

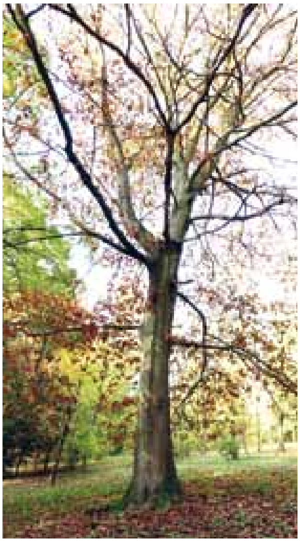

Silvicultural, production and environmental

POTENTIAL OF THE MAIN INTRODUCED TREE SPECIES

in the Czech Republic

Vilém Podrázský
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(editors)

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SILVICULTURAL, PRODUCTION AND ENVIRONMENTAL POTENTIAL OF THE MAIN INTRODUCED TREE SPECIES IN THE CZECH REPUBLIC

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6.

Black locust (*Robinia pseudoacacia* L.)

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Abstract

The chapter summarises the existing knowledge on black locust (Robinia pseudoacacia L.) with the focus on Central Europe and Czech Republic. General characteristics of the species are described. The origin and introduction pathways of black locust to Europe and across the continent are discussed. Attention is paid to the invasiveness of this species. In the Czech Republic, black locust is not included in the conventional forestry schemes because of environmental hazards related to its invasive disposition. However, black locust could play a significant role, e.g. in energy plantations, short rotation production plantations (lignicultures) or in urban greenery. In the European Union, there are countries like Hungary and Romania, where black locust represents an integral and important part of forestry. On the other hand, in numerous cases, strict control and/or eradication of black locust is of crucial importance.

Keywords: invasive species; introduction; neophyte; hazard to nature conservation; benefits of black locust; black locust control

6.1 Introduction and use in the Czech Republic

The area of natural occurrence of black locust is probably the Appalachian Mountains and the highlands of Ozark and Ouachita between Missouri, Arkansas and Oklahoma (Fig. 6.1a, 6.1b). Human activity helped black locust gradually spread over most of the United States and partly Canada, so it is more frequent now in the eastern part of the continent (Cierjacks et al. 2013). Black locust natural area has a rather humid climate, with average annual precipitation ranging from about 1,000–1,800 mm, with average annual precipitation in the form of snow ranging from 50 mm to 150 mm (Huntley 1990). In the Appalachian Mountains, black locust naturally climbs to a height of 1,620 m a.s.l., with the majority of population at about 1,000–1,200 m a.s.l. (McAllister 1971), where it shares the habitat e.g. with Northern red oak (*Quercus rubra* L.).

Cultivation outside its natural range

Black locust is the most commonly used non-native tree species on the European continent, where it occupies an area of about 2.3 million ha (Brus

Fig. 6.1a: Original natural range of black locust in North America (modified to Huntley 1990) (source: https://www.sciencebase.gov/catalog/item/5287e027e4b03b89f6f1ac97)

in Nicolescu et al. 2018). Very likely there were more pathways through which black locust came to Europe. Therefore, we have diverse information about its European introduction. Presumably, black locust seed was first introduced to Europe in 1601 (Tokarska-Guzik 2005) or perhaps 1603 (Kolbek et al. 2004). Black locust seed, imported from North America, was cultivated in France by Jean Robin (1550–1629), gardener and botanist at the court of the French kings George III, George IV and Louis XIII. His son Vespasian took over black locust cultivation after Jean Robin. Jean and Vespasian refer to the generic name of the black locust in Carl von Linné's nomenclature. But France was probably not the first European country to have North American black locust seeds imported. On the basis of historical sources, Hungarian polyhistor Ernyey (1927) cast doubt upon that Jean or Vespasian Robin directly participated in the introduction of black locust to Europe from North America. According to Ernyey, it is more likely that black locust was imported to Europe by the Spanish, the English or the Portuguese, and that black locust probably came later to Vespasian Robin (after 1640). Ernyey argues that the current black locust population in Europe does not come from one place and one tree. A later study (Peabody 1982) suggests that black locust reproduction material probably arrived in Great Britain first, and, later, got from there to France, probably after 1630.

