMARIS	0	0.35	8.23	1.36	0.75
	50	0.38	7.46	0.45	4.72

(8.82). The average pH of all analyzed soils was found to be 8. (Table 2). In other words, all soils have been determined to be slightly or strongly alkaline, with the exception of the sample taken from the study area, which is located far from the road in the Marmaris district. According to Acar et al. (1993), the soil pH value of the sweetgum plant is between 7 and 8, and they prefer basic soils. The electrical conductivity (EC) values of the soils where the sweetgum plant grows were determined to be the lowest in the Marmaris roadside (0.35 dS/m) and the highest in the Fethiye district (1.05 dS/m). The average electrical conductivity (EC) of the soils in the study area was calculated to be 0.55 dS/m (Table 2). According to Waters et al. (1972), the limit values for electrical conductivity (EC) in soils should be between 1.51-2.25 mS/cm. Considering the limit values, it is clear that all of the soils in the studied region are salt-free and have no salinity issues.

When the lime contents of the soils belonging to the research plant were examined, the soils of the Koycegiz Sweetgum forest and the Marmaris district 50 m away from the road had the lowest 0.45%, and the soil samples from the Fethiye district had the highest (14.8%). The average lime rate of all soils in the study area is 4.06%. (Table 2). According to Allison and Moodie (1965), the adequacy of lime content in soils should be between 5.1 and 15.0%. Given the amount of lime in the study area's samples, 50% was determined at very low rates. The organic matter content of the soils in the area where the sweetgum plant grows has been determined to be 0.75%, with the lowest in Marmaris roadside soils and the highest in the inner part of Koycegiz (6.41%). The amount of organic matter ranged between 0.60-2.74% (Sinik, 2011). When the lowest and highest values in our study were compared, it was discovered that soils where sweetgum plants were grown had higher levels of organic matter.

Heavy metal concentrations in soil samples

Heavy metals accumulated in soil not only have an impact on productivity and ecosystem activities, but they also have an impact on plant health because they affect plant metabolic processes (such as photosynthesis, respiration, growth, and development), as well as animal and human health due to the disrupted food chain (Asri and Sonmez, 2006). This study was conducted to determine whether there is heavy metal pollution of the sweetgum plant, which is primarily used for medicinal purposes but has a variety of other applications depending on its proximity and distance to highways. The samples were taken 50 meters from the highway and road for this purpose, and the results are shown in Table 3.

Heavy metals in the soil are known to have negative effects on soil fertility, living things in the soil, and other living things throughout the food chain at various concentrations. The highest Cd value of all soil samples tested was 1.14 ppm, and the lowest was 0.40 ppm (Table 3). Soil Cd limit levels have been reported to be 2.5 mg kg^{-1} (Saatci et al., 1988). Our results were found to be lower than the reference values, indicating that no cadmium-based pollution exists. According to a study conducted to determine the toxic effect levels of heavy metals in the soil and the toxic doses in the plant, 7.2 and 6.9 mg kg^{-1} Cd in clay and clay loam textured soils (Gedikolu et al., 1997).

Table 3. Heavy Metal Concentrations of Soil Samples Taken from Different Distances of Sweetgum Tree

Location	Road distance (m)	ppm					
		Cadmium (Cd)	Cobalt (Co)	Chromium (Cr)	Molybdenum (Mo)	Nickel (Ni)	Lead (Pb)
FETHIYE	0	0.40	18.07	545.67	0.01	701.45	4.12
	50	0.51	9.74	1128.82	0.07	477.78	1.64
KOYCEGIZ	0	1.14	104.89	565.14	0.04	2883.51	3.53
	50	0.86	82.07	499.70	0.40	2426.99	5.00
MARMARIS	0	0.75	23.41	420.55	0.04	880.14	6.90
	50	0.95	83.29	445.14	0.09	2467.19	4.60

The Co value of sweetgum plant soil samples was determined to be 104.89 ppm at the highest and 9.74 ppm at the lowest. The Co pollution value is 50 ppm, according to Kabata-Pendias (1979). There is a high level of Co pollution in Koycegiz soil samples and in areas far from the road where the Marmaris Sweetgum plant grows (Table 3). Co pollution should not be blamed solely on automobiles or industrial activity. That is, it is possible to develop the interpretation that fertilizers and pesticides used in agricultural activities near the Koycegiz Sweetgum forest contribute to heavy metal pollution. Yan et al. (2013) examined soil samples taken from the Tibetan Plateau's roadside and discovered that the Co (cobalt) concen-

tration in the soils decreased as they moved away from the traffic density. In the Fethiye and Koycegiz samples, the Co value decreases as you move away from the road, whereas the opposite is true in the Marmaris sample. In another study, samples taken from roads and park areas were examined, and the Co (cobalt) content was found to be 102.48 ppm in the sample taken from the campus's roadside (Keleş, 2007).

