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MINERAL NUTRITION OF ROMANIAN WHITE OAK SPECIES: A SHORT REVIEW

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Abstract: *Oak species occupy about 16% of the forest area in Romania and have a high ecological and economic value. Even though many research efforts were done in order to assess nutritional status of oaks, there are still issues to be clarified, due to the many factors involved in this process. Previous studies have shown that the assessment of nutritional status is possible at two levels: soil and the foliar. In this review we focused on macroelements category due to their use in higher amounts in the nutrition process. It has been found that macroelements are very inhomogenously distributed in the soil, while at the foliar level records a different seasonal variation.*

Key words: *mineral nutrition, macroelements, white oaks.*

1. Introduction

In Romania, there are 7 indigenous European white oak species, as follows: *Quercus robur* L. – the pedunculate oak; *Q. pedunculiflora* K. Koch – the grayish oak; *Q. petraea* (Matt.) Liebl. – the sessile oak; *Q. frainetto* Ten. – the Hungarian oak; *Q. cerris* L. – the Turkey oak; Q. pubescens Willd. – the pubescent oak and *Q. virgiliana* Ten. – the Italian pubescent oak [24], [29]. The forest area covered by oak species in Romania is 16% (1.221.733 ha), according to the National Forest Inventory 2008-2012 [32]. The genus *Quercus* is widespread in the Northern hemisphere, "occupying a wide range of environments from flood plains" to dry region with thorn shrubs and semi-desert, having a great ecologically and hydrologically importance [11], [24]. Valuable oak timber will be always an important objective [27].

Understanding of mineral nutrition of forest trees still remains a challenge for science, ever since 1900 when in Europe the first signs of decline and mortality of oaks appeared [11]. Nowadays, an important role in the oaks decline consists in "severe drought, prolonged flooding, rapid fluctuation of soil water levels and cold winters" [11]. Forest trees nutritional status is usually assessed at the soil or foliar levels, or both. Over time, research has shown a strong dependence of the level of soil supply with nutrients and their concentrations in leaves [25].

The major goal of this paper is to make a short review about the assessment of nutritional status of forest trees.

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2. Overview of studies on mineral nutrition for some indigenous European white oak species - general information

"The process of taking substances from the soil or the surrounding environment, and their chemical transformation inside the plant body, is called nutrition" [26].

The assessment of the nutrition status is possible determining the amount of nutrients in the nutritional environment (by soil analyses) or/and determining the amount of nutrients in the leaves (by foliar analysis or diagnosis), which can be further processed as foliar ionic ratios [8], [15], [21]. To assess the nutrition status of forest trees, A. Alexe proposed a system of 88 chemical and biochemical indicators [4]. Out of those, 50 relate to leaves, 15 to roots, and 23 to the soil [4].

In the absorption of nutrients, climatic and edaphic (soil properties) conditions have dominant effect [7], [22]. Out of all environmental conditions affecting the forest trees nutrition, soil properties have the largest impact [7]. As an example, table 1 shows the amount of nutrients in the soil under a stand of sessile oak.

Table 1

The nutrients content of the soil (average 0-40 cm depth) in apparently healthy trees in a stand of sessile oak 55 years old [5]

pH	Humus [%]	Nt [mg/kg]	Accessible forms [mg/kg]			
			Mg	P	K	Ca
4.78	2.2	882	127	12.7	110	1088

Even though threshold values and limits, differentiated by species, have been set, in studies of nutrition, there are interpreting problems, due to the many factors involved in this process. Accurate thresholds of deficiency or toxicity may be defined only in laboratory experiments, under controlled environment conditions, and supply of nutrients in various concentrations [23]. In table 2 there is an interpretation example for essential mineral elements' values in *Quercus robur* leaf [13].

Table 2

The significance of mineral elements contained in the leaves of Quercus robur [13]

Element	Mineral elements content in leaves [mg/kg dry biomass]	Nutrition level	Content level
Nitrogen	< 20000	Deficiency	Low
	20000-30000	Optimal	Average
	30000-35000	Excess	High
	35000-40000		Very high
	40000-45000		Exceptional
Calcium	< 3000	Deficiency	Low
	3000-15000	Optimal	Average
	15000-16000	Excess	High
	16000-17000		Very high
	17000-18000		Exceptional
Magnesium	< 1500	Deficiency	Low
	1500-3000	Optimal	Average
	3000-4000	Excess	High
	4000-5000		Very high
	5000-6000		Exceptional

3. Mineral nutrition with macroelements

In the forest soils, the distribution of mineral nutrients (available for plants) is extremely non-homogeneous [18]. Soil texture and its pH affect the availability of the nutrients for the plants [19]. Macroelements content variability within the same trees population is mainly given by the spatial variability of soil properties, the stand conditions (canopy and light penetration to the soil surface) and genetic characteristic of the tree [7].

