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Original Research

Investigation of Some of the Bioactive Chemicals and the Elemental Profile of Monumental Plane Trees in the Abana-Harmason Region

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Abstract

This study aimed to conduct an ecophysiological investigation of monumental plane trees (*Platanus orientalis* L.) located in the Abana district of Kastamonu province. To this end, we measured the amounts of some bioactive chemicals in the leaves of the trees and young plane trees in the immediate vicinity, in addition to enzyme activities and nutrient contents. The data show that the oldest trees have the highest contents of chlorophyll and carotenoid pigment, proline, and protein, in addition to APX activity, and that the contents of glucose and pyruvic acid, in addition to the chlorophyll a to chlorophyll b ratio and CAT and SOD activities are higher in young trees. K, P, S, Cl, Zn, Ni, and Cu ions show the highest value in monumental trees, but Mg, Ca, Na, Si, and Fe show the highest value in young trees. The results show that photosynthetic pigments, proline, protein, hydrogen peroxide (H_2O_2), sucrose, and K, P, S, Cl, Zn, and Cu have had a positive effect on the growth physiology of monumental plane trees. The findings indicate that understanding the ecophysiology of plane trees may help in ensuring the long-term and damage-free survival of these trees.

Keywords: bioactive compound, monumental, plane, Kastamonu

Introduction

Humans are dependent on nature for their physical, physiological, and psychological needs. Thus, people have a relationship with all living and inanimate elements of the environment in which they live. People find relaxation and an escape from the stress of daily life in activities such as picnics, strolls, walks, and holidays in green areas. In Turkey, ecotourism, which is increasingly popular, enables people to have fun, to learn, and to see new environments while ensuring awareness of the protection of the country's biodiversity and natural resources through leisure activities that ensure the sustainability of the natural environment while contributing to the socio-economic development of local people without being detrimental to nature [1, 2]. Important resources in terms of ecotourism include ecosystems made up of canyons, lagoons, cascades, travertines, hydrophore forests, monumental trees, forests, and relict and endemic tree and plant species [3, 4]. The importance of single monumental trees and forest areas increases continuously. Monumental trees,

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which are silent witnesses of nature, are aspects of natural heritage that connect the past to the future. With their gigantic size and majestic appearance, they are one of the most interesting natural elements of urban and rural landscapes. They have a special meaning in the folklore, culture, and history of the regions they are found in [2-5]. Monumental trees not only affect the appearance of the areas where they are found but are also dendro-climatological, dendro-ecological, and dendro-chronological resources that give insight into microclimates and climate changes, in addition to fire and disease damage in their habitats through analysis of age rings described as "time capsules" because they adapt to the air conditioning-edaphic-biotic conditions of that area. Moreover, as they adapt to the conditions in their habitats, they form biogenetic materials as they provide advantages in stand formation studies with these species [6, 7]. The climatic, topographical, and geographical characteristics of Turkey give rise to a rich variety of plants in the country. In addition, there are many tree species and quite high numbers of trees with monumental features [1, 4, 7]. In particular, the steep and mountainous topography of Northern and Southern Anatolia has enabled some areas with monumental trees to survive without being subjected to human activity. Asan [5], Erik [10], Sarıbaş [9] reported that there are more than 2.000 registered monumental trees in Turkey. Studies have shown that the most common species in Turkey are Oriental plane (*Platanus orientalis*), Taurus cedar (*Cedrus libani*), Oak (Quercus sp.), Gray juniper (*Juniperus excelsa*), English yew (*Taxus baccata*), and Anatolian chestnut (*Castanea sativa*) [4, 6, 11]. The registration of monumental trees is an important factor in their protection, enabling them to live for longer and carrying them into the future. To sustain a monumental tree for many years, it is very important to support it in its ecological environment [1, 3, 7]. In this context, determining the climate parameters, soil characteristics, and bioactive chemical components that will negatively affect the physiological, biochemical, and morphological processes that regulate the vital activities of monumental trees will help in understanding the ecophysiological requirements of monumental trees [3, 12, 13]. It is important to determine the cause-effect relationships of growth and development physiology in predicting the life span of a tree species and in determining the factors that it will be affected by. Developments in tree height, diameter, body surface, volume, and weight [12-14], in addition to changes in chemical components that play a role in the formation of organic mass in leaf samples of tree species, are among the most important parameters affecting the life span of the tree [11]. There are many extensive studies in Turkey, which indicating the effect of abiotic and biotic stresses on the growth and development of woody, shrubs and herbal plant species. The number of studies, however, related to the changes of the chemical constituent of leaves of monumental trees is almost non-existent. This study focused on the ecophysiology of monumental plane trees *(Platanus orientalis* L.) in the Harmason zone of the Abana district of Kastamonu province in Turkey. We measured the diameters and heights of monumental tree in the same area, in addition to nutritional element changes in leaf samples, photosynthetic pigmentation, nitrogenous compounds (proline, soluble protein), simple sugars (glucose, sucrose, total soluble carbohydrate), and antioxidant enzymes, while taking into account younger plane trees and soil nutrients in the same area. This investigating is the first study to compare the ecophysiological aspects of monumental plane trees considering the change of some bioactive chemicals and the amount of nutrient levels of tree leaves in Kastamonu. It is hoped that the obtained results will provide important clues as to how-long term tree species survive in grown areas.

