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Soil-plant interactions in the monumental plane trees (*Platanus orientalis*) grove-Çanakkale-Turkey

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Abstract

Aim : To study ecological features of monumental plane trees. Evaluate soil-plant interactions and mineral nutrition status of 150 to 800 year-old-chosen trees.

Methodology : Soil and plant samples were collected and analysed using Kjeldahl, spectrophotometer, Flame photometer and ICP-OES.

Results : The pH, electrical conductivity, calcium carbonate, organic matter, total nitrogen, phosphorus, sodium, potassium, calcium, magnesium, iron, manganese, zinc and copper values in the soil samples ranged between 6.6-7.4, 0.58-1.26 (dS. m^{-1}), 0.00-1.52%, 1.55-5.05%, 0.08-0.29%, 4-28 ppm, 20-33 ppm, 50-314 ppm, 1086-3041 ppm, 54-302 ppm, 3.57-15.30 ppm, 3.37-13.29 ppm, 1.84-4.17 ppm, and 0.41-1.48 ppm, respectively. The mineral element values in young root, young stem, elderly stem, stem bark and leaf showed normal range. A strong relation has been noted among the Mg, P, Na, Mn, Fe, total N and Zn.

Interpretation : Excess amount of Fe and Ca get accumulated in different plant parts.

Nutrient turnover in the monumental plane trees

Introduction

Nearly ten percent of all trees are threatened to extinction on our planet at present and the best way to prevent their extinction is to protect them in their natural habitat (Cavender *et al.,* 2015; Decker *et al.,* 2016). The monumental trees are included in this group and the threats they are facing lately has attracted the attention of researchers towards their conservation because of their social, cultural and aesthetical importance. The monumentals fulfill many ecological functions like habitat connectivity, facilitating range expansions in plant taxa and their adaptation to climate change. A loss of such trees produces a negative impact on the ecosystem services as their coarse woody debris forms a microclimate rich in nutrients which serve as a resource and shelter for other species. This gives them a character of a keystone species since they provide critical habitat for a range of taxa (Stagoll *et al.,* 2012).

The gaps in our knowledge on the taxonomy-phylogeny, reproductive ecology, seed biology and distributional aspects of monumentals limit us to prioritize them for conservation (Cavender *et al.,* 2015). Many plant species can comfortably live as long as several hundred years in their natural habitats leading to the concept of monumental trees. The ecological value of a monumental tree increases with its age (Vuidot *et al.*, 2011; Bütler *et al.*, 2013). They hold a special position in the history, culture and folklore of an area, used on flags, in motifs, being old enough connecting the past with the present as well as present with the future, with longer life spans than other plant species and living entities and contribute to the tourism of the area (Asan1987; Genç and Guner 2000; Arı *et al.*, 2015). In recent years a conservation strategy to save this cultural heritage within the framework of laws in Turkey has increased as in the other parts of the world (Oner *et al.,* 2010; Efe *et al*., 2011, 2013).The monumental trees have been regarded as a symbol of reconciliation between the states as well as subject of mythology and epics due to their being accepted as an indicator of fame, honour, wealth and sublime (Arı *et al.*, 2015). According to Genç and Güner (2003) the monumental trees can be classified as historical, folkloric, mystical and dimensional types. In fact there is a great need to record them and transfer it to the next generations due to their philosophical, esthetic, recreational, mythological, ecological and educational value (Yaltırık, 1994).

There are trees on earth that are almost 4000 year old from ancient periods (Efe *et al.*, 2011). Nearly 17 species of trees, almost all conifers, have been reported from all over the world which are 1000 year old (URL 1). The 5000 year-old-*Pinus longaeva* trees from America are accepted as the oldest record (Currey, 1965). However, *Gaylussacia brachycerium* and *Larrea tridentata* are known to be over 10,000 year-old. Similarly, certain varieties of old grapes have been propagated for over 800 years (Thomas, 2003; Arnan *et al.*, 2012). European continent as a whole embodies 725 species of trees and shrubs, whereas Turkey alone has 475 species out of which 205 are trees (Ozturk *et al.,* 2010). Although, the trees in Turkey show shorter life spans because of climatic features, but we do come across examples of more than 10 centuries-old-trees and many trees of more than thousand years age have been identified in Turkey (Efe *et al.*, 2011, 2013). The information published by the Ministry of Forestry in Turkey reveales that there are over 110 natural monuments found in Turkey. Out of these, 37 are found in the Mediterranean region, 25 in the Black Sea region, 22 in the Aegean region, 21 in the Central Anatolian part, 3 in the Marmara region, 3 in the East Anatolian region and 1 in the Southeastern Anatolia region (URL 2).