3.1. At the soil level

Nitrogen. The amount of nitrogen in the forest soils can vary from 100 kg/ha to 15,000 kg/ha [14]. Over 50% of the total nitrogen amount in forest soils is in the top 20 cm [30], [31]. Nitrogen is considered the most abundant macroelement, and its distribution and amount in different soils depend on many factors: mean annual rainfall, mean annual temperature, pH, clay content, organic matter amount, oxygenation degree and mechanical pressure (grazing) [6], [9], [12]. High mean of annual rainfall and low soil pH affect adversely nitrogen supply or nutrition [9]. What really matters is its availability as ions, i.e. - $NH4^{+}$ - ammonium, $NO3^{-}$ – nitrate, but this may still do not provide adequate nitrogenous nutrition due to antagonisms and synergisms of these available forms with other ions, like nitrate is antagonistic to potassium and ammonium has synergisms with phosphorus, potassium and calcium [6].

Phosphorus and potassium. The total phosphorus content of the soils is 0.02 to 0.08% [14]. The potassium content is between 0.2-4% and it is mostly found in the crystal lattice of primary minerals [28]. The mobile phosphorus content decreases as soil acidity increases, especially when the mobile aluminum content increases [17]. The highest availability degree of the phosphorus is found in soils with slightly acidic - neutral reaction [30], [31]. As a result of a study conducted in Greece, positive and quite strong correlations were obtained between the characteristic parameters of phosphorus absorption and clay content (r = 0.94), cation exchange capacity, the amount of basic cations (r = 0.90) [10]. In the soil, potassium availability is antagonistic to calcium [20], excessive calcium presence resulting in lower absorption of potassium [1]. Below, there is the total phosphorus and potassium content of soils under oak and sessile oak stands (Table 3).

Table 3

Total phosphorus, potassium, calcium and magnesium content in soils of two oak stands [25]

Species	**Depth [cm]**	**Total phosphorus in the soil**	**Total potassium in the soil**	**Total calcium in the soil**	**Total magnesium in the soil**
		[mg/kg]			
Oak	0-10	744.7	2542.6	3119.5	4227.5
Sessile oak	0-10	434.7	1117.6	970	2740.5

Calcium and magnesium. Soils usually contain between 0.1-1.2% calcium, and 70-80% of the calcium consumed, returns in the soil through leaf litter [14]. Excessive calcium in the soil solution reduces absorption and use of magnesium, potassium, iron, manganese, zinc, aluminum, ammonium to form insoluble calcium phosphates, thus, phosphorus becoming less accessible [1], [2]. In the table above, there are the amounts of total calcium and magnesium in soils under stands of oak and sessile oak (Table 3).

3.2. At the leaves level

Nitrogen. In leaves, nitrogen can be found in a concentration of about 1.61% [20], and 75-80% of the total annual consumption returns to the soil through litter [28]. In an experiment conducted to observe seasonal variation of nitrogen content in leaves under the effect of artificial fertilization (nitrogen based fertilizer), several variants were considered against a control non-fertilized one, fertilization with 250 kg N/ha (N 250), with 500 kg N/ha (N 500) and 1000 kg N/ha (N 1000) [20]. It was found that the fertilization with increased amounts leads to higher foliar nitrogen content and it is higher in spring than in autumn (Figure 1) [20]. Figure 2 shows variation over a vegetation season of nitrogen content in the leaf and the stalk for Hungarian oak, (*Quercus frainetto*) and Turkey oak (*Quercus cerris*).

