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Natural Filters: The Impact of Urban Plants on Air Quality

Doğal Filtreler: Şehir Bitkilerinin Hava Kalitesine Etkisi

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Abstract

Plants are among the first solutions considered in the fight against air pollution. As natural and effective agents, they play a vital role. However, success depends on selecting the right species and placing them in suitable climates and locations. When properly chosen, plants can significantly improve air quality and support sustainable urban environments. This study focuses on the concept of "natural filtration," particularly "the role of trees," using the city of Trabzon as the study area. Two sites were selected: one with dense urban vegetation and the other with sparse vegetation. Emission measurements were conducted and analyzed statistically. Results revealed that broad and oval-leaved plants had greater potential to enhance micro air quality. Among all species, *Rhododendron cynthia* had the most consistent positive effect across all seasons. In spring, the park's average air quality was 95.48 µg/m³, with R. cynthia recording 357.44 µg/m³. In summer, the average was 106.87 µg/m³, while this species measured 310.37 µg/m³. Autumn showed 124.74 µg/m³ overall, and *Rhodendron cynthia* had 201.43 µg/m³. In winter, it had the lowest CO emission at 1.03 µg/m³, while the average was 107.96 µg/m³. These findings emphasize the species' strong potential to improve air quality. Furthermore, 80% of the species with the highest air quality contribution were trees, suggesting they should be prioritized in landscape planning. ANOVA results showed that broad and oval-leaved trees had a significant positive impact, while the difference between deciduous and evergreen species was not significant. In conclusion, urban plants' effectiveness in improving air quality depends on species, leaf shape, and growth form. These findings serve as a guide for environmentally sustainable and informed landscape planning.

Özet

Bitkiler, hava kirliliğiyle mücadelede ilk akla gelen çözümler arasındadır. Doğal ve etkili unsurlar olarak önemli bir rol oynarlar. Ancak bu süreçte başarı, doğru bitki türlerinin seçilmesi ve uygun iklim koşullarına ve alanlara yerleştirilmesine bağlıdır. Uygun seçimlerle, bitkiler hava kalitesini artırabilir ve sürdürülebilir kentsel çevreler oluşturabilir. Bu çalışma, "doğal filtrasyon" kavramı ve özellikle "ağaçların rolü" üzerine odaklanmakta olup, çalışma alanı olarak Trabzon kenti seçilmiştir. Biri yoğun bitki örtüsüne, diğeri ise az bitki örtüsüne sahip iki alan belirlenmiştir. Bu alanlarda emisyon ölçümleri yapılmış ve istatistiksel olarak analiz edilmiştir. Sonuçlar, geniş ve oval yapraklı bitkilerin mikro hava kalitesini artırmada daha etkili olduğunu göstermiştir. Tüm türler arasında *Rhododendron cynthia,* dört mevsim boyunca hava kalitesini en fazla iyileştiren tür olmuştur. İlkbaharda parkın ortalama hava kalitesi 95.48 µg/m³ iken, *Rhododendron cynthia* 357.44 µg/m³ değerine ulaşmıştır. Yazın ortalama 106.87 µg/m³, bu türde ise 310.37 µg/m³ ölçülmüştür. Sonbaharda genel ortalama 124.74 µg/m³ olup, *Rhododendron cynthia* 201.43 µg/m³ değer göstermiştir. Kışın ise ortalama 107.96 µg/m³ iken, bu tür en düşük CO emisyonunu 1.03 µg/m³ ile göstermiştir. Bulgular, bu türün hava kalitesini artırmadaki güçlü potansiyelini ortaya koymaktadır. Ayrıca, hava kalitesine en fazla katkı sağlayan türlerin %80'inin ağaç formunda olduğu tespit edilmiş ve bu türlerin kentsel peyzaj planlamasında önceliklendirilmesi gerektiği sonucuna varılmıştır. ANOVA testi sonuçlarına göre, geniş ve oval yapraklı ağaçlar hava kalitesine daha fazla katkı sağlarken, yaprağını döken ve herdem yeşil türler arasında anlamlı bir fark bulunmamıştır. Sonuç olarak, kentsel bitkilerin hava kalitesini iyileştirme potansiyeli; tür, yaprak morfolojisi ve büyüme formuna bağlıdır. Bu bulgular, çevresel sürdürülebilirliği destekleyen bilinçli peyzaj planlaması için önemli bir rehber niteliğindedir.

INTRODUCTION

Air pollution is among the biggest environmental problems of our time (Locosselli 2019). Martyr trees have a significant impact on this issue (Paoletti 2004). However, studies indicate that plants have a role in improving air quality and that some species help reduce urban ozone levels (Nowak et al. 1996, Nowak et al. 2006, Jin et al. 2024, Vashist et al. 2024). Improving air quality by producing oxygen, They capture Particulate Matter (PM) with their leaf surfaces. They prevent overheating in cities by blocking sunlight with the help of their leaves and other organs. Urban trees reduce carbon emissions by storing carbon in the atmosphere during their growth. However, there are still complexities about which plant should be selected and which plant has a role in improving air quality (Grote et al. 2016). For example, *Pinus taxa* are much more widely used in Europe. The main reasons for this are that they improve air quality and are relatively more resistant to stress (Grote et al. 2016). Urban trees play important roles in terms of the ecosystem services they provide in urban areas (Tülek et al. 2024). These beneficial roles include combating air pollution and absorbing polluted emissions (Nowak 2002, Escobedo and Nowak 2009, Manes et al. 2012, Sicard et al. 2018), absorbing harmful emissions such as CO_2 (Nowak et al. 2013), and balancing air temperature (Livesley et al. 2016) (Locosselli et al. 2019). For example, some taxa that are effective in reducing ozone in Brooklyn, NY are as follows; *Morus* spp., *Prunus* spp., *Tilia* spp. and *Gleditsia* sp. (Nowak 2002). Among the street trees, broad-leaved trees are effective in retaining PM2.5, but when placed incorrectly, they can slow down airflow and cause pollutants to accumulate (Jin et al. 2024). Therefore, species selection is very important in terms of air quality.