Platanus orientalis is one of the most frequent trees reported among the monumental trees from Turkey. It holds a significant place in Turkish culture, for example the plane tree in Yalvaç with 7 coffee houses under its branches is a conversation plane tree whereas, Kanlı Kavlan in Eğirdir district of Isparta is still standing today as an execution plane tree (Genç and Güner, 2000, 2003). Their mystical effects on humans have led to such concepts as commitment to heritage and love of homeland (Efe *et al.,* 2013). Several monumental trees still standing have deeply inspired literature such as"Eskicibaba Plane Tree" in the yard of Bursa Orhan Mosque which inspired Ahmet Hamdi Tanpınar in his work titled "Time in Bursa". Similarly Emirgan Çınaraltı (under the Plane Tree) Coffee House in Istanbul holds a significant place in Turkish literature. Several notable people used to gather under this tree for conversations and it was a sort of academy. The plane tree in Büyükdere-Istanbul is believed to have a 4000-year history, but it was destroyed after World War I. It is known that a plane tree used to be planted in the name of each Sultan's son just as poplar tree was planted for any newborn in many parts of Turkey. An analysis of how tree species will react with changes in the environmental conditions has great importance (Efe *et al.,* 2013). For this purpose, the tree rings are a good source to trace the past climatic conditions, because they enable us to reconstruct the plant species responses to environmental changes (Fritts, 2001). The scarcity of dendro climatological studies in the Mediterranean is due to the lack of ancient natural forests in the region because of intensive historical logging, burning and grazing (Cherubini *et al.*, 2003; Arnan*et al.*, 2012; Cavender *et al.,* 2015).

The aim of the present study was to understand the ecological behaviour of age old plane trees by investigating their soil-plant interactions and mineral nutrition status.

Materials and Methods

Study area : The study site Kirkgeçit hot spring area is located within the Biga Peninsula (Fig. 1) surrounded by the Sea of Marmara at north, Aegean Sea at west and South, with the most significant topographic height as Kazdag (Mount Ida) 1774 m above sea level (Yalçın 2007). The area is composed of quartz

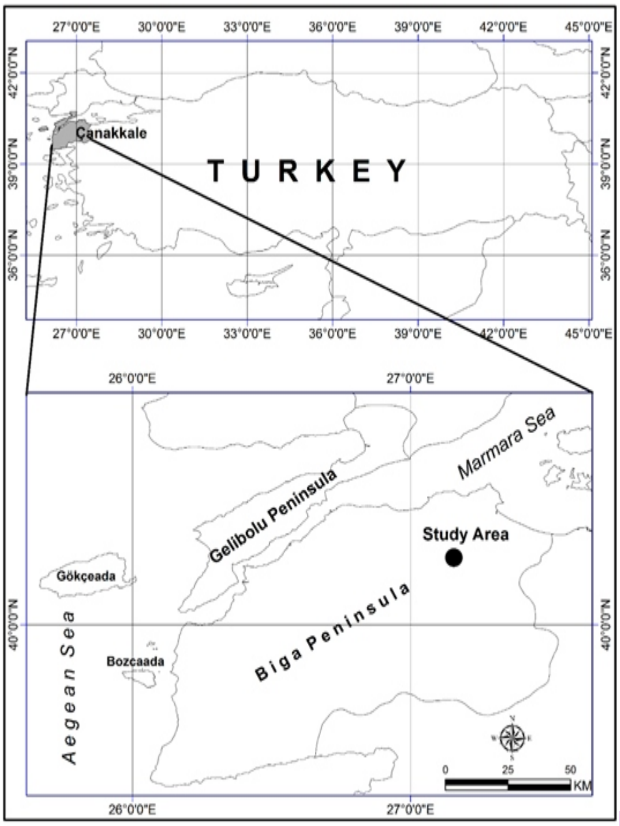


Fig. 1 : Map showing the study area

mica schist and quartz schist with good foliation. In the upper part there are lens shaped marbles and in some parts limestones (Pehlivan, 2003).

