FORESTRY IDEAS, 2020, vol. 26, No 1 (59): 15–29

THE EFFECTS OF ALTITUDE ON MACRONUTRIENT CONCENTRATION IN BIRCH LEAVES (*BETULA PUBESCENS* EHRH. AND *B. PENDULA* ROTH) ALONG HIGH-ALTITUDE GRADIENT IN NORTHERN URALS

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Received: 25 September 2019 Accepted: 23 December 2019

Abstract

Latitude and altitude affect the geographical distribution of plant communities on Earth from the equator to the poles. While latitude has influence on the horizontal distribution, the altitude confines the vertical range of plant communities, shaping the floral composition and their eco-physiological features such as macronutrients that control the growth. In this research, the effects of different altitude gradients on plant macronutrients (N, P, K, Mg, Ca, Na) content in leaves of two different birch species (*Betula pubescens* Ehrh. and *B. pendula* Roth) distributed in the Northern Urals region were investigated for two years. Tree leaves were collected in growing seasons in 2006 and 2008, and all measured macronutrients concentration levels were compared according to altitude and year, respectively. As a result, leaf concentration of N and P were increased by altitude in Downy birch (*B. pubescens*), while the macronutrient concentration levels were decreased in Silver birch (*B. pendula*) species. In addition, although concentration of N, P, and K levels changed in both species, the N concentration level was not significantly changed in two years. Moreover, N, P, K, and Mg concentration levels in the leaves of Silver birch increased from 2006 to 2008. This reason was likely due to the later start of the growing season and higher percentage of humidity in 2006. Consequently, altitude gradients played a significant role on macronutrient contents of birch species' leaves.

Key words: ecological chemistry, highlands, micronutrients, nitrogen, plant productivity.

Introduction

Development of the plants and their ability to adapt to certain environment are very important for physiology, agronomy and forestry studies, because plant productivity mainly relies on the adaptability to specific soil and climatic conditions. The most important adaptation mechanism of woody plants in extreme environmental conditions is related to evolution of many transformation ways of the plants. Physiological and biochemical studies allow a comprehensive analysis in terms of assessing resilience to adverse environmental conditions for woody plants (Pavlov 2006, Marakaev et al. 2006).

Nitrogen (N), phosphorus (P) and potassium (K) are the macronutrients that are commonly studied for plant growth relations. Fluctuations in the content of these three elements in plants most strongly affect their growth and productivity. In addition, these three elements usually limit trees' radial increment. They are also considered as one of the indicators for site index in forestry. It is known that the ability of plants to absorb, accumulate and use chemical elements is genetically determined (Zhurbitsky and Lavrichenko 1982). Therefore, nutrient concentration level is mainly related to genus, as well as to species properties. However, within one genotype form, the pattern of plant absorption under the influence of external conditions can markedly vary. The concentration of elements in the substrate, and the associated ratio of chemical elements in the environment play a crucial role in productivity (Barsukova 1997).

Representatives of the genus *Betula* are one of the main forests forming species in Russia, which cover more than half of the total area among the deciduous forests (Drozdov et al. 2014). Silver birch and Downy birch are two important tree species for timber production in Russia. Due to their wide distribution in the country, birch species appeared as a good object to study the influence of environmental factors, such as soil and air temperature and humidity on the chemical composition of leaves. Downy birch is better adapted to drained peatlands, and it is a more common species than Silver birch. Especially on peatlands, these tree species are usually exposed to several nutritional problems including deficiencies of the main macronutrients (i.e., P and K) (Sarjala and Kaunisto 2002).

Doing investigation on variability of biochemical and physiological parameters within the altitude gradients may be one of the approaches for identifying mechanisms of adaptation to environmental conditions. The altitude parameter, which is one of the ecological factors in forest ecosystems, may adversely affect plant growth due to the decrease in soil temperature and shortening of growing period by varying altitude (Coomes and Allen 2007). Previous studies show that nitrogen concentration in the leaves of Downy birch is increased by high-altitude gradient (Karlsson and Nordel 1988). It is assumed that the increased nitrogen concentration in leaves of high-mountain birch seedlings is genetically determined, and it has an adaptive value in a cold environment (Weih and Karlsson 1999). Thus, nutrient concentration in leaves may be used as an important parameter to recognize nutrient cycling at ecosystem level which act as regulators of plant productivity, biomass accumulation, and decomposition processes (Rossatto et al. 2015). However, our knowledge related to chemical variations among the adults that naturally regenerated birch trees in native populations has been limited.

The harsh climatic conditions put mountain ecosystems on a par with such 'extreme for life' coenoses as zonal tundra and arctic deserts contributed to the formation of similar features of high-latitude and highland biota. In terms of understanding the response of arctic/subarctic vegetation to climate change, the boreal forest-tundra ecotone represents a particularly important region. Because in this area, tree species are growing at a limited environmental condition (Hustich 1953).