When harmful emissions are examined, Particulate matter 2.5, Particulate matter 10, ozone, Carbon dioxide, Carbon monoxide, Formaldehyde, Sulfur dioxide, Volatile Organic Compounds VOCs are among some harmful emissions in the city. Within the scope of this study, $PM_{2.5}$, PM_{10}, CO, CO_2 and Air Quality index calculations were made. The reason why 4 emissions were selected within the scope of the study is listed as follows;

- PM2.5 (particles smaller than 2.5 micrometers) can reach the lungs and even the bloodstream, causing respiratory and cardiovascular diseases. PM10 (particles smaller than 10 micrometers) can accumulate in the respiratory tract and trigger diseases such as asthma and bronchitis. PM2.5 and PM10 are one of the most critical pollutants in determining air quality, and the World Health Organization (WHO) limit values have been determined according to these pollutants (Xing 2016, Yang et al. 2019, Yang et al. 2020, Cui et al. 2022, Zhu et al. 2023).

- CO can cause a lack of oxygen in the bloodstream. Especially in closed areas, CO accumulation can lead to fatal poisoning. CO levels in cities increase due to transportation and energy use. Therefore, it is one of the important indicators of urban air pollution (Saxena and Naik 2019).

- CO_2 is a greenhouse gas and one of the main causes of climate change. High CO_2 levels reduce the quality of life by increasing the heat island effect in cities (Lukac et al. 2010, Özsoy 2023).

STUDY AREA AND METHODOLOGY

Study Area

Geographical Location and Design Features

The main material of the study is Trabzon Atatürk Area Square Park. Atatürk Area Square Park is located at 41.005219 latitude and 39.730820 longitude (URL-1). Trabzon Atatürk Area Square Park is an important green area in terms of urban landscape located in the city center. This park is a part of the historical and cultural texture of Trabzon and is also designed to meet the needs of city residents for rest, social interaction and being in touch with nature. The study area was rebuilt with a project in 2011 and was added to the city with many functions and activity areas (Sancar and Acar 2016, Bekar et al. 2016).

Trabzon Atatürk Area is located in a location that is easily accessible, among the busy traffic and commercial areas of the city center. This park establishes a direct connection with the urban ecosystem as one of the green areas surrounding the city. Meydan Park attracts attention with its wide green areas, walking paths, tree-lined rest areas and aesthetic arrangements. In terms of landscape architecture, local plants and various tree species were used in the design of the park, reflecting an approach appropriate to the climate and ecosystem of the region.

Figure 1. Study area (Left: Google Map Pro, Right: Meteoblue)

Study Area in Terms of Air Quality and Emissions

Trabzon Atatürk Square Park is an important green area that improves the air quality in the city. The trees in the park filter Particulate Matter (PM), Carbon Dioxide (CO_2), Carbon Monoxide (CO) and other air pollutants, thus positively affecting the air quality. However, the fact that the park is located in the city center, the density of businesses around it and its proximity to important transportation networks of the city cause the park to be in constant contact with air pollutants. This means that the positive effects on air quality provided by the park may be limited and the effect of pollutants is further increased by pollutant emissions originating from heavy traffic and industrial activities around the park. Nevertheless, the green area function and natural filtering capacity of the park continue to contribute to the air quality of the city.

Methodology

The study consists of two stages. In the first stage, Trabzon's urban plants were analyzed in detail. In this analysis process, a survey was conducted with an expert group. In line with the purpose of the survey, an open-ended question was directed to the expert group. The question was determined as follows: "When you think of Trabzon Atatürk Area Square Park, list the first 15 ensured data consistency. Measurements were meticulously conducted based on predetermined coordinates. These coordinates were determined characteristic plant taxa that come to your mind." This stage was an important step to collect expert opinions on Trabzon's urban plants and to better understand the relationship of these plants with air quality.

In the second stage of the study, measurement studies were carried out. In this stage, a location was selected where each of the plants determined in the first stage was located in the same area. While choosing the location, care was taken to include different plant groups with similar vegetation characteristics in the same area and a study area suitable for these criteria was determined. Thus, it was possible to compare and analyze the effects of different plant species on air quality more effectively. Measurements were made in 2 different ways. In order to measure the effects of plants, micro measurements were made under 10 different plants and the general air quality index of the park was measured and calculated.

Measurements were conducted regularly over the course of one year, with each season analyzed separately to identify seasonal variations in detail. The measurement frequency was planned as twice per week, resulting in a total of 650 micro-measurements. To enhance reliability and minimize error rates, all measurements were performed at the same times (09:00 and 11:00) and from the same location. This approach helped reduce the influence of external factors on measurement results and according to the locations of trees selected by an expert group. The measurement process was carried out each week at the same time and from the same coordinates.

Additionally, to ensure consistency in the measurements, the process always started from the same point and was completed at the same endpoint. Thus, the accuracy and comparability of the data were maintained at the highest level.

The measurements were carried out using a handheld, manually operated infrared device. Due to the handheld nature of the device, the measurement height varied depending on the operator's stature but was generally maintained at the sub-canopy level. This approach was implemented as a precaution to standardize the measurement process. Additionally, special attention was given to maintaining a consistent angle and distance during measurements to ensure accuracy and repeatability.