In Central Europe, the first mention of black locust comes from Germany, specifically from Berlin in 1672 (Vítková et al. 2017). The period of the first introduction to Bohemia and Hungary dates from 1710 to 1720 (Keresztesi 1983). Among other Central European countries, black locust was first mentioned in 1720 in Slovakia, 1800 in Switzerland and 1806 in Poland.

Initially, black locust was an ornamental tree species in parks and alleys along the roads. Soon, it was also used in afforestation, particularly in Germany before 1700 (Kolbek et al. 2004). Black locust was subsequently introduced to forest cultures in other countries: Hungary in 1750, Czech Republic 1760, Slovakia 1769, Germany 1787, Switzerland ca 1850, Slovenia 1858 and Poland 1860 (Vítková et al. 2017). Records on the use of black locust in Bohemia are summarized in Nožička (1957), who finds evidence of black locust cultivation around Křivoklát since 1785, Červený Hrádek (1795), Drhovel, Písek (1800), Židlochovice (1802) and Valdice Game Preserve near Jičín (1803).

During the XVIII and XIX centuries black locust became a very popular tree species. Besides Europe, it has been grown in other parts of the world (Kolbek et al. 2004). In addition to its natural range, black locusts now grows in most European countries, from Portugal to the Caucasus and Sicily to southern Norway (Sitzia et al. 2016b). We can find it also in the subtropical and temperate belt of Asia, Africa, Australia and South America (Li et al. 2014). In Europe and Asia (except China, where black locust is also frequently used), black locust stands increased from 337 thousand ha in the 1960s and 1970s to 1,890 thousand ha. Attention was also paid to the use of black locust in South Korea (Keresztesi 1983).

Of the European countries, Hungary has the largest population of black locust. The area of its stands reaches about 465 thousand ha, average rotation is 31 years and average stock of mature stands is 190 $m^3.ha^{-1}$. Black locust stands thus account for 24% of the total forest area and stand for approximately 25% of the total harvest (Rédei et al. 2017).

Other European countries with a significant area of black locust stands include Ukraine (423 thousand hectares), Italy (377 thousand hectares), Romania (250 thousand hectares), France (191 thousand hectares), Serbia (191 thousand hectares) and Bulgaria (151 thousand ha) (Nicolescu et al. 2018).

Fig. 6.1b: Habitus, fruits, seeds, foliage and twigs of black locust (photo: V. Bažant)

Cultivation in the Czech lands

In Hungary, Austria and Poland, black locust stands were predominantly established on flat terrain, while in the Czech lands they were often planted on steep slopes around rivers, abandoned pastures and erosion-endangered land to protect the site against erosion and to help regenerate shallow damaged soil. The black locust stands in the mid and lower Vltava valley serve as a good example. In Prague and its surroundings, black locust stands were also expected to increase the aesthetic value of the landscape, while around the town of Mělník and in the České středohoří highlands the stands also had a melliferous function (Kolbek et al. 2004). Black locusts were also grown near the vineyards (their durable wood was used for vineyard columns).

In 1978, in the entire Czechoslovakia, black locust was recorded on a reduced area of 28 thousand ha (Keresztesi 1983). At present, black locust occupies approximately 14 thousand ha (Podrázský et al. 2013; Vítková et al. 2016) which is approximately 0.52% of the whole stand area. The mean age of black locust stands was 66 years in 2018 and the average standing stock was 125 $m^3.ha^{-1}$ i. b. (Úhúl 2019). The low value of the stock is given by the extremity of the habitats where black locust was grown, preferentially. Black locust also occurs outside forest land. The real area of black locust is, therefore, higher.

At present, in the Czech Republic, new plantings of black locust can be encountered only as part of landscaping in urban areas of municipalities. New black locust forestry plantings are not performed nor planned, and in many places (e.g. in forests in the capital city of Prague) the black locust stands are gradually being converted to stands corresponding to the natural species composition.

6.2. Black locust production and site demands

In favourable conditions in Central Europe, black locust can reach a height of up to 35 m (Keresztesi 1983). Usually, even in their natural range, mature trees reach a height of only about 12–18 m (Huntley 1990). It grows rapidly especially at young age (Clark 1954; Boring, Swank 1984; Huntley 1990) but the increment soon begins to slow down. In America, this occurs at about the age of 30 (Huntley 1990). Spontaneously growing coppice stands can reach high densities and close canopy in 1 to 2 years (Nicolescu et al. 2019). In Hungary, the height increment in black locust culminates in the first five years and diameter increment in the first decade of the stand age. The current volume increment culminates at the age of about 20 years and the mean annual volume increment at the age of 35–40 years (Rédei et al. 2011).