The complex mutual relations among climatic, geochemical, and biotic factors determine the variability of the chemical composition in plants (organic compounds and the chemical elements), and they may be defined by species properties (Mitrofanov 1977). Studies have shown a strong relationship between soil nutrient content and leaf nutrient concentration level. In a study, Rossatto et al. (2015) found significant positive relationships between soil P and plant leaf P concentration, as well as between soil Ca and plant leaf Ca concentration. However, the same study reported that there were not significant relations between soil and leaf K and Mg concentrations (Rossatto et al. 2015). In addition, the nitrogen condition in the soil limits the growth conditions by affecting the physiological activity of the plants (Da Silva et al. 2014). It is reported that soil nutrient content can be reflected in leaf nutrient concentration (Kimmins 2003).

Macronutrients (N, P, K, Mg, Ca, Na) considered to be particularly important for the tree growth and their life cycle. Therefore, in this research, we examined how the macronutrients concentration in the leaves of two different birch species changed over two years according to the altitudinal variations. We also observed the changing of macronutrient concentration levels annually depending on the zone in the highlands of the Northern Urals.

In this research, the effects of different altitude gradients on plant macronutrients (N, P, K, Mg, Ca, Na) concentration in leaves of two different birch species (*Betula pubescens* Ehrh. and *B. pendula* Roth) distributed in the Northern Urals region were investigated in 2006 and 2008. In other words, macroelement levels in leaves, i.e. plant productivity of two birch species in different mountain belts on sites with relatively severe climate and soil conditions have been observed.

Materials and Methods

The investigation area and species

Mount Konzhakovsky Kamen (59°37’9” N, 59°8’11” E) is the highest point of the southern part of the Northern Urals (1569 m). The climate of the region is cold, excessively humid and characterized by short and moderately warm summers, long and cold winters, and very early snow cover starting in the end of September. The vegetation period in the highland region of the Urals is significantly shorter than in the taiga zone (Gorchakovsky 1975). Downy birch widespread in mountain forests is replaced by a closely related mountain birch in the mountain-tundra belt (*Betula pubescens* var. *pumila* (L.) Govaerts) (Moiseyev 2008). The average wind speed during the year ranges from 2.4 to 4.5 m/s, and increases with altitude up to 8–9 m/s in the barren land. The warmth of the soil is very small. In summer, in the mountain tundra, only the most superficial layer of soil (5–8 cm) heats up to 12–15 ºC. The air temperature decreases with increasing absolute height by 0.5˚C, for every 100 m of height (Gorchakovsky 1975).

Description of the five study sites:

- The control site (207 m a.s.l.): thickness of the snow cover – 60 cm, annual precipitation – 600–700 mm/y, forest type: pine forests, dark-coniferous and birch forests.

- The lower (423 m a.s.l.) and upper boundaries (555 m a.s.l.) of the mountain forest belt: thickness of the snow cover – 70–80 cm, annual precipitation – 500–700 mm/y, forest type: dark coniferous taiga, birch forests.

- Subgoltsy (830 m a.s.l.): thickness of the snow cover – 200 cm, annual precipitation – 1200 mm/y, forest type: larch woodlands, fir-spruce forests, cedar forests.

- Mountain-tundra (1117 m a.s.l.): thickness of the snow cover – 20 cm, annual precipitation – 1200 mm/y, forest type: rocky, moss, grass-moss tundra.

For the research, meteorological data recorded at Serov meteorological stations (Fig. 1) were used. Serov station is located 78 km east of the investigation

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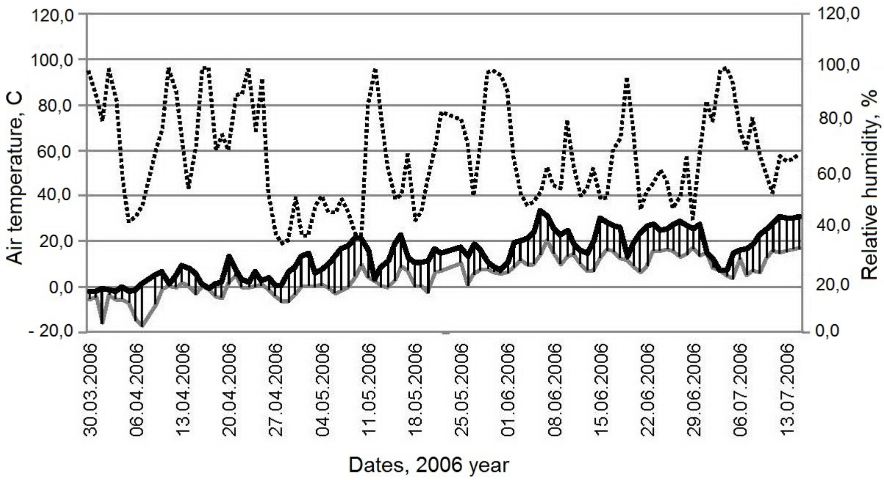