FINDINGS

Identification of City Plants

A plant list was created with a group of 50 landscape architects who are experts in their fields. While creating the plant list, the first 10 plants from the plant species that were written the most in the open-ended questions were selected (Figure 2, Figure 3, Table 1). These plants are “Acer palmatum 'Atropurpureum', Betula pendula, Cedrus deodora, Fagus sylvatica, Laurus nobilis, Magnolia grandiflora, Malus floribunda, Platanus orientalis, Prunus serrulata, Rhododendron cynthia (Figure 2). These identified plants were examined in Table 1 according to Leaf Phenology, Plant Growth Habit, Priority in Planting Design, Area of Use in Urban Spaces, Exotic/Natural, Leaf Morphology, Light intensity under the crown, Number of branches groups and the second stage of the study was started.

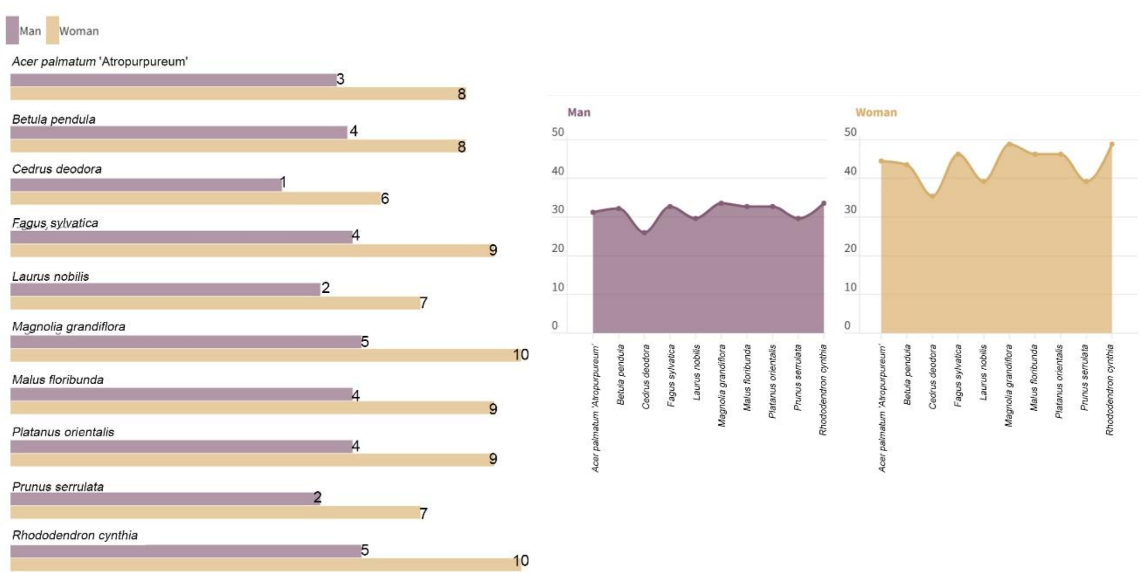

Figure 2. Participants' preference of urban plants

Table 1. Characteristics of some urban plants identified by the expert group

Scientific name		**Turkish name**	**Leaf Phenology**	**Plant Growth Habit**
1	*Acer palmatum* 'Atropurpureum'	Japon Akçaağacı	Deciduous	Tree
2	*Betula pendula*	Sarkık Huş	Deciduous	Tree
3	*Cedrus deodora*	Himalaya sediri	Evergreen	Tree
4	*Fagus sylvatica*	Avrupa Kayını	Deciduous	Tree
5	*Laurus nobilis*	Akdeniz Defnesi	Evergreen	Shrub
6	*Magnolia grandiflora*	Büyük Çiçekli Manolya	Evergreen	Tree
7	*Malus floribunda*	Süs Elması	Deciduous	Tree
8	*Platanus orientalis*	Doğu Çınarı	Deciduous	Tree
9	*Prunus serrulata*	Süs Kirazı	Deciduous	Tree
10	*Rhododendron cynthia*	Orman Gülü	Evergreen	Shrub
Scientific name		**Priority in Planting Design**	**Area of Use in Urban Spaces**	**Exotic/ Natural**
1	*Acer palmatum* 'Atropurpureum'	Form, Leaf	Visual	Exotic
2	*Betula pendula*	Leaf, Stem, Calligraphy	Visual, Ecological	Exotic
3	*Cedrus deodora*	Form	Visual	Exotic
4	*Fagus sylvatica*	Form, Leaf, Calligraphy	Visual, Ecological	Exotic
5	*Laurus nobilis*	Leaf, Flower, Fruit	Visual, Functional, Ecological	Natural
6	*Magnolia grandiflora*	Form, Leaf, Flower	Visual, Functional	Exotic
7	*Malus floribunda*	Leaf, Flower, Fruit	Visual	Exotic
8	*Platanus orientalis*	Form, Fruit, Body, Calligraphy	Visual, Functional, Ecological	Natural
9	*Prunus serrulata*	Flower	Visual, Functional	Exotic
10	*Rhododendron cynthia*	Flower	Visual	Exotic
Scientific name		**Leaf Morphology**	**Light intensity under the crown**	**Number of branches**
1	*Acer palmatum* 'Atropurpureum'	Palmate, slender and lobed	Medium (partial shade)	15-25
2	*Betula pendula*	Triangular, with toothed edges	High (light shade)	10-20
3	*Cedrus deodora*	Coniferous	Low (dense shadow)	25-40
4	*Fagus sylvatica*	Oval, with wavy edges	Medium (partial shade)	20-30
5	*Laurus nobilis*	Skin-textured, lanceolate	Medium (partial shade)	5-15
6	*Magnolia grandiflora*	Large, shiny, oval	Low (dense shadow)	10-20
7	*Malus floribunda*	Small, oval, slightly hairy	Medium (partial shade)	10-15
8	*Platanus orientalis*	Large, palmative, toothed	High (light shade)	20-30
9	*Prunus serrulata*	Oval, toothed edge	Medium (partial shade)	10-15
10	*Rhododendron cynthia*	Large, leather textured, oval	Low (dense shadow)	5-10