Materials and Methods

The Study Area of Monumental Plane Trees

This study was carried out in the Harmason neighbourhood of Abana district, 86 km from Kastamonu city centre. This area is located geographically in the Western Black Sea Region between 41º58'48'' north latitude and 33º59'54'' east longitude. In Harmason, monumental plane trees (>600 years old and >500 years old) are located side by side just west of Ezine Stream in an area 150 m from the sea and 140-145 m from the main road (D010). Young plane trees (≥75 years old and ≥150 years old) in the same area are growing within 52-53 m of old plane trees. In 2019, the trees were maintained under the control of the Natural Assets Protection Branch Office of the Kastamonu Provincial Directorate of Environment and Urbanization. The team removed dried and decayed branches from the trees and tied weak branches to the main trunk with insulated steel ropes to strengthen them. The surface of the tree bark has been covered with protective paste to guarantee protection against diseases and external influences. The study area faces north and is 0-5 m above sea level. It has terrestrial climatic conditions, with long, cold, and snowy winters and is short and warm summers. The seasonal and daily temperatures show high extreme values and rainfall is generally low. Climate data from the meteorology station (1960-2017) show that the highest annual average temperature in the area, at 30.2ºC occurs in July and August, whereas the coldest temperature, at -3.5ºC, occurs in January and February. In the humid summer season, the wettest month is December, with 142.2 mm rainfall. The driest month is July, with 48.1 mm rainfall [15]. Erik [10] provides details of some silvicultural features of monumental trees >600 years old in the study area. We obtained similar results from our measurements in the study area. For plane trees ≥75 and ≥150 years old, we counted the annual rings on the increment items taken from the body height (1.30 m)

Table 1. Some silvicultural characteristics related to plane trees.

Age ot trees	Height (m)	Diamater ($d_{1.30}$) (cm)	Diameter (d0.30) (cm)
≥600	20	550	620
>500	19-20	525-530	615-620
≥150	25-30	191	200
≥75	25-30	165	180

