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Accumulation and Transfer of P and K, Macronutrient Elements for Plants, in *Corylus colurna* L. Stem Sections

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Abstract: One of the most essential factors in plant development is the nutrient content in the soil. Phosphorus (P) and potassium (K), essential macronutrients in plant nutrition, are vital in plant growth and development. Therefore, although many studies have been conducted on these elements in agricultural plants, the number of studies on forest trees could be much higher. In particular, there needs to be more information about the accumulation and transfer of these elements in different plant tissues. This study examined the change and transfer of P and K concentrations in the *Corylus colurna* tree's trunk parts. Within the scope of the study, the differences in P and K concentrations in the *Corylus colurna* trunk were examined based on organ, direction, and period. As a result, the most elevated concentrations of both elements were in the barks; the difference in direction was not evident in the wood, and both elements could be transferred within the wood.

Keywords: Annual tree ring, Phosphorus, Potassium, Turkish Hazelnut

Öz: Bitki gelişiminde en önemli faktörlerden biri topraktaki besin içeriğidir. Bitki beslenmesinde temel makro besin elementleri olan fosfor (P) ve potasyum (K), bitki büyümesi ve gelişimi için hayati öneme sahiptir. Bu nedenle, tarımsal bitkilerde bu elementler üzerine birçok çalışma yapılmış olmasına rağmen, orman ağaçları üzerine yapılan çalışmaların sayısı çok daha fazla olabilir. Özellikle, bu elementlerin farklı bitki dokularındaki birikimi ve transferi hakkında daha fazla bilgiye ihtiyaç vardır. Bu çalışmada, *Corylus colurna* ağacının gövde kısımlarındaki P ve K konsantrasyonlarının değişimi ve transferi incelenmiştir. Çalışma kapsamında, *Corylus colurna* gövdesindeki P ve K konsantrasyonlarındaki farklılıklar organ, yön ve dönem bazında incelenmiştir. Sonuç olarak, her iki elementin de en yüksek konsantrasyonlarının kabuklarda olduğu; yön farklılığının odunda belirgin olmadığı ve her iki elementin de odun içinde transfer edilebildiği görülmüştür.

Anahtar Kelimeler: Yıllık ağaç halkası, Fosfor, Potasyum, Türk Fındığı

1. Introduction

Since plants are living things that can produce food from CO_2 in the air, all other living things on Earth are directly or indirectly dependent on plants [1]. In addition to these essential and vital functions, plants also fulfill many ecological, economic, and social functions [2-3]. Plants can fulfill these functions only if they grow and develop healthily. Plant development is shaped by the interaction of genetic structure [4] and environmental factors [1, 5-7]. Among the environmental factors, soil and especially the nutrient content in the soil are among the most critical factors that directly affect plant development [8-10].

Nutrient elements needed by plants are classified as macro and micronutrients. Potassium (K), one of the elements plants need most, has fundamental roles in stomatal opening, plant growth, and cell growth. It is also necessary for the transportation of carbohydrates produced as a result of photosynthesis to the fruit or roots via the phloem. K, which is effective in the transport of anions in the xylem and phloem, is critical for adaptation to various stress conditions, photosynthesis, protein synthesis, energy transfer, osmoregulation, enzyme activation, stomatal movement, phloem transfer and cation-anion balance, and plant water relations [11]. Phosphorus (P), another macronutrient, is one of the essential plant nutrients needed by plants, especially for root development and flowering [12]. Various studies have determined that P is essential, especially in developing agricultural plants, and that P fertilizers affect plant growth [13].

Nutrient elements are the basic building blocks of plants and are found at different levels in different organs of plants after being taken from the soil. Speciation of nutrients within the plant after they are taken from the soil, determining their contribution to plant development, and knowing their transfer between organs are of great importance in terms of fully understanding the factors affecting plant development [14-16]. This study aims to contribute to eliminating the knowledge gaps in this field. Within the scope of the study, it was tried to determine to what extent P and K concentrations of macronutrient elements accumulate in the trunk organs of *Corylus colurna* (Turkish Hazelnut) and to what extent they are transferred within the wood.

2. Material and Method

Study area and sampling

This study used samples taken from the main trunk of a *Corylus colurna* tree growing within the borders of Müsellimler Village of Ağlı District of Kastamonu province. The sample log was taken at the end of 2020, and the north direction was marked before cutting. The approximately 10 cm thick log surface, which was cut from the trunk at a height of approximately 50 cm from the ground, was smoothed in the laboratory. Annual rings were grouped into ten years, and samples were taken from the outer bark, inner bark, and wood of all ages with the help of a steel drill.

