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Annual N and P Nutrient Levels and Foliar Resorption in *Alnus Glutinosa* Subsp. *Glutinosa* (Betulaceae) Leaves

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Abstract

Alnus glutinosa (Betulaceae) has a widespread distribution in the Central Black Sea Region of Turkey. In this study, annual nitrogen (N) and phosphorus (P) and foliar resorption efficiency and proficiency were investigated in *A. glutinosa.* N and P concentrations were decreased in senescent leaves. Statistically significant differences were found in P concentrations while there were no found significant differences in N concentrations with respect to months. A negative correlation was obtained between SLA and LMA, SLA and N concentrations. However, there were significant correlations between LMA and N concentrations. N and P resorption efficiency (NRE, PRE) and proficiency (NRP, PRP) values were high as compared to the other deciduous species. These results indicate efficient internal cycling of nutrients especially P in *A. glutinosa*.

Key Words: *Alnus glutinosa,* nitrogen, phosphorus, resorption efficiency, resorption proficiency, specific leaf area.

INTRODUCTION

Nutrient resorption is known to be one of the most important strategies employed by plants to economize nutrients before senescing. The resorption of nutrients, their removal from senescent leaves, and their accumulation or storage in the perennial parts of trees is a common phenomenon. This resorption of nutrients may supply a significant part of the nutritional requirements for the production of new biomass. Similarly, resorption is a benefical process because the tree is less subject to losses through biomass decomposition [1]. Nitrogen and phosphorus are largely withdrawn from senescing leaves before abscission, and used for new growth or stored in vegetative tissue until the next gowing season [2].

Foliar resorption is an important mechanism of nutrient conservation, recycling 50 % of maximum foliar N and P content in a wide range of perennial life-forms [3, 4]. The rate of nutrient resorption from senescing leaves may also vary with the availability of nutrients for resorption. This implies that, in addition to leaf fall patterns, leaf chemistry can further amend the time-dependent controls on nutrient losses [5]. Foliar resorption can potentially supply the major part of the nutrients needed for the production of new foliage in the following year and such conservative behaviour lead to a tight circulation in the ecosystem [6].

Resorption can be expressed in two ways: as resorption efficiency and resorption proficiency. Resorption efficiency is most accurately calculated for any nutrient as area-specific mass in green leaves minus area-specific mass in senesced leaves divided by area-specific mass in green leaved, and the quantity multiplied by 100. A new measure of resorption was introduced by Killingbeck [7] as resorption proficency. Proficiency is simply the amount of a nutrient that remains in fully senesced leaves [8]. From a biological perspective, an important advantage of measuring resorption as proficiency rather than efficiency is that proficiency is a more unequivocal measure of the degree to which selection has acted to minimize nutrient loss in ephemeral leaves efficiency [8].

The present study addresses two main objectives: (a) to examine nitrogen and phosphorus resorption efficiency and proficiency in *A. glutinosa* along an elevational gradient and to compare the results with the other deciduous species (b) to show monthly variation in nitrogen and phosphorus concentrations, and to show the interactions among resorption efficiency and proficiency and leaf and soil parameters.

MATERIAL AND METHOD

The study area

This study was conducted in natural *A. glutinosa* populations at Ordu (41°05 N´; 37°45´E) county from April 2006 to December 2006. Ordu is situated in the northern part of Turkey in Black Sea Region of Turkey. The study area is characterized by V-shaped river valleys. In this area the individuals of this subspecies are very widespread. Mean annual temperature in the sudy area is 14.4°C. Mean annual precipitation is 1053.9 mm [9] (9 Meteorological Bulletin 2006). Maximum temperature for the hottest month is August with is 30.1°C and minumum temperature for the coldest month is January with is 3.1 °C. According these data rainy Mediterranean climate is seen in the study area by the method of Emberger. The study area is located at A6 square based on the grid system of Davis [10].

Sampling

Plant samples were collected every month from April 2006 to December 2006 from 3 localities along a river valley. In this area the individuals of this subspecies are very widespread. 20 x 20 m (400 m^2) plots were chosen along a river valley at sea level, middle and far distance from sea. In each plot, at least five individuals were randomly selected and flagged. Individuals were selected more than 3 m. from the stems of neighboring canopy trees to avoid potential microsite variation [11]. Leaf samples from throughout the midcrown per individual were taken to avoid effects of crown position of the canopy and subcanopy species and consisted of the leaves with no evidence of insect attack.

Chemical Analyses

Leaf samples were dried at 70^{o}C until constant weight, ground, and sieved and digested in a mixture of nitric and perchloric acids with the exception of samples for N analysis. Nitrogen was determined by the micro Kjeldahl method with a Kjeltec Auto 1030 Analyser (Tecator, Sweden) after digesting the samples in concentrated H_2SO_4 with a selenium catalyst. P was determined with stannous chloride method by using a Jenway spectrophotometer [12] .