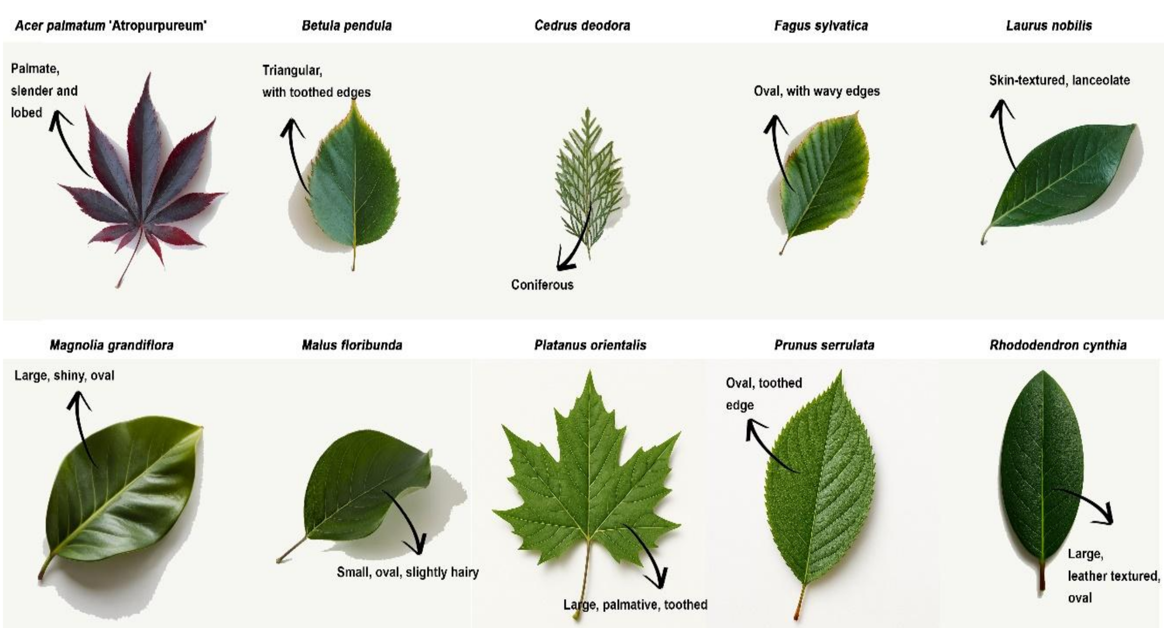

Figure 3. Characteristics of 10 plant leaf forms

Determining the Accuracy of the Data

Analysis of Variance (ANOVA) was used to determine whether there are significant differences between the emission measurements of different plant species, in line with the primary aim of the study. ANOVA is a parametric test that compares within-group and between-group variances to assess whether the means of the groups are significantly different from each other. This test is particularly preferred when comparing multiple groups, and in this study, it was applied to examine whether the effects of plant species on micro air quality differ. In the study, emission measurements related to micro air quality were collected for each plant species within predefined parameters. After the data was collected, the means of each plant species group were compared using a one-way ANOVA test. This test has two primary hypotheses: the null hypothesis, which assumes there is no significant difference between the means of the groups, and the alternative hypothesis, which suggests that at least one group mean differs. The p-value determines whether the test result is random or not. In this study, the p-value was found to be below 0.05, indicating that there are significant differences between plant species, and that these differences have statistically significant effects on micro air quality. As a result, the ANOVA test revealed that these urban plants have a significant impact on micro air quality. This finding supports the notion that the selection of plant species used to improve air quality in urban environments plays a crucial role in air pollution management (Table 2).

Table 2. Results of Analysis of variance (ANOVA) for plant emissions

Parameters	t	Sig.(2-tailed)	Mean Difference	Std. Deviation	95% Confidence Interval of the Difference	
					Lower	Upper
CO	25.782	.000	275.81450	275.81450	254.1758	297.4532
CO_2	97.389	.000	101.72650	101.72650	99.6137	103.8393
$PM_{2.5}$	19.502	.000	1.88575	1.88575	1.6902	2.0813
PM_{10}	68.428	.000	68.90200	68.90200	66.8653	70.9387

Conducting Emission Measurements

Looking at the emission results obtained during the spring seasons, *Acer palmatum* 'Atropurpureum' took the value of 357.44 µg/m³, *Betula pendula* 205.74 µg/m³, *Cedrus deodora* 217.57 µg/m³, Fagus sylvatica 202.76 µg/m³, *Laurus nobilis* 209.76 µg/m³, *Magnolia grandiflora* 198.64 µg/m³, *Malus floribunda* 223.74 µg/m³, *Platanus orientalis* 196.77 µg/m³, *Prunus serrulata* 196.13 µg/m³ and *Rhododendron cynthia* 194.37 µg/m³. The average AQI value was determined as 95.48 µg/m³. The best air quality measurement was obtained from *Rhododendron cynthia* taxon (Table 3, Figure 4).