Black locust usually forms a rather shallow but very rich root system. The shape and dimensions of the root system are generally determined by the features of the habitat and the depth of soil at the site. On sufficiently deep soils, black locust has a heart-shaped root system where the length of the lateral and diagonal roots is usually comparable to the depth of the root system (Anonymous 1980). Sometimes, however, the root system can extend to a considerable distance from the parent tree, up to about 1.5 times the height of the tree (Cutler in Huntley 1990). The roots are able to penetrate to a greater depth, more than 8 m (Bunger, Thomson in Ranney et al. 1990) which is one of the ways to endure drought (Ranney et al. 1990). However, this mechanism is difficult to apply if the tree grows on shallow soils covering rocky subsoil without enough cracks, and this may be a topical issue in many stands in the Czech Republic.

On degraded chernozems or brown-earth soils in southern Slovakia, black locust forms plastic root systems without main or tap roots. The roots reach a depth of up to about 3 m and a horizontal length of up to 19 m. The highest volume of underground biomass was in the 27-year-old stand with stand density of 0.8 to 0.9 (1,100 trees per hectare); the amount of dry matter reached approximately 34 $t.ha^{-1}$ (Benčať 1988).

Black locust is able to grow on soils of various chemical composition. It can withstand an active soil reaction (pH/H_2O) ranging from 3.2 to 8.8 and a 30–100% range of the sorption complex saturation with bases. However, it requires sufficiently aerated soils and does not tolerate heavy compacted substrates and permanent soil-profile waterlogging (Vítková et al. 2015).

Black locust is able to bind air nitrogen via soil symbiotic bacteria. Acquisition rates of air nitrogen range from 23 to 300 $kg.ha^{-1}.year^{-1}$ (DeGomez, Wagner 2001; Cierjacks et al. 2013).

6.3 Black locust silviculture

Methods of propagation, seed production and nursery practice

In Hungary and Romania, locusts are most often propagated by seeds and, vegetatively, by root cuttings obtained from mother plants (Keresztesi 1983; Rédei et al. 2011), or grafting (Nicolescu et al. 2018). Vegetative propagation is used in elite trees and cultivars (Rédei et al. 2011). In vegetative propagation from roots, ca 10 cm long root cuttings or short segments of roots are used (Keresztesi 1983; Rédei et al. 2001). The root cuttings (8–10 cm) are placed vertically at 80 × 10 cm spacing so that the upper section of the cutting is about 1 cm below the soil surface, to avoid its exposure after initial irrigation. When using short root segments (3–5 cm), planting takes place in approx. 10 cm wide and ca. 4 cm deep furrows (Rédei et al. 2001).

Black locust usually begins to produce seed around the age of six and seed years repeat every other year, often annually (Olson 1974; Nicolescu et al. 2018). Black locust seed germinates epigeically and, for generative propagation, is obtained manually by peeling the pods (Olson, Karrfalt 2008), with germination rate of up to 30% (Huntley 1990; Hoffmann et al. 2007). Seeds can also be collected mechanically by sieving overlying humus and soil (Nicolescu et al. 2018; Rédei et al. 2001, 2011). This way, though, we get seed of different age. However, this drawback is compensated for by the relatively long seed life – ten years or more (Nicolescu et al. 2018).

The number of seeds in 1 kg of pure seed is ca. 50 thousand pcs, the yield is generally up to 25 thousand seedlings from 1 kg of seed (Olson 1974; Huntley 1990; Hoffmann et al. 2007). Dormancy of black locust seeds is solely due to the impermeability of the seed coat (Olson, Karrfalt 2008). Although there are sophisticated procedures of dormancy breaking (Jastrzębowski et al. 2017), three pre-sowing methods are mostly used: scarification of seed, maceration in sulfuric acid and soaking the seed in hot water.

Concentrated acid is applied at a dose of 720 ml per 4.5 kg of seed and allowed to act for 10–90 minutes. It is desirable to test specific times first on a sample from a particular compartment; generally, larger seeds macerate for a shorter time. The seed is then removed and thoroughly washed in running water (Olson, Karrfalt 2008). In the case of soaking in hot water, the seed is poured into boiling water, allowed to cool slowly and then left in the water for at least 9 hours (Olson, Karrfalt 2008). Thus, germination rate can be increased from the initial 10% to more than 70%, and even more in the case of mechanical scarification (Carl et al. 2019).