of the trees in the trial area using a Pressler increment auger. In using the increment auger to determine the tree age, we took care to keep the increment items in directions perpendicular to each other to prevent errors that may arise in the annual ring measurement (Table 1) [16]. We used a tree diameter gauge to determine the diameters of the trees diagonally from the upper slope of the tree with centimetre sensitivity from the body surface. The measurements showed that monumental plane trees >600 years old are approximately 20 m in height, approximately 550 cm in circumference (at chest height: 130 cm) and 620 cm in bottom circumference [10]. Measurements of other age groups revealed that the chest height circumference of trees more than ≥150 years old was 191 cm, whereas that of trees more than ≥75 years old was 165 cm (Table 1). In the soil sample taken from the field of trees, the K, Mg, Ca, P, and S contents were 22860 ppm, 3584 ppm, 38030 ppm, 2566 ppm, and 5483 ppm, respectively (Table 2). In addition, the Na, Cl, Mn, Fe, Ni, and Cu contents were 5960 ppm, 7845 ppm, 94.2 ppm, 812.8 ppm, 43.1 ppm, and 22.2 ppm, respectively (Table 2). Fresh leaves under the canopy trees from each age group in the sampling area were taken from each direction of trees during the second half of July 2017. A total of 40 leaf samples were taken for each tree, 10 from the north, south, east, and west side of each tree. Since there are 2 old (monumental) plane trees and 2 young trees in the study area, leaf samples were sampled from only four trees. Leaves were washed with pure water in the laboratory and moisture was removed using blotting paper. Some of the fresh leaf samples were used for chemical analyses. Some leaf samples were dried at 65ºC for 48 hours, powdered using a laboratory blender, and used in elemental analysis at the Central Research Laboratory of Kastamonu University. To collect the soil samples, approximately 200 g of soil samples to levels of 20 cm and 40 cm taken from the four-point of the study area where the trees were located. After these samples were air-dried, they were all powdered by mixing in a blender, and then used in elemental analysis at the Central Research Laboratory of Kastamonu University.

Chemical Measurement of Leaf Samples

To determine the chlorophyll content, 0.5 g of the fresh leaf was crushed in liquid nitrogen and

Table 2. The nutrient status of soil samples collected from the area where plane trees grow (ppm).

	K	Mg	Ca	P	S	Mn	Na	Cl	Fe	Zn	Ni	Cu
Soil	22860±20	3584±931	38030±30	2566±64	5483±6	94.2±0.5	5960±300	7845±6	812.8±1.8	35±0.2	43.1±0.4	22.2±0.3

homogenized by adding 10 ml of 80% acetone in an ice bath [17]. The mixture was centrifuged for 10 minutes at 3,000 rpm, and triplicate spectrophotometric (Shimadzu UV-260) readings of the supernatants noted were obtained at values of 652 and 450. The Bates method [18] was used to estimate the proline content of the leaves, and the Bradford method [19] was used to measure the soluble protein content. The nitrate content of the leaf was estimated using the rapid colourimetric method according to Cataldo et al. [20]. The level of lipid peroxidation was measured and expressed as MDA (malondialdehyde) content following the method of Çakmak and Horst [21]. The H_2O_2 (hydrogen peroxide) concentration was determined according to the method of Velikova et al. [22]. The total soluble carbohydrate was estimated by spectrophotometry at 620 nm following the Antron Method [23]. Glucose and sucrose contents were measured following the Antron Method by spectrophotometry at 630 nm for glucose and 620 nm for sucrose [24]. The pyruvic acid content was determined via the colourimetric method following Schwimmer and Weston [25]. To determine the enzyme activities of fresh leaf samples, 0.5 g of the fresh leaf was crushed in liquid nitrogen and then homogenized with 5 ml of 50 mM (pH = 7.6) KH_2PO_4 (pH = 7) buffered solution containing 0.1 mM Na-EDTA (Sodıum- Ethylenediaminetetraacetic acid). The mixtures were centrifuged for 10 minutes at 10,000 g and 4ºC. Enzyme activities in this supernatant were estimated. APX (ascorbate peroxidase) was determined following the method of Nakano and Asada [26] by measuring the oxidation rate of ascorbate at 290 nm (E = 2.8 mM cm^{-1}), CAT (catalase) activity was measured following the method of Bergmeyer [27], and SOD (superoxide dismutase) enzyme activity was measured following the method of Çakmak & Horst [21]. The plane leaf samples and soil samples were also analyzed for nutrients concentrations using the SPECTRO brand XEPOS model XRF instrument at the Central Research Laboratory of Kastamonu University.

Statistical Analysis

Whether each parameter of the bioactive components found in the leaves differed significantly by age class or not was presented through the F-test of the Analysis of Variance (ANOVA) using the SPSS program (Version 11). According to the ANOVA results ($P \leq 0.05$), to determine statistically significant differences between means Tukey test as a multiple range test was applied.