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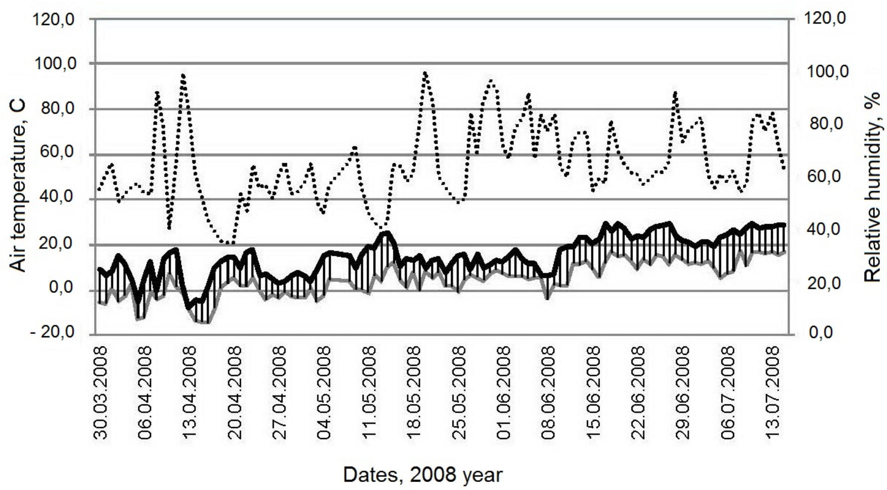

relative humidity (%) at a height of 2 m above the ground
maximum air temperature (°C) for the past period (not more than 12 hours)
minimum air temperature (°C) for the past period (not more than 12 hours)

Fig. 1. Average daily air temperatures (°C), and daily relative humidity (%) near Serov city from 30 March to 15 July, years 2006 (A) and 2008 (B).

Note: the distance from Mount Konzhakovsky Kamen – 78 km; the Meteorological Station of Serov city provided data.

area at an elevation of 134 m a.s.l. The average temperatures from 30 March to 15 July were 9.9 ºC in 2006 and 10.1 ºC in 2008, while the relative humidity was 66.5 % and 65.5 % in 2006 and in 2008, respectively.

Leaf sampling

The studies were carried out in 2006 and 2008 in all mountain belts of Mount Konzhakovsky Kamen, and the control site (the most typical type of forest for this area). The forests selected for this research are naturally regenerated, mixed Silver birch and Downy birch. The trees of Downy birch were selected in the control site, and at the lower and upper boundaries of the mountain forest belt, in the subgoltsy and tundra belts. Silver birch trees were selected at the control site at the lower and upper limits of the mountain forest belt, because Silver birch does not grow in the upper belts. Leaves were collected in 2006 and 2008 in the second half of July.

To investigate individual variability, 15 trees of both species were marked at each mountain belts; leaf samples were taken from each of the 15 selected trees. Because the chemical composition of leaves is influenced by leaf development, we used leaves from short shoots to ensure that they were of the same age. A total of 240 leaf samples were analysed. From each tree, leaves were collected from the top third of the canopy. The leaves were first dried at room temperature (23–25 °C), then at 60 °C for 24 h and ground and corrected on dry weight basis by drying at 105 °C for 24 h, placed individually into paper bags.

Total N was analysed by the Kjeldahl method (Kjeldahl nitrogen analyser UDK 152 – Velp scientifica). The analysis of phosphorus was made spectrophotometrically from dry-ashed material with molybdenum blue (Anonymous 1990). The analyses of potassium, calcium, magnesium, sodium were performed using a flame atomic spectrophotometer (AA-300). The results were recalculated in the ratio of elements.

The resulting data was analysed using the method of statistical analysis in the program (Statistica 10 for Windows 10.0). Differences between species and between 2006 and 2008 were tested by Student's t-tests. Changes between mountain forest belts in the concentrations of macronutrients were tested by one-way ANOVA followed by Fisher's test ($p<0.05$). The influence of climatic factors on the plant N, P, K, Ca, Mg, Na concentration of Downy birch and on the N: P: K ratio were analysed using an ANOVA model with year and altitude as factors.

Results and Discussion

The concentration of nutrients in the leaves of birch trees along the high-altitude gradient of the Northern Urals

The features of the accumulation of the macronutrients in the leaves of birch trees, the individual variability of macronutrients concentration along the altitude gradient of Mount Konzhakovsky Kamen, as well as interspecific differences are revealed. The foliar macronutrients concentrations of silver and Downy birch in different years and altitude belts were different. Distinctions between the species in the altitudinal gradient were identified. Our results show that the concentration of individual birch leaf macronutrients follows different patterns. The differences of the two birch species appear in the opposite direction of accumulation of macro-elements along the altitudinal gradient.

The most significant trends were associated with changes in the content of nitrogen, phosphorus and potassium. In the nitrogen concentrations of Downy birch leaves, there were highly significant differences between the years, and between the mountain belts (p<0.05). The nitrogen concentration in the leaves of Downy birch increased along the altitude gradient from control to tundra for both years (Fig. 2a). Despite significant between-year variability, trends were stable in 2006 and 2008. In 2006, the nitrogen concentration in the leaves of Downy birch increased along the altitude gradient from 22.04 ±0.78 mg/g in the control, to 30.7 ±1.5 mg/g in the tundra where it reached its maximum value (Fig. 2a). In 2008, the maximum nitrogen concentration found in the tundra belt was 39.1 ±1.0 mg/g, which was significantly different from the other belts in the high-altitude series. At the lower boundary of the mountain forest belt, the lowest nitrogen concentration in the leaves was 27.7 ±0.6 mg/g, indicating that no significant differences between this point and the control were found.