Seeds are sown in strips about 5–8 cm wide and 3 cm deep, up to 50 pieces of fully germinable seeds per 1 meter of line, the strips being at least 35 cm apart (Rédei et al. 2001). It can also be sown in rows approximately 15 to 20 cm apart, at a dose of 65 to 100 seeds per 1-meter row (Olson, Karrfalt 2008). A slightly higher sowing rate (150 pieces per 1 m) was reported by Mattoon (1941). The recommended layer of the backfill (preferably a mixture of sand and matured sawdust) is 6–7 mm (Mattoon 1941; Olson, Karrfalt 2008).

Black locust prefers sandy-loamy to loamy soils with weak acid to neutral reaction (Rédei et al. 2001). On one hectare of production area, it is possible to grow about 200 to 250 thousand 40–90 cm high seedlings with 5–12 mm wide root collar. (Richardson, Rejmánek 2011).

Establishment of plantations

Currently, black locust is cultivated in Central Europe, especially in Hungary, as an important part of local production forests. Even there we register opinions pointing out risks of black locust cultivation (Bartha et al. 2008), but the Hungarians generally perceive black locust as their unofficial national tree (Vítková et al. 2017) and count on its intensive use in the future. During the following 50 years, according to initial estimates, afforestation of approx. 720 thousand ha of agricultural land is expected in Hungary. About a third of this area will be afforested by black locust (Nicolescu et al. 2018).

In the past, they used 10,000 black locust seedlings per 1 ha at a 1 × 1 m spacing. The use of large seedlings (rooted cuttings) allowed the numbers to be reduced to 4,000 pcs.ha^{-1} (Keresztesi 1983; Rédei et al. 2017). In Romania, 4,000–5,000 seedlings are planted per ha (Nicolescu et al. 2018). The optimal density in terms of increment and production is at a 1.6 × 1 m spacing, i.e. 6,000 pcs.ha^{-1} (Rédei et al. 2009).

When establishing black locust plantations for power industry use, higher density and shorter rotation are considered (e.g. Anderson et al. 1983). Specifically, in a 5-year-old stand, a 1.5 × 0.3 m pattern, in a low-precipitation area in Hungary, the biomass stock (dry matter) reached 32 t.ha^{-1} (Rédei 1999). Even higher production and earlier increment culmination can be achieved in a more humid habitat. The rotation period of coppice stands planted for power industry use should be at least 5 years (Rédei et al. 2011) because a shorter rotation increases, inter alia, the risk of damage to the stands by biotic pests (Rédei 1999; Rédei et al. 2010). Experiments in North America (Bongarten et al. 1992) showed that black locust plantations can be cultivated also at lower density (optimally at a 2.4 × 1.2 m pattern), facilitating mechanized harvest. Furthermore, the study shows a significantly beneficial effect of irrigation on the increment, but only a partial benefit of artificial fertilization.

Tending and regeneration

Black locust is usually cultivated in pure stands. In Hungary, on sandy soils between the Danube and Tisza, mixed forests can also be found, where black locust grows most often in a mixture with white poplar (Rédei et al. 2006), black pine (*Pinus nigra*) and Scots pine (*Pinus sylvestris*) (Keresztesi 1980). In northwestern Romania, black locust is locally cultivated with (invasive) wild black cherry (*Prunus serotina*) on degraded sandy soils (Nicolescu et al. 2018). The mixture of white poplar with black locust usually shows higher increments than pure stands (Rédei et al. 2006), similarly as in the case of admixed black locust to pine stands, where enhanced growth and health of pines was registered, probably related to soil-improving effect supporting humus mineralization and revitalization of nutrient cycles in otherwise slowly decomposing sufrace humus of pine (Keresztesi 1980).

Black locust stands at common forest spacings in Central Europe can respond flexibly to tending interventions up to the age of 10 and 15 years, and quickly close the opening of the canopy after interventions (Rédei et al. 2008; Rédei et al. 2015). Purposeful tending makes sense especially in areas where black locust is not damaged by late frosts and therefore forms straight high quality stems.

