Changes in soil chemistry in the surroundings of wood ant (*Formica polyctena*) nests

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Abstract
Several previous studies reported on how the chemistry of the wood ant nest differs from the chemistry of the surrounding soil. In this contribution, we focused on changes in soil chemistry with distance from the nest. Soil samples 0-5cm deep were taken in a grid pattern at 1-19m from eight *Formica polyctena* nests in a spruce forest in the Czech Republic. Soil pH decreased with distance; pH decreased rapidly between 1 to about 8m and then decreased more slowly. The decrease in pH corresponded with the increase in organic matter content with distance from the nest because pH was negatively correlated with organic matter content. Organic matter content was significantly and positively correlated with available Ca and K, i.e., available Ca and K increased with distance from the nest. The changes in organic matter content, pH, and available Ca and K were apparently caused by ants collecting and using needles as building material.

Key Words
Biogeochemistry, basic cations, litter, nutrients.

Introduction
The group of wood ants includes dominant species of ants in boreal forest ecosystem (Dlusskij 1967). They are known for their large and long-lived colonies that may count several millions of individuals (Seifert 1996). Although the material used for nest building comes from the nest surroundings, soil properties of the nest are rather distinct from surrounding litter and soil (Dlusskij 1967; Frouz and Jilkova 2008; Jurgensen *et al.* 2008).

Through their activities, ants change physical, chemical and also biological properties of the soil (Boulton *et al.* 2003; Dlusskij 1967; Petal 1980). One of the changed soil properties is pH. pH affects nutrient availability to plants, compound solubility and also activity of microorganisms (Brady and Weil 2001). However, the range and cause of variation in pH between ant nests and their surroundings has not been completely revealed yet. In this study we tested the variance in pH and also other soil properties with the distance from the ant nests and we focused on influence of organic matter content and content of basic cations on pH.

Methods
Study site and sampling design
This study was conducted in a spruce forest (*Picea abies*) near Tabor (Czech Republic). Soil samples 0-5 cm deep were taken in a regular grid pattern (2 x 2m) in a rectangular area (4m wide and 20m long) in the close vicinity of the eight *Formica polyctena* nests. 33 soil samples were taken in each grid, 264 in total.

Quantifying of soil properties
Soil pH, organic matter content, available Ca, K, Mg and Na and humic acid composition were studied. Soil pH was measured in a 1:5 soil: water suspension by glass electrode. Basic cations (Ca^{2+}, Mg^{2+}, Na^+, and K^+) were extracted in 1:4 soil:Mehlich I solution (Mehlich 1953) and quantified by atomic absorption spectrophotometry with use of SpectrAA 640 at 420.7 nm (Varian, Inc. USA). Organic matter content was determined based on ignition loss after 5 hours in 600°C. Humic and fulvic acids were extracted for 12 h in 1 N NaOH (1:20 soil:NaOH); the samples then were diluted with deionized water (1:1), and humic and fulvic acid were measured using ELISA (Multi-Detection Microplate Reader, Synergy[TM] 2, BioTek) at 474 and 666 nm, respectively, and with NaOH diluted in deionized water (1:1) as a blank.

Statistics
For correlation of individual chemical parameters with distance from the nest, 2-D Euclidean distance between the nest centre (at ground level) and individual sampling points was calculated. Correlations were also calculated between individual chemical parameters measured and between residuals of the regression between pH and organic matter content.

Results
Soil pH decreases significantly with increasing distance from the ant nest (Figure 1a). This tendency is pronounced up to circa 8 m from the nest. Soil pH is significantly negatively correlated with soil organic matter content (Figure 1b), which shows significant positive correlation with distance from the nest (Figure 1c). This dependence is rather logaritmic, the distance the organic matter content most increases to is also circa 8 m from the nest. There are also other soil properties which have the influence on pH. If we take the residuals of correlation between pH and organic matter content, there is a negative correlation of these residuals with distance from the nest and content of humic and fulvic acids, while available Ca and K content show positive correlation with residuals (Table 1). With the distance from the nest change not only pH and organic matter content but also other soil properties, such as available Ca and K content and content of humic and fulvic acids (Table 1). Organic matter also influences contents of many other soil properties. There is a positive correlation between organic matter content and content of available Ca, Mg, Na and K and also content of humic and fulvic acids (Table 1).

Table 1. Correlation between individual parameters measured in soil surrounding eight *F. polyctena* nests. For each nest, 33 soil samples located 1 to 19 m from the nest were collected. The correlations are based on 264 samples. Correlation coefficients are shown only for significant correlations ($p<0.05$). Distance refers to distance from the nest. pH OM residuals refers to the variation in the correlation between pH and OM that was unexplained by organic matter content. A 474 is absorbance at 474 nm and corresponds to the content of humic acids. A 666 is absorbance at 474 nm and corresponds to content of fulvic acids.

