Source: Haneca K, Verheyden A, Beekmann H, Gärtner H, Helle G, Schleser G (eds.) (2007) TRACE - Tree Rings in Archaeology, Climatology and Ecology, Vol. 5: Proceedings of the DENDROSYMPOSIUM 2006, April 20th – 22nd 2006, Tervuren, Belgium. Schriften des Forschungszentrums Jülich, Reihe Umwelt Vol. 74, p. 200 - 205.

The influence of wood ants on forest tree growth

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Introduction

The impact of wood ants' activity (*Formica polyctena*, Foerster) on the growth of the Norway spruce (*Picea abies* (L.) Karst.) was studied in Central Bohemia. The ants (*Formicidae*) are regular members of forest ecosystems. Not only they are important predators, they also support aphid populations and honeydew production, and have a significant influence on the physical, chemical and biological properties of the soil. They change the physical properties of the soil by transporting lower soil layers to the surface. The chemical content of the nest material is modified by the excrements the ants produce, as well as by the residuals of their nourishment and by the transportation of organic material which occurs as they are building their nests. That is why a considerable amount of nutrients (P, N, K etc.) is concentrated in their nests. Subsequently they spread these nutrients around the nest. The accumulated amount of phosphorus in a nest can be four times as high as in the soil around the nest (Frouz 1997). The temperature inside the nest is higher than the temperature outside the nest. As a result, the microbial degradation of organic to the inorganic compounds occurs faster and the accessibility of the nutrients in the soil is therefore increased. Besides temperature, the pH is another important factor that has an influence on the speed of organic compound degradation. Phosphorus is more accessible for plants in neutral or slightly acidic soils. Due to the ants' activity the pH in the nest is shifted towards the neutral value. Since the higher number of aphids results in a higher production of honeydew that is transported to the nest, the attacked tree's ring increments are lower (Rosengeren & Sundström, 1991). The overall impact of the ants' activity on plants is influenced by the nest density, the number of workers and their territory (Frouz et al. 2005, Frouz 2002). The tree growth is affected by the amount of accessible soil nutrients (Procházka et al. 1998). Since ATP is used for the biosynthesis of many plant biomolecules, phosphorus is important for the growth of plants and the flower/seed formation. Potassium regulates the opening and closing of the stoma by a potassium ion pump. Since stomata are important in water regulation, potassium reduces water loss from the leaves and increases drought tolerance. Calcium constitutes a part of the cell walls. It also regulates the transport of other nutrients into the plant. Nitrogen is an essential component of all proteins, and as a part of DNA, it is essential for growth and reproduction. Nitrogen deficiency typically results in stunting (Mengel & Kirkby 1987).

Given the above mentioned ants' influence on the concentration of nutrients in the soil, we came to the conclusion that the ants' activity might influence the growth of the trees near their nest. On this assumption we proceeded to explore the effects of ants' activity on the soil and forest trees growth, using soil and tree-ring analysis as assessment tools.

Material and methods

The study was conducted in a spruce dominated forest (49° 27´ 53“ N, 14° 49´ 43“ E) with a large complex of *Formica polyctena* nests. The examined sites were situated and classified as follows:

- A1: trees located directly in the ant nest or within 1 m from the nest,
- A2: trees located at a distance of 1–5 m from the nest
- B: trees located at a distance of 5–50 m from the nest,
- C: trees growing at control sites, 100–300 m from the closest ant nest.

The soil samples collected at the above listed sites were taken from a layer of 0 – 5 cm under the surface. The pH was measured in a water solution (1:5 sample:water ratio), the available P by the ion exchange technique, and the available K, Na, Ca, and N-NO_3^- by the ion selective electrodes in a 1% citric acid solution. To determine the statistical significance between particular variables in the soil analysis, the Statsoft Statistica 6.0 software was used. The results were evaluated by means of the multi-factorial analysis ANOVA.

The collection of wood samples was carried out with a Pressler increment borer. In total more than 80 samples were analysed from the vicinity of ten nests. The annual ring widths were measured using a special measuring table with a stereomicroscope. The tree-ring analysis was performed by the PAST software. The rings were measured to the nearest 0.01 mm. The tree rings analyses were performed according to the standard dendrochronology methods (Cook 1990). The degree of the resemblance between the mean curve and the standard chronology was assessed in terms of the correlation coefficient and the coefficient of parallel variation.

Results

A statistically significant difference in the mean pH of the soil was observed between A1 and B sites and between A1 and C sites (Fig. 1). None of the other sites showed any statistically significant differences.