The Cr concentrations in the soils have been determined to range between 420.55 and 1128.82 ppm. The range of Cr reference values in soils is 5.00-1500.00 pmm (Alloway, 1990). The Cr content of the soils we examined was found to be between the reference value. In a 2011 study, Yaylali-Abanuz determined the Cr value to be 10-1161 ppm (Yaylali-Abanuz, 2011). It corresponds to the findings of our study. The adequacy levels of Cr element content in soil, however, are generally used as 100 mg/kg (Saatci et al., 1988; Hakerlerler et al., 1994).

When the Ni values of the soils in the study area are examined, the lowest and highest are 477.78 ppm (soil taken from an area far from the Fethiye road) and 2883.51 ppm (soil from the Koycegiz roadside). According to the data collected, the nickel (Ni) content of the soils varies depending on their proximity and distance to the road.

Leaf Samples' Heavy Metal Contents

The heavy metal content of the leaf parts of the sweetgum plant, which grows naturally in Mugla province's Fethiye, Koycegiz, and Marmaris districts, was investigated. Table 4 depicts the changes in the heavy metal content of the plant leaves under investigation.

The Cd values of the leaf samples collected from all areas studied were 0.09 ppm at the highest and 0.04 ppm at the lowest. In plants, the Cd reference range has been reported as 0.005-0.03 ppm (O'neill, 1993). When the results are compared to these standards, the Cd average of 0.007 ppm, which is within the recommended range, demonstrates that no cadmium-based pollution exists (Table 4). Kratz investigated the accumulation of Pb and Cd on the leaves of the *Pinus sylvestris* (Scotch pine) plant in 1996. It has been suggested that the amount of Pb and Cd in samples taken from cities and rural areas with heavy traffic is higher (Kratz, 1996). The study's findings are similar to ours.

Table 4. Concentrations of Heavy Metals in Sweetgum Leaf Samples

Location	Road distance (m)	ppm					
		Cd	Co	Cr	Mo	Ni	Pb
FETHIYE	0	0.06	0.83	2.85	0.22	13.33	1.13
	50	0.09	0.59	3.96	0.63	9.28	0.97
KOYCEGIZ	0	0.09	1.00	5.58	1.07	40.49	1.15
	50	0.04	0.40	4.42	0.14	15.06	0.52
MARMARIS	0	0.07	1.80	3.76	0.49	30.61	0.93
	50	0.05	0.71	6.87	0.15	16.54	0.73

The allowable limit value for determining our country's soil heavy metal pollution levels has been reported as 50 mg/kg (Saatci et al., 1988; Hakerlerler et al., 1994; Elmaci, 1995). The results of samples taken from the roadside in Fethiye and Koycegiz revealed that the element Ni concentration is extremely high, indicating pollution. Keleş (2007) collected soil samples from roads and park areas in Konya and determined the concentration of Ni (nickel) element in the roadside samples to be 1832 ppm. The highest value was determined in our study in the sample taken from the roadside in Koycegiz, and it shows parallelism with our study.

The total Pb content of the soil samples analyzed ranged between 1.64 and 6.90 ppm. The reference range for soil Pb has been reported to be 2.00-300.00 ppm (Alloway, 1990). The Pb concentration in the soil samples examined in this study was within the acceptable range. According to Koljonen (1992), the Pb concentration in the soil was 17 ppm. The Pb value in the soils studied in this study was lower. Heavy metal contents of soil samples collected from Konya's roads and park areas in 2007 were investigated, with the highest Pb value being 60 ppm (Keles, 2007). According to the findings of the study, it is the inverse of ours.

Heavy metal content was determined in soil samples collected from Denizli's urban, industrial, and semi-urban roadsides. Heavy metal concentrations have been reported to be higher in industrial areas than on urban roads (Celik et al., 2005). This situation served as a model for our research, and the discovery of high concentrations of heavy metals near the road supports the theory that it was caused by vehicle traffic.

The highest Co level determined in the leaves of Sweetgum plant samples taken from Fethiye, Koycegiz, and Marmaris districts was 1.80 ppm in the sample taken from the Marmaris roadside, and the lowest level was 0.40 ppm in the plant sample taken from the Koycegiz district's far area. The Co limit value in plants was stated to be 0.05-0.5 ppm (Kabata-Pendias and Mukherjee (2007), and the Co-related pollution was higher than the limit value in all three locations in the samples taken near the road. According to a 2015 study on the heavy metal ra-

tios of the leaves of the Tea (*Camellia sinensis*) plant along the Eastern Black Sea Coast, the amount of Co in traffic areas was highest on the Rize coastal road and lowest on the Kemalpasa coastal road (Uzuner, 2015). While the Co value was high in the leaves of the sweetgum plant taken from the roadside of Marmaris in our study, it was determined at the lowest level in the samples taken from the area 50 m away from the road in Koycegiz district, which coincides with the result that heavy metal accumulations decrease as we move away from the main road, which we emphasized in this study.

