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SHORT COMMUNICATION

Structure of forest stands of alien tree *Quercus rubra* in Central Europe

Jana Májeková[1] · Jana Medvecká[1] · Katarína Mikulová[2] · Denisa Slabejová[1] · Mária Šibíková[1] · Mária Zaliberová[1] · Iveta Škodová[1]

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Abstract
The diversity of planted forest stands of the alien species *Quercus rubra* L. in Central Europe was studied. The northern red oak is a neophyte that has been cultivated in Europe since the seventeenth century as an ornamental as well as a useful tree. In 38 phytosociological relevés from Slovakia, Poland and the Czech Republic, we recorded a total of 223 vascular plant taxa, of which 10% were alien (with 9 invasive species). The stands were species-poor compared to the most native forests, with an average of 17 species per relevé, and most of the species had a low coverage value (around 5% on average). The representation of endangered species was very low, only three species were recorded. The dense canopy of *Q. rubra* and large cover of litter consisting mainly of fallen old red oak leaves affected the richness of the undergrowth. The mean cover of the tree layer was 84%, the mean cover of the shrub layer was 9% and the mean cover of the herb layer was 22%. The EuroVegChecklist Expert System assigned the relevés to five classes: *Carpino-Fagetea sylvaticae*, *Alno glutinosae-Populetea albae*, *Rhamno-Prunetea*, *Epilobietea angustifolii* and *Robinietea*.

Keywords Alien species · Czech Republic · Neophytes · Northern red oak · Poland · Slovakia

Introduction

Quercus rubra L. (northern red oak) from the family *Fagaceae* is a deciduous tree native to North America, the eastern and central part of the United States and the south-east and south-central part of Canada (Sander 1990). In its native range, it grows at elevations up to 1680 m with mean annual precipitation varying from 760 to 2030 mm and a mean annual temperature from 4 to 16 °C. Typical habitats are lower and middle slopes with northerly or easterly aspects. It grows on various soil types and prefers deep, well-drained loam to silty, clay loam soils. *Q. rubra* is monoecious species with flowering in April and May. The fruits mature in 2 years and ripen from August to October. It begins to be fruitful at the age of 25 years, but abundant seed crops it has only at age 50. Mature individuals are usually from 20 to 30 m tall and 61 to 91 cm in diameter. The average diameter growth is about 5 mm annually. It has very good sprout ability (Sander 1990).

The species was introduced in Europe at the end of the seventeenth century, the first record comes from France in 1691 (cf. Nicolescu et al. 2020). Firstly, it was planted mainly as an ornamental tree because it is very attractive with its red leaves in the autumn. Only in the second half of the nineteenth century, there was a beginning of planting for timber production and reforestation of degraded areas (Daubree and Kremer 1993; Woziwoda et al. 2014a; Nicolescu et al. 2020). It grows well on rather more acidic and dry soils (Dreßel and Jäger 2002). Higher tolerance for environmental stresses and faster growth in comparison with native European oaks (*Quercus petraea*, *Q. robur*) favour it in cultivation (Vansteenkiste et al. 2005; Gubka and Sklenár 2006; Štefančík 2018a; Nicolescu et al. 2020). It is also less prone to fungal diseases than native oaks (Magic 2006; Dyderski et al. 2020; Nicolescu et al. 2020). Although its wood is of lower quality than the native oaks, the timber has a wide range of uses in furniture manufacture, joinery, veneer, construction, railroad ties, pallets, boxes, etc. (Vansteenkiste et al. 2005). Nowadays, red oak is grown in most

✉ Jana Májeková
jana.majekova@savba.sk

[1] Institute of Botany, Plant Science and Biodiversity Centre, Slovak Academy of Sciences, Dúbravská cesta 9, 845 23 Bratislava, Slovakia

[2] BROZ – Bratislavské regionálne ochranárske združenie, Na Riviére 7/a, 841 04 Bratislava, Slovakia

of Europe and covers over 350 000 ha (Dreßel and Jäger 2002; Nicolescu et al. 2020).