Table 3. Spring emission measurement and average AQI

Spring	Taxa name	Emissions				Average air quality index
		CO_2	CO	PM_{25}	PM_{10}	
1	*Acer palmatum* 'Atropurpureum'	357.44	1.67	76.61	112.74	95.48 µg/m³
2	*Betula pendula*	205.74	2.85	75.47	106.74	
3	*Cedrus deodora*	217.57	2.43	70.54	103.64	
4	***Fagus sylvatica***	202.76	1.18	65.84	96.48	
5	*Laurus nobilis*	209.76	1.76	71.65	104.46	
6	***Magnolia grandiflora***	198.64	1.83	60.76	98.48	
7	*Malus floribunda*	223.74	2.34	74.36	102.97	
8	***Platanus orientalis***	196.77	1.07	61.67	99.47	
9	***Prunus serrulata***	196.13	1.34	60.74	99.47	
10	***Rhododendron cynthia***	194.37	1.17	65.71	95.41	

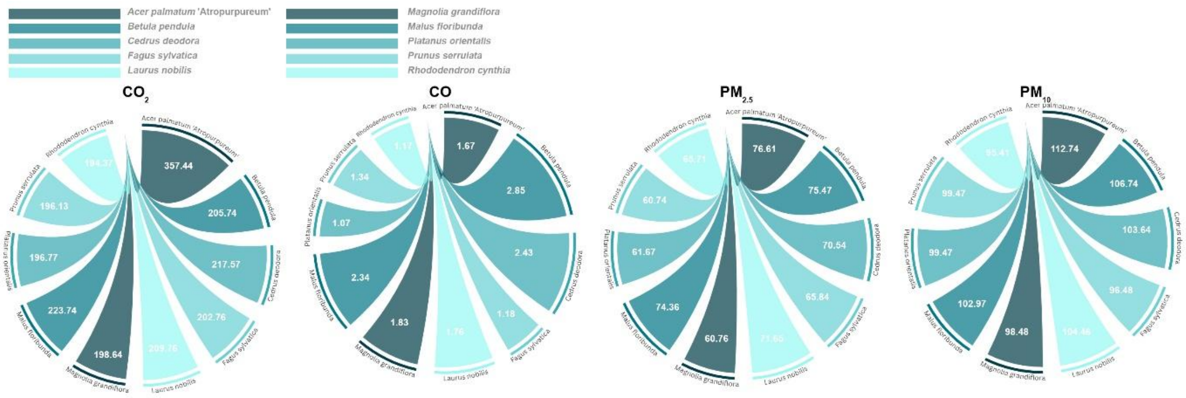

Figure 4. Spring emission graph

Looking at the emission results obtained during the summer season, *Acer palmatum* 'Atropurpureum' had the value of 253.67 µg/m³, *Betula pendula* 351.62 µg/m³, *Cedrus deodora* 314.44 µg/m³, *Fagus sylvatica* 201.77 µg/m³, *Laurus nobilis* 286.73 µg/m³, *Magnolia grandiflora* 216.52 µg/m³, *Malus floribunda* 299.87 µg/m³, *Platanus orientalis* 337.25 µg/m³, *Prunus serrulata* 215.19 µg/m³ and *Rhododendron cynthia* 310.37 µg/m³. The average AQI value was determined as 106.87 µg/m³. The best air quality measurement was obtained from *Rhododendron cynthia* taxon (Table 4, Figure 5).

Table 4. Summer emission measurement and average AQI

Summer	Taxa name	Emissions				
		CO_2	CO	PM_{25}	PM_{10}	Average air quality index
1	*Acer palmatum* 'Atropurpureum'	253.67	1.04	72.24	105.19	106.87 µg/m³
2	*Betula pendula*	351.62	2.94	62.79	94.26	
3	*Cedrus deodora*	314.44	2.66	65.84	91.63	
4	***Fagus sylvatica***	201.77	1.42	67.33	113.72	
5	*Laurus nobilis*	286.73	1.36	69.12	114.14	
6	***Magnolia grandiflora***	216.52	1.37	75.7	110.21	
7	*Malus floribunda*	299.87	1.61	63.99	97.62	
8	***Platanus orientalis***	337.25	2.05	70.28	92.44	
9	***Prunus serrulata***	215.19	1.86	71.85	107.11	
10	***Rhododendron cynthia***	310.37	1.58	60.93	101.0	