Results and Discussion

The chlorophyll content of a tree is the most important reflector of that species' adaptation to its environment, indicating the status of leaf development, the rate of photosynthetic activity, and the status of nutrients in both leaf and soil [28, 29]. In this study, the amount of photosynthetic pigment varied between trees (Fig. 1, Fig. 2). The chlorophyll a (Chl a) content of trees ranged from 0.147 to 0.171 mg/g, the chlorophyll b (Chl b) content ranged from 0.040 to 0.156 mg/g, the total chlorophyll content ranged from 0.187 to 0.326 mg/g, and the ratio of Chl a to Chl b ranged from 1.08 to 3.76 ($p<0.05$). The carotenoid content ranged from 8.86 to 9.71 mg in younger trees and 12.12 to 13.75 mg in older trees. Fig. 1 and Fig. 2 show that the chlorophyll molecule and carotenoid contents were highest in monumental trees, but the ratio of Chl a to Chl b was higher in young trees. A high total chlorophyll content and high ratio of Chl b to Chl a has been associated with trees growing in shady conditions [29-30]. The fact that the total carotenoid content in these trees shows the highest value confirms this result [31, 32]. Shade or shade-tolerant species essentially follow some strategies of optimum use of available sunlight and conservation of energy, including higher chlorophyll and carotenoid level per unit leaf volume, thinner leaves, less plasticity in size and shape, and long-lived leaves and organs [29, 32, 33]. As reported by Stara and Tsıakrıs [3], Nemutlu [34], the plane tree, which is a mesophytic species, shows very high adaptation to full light, lake, and semi-light conditions, and is thus highly preferred in wetlands and urban landscapes. The fact that the total amount of chlorophyll is low in young trees and that the ratio of Chl a to Chl b is quite high suggests that young trees receive more light than do old trees (Fig. 2). In pigment systems, Chl b and carotenoids protect the Chl a molecule from photooxidation at high light intensity. In young trees, the carotenoid and Chl b molecule content may be reduced because they function in preserving the structure of Chl a [30-32]. According to Demming-Adams [35], Yamori et al. [36], plants grown in full light have a high photosynthetic capacity, but their photosynthetic activity is much lower in low light conditions compared to shade plants, and their Chl b content increases in low light conditions. In our opinion, higher levels of total chlorophyll, Chl b, and total carotenoid contribute to increase the length of survival of plane trees [32, 35, 37]. In addition, it was thought that high chlorophyll molecule content in old spikes may be effective in high nitrogen in these trees. As seen in Fig. 3, the nitrate, proline, and soluble protein contents in trees in our study were higher in older plane trees and lower in both mature and younger trees. The highest level of nitrate and proline in the second monumental plane was observed and protein in the first monumental plane was recorded (Fig. 3). Nitrogenous compounds are key elements in chlorophyll synthesis [38, 39]. In our opinion, the high proline, protein, and nitrate contents of the oldest plane trees is a strategy to meet the water requirements proportional to the volume and size of the trees [39, 40]. With the large leaf surfaces and the big size of old plane trees, high stomata activity may have caused high water conductivity [29, 31, 41]. Many

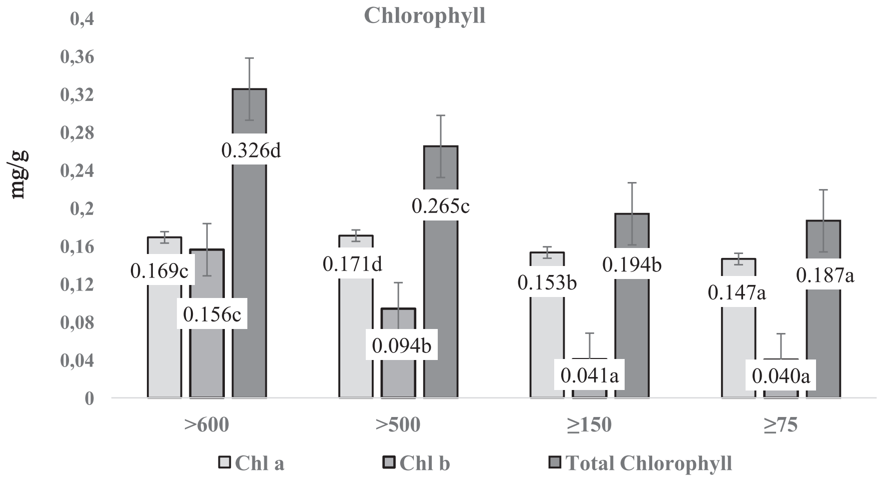

Fig. 1. Variation of Chlorophyll a (Chl a), chlorophyll b (Chl b), and total chlorophyll (Tot. Chl) content of plane trees.

