Introduced tree species in European forests: opportunities and challenges

Frank Krumm and Lucie Vítková (eds.)
5.1 Black locust: from global ecology to local management – a case study from the Czech Republic

Michaela Vítková, Jan Pergl and Jiří Sádlo

Introduction and the introduced range

Black locust (Robinia pseudoacacia L.; Figure 76) is a nitrogen fixing, deciduous tree species growing in open and light habitats, often cultivated and considered as invasive in many countries (Cierjacks et al. 2013). Its native range is the south-eastern part of North America where it occurs in two separate areas: an eastern population centred around the Appalachian Mountains ranging from Pennsylvania in the north to Alabama and Georgia in the south, and a western population present in parts of Missouri, Arkansas and Oklahoma (Fowells 1965). Black locust has been widely planted across the globe and it can now be found in most European countries (DAISIE; http://www.europe-aliens.org/) and also in temperate and subtropical parts of Asia, Africa, Australia and South America (e.g. Weber 2003, Dufour-Dror 2012). It has also been considered as naturalised throughout the northern part of the USA, southern Canada and northern Mexico (Huntley 1990). Although the native range of black locust has a humid temperate climate, it has been successfully introduced into a range of climatic zones including cold oceanic Patagonia, subtropical South Africa, and dry continental Turkey (e.g. Li et al. 2014).

Figure 76. Black locust (family Fabaceae) is one of the first tree species introduced to Europe from North America (photo: M. Vítková).
5.1 Black locust: from global ecology to local management – a case study from the Czech Republic

Black locust was introduced to Europe in the first half of 17th century as an ornamental tree species in gardens and parks (Ernyey 1927). Its economic potential was first recognised in the 18th century; it began to be planted for forestry purposes (Keresztesi 1988), which resulted in ‘black locust mania’. At the end of 19th century and beginning of the 20th century it was planted in sandy areas and dry deforested habitats that were formerly used as pastures. Such developments substantially changed the look and function of many areas where black locust had started to become dominant.

Black locust, a tree species native to North America, has been widely naturalised in many temperate and subtropical regions across the world; in the Czech Republic it currently covers 0.5% of the total forested area (14 087 ha).

Black locust currently occurs in many parts of the Czech Republic at altitudes below ca. 750 m. It is most commonly found in areas with warm climate below the altitudes of ca. 400 m (Figure 77). The species is distributed mainly in rocky valleys in central Bohemia (Figure 78) and western Moravia as well as in some sandy areas in Czech and Moravian lowlands. Black locust is also found in urban and industrial, including mining, areas. According to National Forest Inventory of the Czech Republic (2014), black locust forest stands cover 14 087 ha (0.5% of the total forested area) and contribute with 0.43% (54 790 m³, of which 93% was established by natural regeneration) to the annual timber production. The forest stands dominated by black locust were either artificially established or regenerated naturally between 1920 and 1940.

Figure 77. Distribution of black locust in the Czech Republic (green polygons are large-scale protected areas). The map was compiled from various sources such as Czech National Phytosociological Database (Chytrý and Rafajová 2003) and Nature Conservancy Central Register (AOPK CR).
Black locust is a controversial tree species as it has certain positive socio-economic, but also some negative environmental impacts. However, its economic benefits should not override the fact that it is considered as one of the 100 worst invasive species in Europe.

Figure 78. Many black locust stands occur on steep rocky slopes in river valleys. They were used for upgrade of slow-growing forests or less productive pastures threatened by soil erosion [photo: M. Vítková].

Species status

Black locust is listed in several European databases of invasive species as highly invasive (DAISIE 2006, CABI 2016 and NOBANIS 2016) and according to the DAISIE platform is considered as one of the 100 worst invasive species in Europe (DAISIE 2006). In addition, Richardson and Rejmánek (2011) included it in the list of 40 of the most invasive woody angiosperm species in the world. It has also been included in national ‘Black lists’ in e.g. Norway (Gederaas et al. 2012) and Switzerland (Info Flora 2012).

Although black locust is currently rated as invasive in the Czech Republic (Pyšek et al. 2012, Pergl et al. 2016a), it represents an example of a highly controversial species due to its positive socio-economic effects – e.g. timber and biomass production, beekeeping, ornamental purposes or soil restoration and stabilisation (Rédei et al. 2008), and its negative environmental effects on native vegetation (Vítková and Kolbek 2010). Simultaneously, it is a prominent invader having negative impacts on native vegetation. Therefore, an
optimal strategy for management of black locust should reflect its spatial and environmental context. The management approach should be based on a stratified approach which considers: (i) specific site conditions, (ii) decisions at a local scale, and (iii) existing environmental and cultural values.