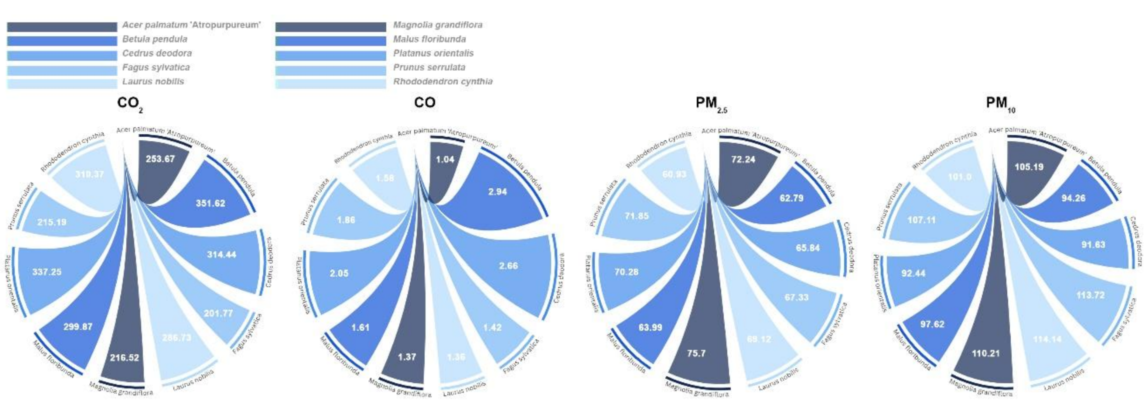

Figure 5. Summer emission graph

Looking at the emission results obtained during the autumn season, *Acer palmatum* 'Atropurpureum' had the value of 290.75 µg/m³, *Betula pendula* 274.18 µg/m³, *Cedrus deodora* 295.85 µg/m³, *Fagus sylvatica* 244.58 µg/m³, *Laurus nobilis* 303.99 µg/m³, *Magnolia grandiflora* 202.63 µg/m³, *Malus floribunda* 272.99 µg/m³, *Platanus orientalis* 218.41 µg/m³, *Prunus serrulata* 202.94 µg/m³ and *Rhododendron cynthia* 201.43 µg/m³. The average AQI value was determined as 124.74 µg/m³. The best air quality measurement was obtained from *Rhododendron cynthia* taxon (Table 5, Figure 6).

Table 5. Autumn emission measurement and average AQI

Autumn	Taxa name	Emissions				Average air quality index
		CO_2	CO	PM_{25}	PM_{10}	
1	*Acer palmatum* 'Atropurpureum'	290.75	2.94	67.77	109.31	
2	*Betula pendula*	274.18	2.55	65.43	94.97	
3	*Cedrus deodora*	295.85	2.88	76.57	90.14	
4	***Fagus sylvatica***	244.58	2.79	67.14	110.39	
5	*Laurus nobilis*	303.99	2.2	65.62	107.67	124.74 µg/m³
6	***Magnolia grandiflora***	202.63	2.84	70.85	108.23	
7	*Malus floribunda*	272.99	1.18	62.82	109.28	
8	***Platanus orientalis***	218.41	1.39	76.04	91.85	
9	***Prunus serrulata***	202.94	1.09	61.49	98.96	
10	***Rhododendron cynthia***	201.43	1.65	79.74	92.9	

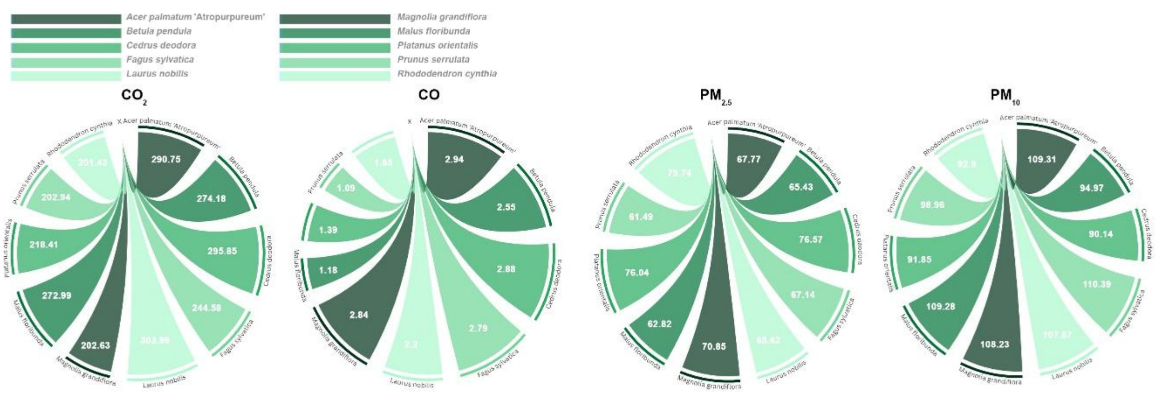

Figure 6. Autumn emission graph

During the winter season, *Acer palmatum* 'Atropurpureum' took the value of 413.12 µg/m³, *Betula pendula* 380.43 µg/m³, *Cedrus deodora* 409.76 µg/m³, *Fagus sylvatica* 374.96 µg/m³, *Laurus nobilis* 289.14 µg/m³, *Magnolia grandiflora* 354.17 µg/m³, *Malus floribunda* 287.61 µg/m³, *Platanus orientalis* 340.17 µg/m³, *Prunus serrulata* 364.11 µg/m³ and *Rhododendron cynthia* 321.01 µg/m³. The lowest value among average carbon monoxide (CO) emissions was recorded as 1.03 µg/m³ in *Rhododendron cynthia* taxon (Table 6, Figure 7).

According to these findings, according to micro air quality measurements, the best air quality was found to be large, oval-leafed plants. When the evaluation was made according to the distinction between deciduous and evergreen plants, no significant results were obtained. 80% of these plants that improve air quality to the maximum extent are in tree form.

Table 6. Winter emission measurement and average AQI

Winter	Taxa name	Emissions				
		CO_2	CO	PM_{25}	PM_{10}	Average air quality index
1	*Acer palmatum* 'Atropurpureum'	413.12	2.14	81.61	106.63	107.96 µg/m³
2	*Betula pendula*	380.43	2.16	79.76	105.66	
3	*Cedrus deodora*	409.76	2.34	79.10	102.04	
4	***Fagus sylvatica***	374.96	1.76	75.63	99.49	
5	*Laurus nobilis*	289.14	2.35	70.31	104.63	
6	***Magnolia grandiflora***	354.17	1.76	67.71	101.37	
7	*Malus floribunda*	287.61	2.05	61.62	99.15	
8	***Platanus orientalis***	340.17	1.63	63.74	98.61	
9	***Prunus serrulata***	364.11	1.17	61.25	95.64	
10	***Rhododendron cynthia***	321.01	1.03	58.46	94.96	