Calculation

Leaf samples were scanned and leaf area was calculated by using software

Programme [13].

Specific Leaf area (SLA) =∑ leaf area (dm^2) / ∑ leaf dry weight (g) [14, 15].

Leaf mass (LMA) = ∑ leaf dry weight (g) / ∑ leaf area (dm^2)

N concentration =∑ leaf dry weight (g) x crude N concentration/ SLA= g / dm^2

P concentration =∑ leaf dry weight (g) x crude P concentration/ SLA= g / dm^2

The index of resorption was calculated using the following equation [16, 17].

$IR = [(Cf - Cy) / Cy] * 100$,

where Cf is the nutrient concentration in fallen leaves and Cy the nutrient concentration in young leaves. A positive index of resorption shows that a certain nutrient is subject to high remobilisation, whereas a negative value indicates that a nutrient is accumulated in senescent leaves [16].

Statistical Analyses

One and two-way analysis of variance (ANOVA) tests and Pearson correlation were carried out by using SPSS 10.0 version [13]. Dependent and independent variables were foliar nutrient concentrations and foliar resorption and, growth period and localities, respectively. Tukey's honestly significant difference (HSD) test was used to rank means following analysis of variance by using SPSS 10.0 version. Pearson correlation coefficients were also calculated by using SPSS 10.0 version [13].

RESULTS

It has been found that foliar N and P concentrations of A.glutinosa were subjected to monthly changes. N concentration was higher in the September and October as compared to the other months. N concentration was highest in the August, whereas the lowest N concentration was observed in the December (Figure 1a). The highest P concentration was determined in the September, while the lowest P concentration was found in the April (Figure 1b).

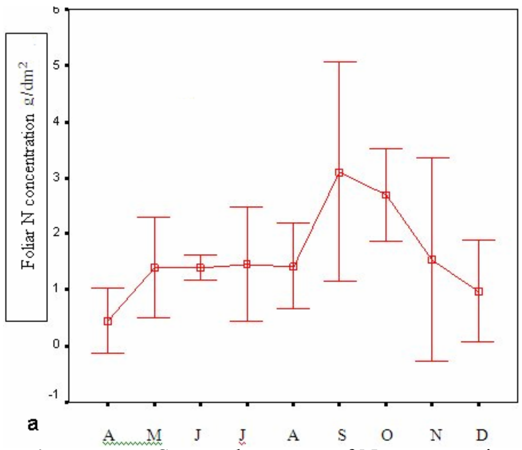


Figure 1. a. Seasonal patterns of N concentrations in leaves of *A. glutinosa* (standart errors are indicated)

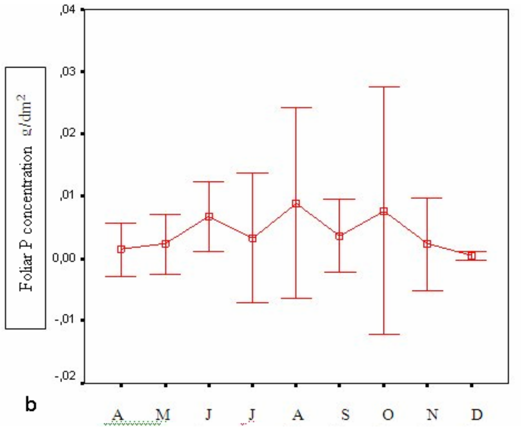
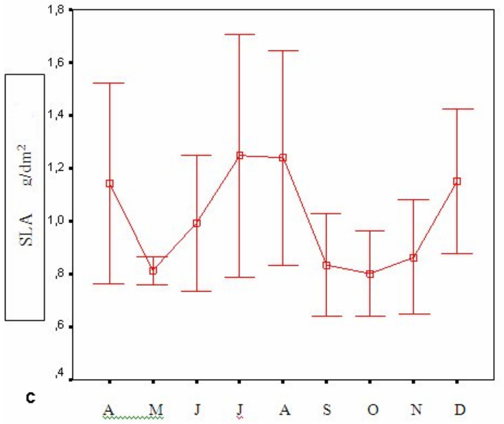


Figure 1.b. Seasonal patterns of P concentrations in leaves of *A. glutinosa*

The highest SLA values were in the July and August, while the lowest SLA value was in the October (Figure 2c). The highest LMA values were found in the May and October. However, the lowest LMA values were found in July and August (Figure 2d).