Environmental aspects

In general, tree species have greater influence on the environmental conditions at a particular site than herbs due to their impact on light regime, litter decomposition and water availability (Richardson and Rejmánek 2011). Black locust is a light-demanding pioneer species that can substantially, and rather quickly, change the habitats which it invades. At sites where it becomes dominant causes a vegetation change towards ruderal and nitrophilous species. Since it is rather short-lived and less competitive in later successional stages, it does not commonly occur in abundance in mature mixed forests. Although black locust tolerates extremely diverse soil properties, it prefers well aerated and drained soils, and it does not grow well on compacted and frequently water-logged soils (Vítková et al. 2015).

Black locust is light demanding, nitrogen fixing pioneer tree species able to tolerate diverse soil properties; its presence in habitats may cause vegetation change towards ruderal and nitrophilous species.

In Europe, black locust occurs in a variety of habitats; e.g. in natural open land, woodlands, ruderal or urban habitats, forests and plantations for biomass production. Habitats most prone to black locust invasion are dry grasslands or shrublands on rocky and sandy soils. However, mesic forest vegetation or even riparian forests are often invaded in Mediterranean Europe (Motta et al. 2009). In the Czech Republic, black locust is considered highly invasive in xeric to mesic and semi-open habitats such as ruderal or shrub vegetation as well as in dry grasslands and forests with a light canopy such as dry thermophilous or acidophilous oak forests, relict pine forests, maple forests on scree slopes, or disturbed stands of oak-hornbeam (Quercus petraea-Carpinus betulus) forests.

Habitats that are generally resistant to black locust invasion include: (i) areas with poorly aerated soils (e.g. gleysols), (ii) intensively managed sites where the vegetation is permanently disturbed (e.g. trampled sites, mown lawns and meadows or arable fields), (iii) dense forests with competitive shade tolerant tree species such as European beech (Fagus sylvatica L.) and (iv) mountain and subalpine areas.

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It is important to note that when black locust is planted in a mixture with other species, it quickly reaches the upper layer of the canopy. Other tree species mostly survive in its presence and occur in an intimate mixture with black locust; this applies to both native species...
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(e.g. oaks – *Quercus* spp.; elms – *Ulmus* spp.; and hornbeam – *Carpinus betulus* L.) as well as introduced tree species (e.g. ash-leaved maple – *Acer negundo* L.; tree of heaven – *Ailanthus altissima* (Miller) Swingle). In old stands, where black locust dominates, seed germination of shade intolerant species (e.g. oak and silver birch – *Betula pendula* Roth) and species which are intolerant to higher nitrogen levels (e.g. beech and conifers) is not successful. However, some shade tolerant tree species (e.g. maples – *Acer* spp., ash – *Fraxinus* spp., and elm) and on steep slopes drought tolerant shrubs such as hawthorn (*Crataegus* spp.), blackthorn (*Prunus spinosa* L.) and wild rose (*Rosa* spp.) will regenerate and are able to replace black locust (Vítková 2014).

Although black locust regenerates mainly through re-sprouting from root and stem suckers, reproduction from seeds is crucial for long-distance dispersal and colonisation of remote sites. Black locust is insect pollinated with pods containing seeds with highly impermeable seed coat resulting in low germination rate but long viability in the seed bank (Roberts and Carpenter 1983). Black locust seedlings are sensitive to shading, which means that seedling mortality is high in forests with closed canopies or in habitats where there is a dense ground vegetation. Black locust has the ability to create clonal stands due to its connective root system which may grow by up to 1 m per year (Kowarik 1996). The suckers grow faster and reach reproduction maturity earlier than seedlings (Vítková and Kolbek 2010). It is also important to note that mechanical damage to the stem or to the root system leads to an increase in the number of ramets, which consequently results in an increase in stem density and creation of a compact clonal colony which may cover hundreds of square meters (Chang et al. 1998).

*Figure 79.* The ground vegetation in black locust stands is most often dominated by nitrophytes, such as nettles, goosegrass and elder and occurs on mesic sites with deeper soils on alkaline bedrock (photo: M. Vítková).
According to laboratory experiments, black locust shows strong allelopathic effects on two edible crops and two weeds (Nasir et al., 2005). Its impact on germination of seed bank under nature conditions have yet to be tested. Vegetation change towards ruderal and nitrophilous species in the presence of black locust is caused by the changes in the availability of soil nutrients rather than allelopathy (Vítková and Kolbek, 2010).