Sample analysis : The samples of young roots, young stems, older stem, stem bark and leaves of *Platanus orientalis* were collected from 150, 300, 350, 700 and 800 year-old-tree. The soil samples were also taken from the same sites under these trees (Table 1). The area is exactly located alongside the Ilıcabasi stream flowing towards the Kocabas river near 101th km of Çanakkale-Biga-Kırkgeçit hotwater springs road. Soil samples were collected from 0-30 cm depth air dried, and sieved using 2 mm mesh. The physical/chemical characteristics were determined following the methods outlined by Ozturk *et al*. (1997).

The plant samples were also taken at the same time, brought to the laboratory, dried at 80 °C for 24 hand crushed. Total nitrogen was determined by Kjeldahl method; phosphorus spectrophotometerically and total potassium and sodium by flame photometer (Ozturk *et al*.,1997). The concentrations of nitrogen, phosphorus, potassium, sodium, calcium, magnesium, zinc, iron, manganese and copper were determined in the young root, young stem, elderly stem, stem bark and leaf as well as the soils supporting these trees by inductively coupled plasma optical emission spectroscopy (ICP-OES)(Table 1).

Statistical analysis : Multidimensional Scaling Technique (MDS) has been applied to investigate the relationships between some soil and plant characteristics of *P. orientalis* under different locations. In this way, it would be possible to determine similar and dissimilar soil and plant characteristics based on their locations. The results of MDS have been shown in Fig. 2a-j. Two different goodness-of-fit criteria namely R^2 and stress coefficient have been used to determine the suitability of MDS technique to investigate the relationships between some soil and plant characteristics of *P. orientalis* under different locations. R^2 and stress coefficient values (all R^2 values were found greater than 0.95 and all stress coefficients were found smaller than 0.032) indicated that MDS technique was one of a good choice to evaluate the relations between soil and plant attributes (Kruskal, 1964; Kruskal and Wish, 1978; Yiğit and Mendeş, 2016).

Results and Discussion

Plants actively absorb several mineral nutrients. However, concentration of some elements in plants is generally much higher than that of the outer medium. The concentration ratio differs with element. Some species can accumulate relatively large quantities of mineral elements in their tissues but, there are small differences in the concentration of cobalt, copper, manganese and iron as a characteristic for certain plant species, and environmental circumstances. The results of analysis of soils carried out during these studies are presented in Table 2. The mean values of soil samples show that the plane trees prefer soils with loamy sand and sandy loam texture, electrical conductivity around 0.58-1.26 dS m^{-1}, with low level of $CaCO_3$, but high level of organic matter content. Kacar (1972) and Kacar and Katkat (2010) reported that N, P, K and Na values were as follows 0.2-

Table 1 : Soil and plant sampling sites from the study area

Locality no	Estimated age (year)	Grift (cm)	Diameter (cm)	Height (m)	Geographical coordinates	Altitude (m)
1	**150**	174	54	16	40°07′ 37.70″ N 27°13′ 00.67″ E	105
2	**300**	210	80	19	40°07′ 38.77″ N 27° 13′ 01.37″ E	88
3	**350**	230	90	22	40°07′ 40.67″ N 27°13′ 00.63″ E	82
4	**700**	620	210	26	40°07′ 42.89″ N 27°13′ 03.23″ E	74
5	**800**	650	240	29	40°07′ 42.13″ N 40°07′ 00.02″ E	80

Table 2 : Physical and chemical analysis of soils from *P. orientalis* localities

