Acta Oecologica 91 (2018) 120–126

Contents lists available at ScienceDirect

Acta Oecologica

journal homepage: www.elsevier.com/locate/actoec

Influence of tree species and soil properties on ground beetle (Coleoptera: Carabidae) communities

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ARTICLE INFO

Keywords:
Arboretum
Carabids
Forest
Soil conditions
Bioindication

ABSTRACT

Although Carabidae is among the best-studied families of beetles in Europe from the faunistic point of view, there is still a lack of available information on the ecological requirements of the particular carabid species. The habitat preferences that determine the distribution of species are largely influenced by habitat structure and microclimate. In addition to other factors, these habitat parameters are influenced by the nature of the vegetation. Therefore, our study investigated the influence of tree species on carabid beetle communities. We conducted the research at 9 stands in the Borová Hora Arboretum (Zvolen, Central Slovakia). Each studied site represents a monoculture of one of nine tree species. At each site, some soil and leaf litter attributes (pH, conductivity, and content of H, C, N and P) were evaluated. Ground beetles were collected by pitfall trapping during the vegetation periods in 2008–2011. In total, 3012 individuals of 29 species were obtained. Significant differences in the total dynamic activity and species richness of the carabid beetle communities among the compared forest stands were revealed. The results of the research confirmed statistically significant relationships among 1) the soil conductivity and both the richness and Shannon diversity of the ground beetle communities, 2) the litter and soil N content and richness, the Shannon diversity and the species composition of the ground beetle communities. The Shannon diversity and richness were negatively related to the soil conductivity and positively related with the N content. Our research showed that dominant tree species indirectly influence diversity and composition of carabid communities via the soil properties.

1. Introduction

Carabids are terrestrial beetles. Although carabids live mainly on the soil surface, some species occasionally live on vegetation. They prey on various invertebrates in different growth stages. In this way, carabid beetles participate in the maintenance of the natural equilibrium of a wide range of habitats (Hůrka, 1996). European carabids are useful model organisms and possibly useful environmental indicators because they are diverse and well-known both taxonomically and ecologically; they efficiently reflect biotic and abiotic conditions, are relevant at multiple spatial scales, and are easy to collect in sufficiently large numbers to allow statistical analyses (Koivula, 2011).

Vegetation cover-related variables, such as moisture, temperature and shade are considered the main drivers of diversity of ground beetle communities since the distribution of carabid species is markedly influenced by microclimatic conditions (e.g., Diefenbach and Becker, 1992; Kostova, 2015; Moraes et al., 2013; Niemelä, 1996; Šustek, 2004; Thiele, 1977; Voronin, 1995). In forest habitats, species composition and structure of a tree layer plays an important role since litter and soil quality and quantity greatly affect niche availability for carabids (e.g. Sklodowski, 2014; Yanahan and Taylor, 2014). Carabid beetles are also sensitive to anthropogenic abiotic conditions, such as pesticide use in agro-ecosystems and the contamination of soils with heavy metals (Butovsky, 2011). Carabids might thus reflect ecological sustainability and 'ecosystem health'. Therefore, carabids may potentially serve as keystone indicators (Koivula, 2011).

Several authors have studied the influence of tree species on the composition of carabid beetle communities. For example, Apigian and Wheelwright (2000) found that the mixed forest support higher total dynamic activity than monospecific stands. Also diversity of carabid

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https://doi.org/10.1016/j.actao.2018.07.005
Received 19 March 2018; Received in revised form 3 July 2018; Accepted 14 July 2018

beetle communities is linked to tree species composition (Zou et al., 2015). Podrázský et al. (2010a,b) summarised the literature on the bioindication potential of ground beetle communities in forest ecosystems and found that ground beetle communities reflect the tree species composition more than the stand structure and that the carabid communities sensitively mirror changes in tree species compositions.

In contrast, the effect of soil properties, which are driven by tree species (Binkley and Giardina, 1998), on carabid beetle communities is relatively understudied. Only few studies examined the importance of soil types and soil physico-chemical properties for carabid beetles (e.g., Baker and Dunning, 1975; Spomer et al., 2015). A research focused on the both, soil- and vegetation-effects, is generally missing (but see Sklodowski, 2014).

Here, we examine the hypothesis that tree species influence soil and leaf litter attributes (pH, conductivity, and content of H, C, N and P) which, in turn, affect ground beetle communities. The Borová Hora Arboretum is especially suitable for this purpose because it enables the assessment of the different ecological properties of various tree species within homogenous area.

2. Material and methods

2.1. Study stands

The Borová Hora Arboretum is an important educational and research facility, of the Technical University in Zvolen. The planting of trees started at the arboretum in 1965 (Lukáčik et al., 2005). The arboretum is located near the middle reach of the Hron River in Central Slovakia, approximately 3 km northwest of the centre of Zvolen, from 48°35′42´´ to 48°36′06´´ N and 19°07′58´´ to 19°10′00´´ E. It lies on the southwestern foot of the Zvolenská Pahorkatina hills. The arboretum has hills ranging in altitudes from 290 m (in the northwestern part) to 377 m in the eastern part (Labanc and Čížová, 1993).