Black locust is able to fix atmospheric nitrogen through symbiotic *Rhizobium* bacteria occurring in its root nodules (Batzli et al., 1992); since the litterfall of black locust is low and its decomposition takes a long time due to the high lignin content (Castro-Díez et al., 2012, Vítková et al., 2015), nitrogen fixation represents the key input in the nitrogen cycle in black locust stands (Liu and Deng, 1991). In soils with a favourable moisture regime, soil nitrogen pool increases, nitrification and net nitrogen mineralisation rates rise and available mineral forms of soil nitrogen tend to accumulate in the A-horizon (Van Miegroet and Cole, 1984, Montagnini et al., 1991). Such changes of soil nitrogen support expansion of nitrophilous plants in herb and shrub layers such as nettle (*Urtica dioica* L.), goosegrass (*Galium aparine* L.), greater celandine (*Chelidonium majus* L.), cow parsley (*Anthriscus sylvestris* L.) Hoffm., garlic mustard (*Alliaria petiolata* M.Bieb.) Cavara & Grande), and elder (*Sambucus nigra* L.) (Vítková and Kolbek, 2010; Figure 79). In drier habitats, the ground vegetation tends to be dominated by perennial grasses such as false oat grass (*Arrhenatherum elatius* L.) P.Beaup. ex J.Presl & C.Presl.), sterile brome (*Bromus sterilis* L.), bush grass (*Calamagrostis epigejos* (L.) Roth), and nitrophilous plants occur on suitable microsites with organic matter deposition. Where black locust has become established it has mostly replaced native and species-rich vegetation including oak or hornbeam forests and dry or mesophilous grasslands. Both grasslands and some forest communities have relict origins; however, they were sustained, modified and spread by human management since the Holocene climatic optimum (Pokorný et al., 2015).

In general, black locust stands have plenty of light reaching the forest floor over the whole vegetation period as the foliage holds for a relatively short period of time; i.e. the leaves appear late in spring (May) and begin to fall rather early, usually during summer droughts (August). High light levels reaching the forest floor enable the survival of local light demanding species in the herb layer or dense shrub layer.

Although it is clear that black locust has negative and irreversible environmental impacts where it becomes dominant, it should be noted that there are some positive effects on biodiversity. It provides habitat for some rare and endangered species of plants such as rare ruderal plants, for example burr chervil (*Anthriscus caucalis* M. Bieb.) or geophytes from...
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the genera *Gagea, Muscari* and *Allium*, saprophytic fungi (e.g. *Crepidotus luteolus* Lambotte Sacc., *Geastrum rufescens* Pers.: Pers., *Leptota griseovirens* Maire), or invertebrates (mainly saprophagous beetles, e.g. *Anommatus reitteri* Ganglbauer) (Vítková and Kolbek 2010, Sliusarczyk 2012, Stejskal and Vávra 2013). In species-poor landscapes dominated by agricultural production, black locust stands preserve biodiversity and play a significant role as migration corridors for woodland animals. Their dense undergrowth of shrubs and complex canopy structure provide nesting opportunities and a food source for many bird species. In addition, Hanzelka and Reif (2015a) observed higher bird abundance in black locust stands than in native oak; however, it was further reported that habitat specialists dominated in oak forests in comparison to habitat generalists (Hanzelka and Reif 2015b). In derelict urban areas, Buchholz et al. (2015) demonstrated that black locust invasion does not decrease the diversity or the number of endangered species and diversity of carabid beetles and spiders.

*Black locust preserves biodiversity in species-poor agricultural landscapes and urban environments where it provides habitat for some rare and endangered species as well as nesting opportunities and a food source for birds.*

**Economic aspects**

Black locust is an economically important species in several countries as it is commonly used as a source of fast growing and long-lasting quality timber that is resistant to insects and fungi (Keresztesi 1988). Due to its exotic appearance, lack of serious natural enemies in the invaded range, fast growth and high production of nectar, it is commonly planted not only for timber production, but also for firewood, erosion control, amelioration and reclamation of disturbed sites, as well as for honey production, animal forage and as an ornamental tree (Göhre 1952, Cierjacks et al. 2013). Until now, it has been planted widely in cities due to its high tolerance of air pollution, salinity and dry or infertile soils (Hillier and Lancaster 2014). Black locust has been planted for the purpose of biomass production in short-rotation energy plantations in Hungary, Germany, Greece, Italy, Poland, Slovakia, Austria, China and the United States (Rédei et al. 2010, Straker et al. 2015).