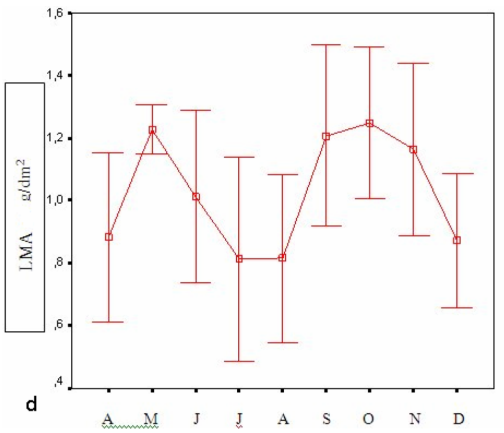
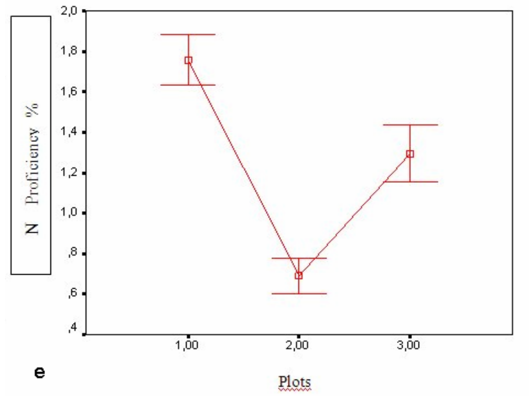


Figure 2. c. Seasonal patterns in SLA in *A. glutinosa*

d. Seasonal patterns in LMA in *A. glutinosa*

The highest and the lowest N resorption proficiency were found at plot 1 and 2, respectively (Figure 3e). The highest N resorption efficiency value was at plot 1, while the lowest N resorption efficiency value was at plot 3 (Figure 3f). However, the highest P resorption efficiency and proficiency values were at plot 2. The lowest P resorption efficiency value was found at plot 3, while the lowest P resorption proficiency at plot 1 locality. (Figures 4g,h).

The soil in the study area is clayey- loamy, slight alkaline and poor in organic matter.



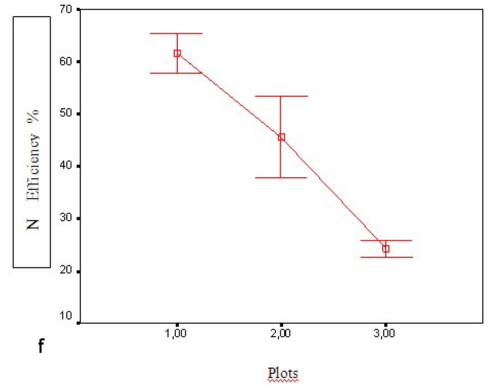


Figure 3. e. Change of N resorption proficiency in A. glutinosa regarding localities

f. Change of N resorption efficiency in A. glutinosa regarding localities

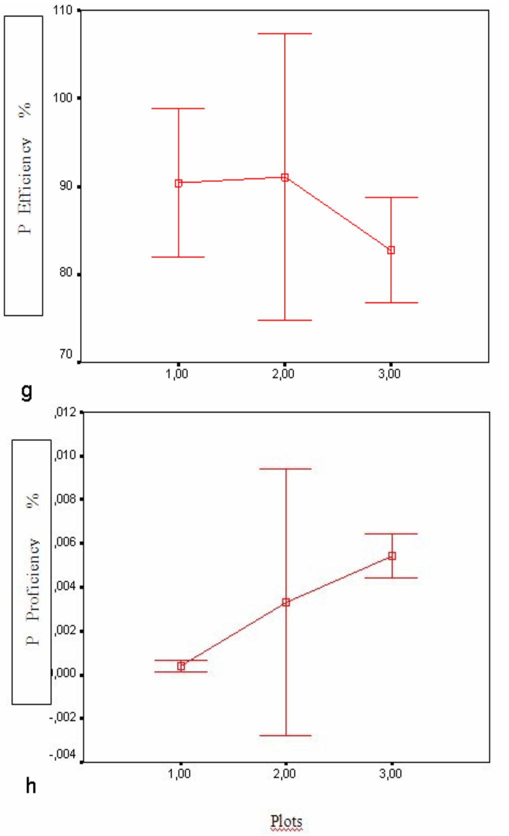


Figure 4. g. Change of P resorption efficiency in *A. glutinosa* regarding localities

h. Change of P resorption proficiency in *A. glutinosa* regarding localities

DISCUSSION

It has been found that seasonal variations were occurred in terms of N and P concentrations in A.glutinosa (Figures. 1a,b). There were statistically significant differences regarding P concentrations (P<0,05). However, no significant differences were found regarding N concentrations in terms of months. N and P concentrations were not significantly different with respect to studied localities.

The highest N concentrations were observed in September. N concentration of leaves decreased later in September. The highest P concentrations was observed in August while the lowest P concentrations was found in December (Figures. 1a,b).

There were negative correlation between SLA and LMA, SLA and N, while were significant positive relationship between LMA and N (Table 1).

Table 1. Pearson correlations among SLA- LMA and N and P concentrations.

