OVERWINTERING OF PLANTS IN UNDERSTORY OF TEMPERATE DECIDUOUS FORESTS: EVERGREEN AND SEMI-EVERGREEN BROAD-LEAVED SPECIES

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In a temperate climate zone with four seasons (spring, summer, autumn and winter) winter is critical period for many plant species because low temperatures (frosts) and snow cover limit their growth. Leaves (in rosettes and/or on shoots) of evergreen and semi-evergreen plant species persist the winter period, being physiologically active. In Spring two generations of leaves in the species are observed: overwintered leaves (from previous growing season) and new spring leaves. In Malé Karpaty Mts. (seven former MaB Forest Research Sites, West Carpathians) and in Bábsky les (former I.B.P. Forest Research Site, Danube Lowland), SW Slovakia, persistence of leaves and perennial plants during the winter periods (1979-1984, 2008-2015, respectively) was observed in understory of several forest communities. Live, green plants and leaves on the forest floor were recorded from November to March/April. Evergreen leaves Asarum europaeum, Hedera helix (liana), Vinca minor, Mahonia aquilegiifolia (alien shrub) were present. Semi-evergreen leaves of woodland herbs Carex pilosa, Galium odoratum, Galeobdolon luteum, Geum urbanum, Glechoma hederacea, Geranium robertianum, Ajuga reptans, Oxalis acetosella, Pulmonaria officinale, Sanicula europaea survivied the frost period. In mild winters leaves of some other species survivied: Mercurialis perennis, Dactylis polygama, Hypericum perforatum, Fragaria vesca, Some species can survivied more days under the snow cover, others (perennial plants with broad leaves, e.g. Pulmonaria officinale) are very sensitive to these conditions. Galeobdolon luteum and Lamium maculatum can form dense cover in clear-cut areas esp. during the winter periods. Leaves of many understory plants are acclimated to survive the season with low temperature and more favourable light conditions in the understory of deciduous forests.

Keywords: winter period, forest understory, leaf persistence, broad-leaved plants, over-wintering, Forest research sites, Malé Karpaty Mts., Bábsky les, Slovakia, Central Europe

INTRODUCTION

In a temperate climate zone with four seasons (spring, summer, autumn and winter) winter is a critical period for many plant species because low temperatures (frosts) and snow cover limit their growth. Vascular plants have been adapted to these specific conditions: different life forms were distinguished on basis of growth tissues (meristems) protection during the unfavorable period of life (Raunkier´s forms, see Goryshina 1979, Larcher, 2003, Eliáš, 1997, 2002). In deciduous temperate forest hemi-cryptophytes are dominated life form in the understory (Ellenberg, 1978, Jurko, Kontriš, 1981). These long-lived plants (perennials) differ in phenological development: they belong to several phenological types (phenorytmotypes) (Goryshina, 1979, Eliáš, 1997). Evergreen plants exhibit leaves which are live on shoots longer than one year (14-16 months) or more. Leaves in semi-evergreen plants are present on the shoots but they belong to different (two to three) generations which exchange during a year (cf. Domin, 1928, Jurko, 1990).

Leaves (in rosettes and/or on shoots) of evergreen and semi-evergreen plant species persist the winter period, being physiologically active (Steinhubel, 1974, 1975 in Biskupský, Larcher, 2003). During winters, leaves of these plants frequently are exposed to a combination of cold temperatures, high solar radiation, and reduced photosynthetic activity. Light conditions on the floor of deciduous forests are favourable during the leafless season of canopy trees. Evergreen woodland herbs in deciduous forests exhibit variation in photosynthetic light responses to that parallels seasonal changes in light availability (Steinhubel, 1975,). Overwintering leaves served as carbon- and/or nutrient-storage and phosynthetic organs. But the photosynthetic and storage functions of the leaves are sometime questioned. They physiological contribution to growth was found to be modest in a forest-floor fern (Tani, Kudo, 2005). Other ecological functions of overwintering leaves, such as suppression of neighbouring plants in spring, were also considered (Tani, Kudo, l.c.).