In addition to its positive properties and uses, many authors point to the negative impact of red oak stands in the secondary area on the structure and composition of the vegetation, soil characteristics and microorganisms, they alter environmental conditions, contribute to biotic homogenization of the understorey vegetation, etc. (e.g. Lodhi 1976; Riepšas and Straigytė 2008; Marozas et al. 2009; Chmura 2013, 2020; Woziwoda et al. 2014b; Miltner et al. 2017; Dyderski et al. 2020; Stanek et al. 2020, 2021).

In Slovakia, the species has been planted since 1855 as an ornamental tree in villages, parks and alleys, and from the beginning of the twentieth century, it was also planted in forest habitats. The first forest stand dates back to 1900 from the Kysihýbel arboretum in Central Slovakia. In Slovakia, *Q. rubra* var. *borealis* is planted (Benčať 1982; Magic 2006). In 1980, the oldest cultivated exemplar of *Q. rubra* was 120 years old, the highest location was at 995 m a.s.l. and the lowest at 110 m a.s.l. (Benčať 1982). The area of cultivated red oak stands in the forests of Slovakia is relatively small, 2193 ha, which represents a share of 0.11% of the total wood composition (Šebeň 2017). It is grown mainly in southern Slovakia in mixed and unmixed stands. It was usually planted in the group of forest types *Carpineto-Quercetum* and *Corneto-Quercetum* (cf. Štefančík 2018a). Research into the growth and development of red oak in Slovakia began to receive attention in the 1960s (Gubka and Sklenár 2006). Several studies have focused on the structure and development of red oak stand with different functions and with production function (Štefančík 2011, 2018b) and comparing selected characteristics in a red oak stand with native oaks (Gubka and Sklenár 2006; Štefančík 2018a). The results showed a higher quantitative production of alien *Q. rubra* compared to native *Q. petraea* and at the same time pointed to the rubble maturity of red oak at the age of ca 82 years (Gubka and Sklenár 2006; Štefančík 2018a). The species is evaluated as a naturalized neophyte in Slovakia with abundance class 3 (i.e. 15–49 localities in the wild in the country; Medvecká et al. 2012).

Q. rubra was introduced to the Czech Republic in 1799 (Koblížek 1990) and it is planted in an area of approximately 6000 ha, which represents 0.14% of the total forest area of the country (Viewegh et al. 2016). The first occurrence of the species in Poland dates back to 1806 (Chmura 2004; Tokarska-Guzik 2005) and the total area of the *Q. rubra* stands is 14,300 ha that is 0.16% of the total forest area (Woziwoda et al. 2014a).

Although natural regeneration of the species is quite difficult in the native area, it recovers relatively well in the secondary area and abundant seedlings have been observed in several European countries (Steiner et al. 1993; Vansteenkiste et al. 2005; Riepšas and Straigytė 2008; Major et al. 2013; Miltner and Kupka 2016; Nicolescu et al. 2020). This allows the successful naturalization of the species in the secondary area. *Q. rubra* is already naturalized in several areas of Europe and the suboceanic area. It behaves as an agriophyte – an alien plant that may persist also in the natural vegetation (Dreßel and Jäger 2002). However, opinions on its invasiveness in Europe differ. While in Slovakia it is evaluated as naturalised (Medvecká et al. 2012), it is considered invasive in the Czech Republic (Pyšek et al. 2022), Poland (Tokarska-Guzik 2005; Tokarska-Guzik et al. 2014), Slovenia (Zelnik 2012), Lithuania (Riepšas and Straigytė 2008), Belgium and Germany (Nicolescu et al. 2020). In Slovenia, *Q. rubra* belongs among the 27 most common invasive plants and the 20 most common invasive plants in natural and extensively managed habitats (Zelnik 2012). Lambdon et al. (2008) included *Q. rubra* among the 150 most widespread alien plant species in Europe with naturalised status in 19 countries, casual status in 5 and unspecified in 10 countries. Dyderski et al. (2020) reported it as naturalised in 23 countries. Its lag phase, i.e. time between introduction and the initiation of invasion, was 114 years in Germany (Kowarik 1995). In Poland, red oak is widely distributed especially in the southern part of the country and colonises also natural forests. The species is still expanding in the country and behaves there as a transformer (Tokarska-Guzik 2005). Chmura (2004, 2013) classified it as a competitor. It also spreads into nature reserves (Chmura 2004; Chmura and Sierka 2006) and Bomanowska et al. (2019) considered red oak the 6th most common invasive plant in Polish national parks while in some parks, there is an effort to its eradication.