	Loc. 1	Loc. 2	Loc. 3	Loc. 4	Loc. 5
pH	7.4	7.2	6.9	6.6	6.6
$CaCO_3$ (%)	1.52	0.77	0.00	0.00	0.00
Organic matter (%)	1.55	1.57	3.21	5.05	4.48
Total N (%)	0.10	0.08	0.18	0.26	0.29
P (ppm)	14	7	4	28	20
K (ppm)	91	50	137	314	287
Ca (ppm)	3041	1962	1097	1086	2673
Mg (ppm)	191	104	54	104	302
Na (ppm)	32	20	20	24	33
Fe (ppm)	3.57	6.12	6.70	15.30	4.12
Mn (ppm)	3.37	5.00	8.14	10.71	13.29
Zn (ppm)	1.84	2.19	3.30	3.42	4.17
Cu (ppm)	0.41	0.61	1.03	1.48	1.13
EC (dS. m^{-1})	0.68	0.58	0.60	0.61	1.26
Sand %	86.27	86.29	78.02	86.29	75.95
Clay %	7.6	7.59	9.68	5.55	11.74
Loam %	6.13	6.12	12.3	8.16	12.31
Texture	Loamy sand	Loamy sand	Sandy loam	Loamy sand	Sandy loam

6%, 2.000 (ppm), 2.000-110.000 (ppm) and 100-10.000 (ppm) respectively in plants. The mineral nutrient levels (N, P, K and Na) in the soils were sufficient enough to support the well growth of older plane trees (Table 2).

The results of the analysis of young roots, young stems, elderly stems, stem bark, and leaves collected during mid summer on dry weight basis are presented in Table 3. The results obtained were within the normal range for N, K and Na, but P showed lower levels. The aged trees of *P. orientalis* showed a normal uptake of these elements. The interrelation between mineral element contents in the soil and plant showed that the normal limits of Cu, Fe, Mn and Zn in plants are reported to be in the range of 7-104, 10-100, 5-30, 2-250, 30-300, 0.1-5, 25-150 mg kg^{-1} and between or over 400, 50-200, 20-100, 400-1000, 300-500, 10-100, 100-400 mg kg^{-1} are accepted as toxic levels (Kacar and Katkat, 2010). The results for Cu were within normal ranges for all plant parts; but for Zn within normal range for young root, while all other plant parts showed lower levels; for Fe the values are within the normal ranges for young stem elderly stem, and leaf, while young root and stem bark show higher levels; and for Mn values lie within normal ranges for young root, stem bark, and leaf, but for young stem and older stems the levels are lower in the trees investigated here. The values in the soils were within normal limits for Fe, Cu, Mn and Zn were found in low level (Tables 2 and 3).

Barker and Pilbeam (2007) reported 0.03-0.80% Mg in soils. The results for Mg in the soils of our study were lower than the normal levels. In addition, Kacar and Katkat (2010) reported 0.15-1% Mg in plants. The results for mineral nutrients in all of the monumental plane trees investigated here were within the normal range for young root, stem bark and leaf while young stem and older stems showed lower levels (Tables 2 and 3). According to Chapman (1967) Ca content was 9.3 g kg^{-1} in plants. The mean Ca content was within the normal limits in the young root and older stems, while young stems showed lower levels, but stem bark and leaf exceeded normal limits (Table 3). The Cu (in all plant parts) Zn (in only young roots), Mn (in young roots, stem bark and leaves) and Mg (in young roots, stem bark and leaves) content in this study were within the normal limits in the plant, but the level of Fe (in young roots and stem bark) and Ca (in stem bark and leaves) was higher than other plant parts in the trees studied during this investigation. It shows that these plants have a unique ability to accumulate excess of Fe and Ca in their plant parts.

Soil solution pH is a major factor affecting the availability of micro-elements. The most important effect of pH is mainly on the solubility of nutrients and their ionic forms (Ronen, 2007). In this study, average pH values was around 6.94. The degree of K fixation partly depends on pH and plant potassium, as well as soil potassium together with plant calcium showed a significant and positive correlation. A negative correlation was seen between soil organic matter and plant sodium and soil organic matter and plant manganese content. The findings indicate that the soils of these plants are poor in nutrients. A positive correlation between soil K and plant Ca, also plant Na and Mn levels was recorded. The Mg levels in plants are influenced by several factors. When soil level of K to Mg exceeds 4:1 or when the soil level of Ca:Mg exceeds 8:1, Mg uptake by some plants is depressed (Hodges, 2010). A proper balance of Mg to both K and Ca is important. In this study, the balance of Mg to K and Ca was proper, and therefore uptake of Mg by the plant was not inhibited. These results clearly show that accumulation levels of elements differ with plant species, the