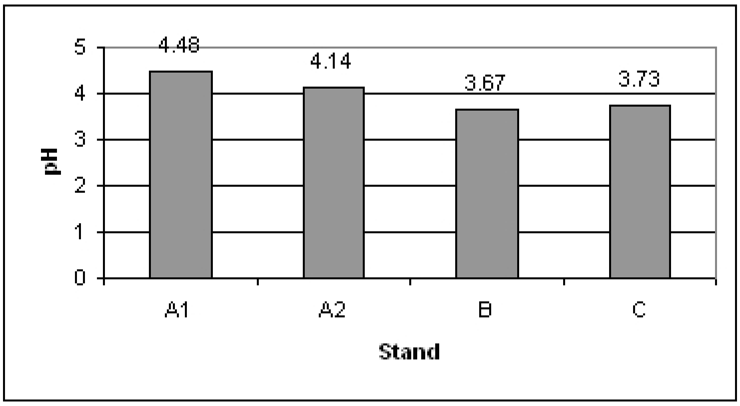

Figure 1: The pH of soil at different sites.

The biggest amount of accessible phosphorus was detected at the A1 site. The phosphorus levels at the A1 site were at least 2.6 times higher in comparison to the B site and at least 3.3 times higher as on the C site (Fig. 2). The mean value of the phosphorus content at the A1 site showed a statistically significant difference, compared to the other sites.

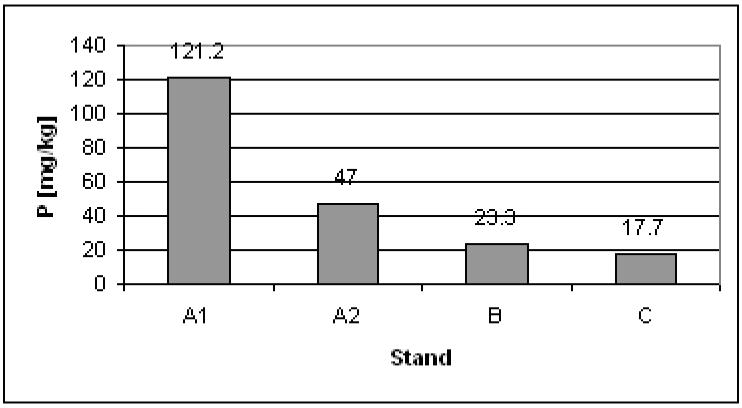

Figure 2: The content of P in soil from different sites.

The mean value of $N\text{-}NO_3^-$ content at the A1 site proved to be statistically different in comparison to the other sites. There were no mutual statistically significant differences in $N\text{-}NO_3^-$ content among the remaining sites (Fig. 3).

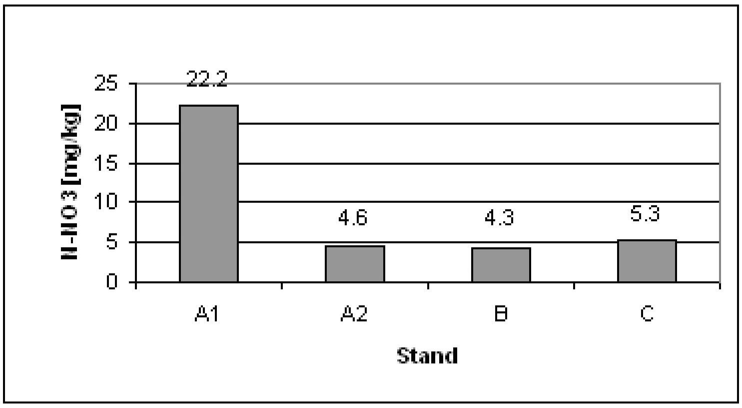

Figure 3: The content of $N\text{-}NO_3^-$ in soil from different sites.

The maximum content of potassium was detected at the A1 site. There was an evident decrease in the mean amount of potassium related to the growing distance between the A1 site (the ant nest) and the examined sites (Fig. 4). The statistic tests pinpointed statistically significant differences in the mean potassium amount between the A1 and B sites and between the A1 and C sites.