Although much work has focused on the properties of red oak and the impact of its stands on natural vegetation, little work has focused on the composition and structure of forest monocultures of the species. Only a few phytosociological relevés with dominant *Q. rubra* were published, e.g. from the Czech Republic (Viewegh et al. 2016) and Germany (Dreßel and Jäger 2002). Chmura (2014) studied forest vegetation with the spontaneous occurrence of red oak in Poland but avoided monoculture stands. Therefore, the aims of our study were: i) to study the floristic structure and composition of *Q. rubra* stands in Central Europe, ii) to evaluate the representation of alien and endangered species in the stands, iii) and to classify the stands syntaxonomically.

Materials and methods

Field sampling was carried out from May to August 2016 and 2017. A total of 38 phytosociological relevés were sampled: 27 in Slovakia, 10 in Poland and 1 in the Czech Republic (Fig. 1). Relevés were recorded according to the Zürich-Montpellier school (Braun-Blanquet 1964; Westhoff and van

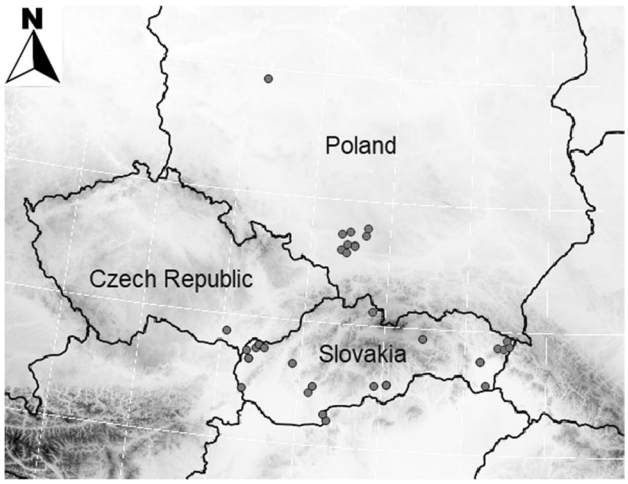


Fig. 1 Distribution map of the studied *Quercus rubra* stands in Central Europe

der Maarel 1978) using the 9-degree scale of abundance and dominance (Barkman et al. 1964). The stands were dominated by *Quercus rubra* in the tree layer (frequency over 50%), and the plot size was 20 × 20 m. For each relevé geographic coordinates, altitude, aspect, slope, the cover of the tree, shrub, herb and moss layer, the height of the tree, shrub and herb layer, cover and thickness of litter were recorded, too. Canopy cover was measured using the Gap Light Analysis Mobile Application (GLAMA, Tichý 2014, 2016); five measurements for each relevé were taken, from which the average value was calculated. The phytosociological relevés were stored in the database program TURBOVEG (Hennekens and Schaminée 2001) and then edited and analysed using the JUICE 7.0.207 program (Tichý 2002; Tichý and Holt 2006). For the classification of relevés to vegetation classes, the EuroVegChecklist Expert System was used (for class identification, a measure Sum of powered species cover – PSC – was used with Square root transformation of cover data; Mucina et al. 2016). Variation in vegetation was analysed by principal correspondence analysis (PCA) from the CANOCO 4.5 package (ter Braak and Šmilauer 2002) due to the short gradient in species composition (2.54). Ecological indicator values for soil moisture, soil nitrogen, soil reaction, light and temperature (Dengler et al. 2023) and Shannon–Wiener's diversity index (Hill 1973) were plotted onto the PCA ordination diagram as supplementary environmental data. The Spearman correlation coefficient was used to calculate the correlation between ecological indicator values and the first two ordination axes (p-level was set to 0.01) using STATISTICA software.