Table 3 : Chemical analysis of the plant parts

	Plant samples	Total N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
1. Locality	Young root	0.45	2200	3990	14425	2725	399	2255	95	24	13
	Young stem	0.43	1250	3990	4562	700	224	51	12	10	9
	Leaf	1.05	1200	15410	21220	3085	327	307	61	20	6
	Elderly stem	0.26	100	147	3007	205	88	179	8	11	3
	Stem bark	0.68	500	881	35045	3000	158	585	44	16	8
2. Locality	Young root	0.72	900	3097	9620	1850	510	1100	43	25	8
	Young stem	0.31	650	2078	7705	925	283	52	14	33	3
	Leaf	1.30	1100	6650	19270	3185	224	151	50	17	5
	Elderly stem	0.45	400	4231	18295	2305	262	385	31	18	7
	Stem bark	0.63	350	959	37545	3260	206	2010	105	21	11
3. Locality	Young root	0.62	1550	3680	14905	2405	350	957	40	21	16
	Young stem	0.22	750	2757	8185	860	158	53	12	4	4
	Leaf	1.10	750	8430	27600	3115	224	193	106	19	6
	Elderly stem	0.56	350	806	15875	1890	426	1250	65	15	9
	Stem bark	0.50	450	1212	43590	2880	224	1680	61	13	9
4. Locality	Young root	0.60	2200	8060	5800	1990	189	600	30	19	9
	Young stem	0.36	2050	10400	2367	1160	350	76	13	15	11
	Leaf	1.35	1450	19085	18780	3080	327	226	59	31	11
	Elderly stem	0.15	150	1212	4664	1070	131	56	9	3	3
	Stem bark	0.57	650	2757	27600	3090	242	331	54	10	14
5. Locality	Young root	0.57	1600	5675	13460	2875	242	2190	75	32	11
	Young stem	0.37	2100	5675	4613	1335	173	107	21	13	8
	Leaf	1.32	2050	13480	21705	3330	262	164	55	30	10
	Elderly stem	0.16	100	270	7230	430	108	71	8	5	2
	Stem bark	0.57	350	632	48160	3050	158	620	34	15	8

accumulation capabilities of the individual plants and their habitat features. The results of this investigation suggest that plant species can play an important role for the uptake and accumulation of specific elements which may not be toxic to that species but which may be harmful to another.