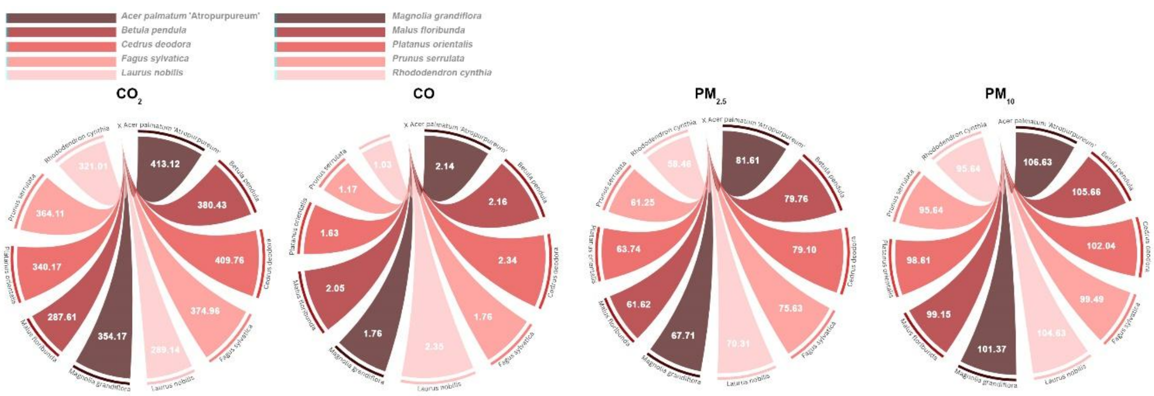

Figure 7. Winter emission graph

Analysis of Micro Air Quality Index Values According to Seasons

When the micro air quality index value is examined in the emission results obtained, it is 95.48 µg/m in the spring season, 106.87 µg/m³ in the summer season, 124.74 µg/m³ in the autumn season and 107.96 µg/m³ in the winter season. When the relationship between these values is evaluated, the best air quality was obtained in the spring season and the lowest air quality was obtained in the autumn season (Figure 8).

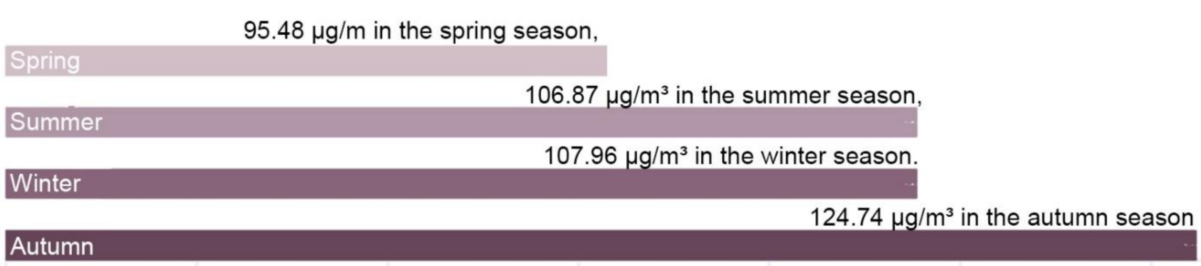

Figure 8. Avarage air quality index value between seasons

DISCUSSION

Broad-leaved plant species such as *Rhododendron cynthia* have been found to be more effective in improving air quality. This finding aligns with the studies conducted by Nowak et al. (2006). Nowak et al. (2006) and Li et al. (2019) stated that broad-leaved trees are more effective in capturing particulate matter and gaseous pollutants, thereby playing a significant role in improving air quality. Additionally, another study conducted by Escobedo and

Nowak (2009) emphasized the potential of urban trees to reduce air pollution and noted that the effectiveness of different tree species varies in this regard. The results obtained in our study also support these findings. This finding is consistent with the literature, which suggests that plants with large leaf surface areas have a higher capacity to filter particulate matter and harmful gases (Steinparzer et al. 2023).

The study also revealed that tree-form plants have a higher capacity to improve air quality. According to the findings, 80% of the plants that enhance air quality are in tree form. This can be explained by the fact that trees have large surface areas, can filter more pollutants throughout their long lifespans, and provide a more continuous air purification potential in urban environments (Li et al. 2019). However, it has been determined that the impact of plants on micro air quality is related not only to leaf area but also to leaf shape. The findings indicate that broad and oval-leaved plants improve micro air quality more significantly. It is thought that oval-leaved plants filter atmospheric pollutants more efficiently due to their larger gas exchange surfaces. In particular, *Rhododendron cynthia* has been identified as the species that provides the best air quality throughout all four seasons.

The study by Leghari and Zaidi (2013) found that the morphological characteristics of different leaf types influence air quality. While this study shows similarities in this regard, the fact that *Rhododendron cynthia* was not included in that study constitutes a difference. It has been found that the effects of plant species on air quality vary seasonally. Specifically, air quality was observed to be better in spring and summer, whereas it decreased in autumn and winter. This situation can be associated with seasonal changes in photosynthetic activity and leaf density. The literature includes studies demonstrating that the effects of plants on air quality change seasonally (Manes et al. 2012, Sicard et al. 2018). These studies state that seasonal variations in leaf surface area and stomatal openings affect plants' capacity to remove air pollution. They also emphasize the significant role of urban green spaces in improving air quality.

It is scientifically recognised that vegetation can improve air quality (Leung et al. 2011, Li et al. 2023). and reduce global warming. However, since some plant species emit biogenic volatile organic compounds, planting some species increases the ambient concentration of ozone and particulate matter (Leung et a.2011). Therefore, plant selection species should be very careful.