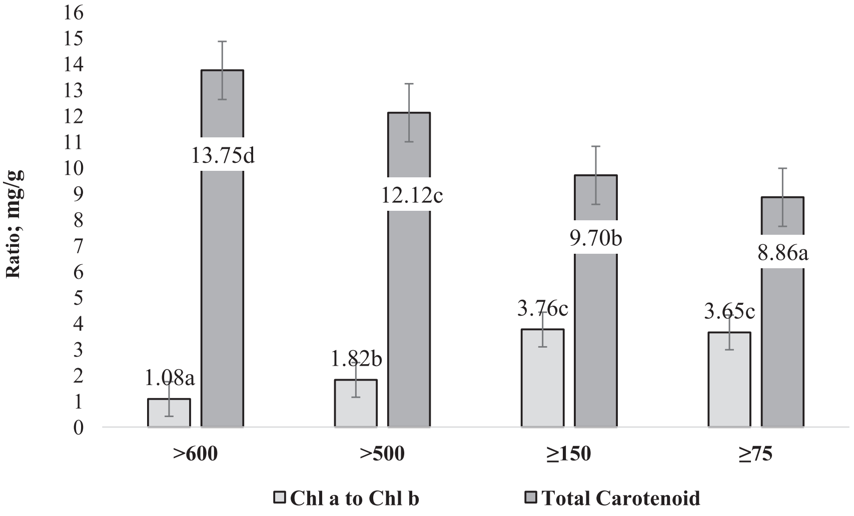

Fig. 2. Variation of Chl a to Chl to ratio and total carotenoid content in the leaf samples of plane trees.

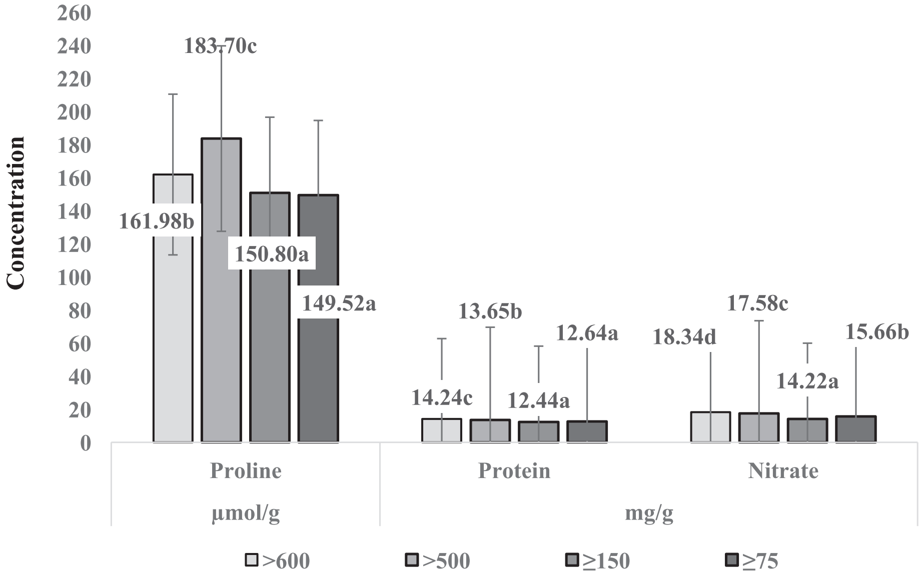

Fig. 3. Variation of nitrogenous compounds (proline, soluble protein, and nitrate) levels in the leaf samples of plane trees.

authors have stated that osmoprotectants such as proline and soluble protein may cells' turgor, osmotic balance and water relation of tissue and organs [42-44].