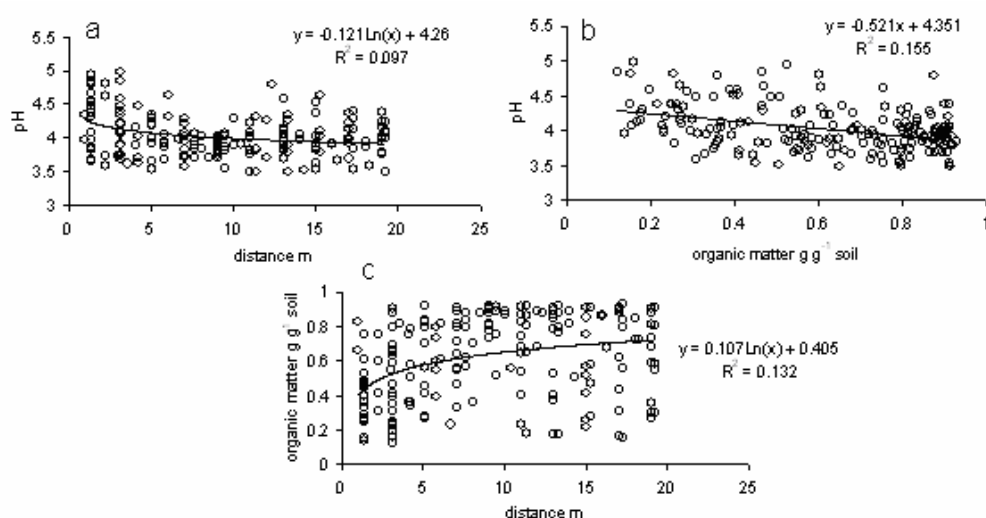|	pH	OM	Ca	Mg	Na	K	A 474	A 666	pH OM residuals
Distance	-0.226	0.295	0.191			0.153	0.221	0.230	-0.122
pH		-0.385					-0.593	-0.533	0.917
OM			0.602	0.144	0.421	0.573	0.797	0.666	
Ca				0.221	0.446	0.704	0.410	0.292	0.196
Mg					-0.411	0.152	0.321	0.258	
Na						0.581			
K							0.369	0.279	0.189
A 474								0.903	-0.301
A 666									-0.292

Figure 1. Relationships between soil pH, organic matter content, and distance from *Formica polyctena* nest. (a) A plot of pH on distance for all 264 samples; (b) A plot of soil pH on soil organic matter content for all 264 samples; and (c) A plot of soil organic matter content and distance for all 264 samples.

Discussion

It seems that pH changes are connected with changes in organic matter content. pH is strongly negatively correlated with organic matter content and so decrease in pH with distance from the nest seems to be caused by increasing organic matter content. Similar results shows Frouz *et al.* (2003). Although organic matter content explains a large portion of data variability, a significant portion of data variability remains unexplained. This portion correlates negatively with both humic and fulvic acid content and positively with basic cation (Ca and K) content. The negative correlation with humic acid is not surprising given that humus in coniferous soil is typically highly acidic (Brady and Weil 2001). Similarly, the positive correlation with basic cations is not surprising because such cations act in the cation exchange complex and thereby tend to increase soil pH (Brady and Weil 2001).

Content of basic cations strongly correlates with organic matter content and increases with increasing distance from the nest. Based on this study and previous literature data (Domisch *et al.* 2009; Frouz *et al.* 1997), we expect that cation enrichment in the nest and depletion in surroundings are given by two different mechanisms. We expect that nutrient enrichment in the nest is mostly caused by accumulation of food residues and excreta. Enrichment of the nest in close surroundings by basic cations can be the reason why these cations significantly explain residuals of pH after the effect of organic matter was removed. Depletion of nutrients in nest surroundings is connected with removal of needles, small branches and other litter particles which are used for nest building. Similarly these two mechanisms seem to affect pH around the nest.

Conclusion

Changes in pH seem to be caused by changes in organic matter content and content of basic cations and humic and fulvic acids. Ants are most probably responsible for these changes through their activities.

Acknowledgements

References

Boulton AM, Jaffee BA, Scow KM (2003) Effects of a common harvester ant (*Messor andrei*) on richness and abundance of soil biota. *Applied Soil Ecology* **23,** 257-265.

Brady NC, Weil RR (2001) 'The Nature and Properties of Soils.' (Prentice-Hall: New York).

Dlusskij GM (1967) 'Muravji Roda *Formica*.' (Nauka: Moskva).

Domisch T, Finer L, Neuvonen S, Niemela P, Risch AC, Kilpelainen J, Ohashi M, Jurgensen MF (2009) Foraging activity and dietary spectrum of wood ants (Formica rufa group) and their role in nutrient fluxes in boreal forests. *Ecological Entomology* **34,** 369-377.

Frouz J, Jilkova V (2008) The effect of ants on soil properties and processes (Hymenoptera: Formicidae). *Myrmecological News* **11,** 191-199.

Frouz J, Santruckova H, Kalcik J (1997) The effect of wood ants (*Formica polyctena* Foerst.) on the transformation of phosphorus in a spruce plantation. *Pedobiologia* **41,** 437-447.

Jurgensen MF, Finer L, Domisch T, Kilpelainen J, Punttila P, Ohashi M, Niemela P, Sundstrom L, Neuvonen S, Risch AC (2008) Organic mound-building ants: their impact on soil properties in temperate and boreal forest. *Journal of Applied Entomology* **132,** 266-275.

Petal J (1980) Ant populations, their regulation and effect on soil in meadows. *Ekologia Polska – Polish Journal of Ecology* **28,** 297-326.

Seifert B (1996) 'Ameisen: Beobachten, Bestimmen.' (Naturbuch-Verlag: Ausburg).