Wood samples were turned into sawdust, labeled, and placed in glass petri dishes. They were left open for 15 days to air dry, then dried in an oven at 45 °C for a week. 0.5 g of dried samples were taken, 6 mL of 65% HNO_3 and 2 mL of 30% H_2O_2 were added and placed in the microwave oven designed for the analysis. The program of the microwave device was set to rise to 200 °C in 15 minutes and remain at 200 °C for 15 minutes. After the samples were burned in the microwave, the liquid solution samples were taken into flasks and diluted to 50 mL with ultrapure water. Heavy metal analyses were performed with the ICP-OES device. This method has been frequently used for heavy metal analysis in recent years [17]. All analyses in the study were performed three times.

Statistical analyzes

Variance analysis was applied to the obtained data with the help of the SPSS package program. Homogeneous groups were obtained by applying the Duncan test for the factors that were found to have statistically significant differences at at least 95% confidence level (p<0.05), and the data were simplified and interpreted.

3. Findings

The results of the analysis of variance regarding the changes in K concentrations by organ and direction are given in Table 1.

Table 1. Difference of K (ppm) concentrations by organ, period and direction

Age Range	South	West	North	East	F-value
2011-2020	753.3^{Ci}	577.9^{Aj}	743.5^{Ck}	661.1^{Bl}	224.12***
2001-2010	711.4^{Ch}	503.4^{Ag}	697.4^{Bj}	757.0^{Dn}	1604.41***
1991-2000	784.0^{Cj}	623.0^{Ak}	639.9^{Ai}	675.4^{Bm}	123.86***
1981-1990	658.4^{Bg}	343.8^{Aa}	804.6^{Cl}	655.6^{Bl}	1442.21***
1971-1980	764.8^{Di}	391.5^{Ab}	573.6^{Ch}	527.4^{Bh}	2926.69***
1961-1970	791.4^{Cj}	396.8^{Bbc}	392.9^{Ba}	325.1^{Aa}	847.81***
1951-1960	442.6^{Cd}	419.1^{Bd}	392.1^{Aa}	384.4^{Ab}	37.26***
1941-1950	363.2^{Aa}	394.5^{Bbc}	413.8^{Cb}	448.6^{De}	131.97***
1931-1940	384.6^{Abc}	413.8^{Bd}	866.8^{Cm}	417.1^{Bc}	2176.45***
1921-1930	396.5^{Ac}	410.2^{Acd}	503.5^{Cf}	436.1^{Bd}	65.01***
1911-1920	376.4^{Aab}	442.4^{Be}	447.6^{Bc}	513.8^{Cg}	165.06***
1901-1910	379.1^{Aabc}	464.0^{Cf}	444.9^{Bc}	557.3^{Dj}	550.86***
1891-1900	393.9^{Abc}	452.6^{Bef}	463.5^{Bd}	546.8^{Cij}	337.57***
1881-1890	433.6^{Ad}	511.7^{Cg}	484.4^{Be}	579.8^{Dk}	186.56***
1871-1880	433.9^{Ad}	581.0^{Dj}	494.2^{Bef}	538.7^{Chi}	98.16***
1861-1870	460.6^{Ae}	533.2^{BCh}	515.5^{Bg}	549.7^{Cij}	32.59***
1851-1860	487.2^{Af}	553.4^{Bi}	482.0^{Be}	486.0^{Bf}	38.33***
1841-1850	470.2^{Bef}	561.2^{Ci}	451.3^{Ac}	481.9^{Bf}	161.66***
F-value	743.664***	232.579***	1268.422***	651.111***	

Wood	526.9^{Ba}	476.3^{Aa}	545.1^{Ba}	530.1^{Ba}	3.02*
Outer Bark	866.6^{Ab}	1048.6^{Cb}	1551.6^{Dc}	932.3^{Bb}	6382.67***
Inner Bark	1062.1^{Bb}	1316.2^{Dc}	1264.8^{Cb}	897.2^{Ab}	1774.34***
F-value	22.70***	234.29***	110.81***	36.90***	

According to the results of Duncan's test, values followed by the different letters (a, b, A, and B) refer to significant differences among species within each direction. ***=p<0.001; **=p<0.01; *=p<0.05; ns = not significant. Capital letters indicate the difference between horizontally, while lowercase letters indicate vertically. These explanations are also valid for Table 2.