Plant taxa nomenclature follows Euro+Med PlantBase (Euro+Med 2006). Species origin and invasiveness for Slovakia are from Medvecká et al. (2012), the Czech Republic from Pyšek et al. (2022) and Poland from Zając and Zając (2011), Tokarska-Guzik (2005), and Tokarska-Guzik et al. (2014). Endangered species are following Eliáš et al. (2015) for Slovakia, Grulich (2012) for the Czech Republic, and Kaźmierczakowa et al. (2016) for Poland.

Relevés in the phytosociological table (Supplementary table) are arranged into classes according to the EuroVegChecklist Expert System (Mucina et al. 2016) and within classes by the countries. Taxa are arranged as follows: *Q. rubra* in the tree (E3), shrub (E2), and herb layer (E1); diagnostic species for individual classes and other taxa. Bryophytes were not identified in the relevés. Cover values 2m, 2a, and 2b were shortened to the form m, a, and b in the table.

Results

We recorded 38 relevés with dominant tree species *Quercus rubra* in Slovakia, Poland, and the Czech Republic in altitudes from 75 to 727 m a.s.l. (Fig. 1). A total of 223 vascular plant taxa were included in relevés, with an average of 17 taxa per relevé; minimum number of taxa in relevé was 4, maximum number was 37. The cover of the tree layer varied from 70 to 95%, with an average of 84%. The cover of the shrub layer varied from 0 to 50%, with an average of 9%. The cover of the herb layer varied from 1 to 70%, with an average of 22%. Bryophytes were present very seldom, with a maximum of 2% coverage. Canopy cover measured by GLAMA was from 69 to 92%, with an average of 82%. The studied stands were characterized by a large cover of litter, ranging from 60 to 99%. It consisted mainly of fallen old red oak leaves with a thickness of 1 to 8 cm.

Alien species represented ca 10% of the species diversity of the stands. We recorded 23 aliens with neophytes dominated (15 species). In addition to *Q. rubra*, which was planted, *Fraxinus pennsylvanica*, *Juglans nigra*, *Pinus nigra*, *Pseudotsuga menziesii*, and *Robinia pseudoacacia* were occasionally found in the tree layer, all with occurrence only in one relevé. *Q. rubra* was common also in the shrub layer (with 63% frequency), other aliens were *Prunus serotina* (8%), *Pseudotsuga menziesii*, and *Robinia pseudoacacia* (both 3%). The most frequent alien species in the herb layer were seedlings of *Q. rubra* (with 97% frequency), but *Fallopia convolvulus* (21%), *Impatiens parviflora* (26%), and *Robinia pseudoacacia* (11%) were also common. Invasive taxa were represented in all layers with the following species: *Acer negundo*, *Bidens frondosus*, *Erigeron canadensis*, *Fraxinus pennsylvanica*, *Impatiens parviflora*, *Prunus serotina*, *Reynoutria japonica*, *Robinia pseudoacacia*, and *Solidago gigantea*.

Endangered species were almost completely missing in the studied stands. We recorded only *Convallaria majalis* and *Ornithogalum boucheanum* with category LC in Slovak relevés, and *Myosotis sparsiflora* with category NT in Czech relevé.