Unlike Downy birch, Silver birch showed a tendency to decrease of the macronutrients concentration in the leaves with increasing altitude. In both years, the nitrogen concentration in the leaves of Silver birch decreased along the altitude gradient from the control to the upper boundary of the mountain forest belt (Fig. 2a). The maximum nitrogen concentration in the leaves of Silver birch in 2006 found in the control was 24 ±0.5 mg/g, which is not significantly different from the Downy birch (p>0.05), the lowest – at the top (19.7 ±0.6 mg/g) and lower (20.3 ±0.4 mg/g) boundaries of the mountain forest belt. Nitrogen concentration in 2008 was 27.2 ±0.7 mg/g in the control, and decreased to 25.7 ±0.8 mg/g at the lower boundary of the mountain forest belt and to 24.0 ±0.5 mg/g at the upper boundary of the mountain forest belt. The N concentrations in 2008 were higher than in 2006 for both species (p<0.05). The nitrogen concentration in the tundra zone compared with the control increased by 26 % in 2006, and by 21 % in 2008 for Downy birch.

In contrast to the nitrogen concentration, the phosphorus concentration in the leaves of Downy birch showed no definite trends. In 2006, no significant differences between the belts were found, while in 2008 the phosphorus concentration fluctuated, and the differences of this indicator among the mountain belts were revealed (Fig. 2b). The maximum phosphorus concentration was found in the tundra belt (11.9 ±0.4 mg/g), which is significantly different from the control (9.1 ±0.4 mg/g), lower (10.6 ±0.3 mg/g) and upper (6.8 ±0.2 mg/g) of the boundaries of the mountain forest belt and the subgoltsy belt (9.5 ±0.3 mg/g). The between-year comparisons showed the significant differences in phosphorus concentration at all points of the altitude range. In all cases, the phosphorus concentration in 2008 was significantly higher (p<0.05) than 2006.

Silver birch has a tendency to decrease the phosphorus concentration with an increasing of the altitude, in contrast to the Downy birch (Fig. 2b). In 2006, in Silver birch, the phosphorus concentration decreased from control (8.4 ±0.3 mg/g) to the upper limit of the mountain forest belt (5.8 ±0.2 mg/g), and significantly differed between the mountain belts. In 2008, the phosphorus concentration also decreased to the upper boundary of the mountain forest belt and amounted to 6.5 ±0.3 mg/g, which was significantly different from the