*Economic utilisation of black locust has different priorities across the European continent.*

In some countries (e.g. Hungary, Germany, Poland), more emphasis is placed on the economic benefits such as timber, biomass and honey production while in the other countries (e.g. Czech Republic, Switzerland, Great Britain), the interest of nature conservation resulting in restrictions on planting of black locust except for gardens and urban areas prevails.

In the Czech Republic, black locust has been planted mostly for protective purposes such as soil stabilisation and reforestation of bare, sandy or rocky areas as well as a fire-barrier along railways (Figure 78), or during mine reclamation. Nowadays, black locust is
only planted in gardens and urban environment and new plantations are not being estab-
lished due to its negative impacts. Management of existing stands dominated by black
locust often aims to replace black locust with other vegetation types, especially in pro-
tected areas.

Management of black locust

Since this species causes conflict among different stakeholder groups (e.g. nature protec-
tion, forestry, urban landscaping, public), integrated action plans towards management
of the existing populations of black locust should be developed where economic and
biodiversity aspects should be taken into an account (Pergl et al. 2016a,b). Therefore, site
specific approaches where black locust is tolerated in selected areas, but strictly eradi-
cated in other, especially valuable sites, is considered the best option. Several practical
scenarios demonstrate some of the management approaches that may be use in areas
where black locust dominates:

The best approach in black locust stands seems to be based on stratified
management tolerating black locust in selected areas and strictly eradicating it
from naturally valuable habitats.

Abandoned plantations. Although it can take a long time, old black locust stands and
scattered black locust trees in forests are naturally replaced during succession by more
competitive trees. Black locust will disappear from the community by shade tolerant trees
over 70 years. Succession without any management can be selected only when we are
able to fulfil two conditions: (i) competitive shade tolerant trees must already be present
in the understory or in the near neighbourhood – e.g. ash (Fraxinus excelsior L.), sycamore
(Acer pseudoplatanus L.), Norway maple (A. platanoides L.), field maple (A. campestre L.),
or in dry sites tall shrubs such as hawthorn (Crataegus monogyna Jacq.); and (ii) in order to
eliminate the risk to biodiversity and human infrastructure, there should be no adjacent
high conservation value sites, traffic corridors or built-up sites. It is important to avoid any
disturbance such as felling broken or dead trees otherwise the black locust stand will
regenerate.

Plantations with regular forestry management. Black locust plantations can be
tolerated but its spread in the surroundings should be restricted. Such approach can be
applied in agricultural landscape where regular management such as ploughing or mov-
ing prevents vegetative spread and survival of seedlings. Care has to be taken in the case
where black locust stands are in contact with fallow land, grasslands or semi-natural
habitats with retaining local biodiversity such as rocky slopes in which young plants of
black locust should be regularly removed.

Intensive short-rotation biomass plantations under coppice management (com-
mon e.g. in Hungary) are a special case of forest plantations. Such areas are characterised
by the intensive growth of coppice shoots and suckers and when abandoned, their spon-
taneous conversion to native vegetation is very slow (Vasilopoulos et al. 2007, Radtke et
al. 2013).
Sites in vulnerable locations. In protected areas and sites prone to the black locust invasion such as open thermophilous forests and grasslands, eradication of black locust is recommended. Focus should be on black locust populations in the close vicinity of vulnerable sites. Rapid eradication is an extreme approach that has to be justified by needs of nature protection or by threats to infrastructure. It is connected with high financial costs and environmental risk (soil erosion, application of herbicides, and strong regeneration ability of black locust). Although there is no widely accepted and efficient method of eradication, a combination of mechanical and chemical approach is recommended as the most effective (Box 23). All black locust trees must be removed together since clones are connected by roots and single surviving stems can regenerate quickly. Subsequent targeted control of the regrowth from root and stem suckers and seedbank is necessary for at least 3–5 years. Where there is little or no natural regeneration, it is the time for artificial regeneration methods to ensure adequate regeneration of target replacement species. This usually does not occur earlier than the third year after felling of the black locust. If possible, usage of shade tolerant species is the best option.