H_2O_2, which can occur in normal metabolic reactions, functions both in cellular redox potential and as a secondary signalling molecule in cells [31, 38, 45]. It can be produced and accumulated within the cell by lipid peroxidation, which damages cellular components and organic molecules [11, 14, 44]. However, antioxidant enzymes such as APX, CAT, and SOD protect the cell from H_2O_2 and lipid peroxidation reactions [38, 42, 45, 46]. In this study, the concentration of MDA in plane trees was highest in the youngest tree (193 µmol), and the H_2O_2 concentration was at the maximum level in monumental plane trees (188.33 µmol and 188.13) ($p<0.05$) (Table 3). The lowest MDA content occurred in mature trees, at 0.145µmol, and the lowest H_2O_2 content was found in the youngest tree, at 129.74 µmol (Table 3). High APX activity and high proline and protein contents in trees have been thought to be effective in showing the mean value of MDA content in old trees (Table 3) [37, 44, 46]. The lowest H2O2 content in young trees was associated with the highest CAT activity and the average value of SOD activity in these trees (Table 3) [45, 46, 48, 49]. It has been proven that stimulation of the activity of enzymes such as CAT, APX, and SOD and accumulation of osmolytes such as sucrose, proline, and soluble protein, is the most important part of the chemical defences that strengthen trees' resistance to unfavourable environmental conditions and enhance their survival capacity [11, 14, 45, 50]. The high MDA content in the youngest tree has been associated with the fact that the light conditions under this tree species grown stimulate peroxidation reactions in the leaves [11, 33, 38, 49]. The high levels of pyruvic acid and glucose in young trees are also in accordance with this result [50, 51].

Glucose and pyruvic acid are the key compounds of the Krebs cycle. They play a role in the formation of precursor molecules of many organic compounds by entering the mitochondria and are also involved in the synthesis of molecules, such as terpenes, carotenoids, hormones, and amino acids, that are active in growth and development during the glycolysis phase [52, 53]. The pyruvic acid content of plane trees was determined to be higher in young trees (163.61 µmol and 175.81 µmol) and lower in monumental plane trees (148.59 µmol and 151.61 µmol) (Table 3). The glucose content ranged from 674.20 to 690.97 µg in young trees and from 536.17 to 537.14 µg in monumental plane trees. The sucrose content of young trees was low (93.34 mg and 94.80 mg), and the total amount of soluble carbohydrate did not differ significantly between trees, although the highest value, of 77.94%, was found in mature plane trees (Table 3). The high levels of pyruvic acid in the youngest and mature planes may be due both to the trees being exposed to lighter conditions due to their open surroundings [37, 52, 54] and to their growth rate being higher than that of the older trees

Table 3. Variation of MDA, APX, CAT and SOD activity in the leaf samples of plane trees.

Age	MDA µmol/g	H_2O_2 µmol/g	APX EU/mg Protein	CAT EU/mg Protein	SOD EU/mg Protein	Pyruvic acid µmol/g	Glucose µg/g	Sucrose µg/g	Total Soluble Carbohydrate %
>600	0.164b*±0.0001	188.18c±0.09	0.135c ±0.91	0.248b±0.002	22.99a±0.13	148.59a±0.0001	536.17a±0.45	96.34b±0.95	76.85a±0.45
>500	0.166b±0.0002	188.33c±0.06	0.108b±0.82	0.235a±0.002	38.13c±0.05	151.61b±0.0002	537.14b±0.30	96.52b±0.57	77.05a±0.53
≥150	0.145a±0.0001	173.97b±0.08	0.104a±0.33	0.424c±0.002	29.63b±0.22	163.71c±0.0001	690.97d±0.37	94.80a±0.28	77.94b±0.31
≥75	0.193c±0.0018	129.74a±0.073	0.104a±0.16	0.445d±0.008	29.74b±0.18	175.81d±0.0002	674.20c±0.36	93.62a±0.70	76.93a±0.3
F	443.58	6486.22	678.67	1552.53	137.52	3876.45	42531.363	446.504	1847.017
Sig.	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

*Means within a group that has a different small letter are significantly different from each other. $P < 0.05$.

Table 4. Variation of the macronutrients profile of leaf samples.