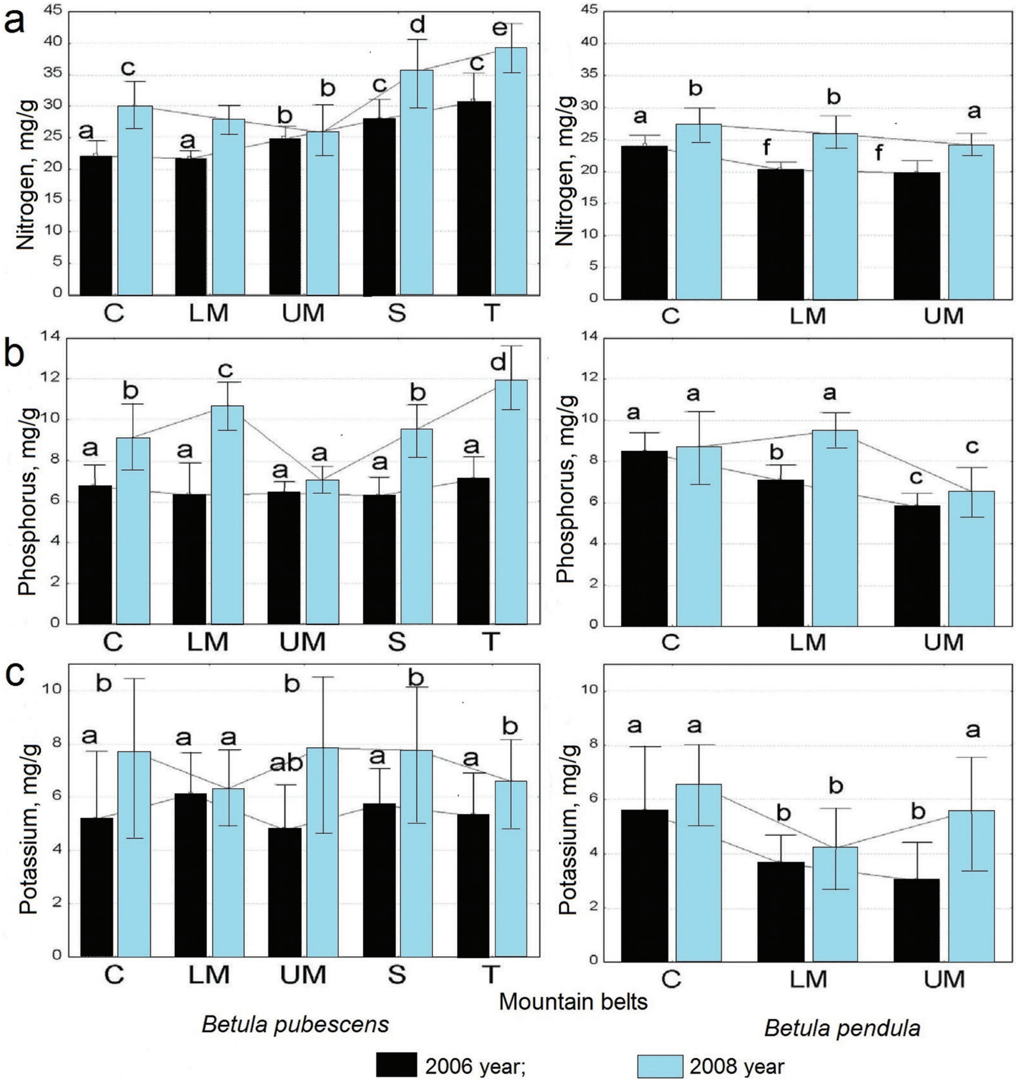

Fig. 2. The total N, P, K concentration in the leaves of Downy birch and Silver birch: a – itrogen, mg/g; b – phosphorus, mg/g; c – potassium, mg/g.

Note: C – control, LM – the lower boundary of the mountain forest belt, UM – the upper boundary of the mountain forest belt, S – subgoltsy, T – tundra. Similar letters above the columns mean no statistically significant differences, distinct letters above the columns mean statistically significant differences between mountain belts and years (p<0.05), based on a Fisher-test, n=15. Values are the means. Bars represent the standard deviation, SD. Bars indicate tree-to-tree variation, represents the mean value of 15 trees.

other belts. Changes over two years were found only in the lower boundary of the mountain forest belt, where in 2008 the phosphorus concentration was significantly higher than in 2006, while the differences between the years were not reliable at other points.

Changes in the concentration of potassium in the leaves of both species were the same as phosphorus. The potassium concentration of Downy birch leaves was stable at the altitude belts for both years, while the level of potassium in 2008 exceeded 2006 at almost all points, which also repeats the phosphorus concentration (Fig. 2c). Although the level of individual variability of potassium was significantly higher (more than 28 %), it was less than 11 % compared with phosphorus.

In the leaves of Silver birch there is a tendency to decrease potassium concentration from the control to the upper boundary of the mountain forest belt (Fig. 2c). There was a high level of individual variability from 29 % to 43 %. In 2006, the control was significantly higher than the upper and lower limits of the mountain forest belt. In the control site, there were no significant differences between the species ($p>0.05$), and between the years. In the potassium concentrations, there were no statistically significant differences between the species in the control.

In the calcium concentration, there was a tendency to a decrease in the leaves of Downy birch along the altitude gradient for both years (Fig. 3a). The significant differences ($p<0.05$) between the lower and upper points of the altitude belts were found. Significant differences between the years were found in all belts, with the exception of the subgoltsy and tundra. The calcium concentration in the leaves of Silver birch also significantly decreased with increasing altitude, which follows the trend of Downy birch (Fig. 3a).

At the same time, for both years, the control was significantly different from the upper and lower limits of the mountain forest belt. Calcium concentration decreased by 38.6 % and 45.5 % for Downy birch, and by 19.2 % and 31.7 % for Silver birch in 2006 and 2008, respectively. The level of individual variability varies from 11 % to 17 % for Downy birch, and from 9 % to 17 % for Silver birch in 2006, while it changed from 11 % to 24 % for Downy birch, and from 15 % to 30 % for Silver birch in 2008. For both years, the magnesium concentration in the control was significantly reduced comparing with the upper belt for Downy birch. The between-year comparisons showed significant differences between the years, and the concentrations in 2008 were higher than in 2006 for both species. There was no significant difference between mountain belts for Silver birch (Fig. 3b).

The individual variability of the sodium content was the highest among the macronutrients – from 35 % to 71 %; it is characterized by a high level. No significant differences were found either between mountain belts, or between investigation years for both species (Fig. 3c).

Table 1 shows the results of two-factor analysis of variance of the macronutrients concentration in the leaves of Downy birch. The concentrations of nitrogen, phosphorus, calcium was closely related to climatic conditions of the current year and the altitude belt, while the content of magnesium and potassium depended only on the year of investigation, and did not depend on altitude. The sodium content did not depend on either the year or altitude.