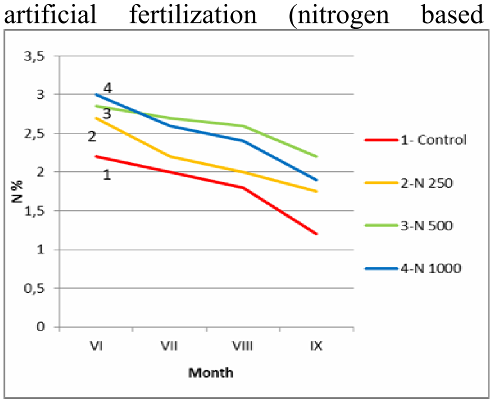

Fig. 1. *Dynamics of nitrogen concentration of oak leaves during the vegetation season for more experimental variants* [20]

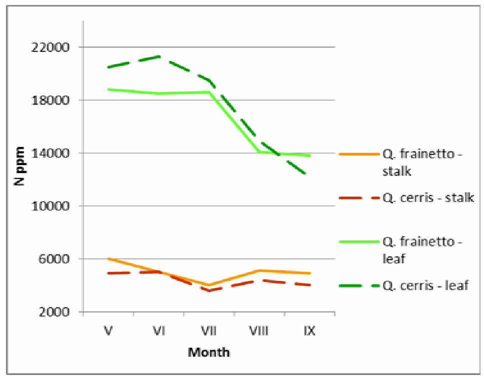

Fig. 2. *Seasonal variation of nitrogen content in leaf and stalk of Quercus frainetto and Quercus cerris* [8]

Phosphorus and potassium. In plant tissues, phosphorus is found in smaller amount than nitrogen, although it is essential in physiological processes [28]. In young oak stands, the leaf phosphorus content was found around 0.45% [20]. In a research conducted in young oak stands [18], in order to study the phosphorus content, four variants were considered against the control one, fertilization with nitrogen (250 kg N/ha), one in which nitrogen (500 kg N/ha) and 200 kg phosphorus were applied (N+200 P) and one with 1000 kg/ha nitrogen and 400 kg phosphorus (N+400 P) (Figure 3) [20]. It was observed that foliar phosphorus decreased from May to August and then in September it begins to increase slightly for almost all experimental variants [20]. Table 4 shows the content of leaf phosphorus and potassium for several species of oaks.

Table 4

Foliar phosphorus and potassium content of the several species of oaks [15]

Species	Phosphorus content [mg/kg]	Potassium content [mg/kg]
Quercus cerris	7000	9800
Q. frainetto	4800	7700
Q. petraea	4700	13900
Q. pubescens	5600	8500
Q. robur	7600	13600

Seasonal variation of foliar potassium was studied within the nitrogen experiment, mentioned above. It was observed a decrease of its content from spring to autumn for all variants [20]. In spring, potassium content ranged between 0.80 to 1.05%, while in autumn it droped to values of 0.50 to 0.80%. It could be noted that nitrogen increase was followed by potassium content decrease (Figure 3) [20]. In figure 4 there is the seasonal variation of the phosphorus and potassium content in the leaves and stalks of Hungarian oak and Turkey oak.

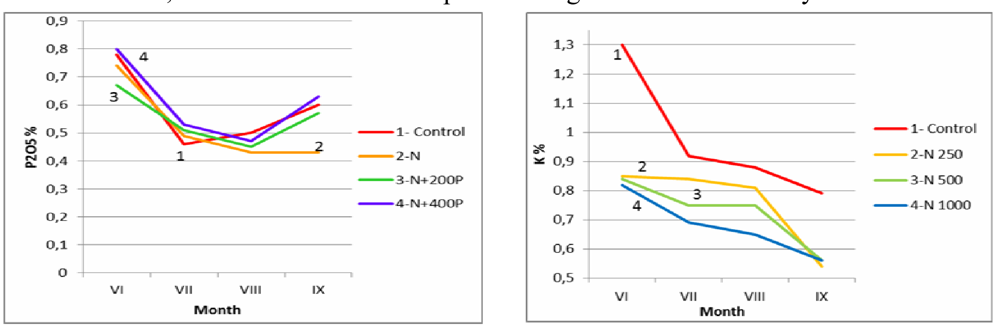

Fig. 3. *Dynamics of phosphorus and potassium concentrations in oak leaves during the vegetation season across the variants studied* [20]