This finding is consistent with the studies conducted by Locosselli (2019). Locosselli stated that urban trees not only reduce air pollution but also contribute significantly to urban ecosystems by mitigating the urban heat island effect and enhancing biodiversity. Furthermore, a study conducted by Tülek et al. (2024) highlighted the carbon storage capacity of urban trees and their role in combating climate change. The results obtained in our study also support these findings.

RESULTS AND CONCLUSION

In this study, the effects of urban plants in Trabzon Atatürk Area Square Park on micro air quality were investigated. The analyses revealed the potential impacts of the plants in the park in reducing air pollution in the surrounding area. The results show that different plant species in the park, particularly large and oval-leaved species, significantly improved micro air quality. However, it was also found that the effects of plant species on air quality varied depending on seasonal changes.

Seasonal Differences and Results According to Emission Measurements

Measurements taken during the spring season showed that the overall air quality of the park was determined to be 95.48 μg/m³, with the best air quality observed in *Rhododendron cynthia* (Table 3). This species exhibited the lowest emission value at 357.44 μg/m³, while the highest emission value among other species was recorded for Acer palmatum 'Atropurpureum' at 413.12 μg/m³. In the summer season, the average air quality was 106.87 μg/m³, and once again, Rhododendron cynthia showed the best air quality (Table 4). The highest emission value in the summer season was measured for Betula pendula at 351.62 µg/m³.

In the autumn season, it was determined that the air quality increased to 124.74 µg/m³, with Rhododendron *cynthia* again exhibiting the lowest emission value (Table 5). In the autumn, the highest emission value was recorded for *Acer palmatum* 'Atropurpureum' at 290.75 µg/m³. In the winter season, the overall air quality was determined to be 107.96 µg/m³, with the lowest CO emission recorded for *Rhododendron cynthia* at 1.03 µg/m³ (Table 6).

Effect of Plant Species

The results of the Analysis of Variance (ANOVA) revealed significant differences between plant species, indicating that these differences have a considerable impact on micro air quality. The ANOVA test showed a p-value below 0.05, confirming that there are statistically significant differences in micro air quality among the plant species. The findings of the study indicate that large-leaved plants, in particular, improve air quality more effectively. The species *Rhododendron cynthia* consistently provided the best air quality across all four seasons, supporting the notion that larger leaf surfaces can more efficiently filter particulate matter and harmful gases.

Analyses indicate that tree-form plants generally improve air quality more effectively. The study results show that approximately 80% of the plants that contribute most to air quality improvement are in tree form. This finding suggests that trees, with their large leaf areas and longer life cycles, provide greater air filtration, making them more effective in enhancing urban air quality.

Air Quality Improvement Potential

Especially considering that fine particles such as $PM_{2.5}$ and PM_{10} are associated with respiratory and cardiovascular diseases, the capacity of plants to filter such harmful emissions is of great importance. *Rhododendron cynthia* species has reduced $PM_{2.5}$ and PM_{10} levels to the lowest levels and the contribution of this species to air quality is quite evident. For example, while the average $PM_{2.5}$ value of *Rhododendron cynthia* was 194.37 µg/m³ in the spring season, this value increased to 310.37 µg/m³ in the summer season. However, still maintaining the lowest emission level, the positive effect of this plant on air quality continued. Moreover, in terms of CO_2 emissions, *Rhododendron cynthia* species provided the lowest value with 321.01 µg/m³ in winter season and it was observed that the capacity of this species to filter carbon emissions was higher than other species. The selection of such plants in urban areas plays an important role in reducing greenhouse gas emissions and mitigating warming effects.

As a result of micro air quality measurements, it was determined that there were significant differences between taxa. The analysis of these differences revealed that some plants positively affected the average AQI (Air Quality Index) values compared to others. In addition, another striking finding is that these plants generally have broad leaves or oval leaves. This result provides an important result in understanding the effect of leaf shape and surface properties on air quality. According to the findings, different effects on air quality were observed among plants such as *Acer palmatum* 'Atropurpureum', *Betula pendula, Cedrus deodora, Fagus sylvatica, Laurus nobilis, Magnolia grandiflora, Malus floribunda, Platanus orientalis, Prunus serrulata* and *Rhododendron cynthia*. The results show the effects of different plant species on air quality. When micro air quality measurements of plants such as *Acer palmatum 'Atropurpureum', Betula pendula, Cedrus deodora, Fagus sylvatica, Laurus nobilis, Magnolia grandiflora, Malus floribunda, Platanus orientalis, Prunus serrulata* and *Rhododendron cynthia* were made, it was determined that the best air quality was obtained from *Rhododendron cynthia*. Measurements made in each season show that *Rhododendron cynthia* has the lowest emission values. For example, 194.37 µg/m³ was recorded in spring, 310.37 µg/m³ in summer, 201.43 µg/m³ in autumn and 321.01 µg/m³ in winter. Although the average AQI value also varies across seasons, it was always observed that *Rhododendron cynthia* was associated with the lowest air pollution. In addition, it was found that large, oval-leafed tree-shaped plants have a higher potential to improve air quality according to plant species. However, the differences between deciduous and evergreen plants did not yield a significant result. In short, the positive effects of plants on air quality are particularly evident in species such as *Rhododendron cynthia*.

These analyses revealed that large and oval-leafed plants affect micro air quality more positively compared to other leaf forms. However, no significant difference was found based on the distinction between deciduous and evergreen plants. The fact that 80% of the plants that improve air quality the most are tree-shaped indicates that these species should be preferred primarily in urban landscaping arrangements.

These results emphasize the importance of plant selection in improving micro air quality and serve as a guide for more conscious landscaping practices that support environmental sustainability.

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