The highest Cr value was 6.87 ppm in samples 50 m away from the road in the Marmaris district, and the lowest value was 2.85 ppm in the Fethiye roadside plant sample. The toxic value of Cr in plants is stated to be 2 ppm (Kloke et al., 1984). Our values are significantly higher than toxic values. This situation can be explained by the fact that this region has a lot of agricultural activities, a mineral deposit, and some social activities like picnics. The Cr concentration in the leaf of *Salix fragilis* L. (crisp willow) was measured in 2018, and Cr values ranged from 0.83-65.94 ppm (Yavuzer et al., 2018). The highest Mo value was found in the sample taken from the roadside in Koycegiz (1.07 ppm), and the lowest value was found in the samples taken from the remote area of the Koycegiz road (0.014 ppm). Mo breakpoints are typically in the 0.1-0.5 ppm range (Kabata-Pendias and Mukherjee) (2007). Except for the Fethiye roadside sample, the study's results were above the reference values, and the Mo concentration was found to be quite high on the roadsides of Marmaris and Koycegiz.

The highest Ni level in the leaves of the plant samples was found in the Koycegiz district roadside area (40.49 ppm), and the lowest Ni level in the samples far from the Koycegiz road (97.13 ppm). The toxic value of Ni has been reported to be 30 ppm (Kastori et al., 1997). When the data was examined, it was discovered that the Ni element was above the toxic value in samples taken from the roadside in Koycegiz and Marmaris, implying that traffic pollution was present. The heavy metal content of leaf samples of the *Camellia sinensis* (tea) plant from the Black Sea coastal road and where there is no traffic was examined in 2015. The Ni element was found to be 7.10-0.37 ppm in the analysis results, indicating that there was traffic-related pollution (Uzuner, 2015).

Finally, when the leaf Pb level of the sweetgum plant was measured, the lowest was 0.52 ppm in samples taken far from the Koycegiz road, while the highest was 1.15 ppm in a sample taken near the road in the same district. The leaf Pb element reference range was reported to be 1.0-5.0 ppm (Kloke et al., 1984). Heavy metal content was determined in the leaves of *Platanus orientalis* L. (sycamore) trees located on both sides of Silahtar Street in Ankara. Pb accumulation has been determined to be more intense, particularly in trees located in the median in the middle of the road (Topa, 1995). It followed the same pattern as our study. Çavuşoğlu et al. (2008) discovered that traffic density and pollution increased in direct proportion to the amount of Pb in larch (*Pinus nigra* var. *caramanica*) tree leaves on the roadsides in Kırıkkale. The high amount of Pb in leaf samples taken near the road can be attributed to the absorption of gases emitted by the leaves as a result of exhaust gases and tire wear on the road.

CONCLUSION

The sweetgum tree (*Liquidambar orientalis* Mill.) is a valuable endemic with numerous applications. There has been a great loss in the number of sweetgum plants over the years due to human intervention and natural reasons. The increased number of vehicles and widespread use of transportation, as a result of the rapidly increasing population and developing technology, harm agricultural and forest products grown along roadsides and cause heavy metal pollution in soils and plants. In light of this information, this study, which is critical for the long-term viability of the medicinal sweetgum plant, examined the levels of some heavy metals originating from the exhaust gases of soil and leaf samples collected from the roadside of Fethiye, Koycegiz, and Marmaris, as well as the inner region 50 meters away from the road. However, our research revealed that some heavy metal contents were above the established limit values. As the study area, it is predicted that tourism activities will be intense and the population will increase significantly, especially during the season, and there may be significant increases in the level of pollution caused by exhaust gases since there are many vehicle entrances and exits on this basis. The pollution levels of plants growing along roadsides were assessed using normal and toxic values reported by various researchers. Metal concentrations in soil and plant structures have been found to decrease as one moves away from the highway. It is hoped that the parts of the sweetgum plant that comprise the study material, especially given its high medicinal value, are below the critical levels of heavy metals established by health institutions. With this study, it is hoped that, in addition to the periodic evaluation of heavy metal concentrations in some edible and medicinal plants growing along roadsides, the plants under study will provide an opportunity to shed light on the continuity of trust and quality.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

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Ethics committee approval is not required.

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