In Spring two generations of leaves in the species are observed: overwintered leaves (from previous growing season) and new generation (spring) leaves, appeared in Spring (Eliáš, Čiamporová, 1987).

In the paper we present some results of long-term field research of leaf survival (leaf longevity, persistency) of understory plants in temperate deciduous forests in Central Europe (Slovakia). The purpose of the study was to identify evergreen and semi-evergreen plant species with overwintering leaves growing in different type of forest communities.

MATERIALS AND METHODS

Reseach Sites

The observations and field records were made in Southwestern Slovakia, Central Europe. Forest Research Sites of international biological/ecological research programmes (MAB=Man and Biosphere Programme, I.B.P.=International Biological Programme) were chosen. In Malé Karpaty Mts. seven former MAB Forest Research Sites (first transect) with the following ecological forest types: subxerophilous oak forest, acidophilous oak (*Quercus petraea*) forest, two beech (*Fagus sylvatica*) forests, , oak-hornbeam (*Carpinus betulus*) forest and alder (*Alnus glutinosa*) forest. Ecological characteristics of the forest communities were published by Jurko and Kontriš (1981), Eliáš (1986, 1987). In Bábsky les, former I.B.P. Forest Research Site (Nitrianska pahorkatina, Danube Lowland) four forest types occurred: oak-hornbeam (*Primulae veris-Carpinetum*) forest with *Carpinus betulus*, *Quercus cerris*, *Q. petreaea* and *Acer campestre* in tree canopy, and other three forest communities (*Carici pilosae-Carpinteum*, *Aceri-Carpinetum* and *Corno-Quercetum*). For characteristics of the site see Jurko, Duda (1970), Biskupský (1975) and the forests Kubíček, Brechtl (1970) and Eliáš (1979, 1997, 2011).

Methods

The persistence of leaves and perennial plants was observed during the winter periods (1979-1984 in Malé Karpaty Mts, 2008-2015 in Bábsky les) in understory of the forest communities. Live, green plants and leaves on the forest floor were recorded from November to March/April of next year. Vitality of plants and damage of leaves caused by frosts were also recorded and documented by photographs. Some plants were collected for herbarium. Abundance of the overwintered species were estimated by cover (%) in understory vegetation.

Snow accumulation (cover duration and depth) were also recorded and measured, respectively. For characteristics of winters in the Nitra region see Pevný-Repa (1976). Length of the snow-cover period as well as snow-cower depth is very limited, in the region.

RESULTS

Leaves of evergreen plant species were recorded in all sample dates. In the Bábsky les research site liana *Hedera helix* was very frequent in some microsites, forming green cover of its leaves in understory of the forests (cf. Kubíček-Brechtl, 1970, Eliáš, 1978, 2012). Other evergreen species were present there: *Vinca minor* and *Mahonia aquilegiifolia* (alien shrub). In the acidophilous oak forests in the Malé Karpaty Mts. *Vaccinium myrtillus* and *Calluna vulgaris* (green twigs) and green leaves of *Avenella flexuosa*, *Genista pilosa*, *Luzula albida* were recorded.

Leaves of perennial (evergreen and semi-evergreen) herbs were also frequent. In December usually 10-15 plant species with green leaves have been observed. In the forest communities we found green leaves of *Carex pilosa*, *Galeobdolon luteum*, , *Glechoma hederacea*, *Galium odoratum*, *Geranium robertianum*, *Geum urbanum*, *Fragaria vesca*, *Ajuga reptans*, *Oxalis acetosella*, *Pulmonaria officinale*, *Sanicula europaea*, *Stellaria holostea*, *Hypericum montanum*, *Euphorbioa amygdaloides*, most of the leaves survivied the frost period (Fig. 1).