On high and medium soil-quality sites, cleaning and thinning is recommended to be taken in two steps. The first cleaning, at a mean stand height of 6 to 7 m (between 5th and 8th year), should reduce the initial number of stems (3,500 pcs.ha^{-1}) to 2,500 or 2,700 pcs.ha^{-1}. During the second cleaning (mean height 11 to 12 m, age 9 to 13 years) the number of stems is reduced to 1,500 or 1,600 pcs.ha^{-1}. The first thinning should be performed at 14–19 years of age at a mean stand height of 15–16 m and the number of stems is reduced to 800 pcs.ha^{-1} on better soil-quality sites, and to about 1,000 pcs in the case of worse soil quality. The second thinning is performed only in better and medium soil-quality stands at the age of 22–24 at a mean stand height of 21–22 m and the density at the best soil-quality sites decreases to a target value of about 500 pcs.ha^{-1}, or to about 700 pcs.ha^{-1} on medium soil-quality sites. Immediately after thinning, selected (target, high quality) trees on better soil-quality sites should be pruned to a height of 4 to 6 m from the base of the stem. On the worst-quality soils, one or both thinnings are skipped, or, perhaps, their intensity significantly reduced, because a reduction in stand density on unfavourable sites does not lead to significantly higher diameter increments (Rédei et al. 2015).

In Romania, the recommended intensity of tending intervention is derived from the stand stock, or rather the stand volume before and after the tending intervention. During the tending intervention, 15–20% of the volume of wood mass that the forest had before the intervention should be extracted from the stand (Nicolescu et al. 2018).

In black locust plantations, regeneration felling takes place much earlier than in other tree species stands. In stands on high quality soils – with the lowest number of stems (reduced by previous intensive tending) – rotation felling is recommended between the ages of 35 and 40. On medium-quality soil sites, rotation felling should start at 30 and, on low-quality soils, at about 20 to 25 years of age. Black locust is able to produce sawmill assortments with 25 cm dbh at the age of 25 on the best-quality soils, while the worse quality soils show lower diameters (Rédei et al. 2015).

6.4 Health, stability and harmful agents

Biotic agents

Black locust in Central Europe is known for its considerable resistance, due, among other things, to the absence of various pests or a milder course of attack. Nevertheless, there are organisms that can negatively affect its vitality. Black locust seed collected on the territory of Prague has been reported to be parasitized with *Eurytoma caraganae* (Kuneš et al. 2019). Black locust seeds are also damaged by pulse pod borer both (*Etiella zinckenella* Treitschke), (e.g. Georgevits 1981; Kulfan 2012). Black locust seedlings can be infected with *Alternaria alternata* (Fr.) Keissl. or *Fusarium oxysporum* Schlechtendahl. Young shoots and leaves are attacked by European fruit lecanium (*Parthenoclanium corni* Bouché), (Rédei et al. 2011). The leaves can be mined by introduced species such as *Phyllonorycter robiniella* Clemens, or *Parectopa* *robiniella* Clemens (Šefrová 2006). The leaves are attacked by the introduced locust gall midge (*Obolodiplosis robiniae* Haldeman) or black bean aphid (*Aphis fabae* Scopoli), (Skuhravá, Skuhravý 2004). Young black locust stands can be browsed by hares (*Lepus europaeus* L.), rabbits (*Oryctolagus cuniculus* L.) and cloven-hoofed game, especially roe deer (*Capreolus capreolus* L.) and red deer (*Cervus elaphus* L.), (Rédei et al. 2011). Black locust pests and diseases are currently of minimal economic importance, both with regard to non-calamitous distribution and with a general effort to eliminate black locust stands. In theory, however, their influence could become more important in the case of purposeful cultivation of black locust.

Ecological limits – abiotic factors

Where black locust is established in the areas of its secondary occurrence, it often behaves differently than in its native range, and often occupies habitats with a significantly different climate than its natural habitat. In Central Europe, not even precipitation is a limiting factor for black locust. Black locust is commonly found in areas with annual precipitation of between 400–800 mm and is characteristic of warmer areas with an average annual temperature of 6 to 11 °C.