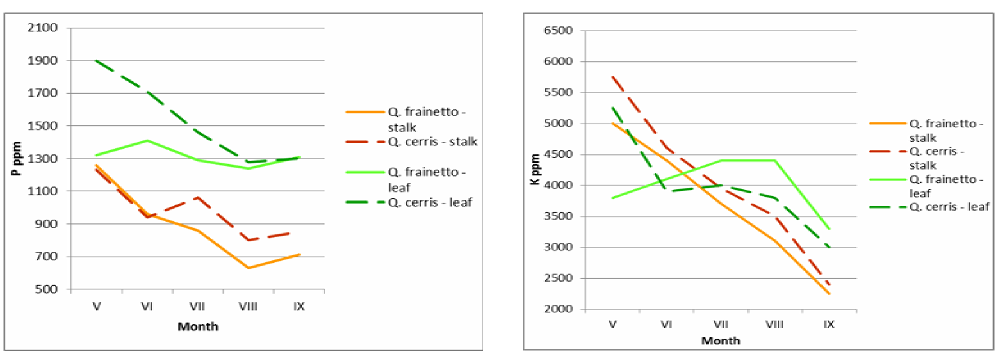

Fig. 4. *Seasonal variation of phosphorus and potassium content in leaf and stalk of Quercus frainetto and Quercus cerris* [8]

Calcium and magnesium. Calcium, together with potassium and phosphorus, is one of the elements which, in the leaf, records large variations from individual to individual, obtaining variation coefficients between 21 and 30% [3]. Calcium, unlike the other elements, which, at the end of the vegetation season are carried from the leaf to other organs, is blocked in the leaves (that is, it has reduced tissue mobility and it is not translocated to other organs), being stored in time [8], [20]. Extensive research conducted at Ştefăneşti - Argeş in the case of the oak species, showed foliar calcium content of 5432.5 mg/kg, and research in Mihăeşti area, in the case of sessile oak, of 3024 mg/kg [25]. Foliar magnesium content was 5395 mg/kg in Ştefăneşti area for oak, and 3874 mg/kg in Mihăeşti area for sessile oak [24]. A study conducted for Turkey oak and Hungarian oak, revealed that at the end of the bioaccumulative season, the calcium content of the leaves increases, by 55% in the Hungarian oak leaves, and by 27% in the Turkey oak leaves (Figure 5) because calcium is not available for the tissues from next spring and it is dependent of ascending sap [8]. As well as in the case of calcium, magnesium content of leaves increases towards the end of the vegetation season (Figure 5), for example, in the case of the Turkey oak, it increased by 50% and in the case of the Hungarian oak, by 17% compared to the beginning of the vegetation season [8].

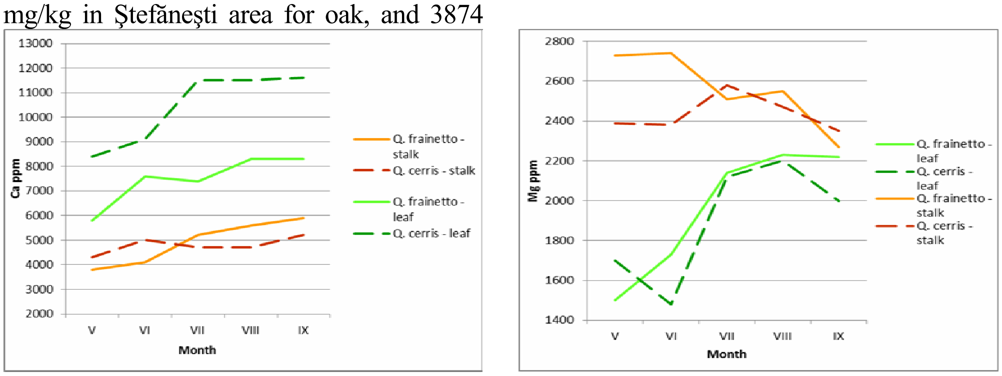

Fig. 5. *Seasonal variation of the magnesium content in leaf and stalk of Quercus frainetto and Quercus cerris* [8]

4. Conclusions

In the forest soils, the distribution of mineral nutrients available to plants is very non-homogeneous [18].

In leaves, macroelements have a different seasonal variation. For example, nitrogen content is smaller in autumn because reserve substances are stored in other plant organs (for example fruits) [20].

Phosphorus content records a decrease towards the end of vegetation season and than a slight increase. This slight increase is probably due to a poor ability of the tree for nutrient resorption or weight change of senescence leaf [16]. Potassium content is higher in spring than autumn.

Calcium content is higher in autumn because it is blocked in the leaves (meaning tissue mobility is reduced) [8], [20]. As well as in the case of calcium, magnesium content increases in autumn.

Because of different mobility of the macroelements and individual large variations, in research on nutrition, it would be better to study some physiological and genetic characteristics of the tree.

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