Age	Macronutrient (ppm)				
	K	Mg	Ca	P	S
>600	19500c*±30	3005b±60	33210b±30	2285d±4	5018b±5
>500	17330b±20	3183c±40	30740a±30	2161c±4	4983b±5
≥150	14720a±20	3607d±37	34100b±30	1549a±4	4872a±5
≥75	17020 a±20	2595a±33	35600c±30	1668b±4	4819a±5
F.	0.98	896460.67	36872568.50	747840.68	608596.50
Sig.	<0.466	<0.0001	<0.0001	<0.0001	<0.0001

*Means within a group that has a different small letter are significantly different from each other. P <0.05.

[55, 56]. Changes in soluble sugars and carbohydrate values have been associated with higher respiration rates in young trees and higher above-ground areas of high sucrose values in old trees [57, 58]. As glucose is the general substrate of respiration and sucrose is an important indicator of the cellular respiration rate, both compounds are an indirect indicator of growth rate [51, 53, 54]. Furthermore, both glucose and sucrose are effective in the regulation of the osmotic potential and turgor of cells [42, 50, 55, 56]. With a higher metabolic rate and high energy, younger trees need more glucose than do older trees and produce more pyruvic acid during growth and development [54-57].

Mineral nutrients play a role in many processes, including structural, biochemical, and osmotic processes, and they ensure the continuation of growth and development, depending on their status in cells or tissues [58, 59]. For example, the P ion, a part of ADP and ATP, is involved in all metabolic reactions [60]; Mg plays a role in the structure of chlorophyll and proteins, in addition to CO2 fixation [32, 37]; and S are essential elements of proteins, enzymes, phospholipids, and nucleic acids; and Ca is the most important component of cell wall structure [61, 62]. As shown in Table 4, old trees had higher K, P, and S ion contents, whereas the Ca ion content (35600 ppm, 34100 ppm) was higher in young trees. The highest K, P, and S contents (19500, 2285, and 5018 ppm, respectively) were found in the first monumental tree >600 years old, the highest Mg content was found in a ≥150-year-old plane tree (3607 ppm), and the highest Ca content (35600 ppm) occurred in a tree aged ≥75 years (Table 4).

Micronutrients such as Fe, Mn, Zn, Mo, Cu, and Mo are important for cellular redox function and enzyme activity because they are components of the active sites of specific enzymes that play a significant role in metabolic reactions to increase resistance to environmental conditions [38, 58, 61, 63]. In this study, the amount of Na ranged from 2280 to 3060 ppm; the amount of Cl ranged from 5716 to 6942 ppm; the amount of Fe ranged from 438 to 603.4 ppm; the amount of Mn ranged from 77.70 to 86.4 ppm; the amount of Zn ranged from 19.6 to 29.0 ppm; the amount of Ni ranged from 29.9 to 32.5 ppm, and the amount of Cu ranged from 10.3 to 16.4 ppm (Table 5). Though the highest Cl, Zn, Fe, Ni, and Cu contents were found in monumental trees, Na and Fe contents were higher in younger sycamores (Table 5). These results related to nutrients agree with those of studies conducted in both woody and herbaceous formations. Many researchers have determined that K, Ca, and Mg are the most abundant essential elements in plants. Amounts of S

Table 5. Variation of the micronutrients profile of leaf samples.

Age	Micronutrient (ppm)						
	Mn	Na	Cl	Fe	Zn	Ni	Cu
>600	81.11b±0.5	2280a±270	6845c±5	509b.3±2	26.4b±0.3	31.5a±0.4	15b±0.3
>500	77.7a±0.5	2460b±270	6942c±5	438a±2.5	29c±0.3	32.5b±0.4	16.4b±0.3
≥150	78.0a±0.5	3060c±250	5716a±4	562.4c±2.1	19.6a±0.2	30.8a±0.4	11.2a±0.3
≥75	86.4c±0.5	2990c±260	6413b±5	603.4d±2.2	19.6a±0.2	29.9a±0.4	10.3a±0.3
F.	696256.4	11232693.5	2100222.8	247623.5	200.17	636448.4	1016.9
Sig.	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