In Central Europe, black locust distribution is determined by ecological limits, which include cold climate with shorter vegetation periods and late frosts. Black locust is able to survive late frosts, but they cause trunk malformations and low-grade tree shapes. Black locust does not tolerate heavy, non-aerated and waterlogged soils. Another limit is a long-term shade by the tree canopy. Black locust is sensitive to external disturbances (grazing, browsing – Vítková et al. 2017). On the contrary, it permeates unmanaged areas ("brownfields" in urban areas of municipalities, unused agricultural land etc.). Such habitats can be colonized and controlled by black locust for several decades (Sádlo et al. 2017). The occupied habitat can be modified by black locust by changing the soil chemistry (including availability of some nutrients), humidity and light conditions. This leads to creation of specific stands with a homogenized tree layer that differ significantly from the original or previous communities (Kowarik 1996).

6.5 Environmental effects

Impact on surrounding vegetation

In stands with predominating black locust, we often encounter a change in the ground vegetation (Kolbek et al. 2004; Vasilopoulos et al. 2007). Black locust is suspected of having allelopathic effects. For example, there are records of its ability to induce the formation of smaller leaves and the drying-out of shoots of birch (*Betula* sp.) and partly in beech (*Fagus* sp.), reduce the increment in elm (*Ulmus* sp.) and reduce photosynthesis intensity in pedunculate oak (*Quercus robur*) by its root chemical extracts (Bartha et al. 2008).

However, rather than allelopathic effects, the process of modifying black locust phytocoenoses in our conditions is probably caused mainly by unnatural enrichment of soil with nitrogen, acidification of the upper layers of the soil and increased leaching of soil bases (Berthold et al. 2009; Vítková 2014; Vítková et al. 2015). Increased nutrient depletion by black locust, whose higher requirements of phosphate, calcium and potassium has to be considered (Kolbek et al. 2004) as well as specific climate, shade (Vasilopoulos et al. 2007; Vítková 2014) and last but not least the tendency to dry out the upper soil layers (Kolbek et al. 2004), probably due to very intensive evapotranspiration exhibited by black locust (Bartha et al. 2008). Although the undergrowth may be relatively rich in species (about 20 to 45 species per 200 m^2), it is usually dominated by nitrophilous species such as barren brome (*Bromus sterilis*), goose grass (*Galium aparine*), common nettle (*Urtica dioica*), common ivy (*Hedera helix*) elderberry (*Sambucus nigra*), (Sádlo et al. 2017), and often blackberry (*Rubus frutricosus* agg.), (Kuneš et al. 2019). It is worth mentioning that in the northern deciduous forests of North America, where black locust is also not native, no differences in ground vegetation between black locust and native deciduous stands and minimal differences in soil chemistry were observed (Deneau 2013).

Distribution and invasiveness

Black locust is a pioneer species capable of colonizing poor and degraded soils, occurring in many localities and habitats, and that relates to its broad ecological valency against a number of habitat factors. Unlike in its native range, where black locust is limited by its light demanding nature (Trimble 1975) and vulnerability to certain insect pests and diseases (Huntley 1990), it is quite competitive in Central Europe and often creates more coherent groups or stands, supplanting some native woody and herbaceous species (Vítková, Kolbek 2010). Nevertheless, black locust retains its considerable light demandind nature in Europe as well (Wojda et al. 2015).

Black locust can reproduce both generatively and vegetatively. It is able to create a long-life seed bank in the soil. The seeds germinate when favourable conditions occur (Bartha et al. 2008). For example, in a fully stocked 115-year-old stand in Prague with 40% share of black locust in its species composition, we found 3.3 to 23 thousand seed per 1 m^2 in the upper 10 cm of the soil under the crown projections.

Vegetative propagation is done by stump (stem) and especially root suckers (Cierjacks et al. 2013). The spreading rate to the surroundings can be up to

1 m per year (Kowarik 1996). If the parent tree is felled, root suckers may appear up to 7 m from the stump (Trylč 2007).

Black locust is among 10 species of neophytes with the widest range of occupied habitats. On the European scale, it is ranked among the 100 most invasive non-native species (Vilà et al. 2009) and, worldwide, among the 40 most invasive woody angiosperms (Richardson, Rejmánek 2011; Vítková et al. 2017). Black locust also acts as an invasive species in some areas of America (especially in the eastern part). It colonizes path and road edges as well as open sites (Kerschner et al. 2008; Kurz, Hansen 2017). In Bohemia, the spread of black locust to surrounding ecosystems was documented in 1874 (Pyšek et al. 2012). However, it is possible that such invasive behaviour had occurred before.