As a result, K concentrations differed significantly (p<0.001) between periods in all directions and between directions in all periods. When the change of K concentration in wood was examined, two issues attracted attention. The first of these is that the values remained in a narrow range. The second is that there was no significant K concentration difference in direction and period. When the change on an organ basis is examined, it is seen that the lowest values were obtained in wood. The highest values in the organs were obtained in the outer bark in the west direction and the inner bark in the north direction. In other aspects, the values obtained on the barks were in the same group due to the Duncan test. Again, there was no significant change in the direction of the barks. Variance analysis results regarding the differences in P concentrations by organ and direction are given in Table 2.

Table 2. Difference of P (ppm) concentrations by organ, period and direction

Age Range	South	West	North	Doğu	F-value
2011-2020	123.2^{Dn}	67.2^{Bm}	86.0^{Cm}	57.6^{An}	10862.13***
2001-2010	60.1^{Ck}	57.4^{Bk}	80.5^{Dl}	56.5^{Am}	2596.99***
1991-2000	67.9^{Cm}	59.2^{Bl}	68.5^{Ck}	54.4^{Al}	902.86***
1981-1990	54.9^{Cj}	13.7^{Ah}	66.6^{Dj}	49.3^{Bk}	15785.71***
1971-1980	66.3^{Dl}	12.4^{Ag}	30.2^{Bi}	38.9^{Cj}	78604.56***
1961-1970	60.3^{Dk}	15.2^{Ci}	9.9^{Af}	11.4^{Bh}	19784.01***
1951-1960	13.7^{Di}	12.1^{Cf}	8.9^{Ad}	10.5^{Bf}	10109.71***
1941-1950	9.5^{Af}	10.8^{Ce}	10.1^{Bf}	12.1^{Di}	881.57***
1931-1940	14.0^{Bi}	10.2^{Ad}	20.3^{Ch}	10.4^{Af}	2581.68***
1921-1930	13.0^{Ch}	10.5^{Ae}	11.4^{Bg}	10.6^{Afg}	337.05***
1911-1920	11.8^{Dg}	8.3^{Ab}	9.4^{Be}	11.4^{Ch}	1378.59***
1901-1910	11.8^{Cg}	9.9^{Bc}	7.2^{Ac}	10.0^{Be}	2822.62***
1891-1900	8.2^{Cd}	6.9^{Aa}	7.4^{Bc}	10.8^{Dg}	792.57***
1881-1890	8.7^{Ce}	8.0^{Bb}	7.0^{Ac}	8.6^{Cc}	154.54***
1871-1880	6.8^{Bb}	8.1^{Cb}	6.2^{Ab}	8.3^{Dc}	744.59***
1861-1870	7.3^{Cc}	6.8^{Ba}	5.6^{Aa}	7.6^{Db}	829.22***
1851-1860	5.9^{Aa}	7.0^{Da}	6.1^{Bab}	6.4^{Ca}	214.57***
1841-1850	8.0^{Be}	15.6^{Dj}	5.6^{Aa}	8.9^{Cd}	1891.48***
F-value	62828.562***	33579.183***	30203.655***	53073.403***	
Wood	30.6^{a}	18.9^{a}	24.8^{a}	21.3^{a}	2.164 ns
Outer Bark	65.9^{Aa}	245.0^{Dc}	90.0^{Bb}	166.8^{Cc}	22082.21***
Inner Bark	153.8^{Bb}	218.6^{Db}	168.6^{Cc}	125.2^{Ab}	4314.58***
F-value	22.96***	351.22***	46.17***	126.43***	

As a result, P concentrations in wood differed significantly (p<0.001) in all directions on a period basis and in all periods on a direction basis. However, according to the average values, the directional change of P concentration was not statistically significant. When the values are examined, the highest P concentration in wood was obtained in wood formed in recent years, while it remained in a narrow range in the past years. Apart from this, it is noteworthy that the concentrations obtained in bark are much higher than those obtained in wood.

4. Discussion

In *Corylus colurna*, the change in the concentration of P and K elements, which are essential nutrients for plants, in the outer bark, inner bark and wood, and annual rings of the 180-year-old plant, based on organ, period, and direction, was determined in this study. As a result of the study, the elements subject to the study accumulated within determinable limits in all directions of all organs. Many studies have shown that some species have different levels of potential to accumulate some elements [18]. Therefore, it is necessary to determine which annual rings of trees are suitable for monitoring the change of which elements in the process. To date, many studies have been conducted on the usability of annual rings, especially in monitoring the change in the concentration of heavy metals in the air over time [19-20]. In the studies, *Corylus colurna* woods also contain Tl [21], Pb, Cr, Zn [22], Co, Mn, Ni [23], Cd, Fe, Al [24] and Sr [25] elements were used to determine the change in the process.