*Means within a group that has a different small letter are significantly different from each other. P <0.05.

and P are also among the most abundant of the other macronutrient found in plants [59, 62, 64]. Moreover, many studies have shown that the most abundant elements occurring as micronutrients in plant tissues are Fe, Mn, Zn, Cl, Ni, C, and Mo ions [63, 64]. Liu et al. [65] investigated the change of nutrient elements in green and aged leaves of 172 plant species, including 34 bush formations and 37 broad-leaf forest trees. They determined that nutrient elements are more in the aged leaf samples and also K, P, Mg, Cu, Fe, Mn, Zn, and Mo are the most abundant elements in green leaves. Yan et al. [66] examined the changes in elements in leaves of forest trees such as Larix spp, *Quercus mongolica*, *Acer mono*, *Juglans mandshurica*, and *Fraxinus rhynchophylla* and found that N, P, K, Ca, Mg, Cu, and Zn are the dominant elements in trees. The predominant elements in the green leaves of the plane trees in this study overlap with those given in the literature [58, 59, 62, 65]. The higher abundance of K, P, S, Mn, and Cl ions in old plane trees indicates that turgor, water conduction, and the amount of nitrogenous compounds are affected in these trees. The high proline and soluble protein contents and high APX and CAT activities in monumental plane leave support this finding [44, 46]. Researchers have reported that K and Cl ions play an important role in regulating stoma movements and controlling the rate of water by transpiration in leaves [65, 68, 69]. Mn is a trace element that is effective in physiological processes by binding to the active sites of enzymes as it is effective in the degradation of water in the photosystem during the light phase of photosynthesis [63-67-68]. The change of nutritional elements in plane trees coincided with the nutrients in the soil. As shown in Table 2, the macro elements K, Ca, Mg, P, and S and the trace elements Mn, Zn, Fe, Ni, Na, Cl, and Cu were higher in soil samples. Sycamore trees absorb nutrients from the soil and transmit them to the leaves [64, 66, 69]. These findings indicate that the amount of nutrients in plane trees has an important effect on leaf development, leaf surface area, and microclimate [70-72].

Conclusions

It is difficult to determine the causality of tree longevity as many factors, each interrelated, influence the lifespan of any species [41, 43, 54, 56]. However, the organ that best reflects the developmental status of a plant is the leaves, and therefore the amounts of pigments, nitrogenous and carbonaceous compounds, enzymes, and also elements in the leaves can give clues to the developmental status and life span of any species [11, 28, 31, 37, 38, 66]. Bioactive components can directly affect the lifespan of any species by providing a source of nitrogen, carbon and energy for growth and development, as well as adapting to environmental changes, and elements indirectly by participating in the regulation of metabolic reactions that play a role in growth and development [13, 42, 45, 56, 59, 62, 66]. Moreover, both bioactive components and nutrients provide mechanical strength to tissues as they regenerate damaged tissues in above-ground and underground organs [13, 14, 43, 53, 54, 70]. The results from this study indicated that the amounts of Chl a, Chl b, total chlorophyll, carotenoid, proline, protein, nitrate, sucrose, H_2O_2, and APX activity are higher in monumental trees. In young trees, the ratio of Chl a to Chl b, the pyruvic acid and glucose contents, and the CAT and SOD, activity are all high. Though monumental trees contain high amounts of K, P, S, Cl, Zn, Ni, and Cu ions, the Mg, Ca, and Na and Fe levels are higher in young trees. Considering the results, it can be said that the bioactive components and nutrients like K, P, S, Cl, Zn, Cu examined in plane trees can be contributed to the longevity of the plane tree. However, the climatic conditions of the environment where the trees grow may have been effective in the longevity of the plane trees. We conclude that the studies related to the ecophysiology of monumental trees will contribute to the determination of the parameters that affect the life span of the trees, and will also contribute to raising awareness for the protection of these trees. And, it would be beneficial to use plane trees in roadside afforestation works and for landscaping in urban parks and gardens due to the long life, magnificent appearance, and historical value of these trees.

Conflict of Interest

As an author, we declare that there is no conflict of interest in the planning, execution and writing of the article.

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