The EuroVegChecklist Expert System (Mucina et al. 2016) assigned most relevés to the class *Carpino-Fagetea sylvaticae* (26 relevés; Supplementary table); 7 relevés were assigned to the *Alno glutinosae-Populetea albae* class, two relevés to the *Rhamno-Prunetea* and *Epilobietea angustifolii* classes and one relevé to the *Robinietea* class (Mucina et al. 2016). These classes belong to both zonal and azonal vegetation. Classes *Carpino-Fagetea sylvaticae*, *Rhamno-Prunetea*, and *Robinietea* are representatives of the zonal vegetation of the nemoral forest zone of Europe. Classes *Alno glutinosae-Populetea albae* and *Epilobietea angustifolii* represent azonal vegetation, while *Alno glutinosae-Populetea albae* belongs to alluvial forests and *Epilobietea angustifolii* to anthropogenic vegetation. In addition to the diagnostic species of the mentioned five classes, species of other forest communities also appeared in the records, e.g. *Quercetea roboris* and *Vaccinio-Piceetea* (Supplementary table). Grassland species were also common, mainly from the classes *Molinio-Arrhenatheretea*, *Trifolio-Geranietea sanguinei* and *Festuco-Brometea*. Synanthropic species were relatively rare, represented by the species from the classes *Papaveretea rhoeadis*, *Artemisietea vulgaris* and *Sisymbrietea*.

The PCA ordination diagram (Fig. 2) illustrates the variation of vegetation. The first ordination axis (x) was significantly negatively correlated with the ecological indicator value for soil nitrogen (correlation coefficient = -0.64) and reaction (-0.59); the main environmental gradient was related to soil parameters – nutrient content and soil reaction. The second axis (y) was significantly negatively correlated with the ecological indicator values for light (-0.55). On the left side of the graph, relevés from the *Alno glutinosae-Populetea albae* and *Epilobietea angustifolii* classes were plotted, while relevés of the *Carpino-Fagetea sylvaticae* class were scattered throughout the graph. Soil nitrogen and higher soil reaction demanding species were represented by *Sambucus nigra*, *Geum urbanum*, *Alliaria petiolata* or *Geranium robertianum*.

Discussion

The studied red oak plantations were floristically quite poor; the average number of taxa per relevé was 17, which is very small compared to the native forests where the average number can reach even 30–40 taxa per relevé (cf. Valachovič et al. 2021); in addition, most of the species had low coverage value (around 5% on average). Similarly, in other studies of red oak stands, poor species composition and reduction of biodiversity were noted (Chmura 2013; Viewegh et al. 2016) and the species-poor understorey vegetation in red oak plantations was compared to that under dense beech canopies (Dyderski et al. 2020). The dense canopy of *Q. rubra* (in our case 70–95% of coverage) prevents light penetration into the lower layers, which can affect the richness of the undergrowth, as light is one of the limiting factors of understorey vegetation (Barbier et al. 2008). *Q. rubra* also has an allelopathic effect, secreting inhibitors that reduce herbaceous plant biomass (Lodhi 1976; Coder and Warnell 1999; Meiners 2014). Plant germination can also be affected by dense litter, which prevents the penetration of light and the germination of seeds (Barbier et al. 2008).

The floristic composition consists mainly of native species, although aliens are also not rare; they make up 10% of the total species spectrum. Excluding red oak, in 61% of the relevés, there were at least one alien species in different layers. Forest habitats are not resistant to invasions by aliens, almost all forests contained some alien species and plantations of alien tree species belong to the most invaded forests (Medvecká et al. 2018). Neophyte species *Impatiens parviflora* (with a frequency of 26%) was the most common alien in our relevés except for *Q. rubra*, followed by the archaeophyte *Fallopia convolvulus* (21%). *I. parviflora* belongs among the 150 most widespread alien plants in Europe (Lambdon et al. 2008) and is also among the most common neophytes in habitats of the Czech Republic (Chytrý et al. 2005; Sádlo et al. 2007). It is the most common neophyte species and the second most common alien species in the forest habitats of Slovakia. It occurs in various types of forest habitats and is not associated with any of them (Medvecká et al. 2018). *I. parviflora* is also the most frequent herbaceous neophyte in Polish forest habitats (Chmura 2004) and together with *Q. rubra* belongs among the three most abundant neophytes in nature reserves in southern Poland (Chmura and Sierka 2006).