The elements evaluated within the study's scope are macronutrients and absolutely necessary for plants [12, 16]. Therefore, it is necessary to determine how the absorption and use of these elements by trees occur. With the development and diversification of industry in the last century, air pollution threatens human health, especially in cities with high population density [26-29]. Heavy metals have an important place among air pollutants. The elements subject to study are not only nutrients but also heavy metals when they exceed their thresholds (become toxic) for plants. Heavy metals are elements that can be highly harmful to humans, other living things, and the ecosystem [30-32]. It is known that heavy metals, many of which can be toxic, carcinogenic, and fatal to humans even at low concentrations, are harmful at high concentrations, even those required as nutritional elements [33-35]. Heavy metals can enter the plant body from the soil through the roots, the air through the leaves, or the trunk parts [23]. However, in the region where the study was conducted, no source would require a high concentration of the elements subject to study in the air. Therefore, almost all plant elements are thought to be absorbed from the soil.

As a result, the highest concentrations were obtained in barks as organs in this study. In many studies, the highest heavy metal concentrations are obtained in barks [20, 36]. This is related to the rough structure of the bark. After heavy metals are separated from their source, they can be transported hundreds of kilometers away from their source with the help of wind [37]. Particulate matter contaminated with heavy metals can be transported far away with the help of wind [18]. The rough structure of the bark makes it easier for particulate matter contaminated with heavy metals to adhere to the bark surface [38]. Many studies on this subject have determined that heavy metal concentrations in the outer bark are very high, especially in areas with high levels of heavy metal pollution [39]. However, there were no sources of the elements subject to study around the sample tree in this study. Therefore, it is thought that the high concentrations determined in the barks are related to the structure of the organs.

As a result, the concentrations of both elements in the wood of *Corylus colurna* were in a narrow range, and there was no significant change in direction. This result shows that the elements subject to the study can be transferred between tissues within wood. The transport of elements within the wood part of plants is primarily related to the cell structure, particularly the cell wall. The cell wall–plasma membrane (CWPM) interface illustrates an apoplastic mechanical barrier and a flexible form involved in stress sensing, perception, and signaling for the metal/metalloid stress. The CWPs responding to various abiotic strains have been extensively identified and represented among crop plants [23]. Valuable information has been obtained in a few studies on this subject, and it has been determined that the movement of heavy metals within the plant varies depending on the plant variety and heavy metal. In studies conducted on annual rings, while Zn and Pb elements were replaced in *Cedrus deodora*, the Cu element was not displaced [40-42], the Ni element was limited [43, 44], and Co was displaced in *Cedrus atlantica* [38], the Bi element is replaced in *Cupressus arizonica*, while the Cd and Ni elements are not [39], and Cd, Fe, and Al were not replaced in *Corylus colurna* [24] were determined by several research [44-48]. As a result, the accumulation of P element in wood formed in recent years was at different levels in this study. Many studies have determined that the concentrations of many elements vary depending on many factors, such as species, organs, and environmental conditions [49-51].

5. Conclusion

The accumulation of elements in the plant depends on the effects of many factors. Most of these factors are factors that shape plant development. Because plant development is shaped by the interaction of genetic structure and environmental conditions. Therefore, all these factors affect plants' nutrient utilization and accumulation potential because plant habitus and development affect the plant's element uptake and accumulation. In addition, all factors that affect plant habitus also affect the entry and accumulation of elements into the plant, which can be shaped by the mutual interaction of many factors such as genetic structure, environmental factors such as climatic and edaphic factors, and stress factors such as drought, frost, UV-B and heavy metals. Therefore, many of these factors, directly and indirectly, affect plants' element uptake and accumulation potential, and information about this complex mechanism is still limited. Therefore, studies such as this study are important. As a result of this study, the most elevated concentrations of P and K elements were in the barks; the difference in direction was not evident in the wood, and both elements could be transferred within the wood.

Conflict of Interest

The authors have no conflicts of interest to declare.

Ethics Committee Approval

Not applicable

Author Contribution

Conceptization: KK, ŞK; methodology and laboratory analyzes: KK, ŞK; writing draft: KK, ŞK; proof reading and editing: KK, ŞK. Other: All authors have read and agreed to the published version of manuscript.

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