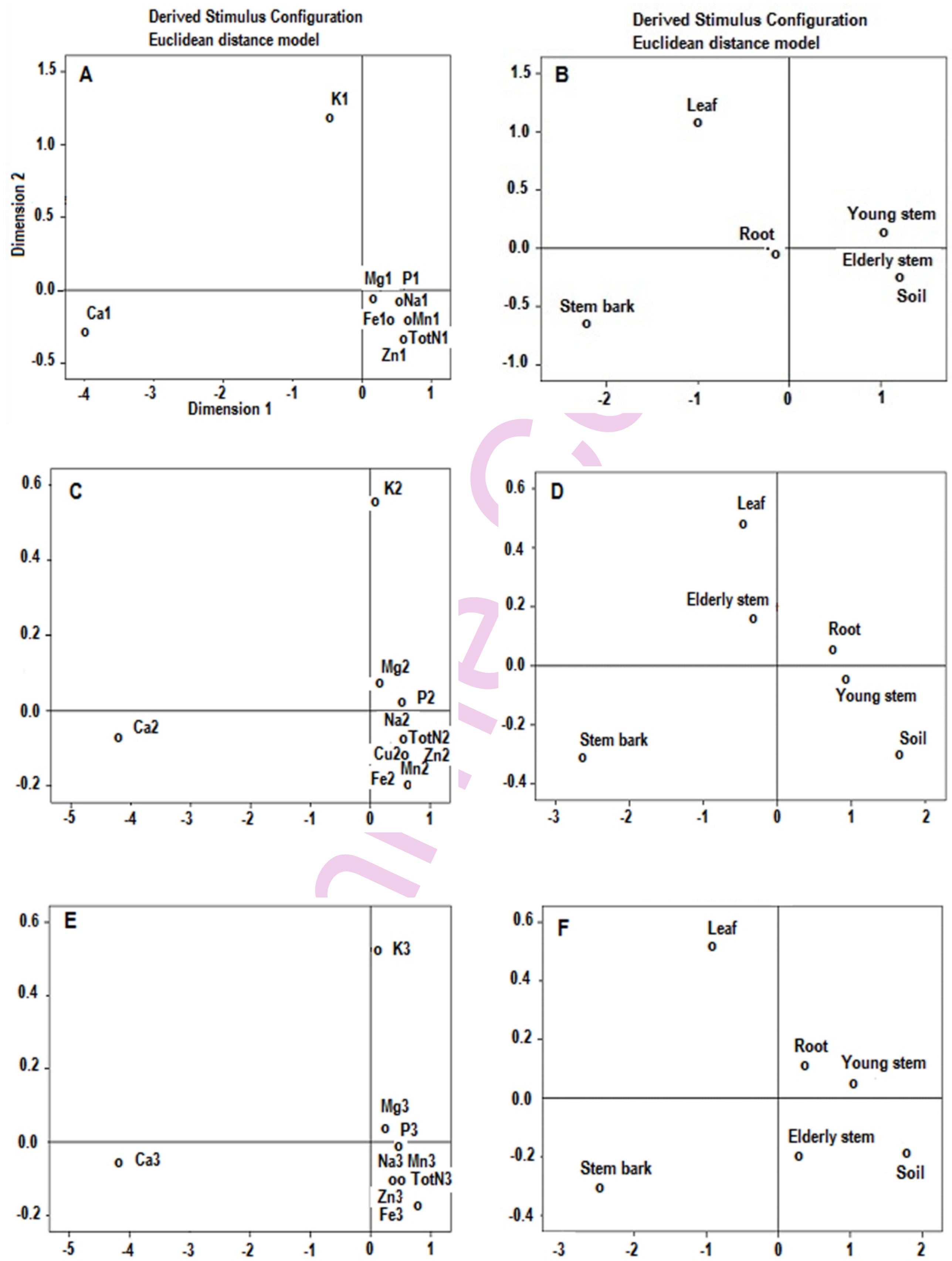
Multidimensional scaling technique (MDS) : Similar and different characteristics of monumental plane trees under the first location is given in Fig. 2a. Fig. 2a shows that Mg, P, Na, Mn, Fe, total N and Zn were placed in the same group, while K and Ca are located at different places. Based on our results it can be concluded that a strong relation existed among Mg, P, Na, Mn, Fe, total N and Zn.

Fig. 2b drawn by using MDS technique aimed to determine similarity in the plant parts of the monumental plane trees namely leaf, young root, stem bark, young stem, older stem and soil in terms of nutrient elements. Fig. 2b depicts that older stem, soil and young stems were located almost in the same group, indicating that when samples were taken from older stems, soil and young stems then nutrients elements of these samples showed similarity with each other. This was more obvious, especially when samples were taken from older stems and soil. Therefore, it is possible to conclude that the nutrient elements of the samples taken from older stems and soil were highly correlated when compared with the nutrient elements of other plant parts (especially leaf, stem bark and young root).

Fig. 2c presents the relationship among the nutrient elements of the samples taken from the second locality. It enlightens the fact that Mg, P, Na, Mn, Fe, total N and Zn were placed in the same group meaning revealing is a high correlation among these variables. On the other hand, K and Ca were located in different places. These finding are very similar to those obtained from the first locality. These findings stress the fact that any change in the localities (localities 3 and 4) does not affect the relations among the nutrient elements.

Fig. 2d represents the uptake of nutrients in similar plant parts. The figure reveals that changes in the localities have significant affect on the relations among the plant parts. Fig. 2b and 2d shows that, the differences were noted clear. However, the relations among the nutrient elements of the samples taken from young stems and young roots wre obviously stronger than those of leaves, stem bark, older stems and soil.