The town of Zvolen belongs to a warm region, with a moderately humid climate and cold winters. The mean annual temperature of this region is +8.8 °C, and the mean temperature during the vegetation period is +15.6 °C. The mean annual amount of precipitation is 640 mm, with 399 mm during the vegetation period (Čížová, 2005).

The research was carried out on 9 stands. The minimum distance between the stands was 100 m. They differed by tree species, and some soil and leaf litter attributes (Table 1). An overview and brief description of the studied stands are given below according to the data of Pagan et al. (1975):

PB – stand of downy birch (*Betula pubescens* Ehrh.), geographic coordinates (GC) – 48°35′45.8″ N and 19°08′09.3″ E, stand canopy (SC) – 50%, altitude (A) – 340 m, exposure (E) – north-northwest, pedogenic substrate (PS) – tuff material slope deposits, sporadically with small additions of silt loams and siliceous gravels, soil (S) –saturated typical Cambisols,
PS – stand of Scots pine (*Pinus sylvestris* L.), GC – 48°35′47.2″ N and 19°08′16.5″ E, SC – 50%, A – 345 m, E − north, PS – silt loam slope deposits and slope deposits of kaolinised andesite tuff, S – Albic Luvisols,
LD – stand of European larch (*Larix decidua* (Mill.)), GC – 48°35′49.1″ N and 19°08′23.0″ E, SC – 60%, A – 350 m, E − north, PS – tuff material slope deposits and slope deposits of kaolinised andesite tuff, S – saturated typical Cambisols,
CB – stand of European hornbeam (*Carpinus betulus* L.), GC – 48°36′03.8″ N and 19°08′42.1″ E, SC – 80%, A – 310 m, E − north-northeast, PS – tuff material slope deposits with larger addition of siliceous gravels, S – saturated typical Cambisols with additions of siliceous gravels,
AA – stand of European silver fir (*Abies alba* Mill.), GC – 48°35′55.1″ N and 19°08′30.1″ E, SC – 100%, A – 330 m, E − north, PS – tuff material slope deposits with larger additions of siliceous gravels, P – two-substratum Albic Luvisols,
PA – stand of Norway spruce (*Picea abies* (L.) Karst.), GC – 48°35′51.1″ N and 19°08′26.7″ E, SC – 80%, A – 335 m, E − north, PS – silt loam slope deposits and slope deposits of kaolinised andesite tuff, S – two-substratum Albic Luvisols,
AI – stand of grey alder (*Alnus incana* (L.) Moench), GC – 48°35′57.8″ N and 19°08′02.8″ E, SC – 80%, A – 290 m, E − none, PS – mainly medium grain size alluvial deposits of the Hron River, S – carbonate Glei patterns,
PN – stand of black poplar (*Populus nigra* L.), GC – 48°35′58.7″ N and 19°08′06.5″ E, SC – 50%, A – 290 m, E − none, PS – mainly medium grain size alluvial deposits of the Hron River, S – carbonate Glei patterns,
UL – stand of European white elm (*Ulmus laevis* Pall.), GC – 48°35′54.0″ N and 19°07′58.0″ E, SC – 70%, A – 315 m, E − north-northwest, PS – silt slope deposit with additions of travertine in the top layers (20–30 cm), S – calcareous Cambisols.

2.2. Methods

The research was carried out between 2008 and 2011. Carabid

Table 1
Measured physico-chemical parameters of soil (s) and leaf litter (l) samples of the studied stands.

Stand/layer	Tree species	pH/H_2O	κ [μS.cm^{-1}][a]	H [%W][b]	C [%$_W$][b]	N [%$_W$][b]	P [mg.kg^{-1}]
BP/s	*Betula pubescens*	5.6	428	2.04	6.0	0.38	19.8
BP/l	*Betula pubescens*	5.8	1000	6.37	45.6	0.45	204.0
PS/s	*Pinus sylvestris*	4.7	175	1.76	2.9	0.24	14.5
PS/l	*Pinus sylvestris*	4.5	350	4.84	35.3	0.56	104.0
LD/s	*Larix decidua*	5.0	146	1.56	2.2	< 0.01	6.6
LD/l	*Larix decidua*	4.2	740	4.64	33.9	0.46	130.0
CB/s	*Carpinus betulus*	6.5	500	1.74	4.2	0.31	24.3
CB/l	*Carpinus betulus*	5.5	770	4.52	30.6	0.66	228.0
AA/s	*Abies alba*	4.8	310	1.59	4.1	0.32	37.0
AA/l	*Abies alba*	5.4	970	4.06	29.0	0.85	199.0
PA/s	*Picea abies*	4.5	98	1.48	2.6	0.21	8.1
PA/l	*Picea abies*	5.6	790	4.13	29.5	0.66	130.0
AI/s	*Alnus incana*	7.0	380	1.48	5.0	0.43	15.5
AI/l	*Alnus incana*	5.6	770	4.76	33.8	0.73	161.0
PN/s	*Populus nigra*	7.2	315	1.41	3.8	0.27	6.8
PN/l	*Populus nigra*	6.9	1300	3.55	24.8	0.93	177.0
UL/s	*Ulmus laevis*	7.1	473	1.74	8.4	0.63	102.0
UL/l	*Ulmus laevis*	6.0	745	4.64	29.5	0.78	249.0

[a] Conductivity in H_2O extract.
[b] % weighted.