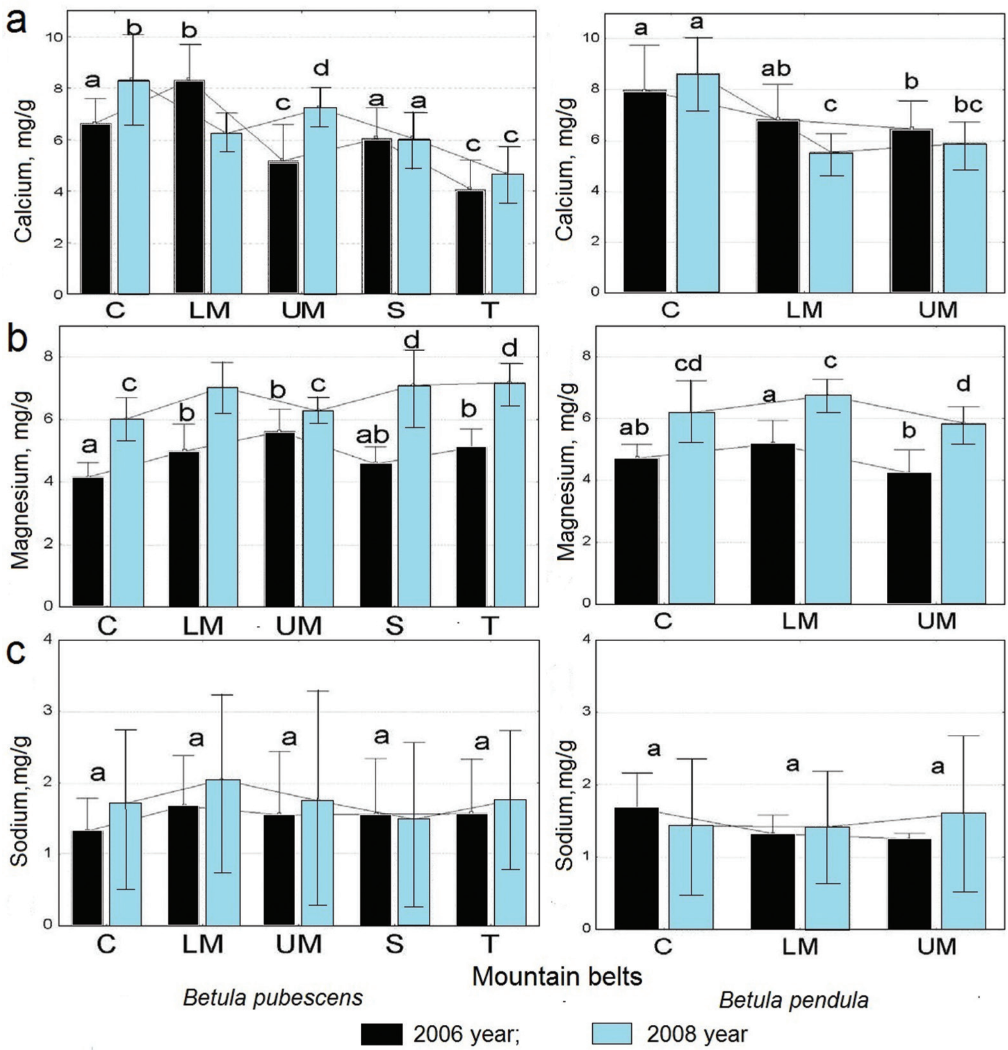

Fig. 3. The total Ca, Mg, Na concentration in the leaves of Downy birch and Silver birch: a – calcium, mg/g; b – magnesium, mg/g; c – sodium, mg/g.

Note: C – control, LM – the lower boundary of the mountain forest belt, UM – the upper boundary of the mountain forest belt, S – subgoltsy, T – tundra. Similar letters above the columns mean no statistically significant differences, distinct letters above the columns mean statistically significant differences between mountain belts and years, (p<0.05) based on a Fisher-test, n=15. Values are the means. Bars represent the standard deviation, SD. Bars indicate tree-to-tree variation, represents the mean value of 15 trees.

Table 1. Analysis of variance results for effects of year and altitude on the plant N, P, K, Ca, Mg, Na concentration of Downy birch.

Factors	Nitrogen	Phosphorus	Calcium	Magnesium	Sodium	Potassium
Year	***	***	*	***	NS	***
Altitude	***	***	***	NS	NS	NS
Interaction of year X altitude factors	**	***	*	***	NS	NS

Note: According to the results of two-factor analysis of variance. Two-order interactions were suppressed in the ANOVA model. NS – F-criterion is not significant ($p>0.05$), * – $p<0.05$, ** – $p<0.01$, *** – $p<0.001$.

The ratio of nutrients in the leaves of birch trees along the altitudinal gradient of the Northern Urals

NPK ratio was calculated as the proportion of nitrogen, phosphorus and potassium in the total amount of elements. The ratio of nitrogen increased with the altitude for both species, while the ratio of phosphorus and potassium in the leaves decreased. Despite the detected tendency of Silver birch to decrease the total nitrogen concentration in leaves with altitude, the ratio of nitrogen to phosphorus and potassium increases for Downy birch.

The percentage ratio of nitrogen increased with the altitude, and this tendency was found for both species. The significant differences between the highest and lowest points of the mountain boundary were found. Comparing Downy birch and Silver birch, there was no differences between the two species in terms of the percentage ratio of nitrogen (Fig. 4). There were also no significant differences between two years at each point of the altitude belts.

In general, although in 2008 positive air temperatures were noted at the end of March, they were accompanied by short frosts until the beginning of May, and also frosts in early June. In 2006, the average positive air temperatures over +5 ºC began on May 1, and did not drop to below zero by mid-July, while the air humidity was lower than in 2008, if we take into account the period from the end of April. The number of rainy days was higher in 2006. It is likely that the beginning of the growing season was delayed in 2006 compared to in 2008. Probably, the later start of the growing season in 2006, accompanied by higher humidity, had an impact on the decrease of the concentration of nutrients in birch leaves. The percentage ratio of nitrogen was a fairly stable parameter, which did not change over the years (Table 2), despite the significant difference in the total N concentration between the years, where 2008 was significantly higher than 2006. At the same time, a significant increasing in this parameter at the highest mountain belts shows stability only within one ecotope, which indicates the presence of zonal variability, while the variability between years is not expressed. That conclusion is also confirmed by the data of two-factor analysis of variance (Table 2). The influence of altitude and year on the N: P: K ratio is shown in Table 2. The percentage ratio of N, P and K was not affected by the weather conditions of both years, and the ratio of NPK was influenced by the altitude belts.