Fig. 2e, 2g and 2i shows the relationships among the nutrient elements for the samples obtained from the localities 3, 4



Derived Stimulus Configuration
Euclidean distance model
A
Dimension 2
Dimension 1
K1
Mg1 P1
oNa1
Fe1o oMn1
oTotN1
Zn1
Ca1
Derived Stimulus Configuration
Euclidean distance model
B
Leaf
Root
Young stem
Elderly stem
Soil
Stem bark
C
K2
Mg2
P2
Na2
oTotN2
Cu2o Zn2
Mn2
Fe2
Ca2
D
Leaf
Elderly stem
Root
Young stem
Soil
Stem bark
E
K3
Mg3
P3
Na3 Mn3
oo TotN3
Zn3
Fe3
Ca3
F
Leaf
Root
Young stem
Elderly stem
Soil
Stem bark

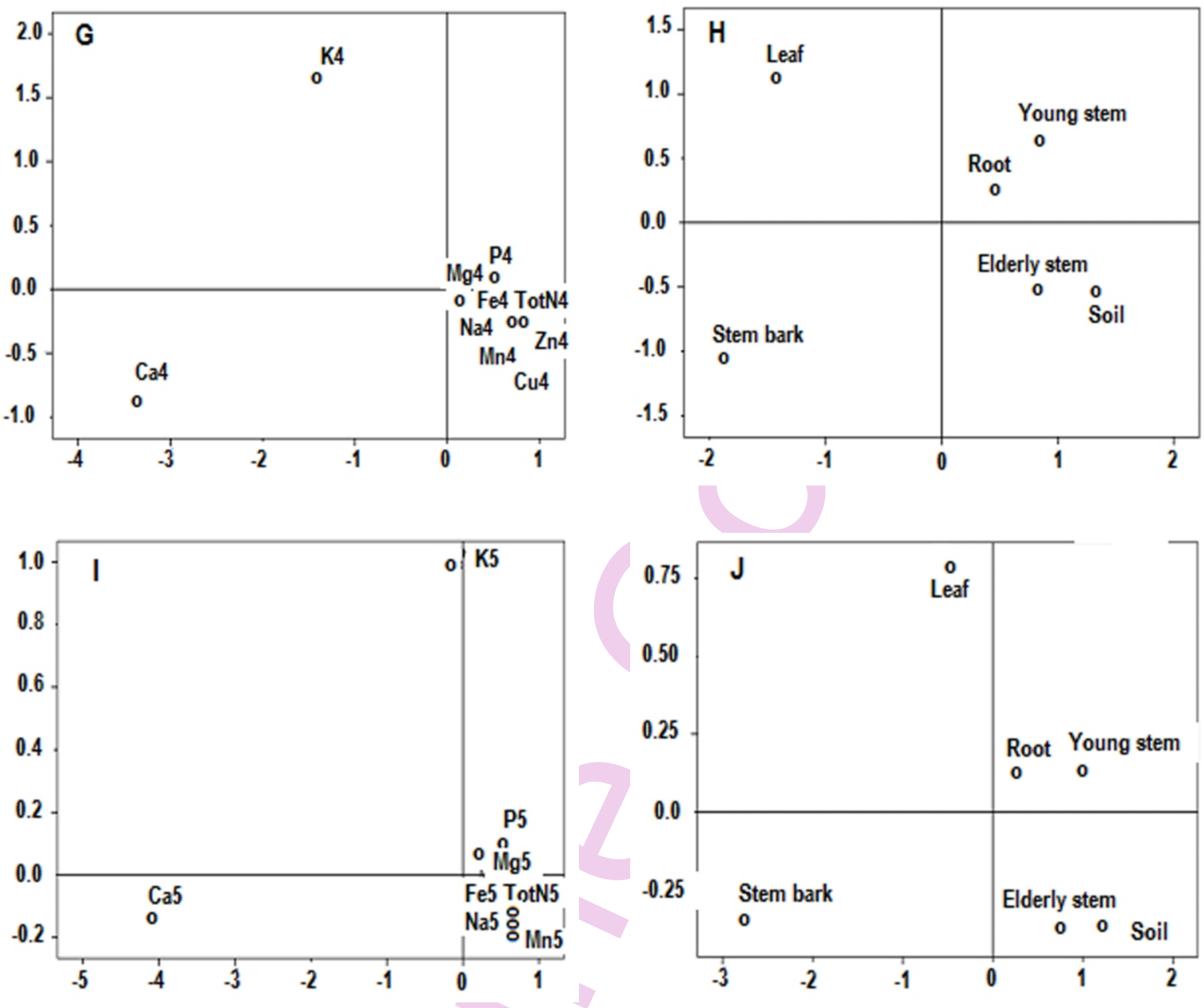


Fig. 2 : (a) MDS map presenting the relationship among the nutrient elements for the first locality; (b) relationships among the plant parts for the first locality; (c) the relationship among the nutrient elements for the second locality; (d) the relationship among the plant parts for the second locality; (e) the relationship among the nutrient elements for the third locality; (f) the relationship among the plant parts for the third locality; (g) the relationship among the nutrient elements for the fourth locality; (h) the relationship among the plant parts for the fourth locality; (i) the relationship among the nutrient elements for the fifth locality; and (j) the relationship among the plant parts for the fifth locality