In Central Europe, thermophilic grasslands, sand banks, shrubberies and azonal forest communities such as dwarf oak forests or relict pine forests are most endangered by black locust (Matus et al. 2003). Seedlings are very sensitive to shading. Thus, they can establish themselves on mechanically disturbed or bare soil or on burnt sites (Vítková 2014).

6.6 Black locust wood

Structure

Black locust is a deciduous wood species; in terms of the arrangement of vessels, it belongs to a group of hardwood ring-porous species. On the cross-section, we can identify two groups of vessels of different sizes. There are the large vessels (pores) of spring wood, visible to the naked eye, and the vessels of summer wood, below the line of visibility, but forming typical clusters, visible as fair dots in the summer wood (Fig. 6.2).

It is a heartwood species, the sapwood is very narrow in comparison to other tree species, approximately 1 cm wide, yellowish in colour. The heartwood diameter around the age of 40 makes above 90% of the total diameter of the stem. The proportion of heartwood in the stem is significantly more dependent on the age of the tree than on the richness of the habitat (Klisz et al. 2015). The heartwood is greenish-yellow, greenish to golden brown, later darkens to reddish brown when exposed to the air. The rings are clearly visible. The spring wood zone consists of 2 to 3 rows of visible pores. In addition, their visibility is enhanced by the presence of thyla (light vascular content) in the heartwood. Fair dots – clusters of summer vessels – are visible in the summer wood (Fig. 6.2 B). Medullary rays are only visible on a radial section. The wood is shiny, with no characteristic odour (Panshin, De Zeeuw 1980; Alden 1995; Wagenführ 2007).

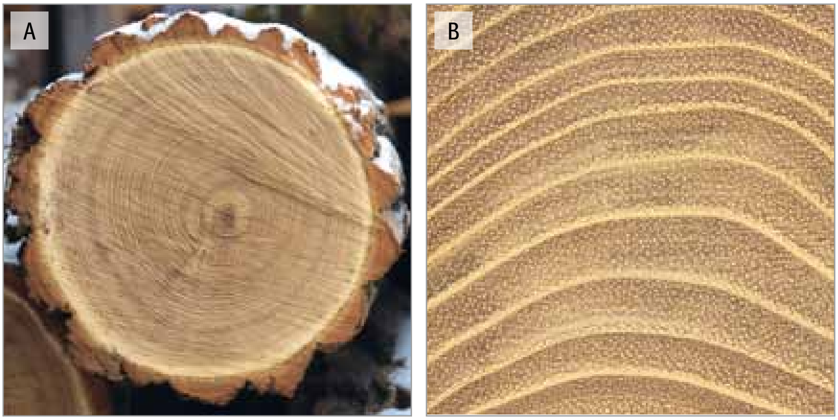

Fig. 6.2: Cross-section of black locust stem with the narrow sapwood (A), detail of the cross section (B) (photo: A.Zeidler)

Properties

Black locust wood is very heavy and very hard. It dries slowly, tends to tear and warp. It shows low shrinkage values and good dimensional stability. It is very resistant to rot (1–2 resistance class), weather conditions and insects, more than native tree species. Black locust is strong and is one of the hardest woods in its native range. Pre-drilling is required before driving in screws and nails. It is also characterized by high impact bending strength, similar to hickory wood (*Carya* spp.). The wood machines, cuts and turns well. Surfaces can be easily treated and lacquered. However, it glues and impregnates poorly. The wood defects include especially problematic twisting and crookedness of the stem. The wood is biologically active and contains extractive substances that may cause irritation in contact with skin (Panshin, De Zeeuw 1980; Alden 1995; Felner et al. 2007; Wagenführ 2007). Black locust wood is highly durable. The heartwood can last up to 1,500 years in a dry environment, up to 500 years immersed in water, and up to 80 years exposed to the outdoor environment (Pacyniak in Wojda et al. 2015). Black locust wood shows

Tab. 6.1: Selected physical and mechanical properties of black locust timber

	Units	Alden (1995)	Wagenführ (2007)	Fellner et al. (2007)
Density	kg·m^{-3}	769	770	761
Volumetric shrinkage	%	10.2	11.4 – 12.2	10.0 – 11.7
Compressive strength	MPa	70.3	72	73
Bending strength	MPa	133.8	136	150
Impact bending strength	J·cm^{-2}	-	14	-

Density and strength are set for 12% moisture content.

considerable calorific values, it heats more than beech and hornbeam. The calorific value of 3.3 m^3 of black locust wood is comparable to 1 tonne of fuel oil (Molnár, Németh 1983). A low water content in fresh wood (approx. 30%) allows it to be burned without prior drying (Wojda et al. 2015). Table 6.1 presents selected values of black locust wood by respective authors.