The obtained trends in the concentrations of macronutrients in the leaves of

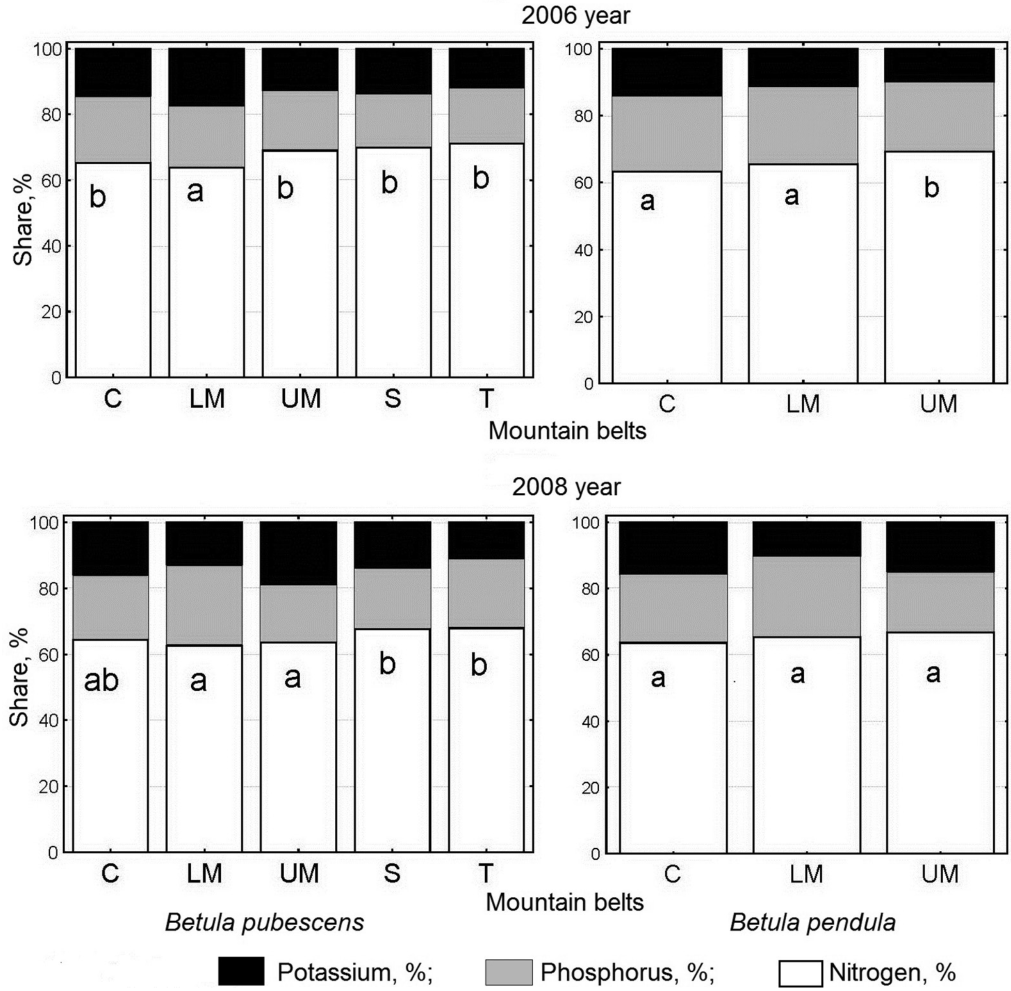

Fig. 4. The ratio of N: P: K (%) in the leaves of *Betula pubescens* and *B. pendula* along the high-altitude gradient of the Mt Konzhakovsky Stone in 2006 and 2008.

Note: C – control, LM – the lower boundary of the mountain forest belt, UM – the upper boundary of the mountain forest belt, S – subgoltsy, T – tundra. Similar letters above the columns mean no statistically significant differences, distinct letters above the columns mean statistically significant differences between mountain belts and years, (p<0.05) based on a Fisher-test, n=15. Values are the means.

Downy birch and Silver birch are probably associated with different physiological mechanisms of plant adaptation to extreme environmental factors. The chemical compounds of leaves reflect the characteristics of adaptation to environmental conditions, and the direction of metabolic processes. It is known that due to low temperatures, the perception of water from plants with dissolved mineral salts is very difficult (Gorchakovsky 1975). A decrease in the temperature of the root

Table 2. Analysis of variance results for effects of year and altitude on the ratio of NPK of Downy birch.