In addition to the planted individuals of red oak in the tree layer, individuals in the lower layers were often present in the studied areas. Seedlings of red oaks were present in all relevés except one and they had coverage from + to 3 (Supplementary table). In the shrub layer, red oak was slightly less common, with a frequency of 63% and the coverage reached from + to 2b. This confirms its natural renewal in the secondary area. Although the natural regeneration of red oak in its native area is very difficult (Sander 1990), its rejuvenation in Europe has been confirmed by several authors (Steiner et al. 1993; Vansteenkiste et al. 2005; Riepšas and Straigytė 2008; Major et al. 2013; Miltner and Kupka 2016; Chmura 2020; Nicolescu et al. 2020) as evidenced by our results.

Syntaxonomic classification of stands is problematic. The stands with the dominant red oak are not included in

the Slovak or Czech overview of vegetation (Chytrý 2013; Valachovič et al. 2021). There can be several reasons, e.g. little phytosociological material or indistinct floristic composition. The species occurring in these stands are more or less random and come from the surrounding habitats. In our study, we noticed diagnostic species from 36 classes according to the EuroVegChecklist Expert System (Mucina et al. 2016), both from the forest and non-forest vegetation (Supplementary table). *Q. rubra* is also not a diagnostic species of any syntaxonomical unit in Slovakia, Czechia, or Poland and neither in EuroVegChecklist Expert System (Matuszkiewicz 2007; Jarolímek and Šibík 2008; Chytrý 2013; Mucina et al. 2016; Valachovič et al. 2021). The occurrence of red oak in other forest types is relatively rare in Slovakia. Medvecká et al. (2018) mention it in the following habitats: Beech forests (Medio-European neutrophile *Fagus* forests), Mixed Oak forests (Medio-European acidophilous *Quercus* forests and *Quercus-Fraxinus-Carpinus betulus* woodland on eutrophic and mesotrophic soils), Thermophilous Oak forests (Steppe *Quercus* woods), and Plantations of non-native trees (*Robinia* plantations). Occasionally, Valachovič et al. (2021) documented the occurrence of the species in the following forest classes in Slovakia: *Alno glutinosae-Populetea albae*, *Robinietea pseudoacaciae*, *Quercetea pubescentis*, *Quercetea robori-petraeae*, *Carpino-Fagetea sylvaticae*, *Dicrano-Pinetea*. In Poland, Chmura (2014) studied forest vegetation with the occurrence of *Q. rubra*, but the syntaxonomic classification of the stands was also difficult. Mainly species from the classes *Alnetea glutinosae*, *Querco-Fagetea* and *Vaccinio-Piceetea* were present in the stands. In its native range, red oak creates pure stands or stands in which it is dominant and this forest cover type is called "Northern Red Oak" (Society of American Foresters Type 55). It is also the major component of the other two forest types ("White pine – northern red oak – red maple" and "White oak – black oak – northern red oak") and is an associated species in the other 15 forest types (Sander 1990). Although the EuroVegChecklist Expert System assigned collected relevés to five classes of forest vegetation, we consider this classification only indicative due to the limited size of our data set. A more extensive study would be required for a comprehensive syntaxonomic classification. Our results provide a first insight into the studied issue, particularly within the territory of Slovakia, as this topic has received only marginal attention in Slovakia until now. The problematic classification of the collected relevés to vegetation units and their overlapping display in the ordination graph suggests that the presence of planted *Quercus rubra* contributes to the homogenization of the understorey species composition. As a result, species characteristic for specific vegetation classes were being excluded, while generalist species with a broad ecological range were prevalent.