	SLA	LMA	N	P	N/P
SLA	1,000	-,868**	-,534**	0,64	,135
	NS			NS	
LMA	-,868**	1,000	,640**	0,48	,165
		NS		NS	
N	-,534**	,640**	1,000	,286	,101
			NS	NS	
P	0,64	0,48	,286	1,000	-,617
	NS	NS	NS	NS	
N/P	,135	,165	,101	-,617	1,000

NS: Not significant. **p<0,01.

It has been reported that foliar nutrient concentrations of deciduous species in early-growing season were high. These values were stable from mid-growing season to beginning of senescence, while they were low in beginning of abscission. Similar results were reported for some evergreen species. However, foliar nutrient concentrations for some evergreen species increase in abscission phases [18]. Foliar N and P concentrations in present study were low in the early-growing season as compared to mid-growing season on the contrary to general pattern for deciduous species. However, N and P concentrations declined in senescence period like other deciduous species (Figures 1a,b). These differences may be due to local microclimatic factors in *A. glutinosa* forests (i.e. seepage due to precipitation during early spring) [33] .

N resorption efficiency was remarkably decreased along the elevational gradient. Similarly P resorption efficiency was clearly decreased at upper positions. De Mars and Boerner [30] are found that resorption efficiency decreased along the elevational gradient in *Lonicera maackii* populations

Huang et al. [19] stated that P resorption efficiency was greater in deciduous species than that in evergreen broad-leaved species. Plants with long leaf life span tend to minimize nutrient loss more by reducing N concentration in leaf litter than by increasing N resorption proficiency [19]. Staaf [20], Boerner [21], Escudero et al. [22] and Cote et al. [23] reported 26.5-72 % N resorption efficiency values for deciduous species. Killingbeck and Costigan [24] and Kutbay et al. [25] reported 29.1-79.7 % P resorption efficency values for deciduous species.

Similar results were found for N resorption efficiency in present study. However, P resorption efficency values were found to be rather high as compared to other deciduous species. These values indicate that efficient internal cycling of P in *A. glutinosa*. The reasons of high P resorption proficiency may relate to high P concentrations of *A. glutinosa*. It can be argued that individuals growing on nutrient-rich sites may have larger resorption efficiency of foliar nutrients, since their mature leaves are likely to have higher concentrations of nutrients of which a greater proportion are in hydrolyzable forms [26]. De Mars and Boerner [27] stated that P resorption was significantly greater in the valley topographic positions.

A new measure of resorption was introduced by Killingbeck [7] as resorption proficency. Killingbeck [7] emphasized resorption proficiency (the concentration of a nutrient in senesced leaves) over resorption efficiency is not subject to temporal variation in nutrient concentration in green leaves and timing of sampling [4, 28]. Proficiency is simply the amount of a nutrient that remains in fully senesced leaves. According to Killingbeck [7], N and P resorption is highly proficient in plants that have reduced nitrogen and phosphorus in their senescing levels to concentrations below 50 $\mu g/cm^2$ and 3 $\mu g/,cm^2$, respectively. According to this threshold values foliar N and P resorption in *A.glutinosa* was biochemically complete (Figs. 3e,h).

The higher and lower SLA values were observed in May and July, respectively. (Figure 2c). There were no significant differences between studied localities in terms of SLA and LMA values. Negative correlations were found between SLA and LMA, and SLA and N, while there were positive correlations between LMA and N (Table 1).

N/P ratio is more important than actual N and P concentrations in terms of mineral nutrition [29]. A foliar N/P ratio below 14 indicated N limitation and foliar N/P ratio below 12.5 indicated an optimal P nutrition. Foliar N/P ratio above 16 indicated P limitation [30, 31]. In the present study, N/P ratio of *A. glutinosa* was found below 14 in August and N limitation is occurred. In August N resorption efficiency was high and this indicates that effective using of N to prevent N losses. N/P ratio above 16 in other months and this indicated P limitation and during this period P resorption efficiency values were high. High P resorption efficiency values of *A. glutinosa* indicated nutrient resorption may play an important role on phosphorous dynamics along river banks and effective internal cycling of P.

Nutrient concentrations are important ecological characteristics, which should be taken in consideration in management planning, land-use changes, water quality control and restoration programs because river valley forests play an important role for ecological function controlling water and nutrient flows from terrestrial to aquatic ecosystems. *A. glutinosa* is occurred along river banks and V-shaped river valleys and formed gallery forests. Because of the microclimate and water holding capacity of these forests are important refuge areas, food and water resources for the local fauna. Seepage is frequently observed in these forests and effective using of nutrients is more important as compared to other ecosystems [32,33,34]. So the indication of nutrient using strategies (i.e. foliar resorption) and N- or P- limitation status of *A. glutinosa* and the other gallery forests will be greatly contribute to habitat planning and management studies along river banks.

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