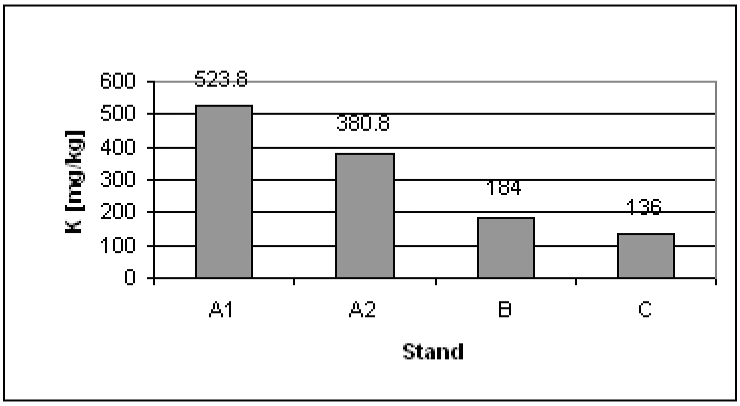

Figure 4: The content of K in soil from different sites.

The maximum mean value of sodium was detected at the A2 Site (Fig. 5). However, it was demonstrated by ANOVA that there is no statistically significant difference between the different sites.

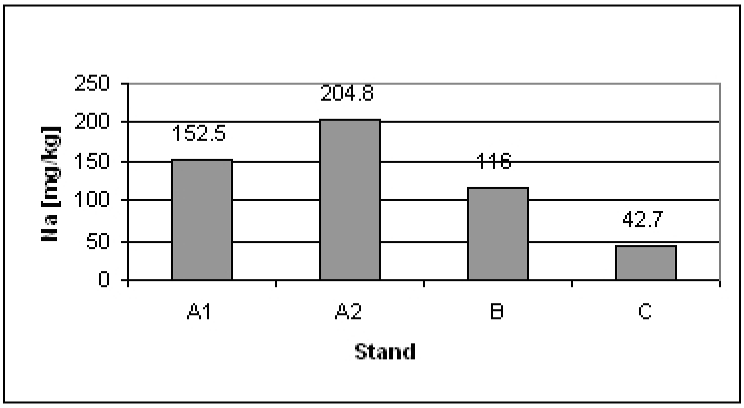

Figure 5: The content of Na in soil from different sites.

The A1 and A2 sites display high mean values for calcium content in the soil. The B and C sites showed lower values, however, there were no significant differences in the amount of calcium between the sites (Fig. 6).

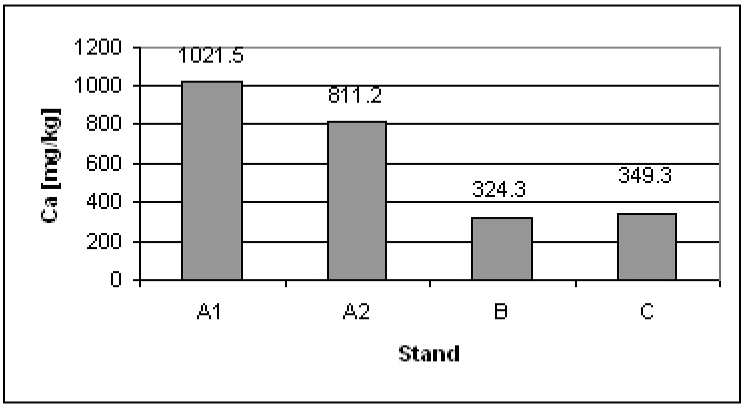

Figure 6: The content of Ca in soil from different sites.

The results of the dendrochronological analysis showed that the mean value of the annual ring width (2.178 mm) at the A1 site (distance from the nest up to1 m) is higher in comparison with the A2 (1.916 mm) and B (1.922 mm) sites. The control site showed the mean value of the annual ring width at 2.499 mm. As ascertained by ANOVA, the sites showed statistically significant differences in mean ring width.
It is evident that there had been a 20-year period of a very low ring width increment at the A2 site. A different growth trend occurred over the last 10 years where ring width gradually increased. The trees from the B site show lower ring width values all the time. Trees from the control site (C) show higher ring widths over the whole examined time span (Fig. 7).