The issue of planting northern red oak in Europe is disputable. Its faster growth and its lower susceptibility to fungal diseases compared to the native European oaks were confirmed (Vansteenkiste et al. 2005; Magic 2006; Gubka and Sklenár 2006; Štefančík 2018a; Dyderski et al. 2020; Nicolescu et al. 2020). Thanks to its ability to grow in dry and more acidic soils (Dreßel and Jäger 2002), it can grow in heavily polluted areas and is used for afforestation of abandoned or poor post-agricultural lands (Woziwoda et al. 2014a). It also provides suitable habitats for wild and game animals, nesting sites or food for birds and mammals, and due to decorative red autumn leaves red oak is planted near forest settlements, along forest roads, in gardens etc. (Vansteenkiste et al. 2005; Rédei et al. 2010; Woziwoda et al. 2014a). The red oak stands proved to be resistant to wind damage, and therefore, they could improve the stand stability of Central European forests (Miltner and Kupka 2016). Kubiak (2006) recorded quite a lot of lichens, even rare ones on the bark of red oak in Poland and points out that the species can play an important role in preserving lichen biodiversity in the forest environment.

On the other hand, *Q. rubra* behaves invasively in many places in Europe, penetrating natural communities and threatening native biodiversity (Chmura 2004; Chmura and Sierka 2006). The monocultures of red oak negatively change the species composition, soil properties, and microbes (Riepšas and Straigytė 2008; Miltner et al. 2017; Stanek and Stefanowicz 2019; Chmura 2020; Stanek et al. 2020, 2021). Richardson (1998) drew attention to the significant impact of alien tree plantations on the environment, and in some countries, and some localities eradication of red oak has begun (Vansteenkiste et al. 2005; Bomanowska et al. 2019). The introduction of alien woody plant species, together with forest fragmentation, supports the naturalization of alien plants in forest habitats (Chmura 2004). The more often an alien tree is grown in the country, the higher the chance of its naturalization and possible invasion (Bucharova and Kleunen 2009). Therefore, when choosing cultivated trees, foresters should consider the advantages and disadvantages of such stands in the country (Medvecká et al. 2018).

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Author contribution Jana Májeková and Iveta Škodová contributed to the study conception and design. Data collection was performed by all authors. Analysis were performed by Jana Májeková and Iveta Škodová. The first draft of the manuscript was written by Jana Májeková and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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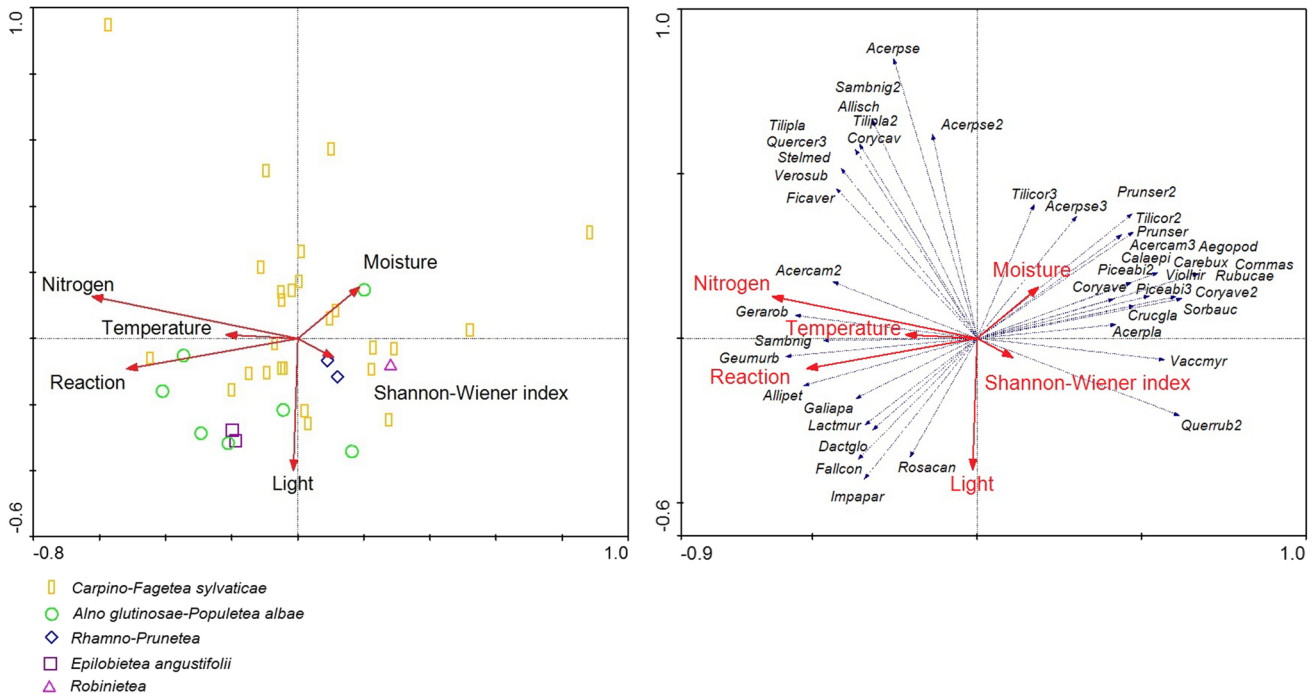