and 5. The values presented here show that the relations among the nutrient elements are very similar regardless of localities from where the samples are taken. As seen in Fig. 2e, 2g, and 2i the Mg, P, Na, Mn, Fe, Total N and Zn were placed in the same group meaning that there was a high relation or correlation among these variables. On the other hand, K and Ca were located in different places. These finding are very similar to the findings obtained from the first and second localities. It is therefore possible to conclude that the changes in localities do not affect the relations among the nutrient elements.

Fig. 2f, 2h and 2j include findings on the similar plant parts of the third, fourth and fifth localities. These figures reveal that young roots, young stems, older stems and soil were close to each other while the leaf and stem bark were located in different places. The conclusion drawn here could be that the relations among the nutrient elements of the samples taken from young roots, young stems, older stems and soil are obviously stronger than those of leaf and stem bark.

Monumental tree stands are among the important elements of rural and urban landscaping with their splendid structures and interesting formations, genetic reserves and unique natural treasures influencing the psychology of a society, contributing to both nature, as well as cultural tourism based on folkloric and mystical values (Efe *et al*., 2013) and therefore need full protection because of the scientific information hidden within their "increment cores" (Genç and Guner, 2000).The stands of these trees are living witnesses of the ecological changes occurring in their environment. They provide an important opportunity to determine the ideal conditions for planting forests (Asan, 1987). The limited number of registered monumental trees is a clear evidence of the situation that these trees are facing. The number of researchers in this subject is highly limited in Turkey (Genç and Guner, 2000; Oner *et al*., 2010). It is important to collect data on the identification, registration and conservation of such trees because it is very crucial. As a requirement in the context of Law 2863 for municipalities, it is a legal obligation for municipalities even other organizations and establishments to undertake studies on this topic (Efe *et al.,* 2013).These trees have specific importance for ecotourism and geotourism due to the effect they create on mankind (Efe *et al.,* 2013). They should be protected, and awareness among people should be increased and protective measures should be adopted (Arı *et al.,* 2015). There is a need to safeguard these aganist such destructive forces as industrialization, urbanization, land clearance, fires, and over-exploitation.

The mineral cycling in the ecosystems inhabited by large trees cannot be understood without referring the mineral element status in individual plant species. The trace elements like iron, manganese and copper are among the essential micronutrients required for the plant growth, however, an excess of these elements affects the growth of plants adversely. Although tremendous literature is available in this connection related to the herbaceous and agricultural species, but, few papers deal with the elemental distribution in large trees in particular monumentals. The monumental plane tree stand investigated here differentiates from its congeners and other plant species in terms of habitat, mineral uptake and transport characteristics and its choice of different soil textures. The biogeographical history of *P. orientalis* suggests that changes in its geographical range seem to be a natural phenomenon, but there is a need to understand the human-induced cause of population decline, which should be stopped. The present study stress on the fact that monumentals are of critical value as keystone species of immense importance from monumental, plant developmental and forest development view. It is important that we understand the value of monumentals as these are critical for biodiversity (Stagoll *et al.*, 2012).

The European Union Biodiversity 2020 Strategy for Monumental Treesunder the Natura 2000 Network is following a programme which deals with the management of elements of the landscape that have key importance for biodiversity. Every country in the European Union is in line with the 2020 Biodiversity Strategy and framework directives on priority action for the Natura 2000 Network, have to incorporate a strategic priority to the conservation of monumental trees, mature forests, centuries-old agricultural trees and the most emblematic treed landscapes of Europe. The oldest trees on this; the Old Continent; still enjoy tremendous appreciation and recognition at a local level and can once again play an essential role in our future prosperity. This study will assist to better understand the ecological requirements of monumental plane trees in the study area for their possible conservation programs.

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