Factors	Nitrogen, %	Phosphorus, %	Potassium, %	Total NPK, mg/g
Year	NS	NS	NS	***
Mountain belts	**	***	**	***
Interaction of year X altitude factors	***	NS	***	**

Note: According to the results of two-factor analysis of variance. Two-order interactions were suppressed in the ANOVA model. NS – F-criterion is not significant (p>0.05), * – p<0.05, ** – p<0.01, *** – p<0.001.

space delays the absorption of ash elements, phosphorus and nitrogen (Korovin et al. 1964), while the absorption of P and its inclusion in organic compounds are most of all delayed.

According to Belyaev and Shcheglov (2012), a decrease in the productivity of tree species is accompanied by a decrease in the proportion of nitrogen in the leaves or needles with some increase (decrease) in phosphorus and potassium (Belyaev and Shcheglov 2012). Thus, an increase in the proportion of nitrogen in the leaves of both species may indicate an increase in the productivity of both species in the high-altitude gradient, despite a significant decrease in the total nitrogen content of Silver birch. However, we found that the concentration of nitrogen and phosphorus in the leaves of Downy birch increased along the altitude, while the contents of macronutrients in the leaves of Silver birch decreased along the altitudinal gradient. A high concentration of nitrogen in the leaves is explained by the tendency of high-altitude plants to store nutrients (Chapin et al. 1990). A similar strategy is proposed as a way of adapting plants to a nutrient-deficient environment (Chapin et al. 1990). A high rate of development of the photosynthesis in high altitude conditions is probably necessary for survival and distribution during a shorter growing season in the mountain-tundra zone. It is also assumed that the high nitrogen concentration of the high mountain populations of Downy birch is genetically determined, and has an adaptive value to the cold climate (Weih and Karlsson 1999).

According to the previous research, a positive correlation between the concentration of nitrogen in the leaves and the rate of net photosynthesis (observed photosynthesis) is expected (Evans 1989). In a study on Silver birch seedlings (Alhalo and Lehto 1997), it was concluded that the accumulation and distribution of dry mass and nitrogen depend strongly on the mode of supply of nutrients. It is suggested that the lack of nitrogen and phosphorus reduce the formation of shoots and leaves. Reduction in the availability of phosphorus leads to a decrease in the export of sugars from chloroplasts to the cytosol (Erricsson 1995), and a lack of potassium leads to a decrease in photosynthesis (Ingestad and Agreen 1991).

In this research, we found that the decrease in the content of macronutrients in the leaves of *B. pendula* with increasing altitude can be associated with the ecological features of the species. Probably, the lowered temperature of the soil inhibits the entry of macronutrients into plants, which is manifested in a decrease of N, P, K and Ca concentration in the leaves of *B. pendula* with increasing altitude. Because the Silver birch does not grow in the sub-goltsy and tundra belt, due to the ecological characteristics of species, we assume that it is also expressed in the characteristics of chemical composition of leaves. Probably, lowered soil temperature does not affect the absorptivity of *B. pubescens*, since the N concentration increases, while P and K do not change, and Ca decreases. *B. pubescens* is less heat and light demanding species than *B. pendula* (Kurets and Drozdov 2006). It can be assumed that the adaptive capabilities of *B. pubescens* are also in sufficient absorption of soil minerals under adverse conditions of high mountains, which allows this species to spread to higher zones, compared with *B. pendula*.

Despite the differences in the amount of N, P, K following two years of research, the percentage of nitrogen in birch leaves remained at the same level, and did not significantly differ. However, according to some researchers, the N: P: K ratio in plants of this species under adaptation conditions is a species genotypic signs and does not depend on geographical and soil-climatic conditions (Lavrichenko and Zhurbitsky 1976). Belyaev and Shcheglov (2012) showed the interrelation of the productivity of tree species and concentration of biophile element in plant assimilating organs, the most indicative of which is not the total concentration of elements, but their ratio (Belyaev and Shcheglov 2012). It was also shown that the N:P:K ratio is not only an indicator of the level of mineral nutrition, but also characterizes the functional state of plants (Vakhmistrov and Vorontsov 1997).

Conclusion

In this research, we found that significant increase in the concentration of N, P, K, Mg in the leaves of Downy birch in 2008 were higher than in 2006. N, P and Mg in Silver birch were also higher in 2008. Changes in the chemical composition of two birch species with increasing elevation were revealed. The main nutrients in the leaves of the two species ranged in order of decreasing of concentration: N>P=Ca=K>Na. The differences between the two species are in an increase in the N content and certain tendencies in the increase in the P concentration in the leaves of the birch leaves, with a decrease in these elements in Silver birch leaves with an increase of the altitude. The similarity of the two types is in the tendency to decrease the Ca concentration with altitude, although the total element concentration was significantly different, as well as in a wide range of individual variability of Na and the absence of differences between the types and belts.

The results confirm that woody species can develop many physiological and chemical mechanisms to adapt to adverse environmental conditions. In addition, these results are very valuable as a basis for practical silvicultural processes to be applied in extreme areas and also allow a comprehensive analysis in terms of assessing ecological resilience of woody plants.

Acknowledgement

The authors would like to thank Prof. Dr. Sezgin Hacisalihoglu, Karadeniz Technical University, Faculty of Forestry, in Trabzon and Assoc. Prof. Dr. Ferhat Kara, Kastamonu University, Faculty of Forestry, in Kastamonu, Turkey, for their valuable contributions to the paper.

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