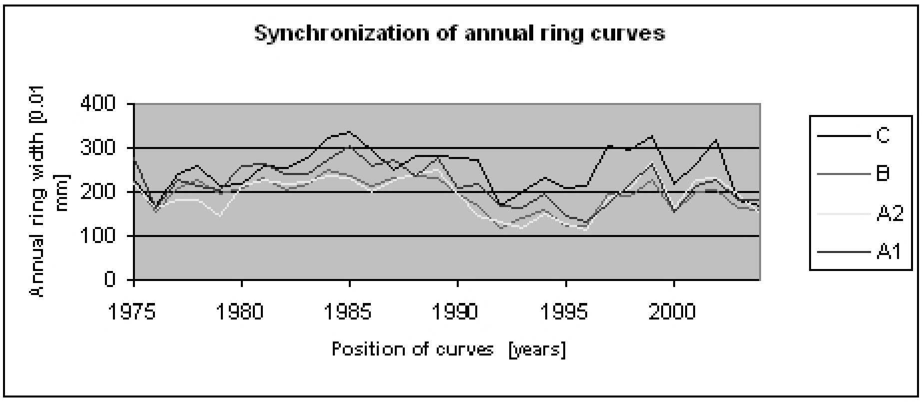

Figure 7: Synchronization of annual ring curves from different sites.

Discussion and conclusions

Our research has showed that the ants' activity shifts the pH of soil towards the neutral value. The increase in the pH to slightly acid or neutral levels results in a higher accessibility of phosphorus in soil. It has been demonstrated that the ants' activity increases the content of some nutrients in the soil (P, K, N). The highest content of the accessible phosphorus has been identified in the nest (A1 Site), which is a conclusion that is underpinned by other soil analyses (Frouz 2002). It is evident that the content of phosphorus in the nest is significantly higher than at the other sites. As far as the content of $N\text{-}NO_3^-$ is concerned, the values are similar. The highest levels have been measured within the nest. Furthermore, it was found that $N\text{-}NO_3^-$ levels decrease with an increasing distance from the nest. The highest mean value of potassium was both encountered at the A1 and A2 sites. This means that the ants have an influence on potassium content not only in the nest itself but also in its vicinity. The statistical analysis on nutrient content in soil demonstrates the influence of wood ants' activity (*Formica polyctena*, Foerster) on the pH value, as well as on the P, N and K levels. No statistically significant difference has been observed in the content of the other monitored nutrients.
The ring width analyses have revealed that the trees located directly in the ant nest or in its immediate vicinity (within 1 m from the nest), i.e. the A1 site, have a higher radial increment than trees located at a distance between 5 and 50 m from the nest (B site). Nonetheless, the trees within 1 m from the ant nests have a lower increment of the ring widths compared to

the trees growing at the control sites without the presence of wood ants (about 300 m from the closest nest). We suppose that the highest increment of the ring widths at this site can be put down to the lack of aphits. The presence of aphits may be considered as a stress factor. All the achieved results are in compliance with Rosengren and Sundström (1991). To summarize, the study has demonstrated that the tree growth might be affected by a complex influence of the ants' activity.

Acknowledgement

The paper was prepared within the framework of the research plan of LDF MZLU in Brno, MSM 6215648902 and the CR Grant Agency 526/03/H036.

References

Cook, E.R., Kairiukstis, L.A. (1990): Methods of Dendrochronology. Dordrecht: International Institute for Applied Systém Analysis. 393.

Drápela, K., Zach, J. (2000): Dendrometrie (Dendrochronologie). Brno: Mendel Univ. of Agriculture and Forestry Brno. 152.

Frouz, J. (2002): Úloha mravenců v půdních procesech. *Formica, 2002:* 27–33.

Frouz, J., Holec, M., Kalčík, J. (2003): The effect of Lasius niger (Hymenoptera, Formicidae) ant nest on selected soil chemical properties. *Pedobiologia, 2003, č. 47:* 205–212.

Frouz, K., Kalčík, J., Cudlín, P. (2005): Accumulation of phosphorus in nests of red wood ants *Formica s. str. Helsinky: Ann. Zool. Fennici 42, 2005:* 269–275.

Frouz, J., Šantrůčková, H., Kalčík, J. (1997): The effect of wood ants (Formica polyctena Foerst.) on the transformation of phosphorus in a spruce plantation. *Pedobiologia, , č. 41*: 437–447.

Hölldobler, B., Wilson, E.O. (1997): Cesta k mravencům. Praha: Academia. 192.

Rosengren, R., Sundström, L. (1991): The interaction between red wood ants, Cinara aphids, and pines. A ghost of mutualism past? In: *Ant – Plant Interactions*. New York: Oxford University Press: 80–91.

Procházka, S., Macháčková, I., Krekule, J., Šebánek, J. (1998): Fyziologie rostlin. Praha: Academia. 484. ISBN 80-200-0586-2

Mengel, K., Kirkby, E.A. (1987): Principles of plant nutrition. International Potash Institute, Bern, 687 p., ISBN 3-906-535-03-7