Fig. 2 Principal correspondence analysis (PCA) of stands with dominant *Quercus rubra* with ecological indicator values plotted onto a PCA diagram as supplementary variables. Species Fit Range was set to 17% of explained variability by the first two PCA axes. Abbreviations of the species: Acercam2 – *Acer campestre* in E_2, Acercam3 – *Acer campestre* in E_3, Acerpla – *Acer platanoides*, Acerpse – *Acer pseudoplatanus*, Acerpse2 – *Acer pseudoplatanus* in E_2, Acerpse3 – *Acer pseudoplatanus* in E_3, Aegopod – *Aegopodium podagraria*, Allipet – *Alliaria petiolata*, Allisch – *Allium schoenoprasum*, Calaepi – *Calamagrostis epigejos*, Carebux – *Carex buxbaumii* agg., Cornmas – *Cornus mas*, Coryave – *Corylus avellana*, Coryave2 – *Corylus avellana* in E_2, Corycav – *Corydalis cava*, Crucgla – *Cruciata glabra*, Dactglo – *Dactylis glomerata*, Fallcon – *Fallopia convolvulus*, Ficaver – *Ficaria verna*, Galiapa – *Galium aparine*, Gerarob – *Geranium robertianum*, Geumurb – *Geum urbanum*, Impapar – *Impatiens parviflora*, Lactmur – *Lactuca muralis*, Piceabi2 – *Picea abies* in E_2, Piceabi3 – *Picea abies* in E_3, Prunser – *Prunus serotina*, Prunser2 – *Prunus serotina* in E_2, Quercer3 – *Quercus cerris* in E_3, Querrub2 – *Quercus rubra* in E_2, Rosacan – *Rosa canina* agg., Rubucae – *Rubus caesius*, Sambnig – *Sambucus nigra*, Sambnig2 – *Sambucus nigra* in E_2, Sorbauc – *Sorbus aucuparia*, Stelmed – *Stellaria media*, Tilicor2 – *Tilia cordata* in E_2, Tilicor3 – *Tilia cordata* in E_3, Tilipla – *Tilia platyphyllos*, Tilipla2 – *Tilia platyphyllos* in E_2, Vaccmyr – *Vaccinium myrtillus*, Verosub – *Veronica sublobata*, Violhir – *Viola hirta*

Declarations

Ethical approval No approval of research ethics committees was required to accomplish the goals of this study.

Informed consent Informed consent was obtained from all individual participants included in the study.

Financial or non-financial interests None.

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