Semi-spontaneous stands in urban or mining sites. This category contains heterogeneous set of stands, that may originate from planting or spontaneous natural regeneration, and may differ in structure (closed forest vs. semi-open stands), and composition (share of native and introduced species). For such stands local context needs to be taken into account for appropriate management. Black locust should be locally eradicated in cases where high conservation value sites are threatened by invasion.

Isolated black locust trees. Solitary or alley of trees occurring along roads have often been planted at memorial sites, e.g. near chapels or roadside crosses. There is usually no reason to remove these trees, especially in cities or if proper management of neighbouring sites is applied.

Social aspects

The attitudes towards the management of black locust differ fundamentally among different groups of researchers, land managers and policy-makers in Europe as they perceive its impacts differently. In some European countries (e.g. Hungary, Slovakia and Germany), black locust is considered mainly for its benefits and is removed only from highly valuable habitats, whereas in other countries, it is listed on local list of dangerous invasive alien species (IAS) with a ban on introduction and planting (e.g. Spain and Great Britain). Such controversy in the perceptions towards black locust resulted in the species being absent from the black list of IAS of EU concern (for more details, please see Chapter 3.2.).

In the Czech Republic, black locust is a popular tree species as it is a part of cultural and historic heritage. It is mentioned in songs, poems and recipes. Possibility of large-scale eradication thus causes unease among beekeepers as well as others benefiting from the advantages black locust provide. The significance of black locust in terms of providing jobs in forestry, facilitating for honey production or delivering positive landscaping values has to be taken into account; it should not, however, override the needs for nature protection at high conservation value sites.
Although there is a lack of agreement on the management of black locust in many European countries, large scale eradication is not considered to be a suitable management. Instead, an integrated and site-specific management strategy seems to be an appropriate approach. The current ambivalent public opinion to the occurrence of black locust and its management is the result of centuries of experience with the species, where enthusiasm related to its use in forestry and other purposes is contrasted with its rejection due to e.g. its negative effect on biodiversity, or the potential threat as a vector of pests such as the European fruit Lecanium (Parthenolecanium corni Bouché; Kolbek et al. 2004).

**Conclusion**

In spite of the varied economic benefits that black locust provides, it is an invasive species with serious implications for nature conservation. The traits supporting black locust cultivation such as vitality, exceptional sprouting ability, rapid growth, abundant production of seeds, or nitrogen fixation complicate its removal from sites of high conservation value. The attitude to black locust is diverse among different stakeholder groups with the perceptions towards this species varying regionally. Since individual stands differ in their economic value and environmental benefit or risk, the site-specific management approach appears to be the best attitude that can be applied to most of introduced tree species also including black locust (Pergl et al. 2016a,b).
Black locust is a tree species with negative environmental impacts comparable to that of species such as knotweeds (*Fallopia* spp., please see Chapter 3.8. for details) or giant hogweed (*Heracleum mantegazzianum* Sommier & Levier) (Hejda et al. 2009) and therefore its management has to be carefully planned (Pergl et al. 2016b). A site-specific approach to management of black locust may be more appropriate, rather than large-scale eradication programmes as may be suitable for other species. For many decades, this species has been a part of the European environment and the complete eradication is thus highly unlikely. In addition, in areas intensively managed for agriculture where the risk of further spread is rather low, black locust presence increases the diversity in the landscape matrix and provides shelter for many organisms. Co-existence of black locust, people and nature thus can in some areas create sustainable system persisting for many decades.

**Box 23. black locust control**

For a rapid eradication of black locust from a site, removal of trees by cutting (at high or low stump) followed by immediate application of herbicide is the best choice. For removal of single black locust trees or stepwise canopy opening, killing the standing main trunk gradually over a period of several years may be preferred. A common method is girdling, i.e. removal of the outer bark (down to the phloem layer) around the entire circumference of the stem. Since this method does not prevent sucker formation below the girdle on the stem (Figure 80), Böcker and Dirk (2008) recommended incomplete girdling. In the first year a strip of bark about 5 cm wide is removed from about 9/10 of the trunk circumference; if possible, the strip should be cut into the xylem, and preferably during winter season. In the second year, the strip is completed. When the tree has fully dried up (usually in the third year), it can be felled. An efficient method is based on a combination of cutting or girdling, application of herbicides, eliminating the root and stem suckers by foliar spraying of diluted herbicide and long-term grazing by goats to control re-sprouting. The best period for application of herbicides is the end of vegetation season (second half of August and September), when assimilates are translocated to the roots (Vítková 2014).

**References**