Fig. 1 Overwintering leaves of some perenial (evergreen and semi-evergreen) herbs are frequent in the understory of temperate deciduous forests in the winter periods. The Bábsky les research Site, December 2014, photo: Pavol Eliáš sen.

Weather conditions during a winter and snow cover influence the number of plant species with overwintering leaves and abundance of green leaves in the season (Goryshina, 1964). In mild winters leaves of some other species survivied: *Mercurialis perennis*, *Dactylis polygama*, *Melica uniflora*, *Hypericum perforatum*, *Viola* spec.div.

Goryshina (1979) stressed to regional differencies in phenorytmotypes of the same species. Two perennial herbs, *Stellaria holostea* and *Galium odoratum* in West-European broad-leaved forests belong to evergreen species but in East-European oak woodlands belong to spring-summer-autumn green plants.

The most shade-tolerant herbaceous plants tend to remain green throughout the year (Grime, 2002). Slow-growing evergreen species such as *Galeobdolon luteum*, *Milium effusum*, *Avenella flexuosa* and *Veronica montana*.

Steinhubel (1975, 1976) studied evergreen woodland herb *Asarum europaeum*, in details. Contribution of the overgreen leaves to carbon gain was evident.

Some species can survivied more days under the snow cover, than others (perennial plants with broad leaves) are very sensitive to these conditions. Large leaves of *Pulmonaria officinale* usually died under the long-time snow cover (two weeks and more) or just after snow milting.

In February overwintering leaves can cover the floor and form green understory vegetation (up to 100 %). In some sites (gaps?) *Galeobdolon luteum* and *Lamium maculatum* usually dominated. The perennial herb *Lamium maculatum* can form dense cover in clear-cut areas, esp. during the winter periods. Domin (1929) found green cover of overwintering leaves of woodland plants in a forest in Brdy Mts. after snow milting. The following species form the stands *Fragaria vesca*, *Veronica chamaedrys*, *Galium rotundifolium*, *Myosotis sylvatica*, *Viola sylvatica* and some others. Green leaves of a grass *Poa nemoralis* were also found.

Leaves of many understory plants are acclimated to survive the season with low temperature and more favourable light conditions in the understory of deciduous forests (Fig. 2).

Overwintering perennials in the temperate zone survive through harsh winters by an induced process termed cold acclimation (CA). This seasonal phenomenon greatly increases their cold-hardiness in response to inductive short photoperiods, low nonfreezing and then sub-freezing temperatures sequentially through early fall and winter (Larcher, 2003, Sakai and Larcher, 1987; Wang et al. 2008).

Fig. 2 Overwintering leaves of some perenial herbs in the understory of temperate deciduous forests survive the frost periods, being acclimated to cold temperatures. The Bábsky les Research Site, February 2015, photo: Pavol Eliáš sen.

Annuals with more generations of plants (leaves) during a year, *Galium aparine* and *Stellaria media*, were found in the forest understory in Báb. Abundance of *Alliaria petiolata* overwintering leaves in rosettes varied evidently between years (biennial herb).

In mild winters some plants were observed in flowering stage (overwintered plants of *Lamium maculatum* and winter annuals).

Fig. 3 In mild winters overwintering leaves of forest-understory perennial (evergreen and semi-evergreen) herbs can form dense vegetation. The Bábsky les Research Site, February 2014, photo: Pavol Eliáš sen.

CONCLUSION

Leaves of many understory plants are acclimated to survive the winter season with low temperature and more favourable light conditions in the understory of deciduous forests.

Evergreen plants exhibit leaves which are live on shoots longer than one year (14-16 months) or more. Leaves in semi-evergreen plants are present on the shoots but they belong to different (two or three) leaf generations which exchange during a year.

Leaves (in rosettes and/or on shoots) of the evergreen and semi-evergreen plant species persist the winter period, being physiologically active.

Overwintering leaves in a plant community play multiple functions from carbon-storage organ for new growth in plants to supporting competition advantage in suppressing neihbouring plant(spedcies) in early spring in plant community.

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