Use

It is not a commercially important wood in its native area. It is mainly used for fences, pit props, stakes, railway sleepers, crates, ship components, small items, dowels and pegs, or wherever high strength, hardness, dimensional stability and especially high durability are required. This is especially true in mountain areas, in contact with the ground, in water structures (e.g. mills) and ships. It can also be used to manufacture furniture, including the production of veneers, and parquet. It is also a source of high-quality fibre. Black locust firewood plantations are also reported (Panshin, De Zeeuw 1980; Burns, Honkala 1990; Alden 1995; Wagenführ 2007).

Comparison with native species

Black locust, similarly to Douglas fir, has no comparable representative of the genus *Robinia* in Europe. It is thus possible to compare black locust wood only with native species of similar wood structure and, above all, similar properties and areas of use. In the case of the Czech Republic, the only comparable, commercially important hardwood is oak.

Although the wood of these species differs in the appearance (colour, visibility of the medullary rays), the differences are not essential and confusion is possible in some areas of oak use. In terms of properties, both species are comparable. In some characteristics, such as the strength and hardness of wood, black locust exceeds oak. Black locust wood shows much higher durability and resistance to weathering and biotic agents. Table 6.2 compares selected properties of black locust wood and our native pedunculate oak.

Black locust is an introduced wood species that provides one of the most valuable woods in our region in all areas of interest. It meets the requirements of aesthetics, but above all it is hard and strong. Its durability in exterior is similar to – substantially more expensive – tropical woods. It can be seen as a substitute for oak, a substitute that surpasses this native tree species in many ways. In Hungary, black locust is one of the most economically important tree species with a wide range of uses, including the production of barrels, which are otherwise seen as the oak domain. Recently, black locust wood has been used for simple outdoor constructions in the CR (playground climbing frames, benches, waste bins and other items). Leaving aside the legislative (environmental) barriers, a wider use of black locust wood

Tab. 6.2: Comparison of selected wood properties of black locust and pedunculate oak

Units	Density kg.m^{-3}	Volumetric shrinkage %	Compression strength MPa	Bending strength MPa
Black locust	770	11.4 – 12.2	72	136
Pedunculate oak	690	12.6 – 15.6	61	88

Author: Wagenführ (2007). Density and strength properties are set for 12% moisture content.

is limited mainly by the crookedness of its stem, its twist and other irregularities of the stem shape.

In history, black locust wood was used for a variety of immensely interesting purposes. Native Americans used it to make bows, and therefore, presumably, black locust was one of the few tree species that was deliberately spread beyond its original range to the east coast of the North American continent to make its wood available for general use. Black locust wood was also used by the first English settlers in America for example as a construction material in the construction of Jamestown (the first permanent English settlement in North America). Black locust played an important role in the Second American War of Independence (1812–1815). In the Battle of Lake Champlain (1814), the Americans defeated the British and stopped the British advance on the mainland, which counted with the support of the fleet. In addition to the US Commodore MacDonagh masterly work, the defeat of the British was supported by the fact that oak dowels and pegs were used as fasteners in British ships and they broke under the cannonade more easily than more resilient dowels and pegs from black locust wood in American ships. Immediately after the end of the conflict, the British began to import black locust fastening items from America (Greene 2015).

6.7 Other use of black locust in forestry and outside forest

Black locust is a very tolerant tree species and can be used in urban greenery. It is also used as a solitary park tree and in urban alleys. It shows very good adaptability to drought (Moser et al. 2016) and a number of stresses typical of the urban environment. Despite the generally lower crown volume (in comparison to linden trees), black locust may have a larger crown projection area, which is more advantageous in terms of shielding (Bayer et al. 2018).

Invasive abilities of black locust, risky for natural and other valuable communities, may represent an advantage in artificial and natural remediation of anthropogenically altered habitats in industrial or urban environments (Kowarik 2011) or in revitalization of mining areas (Mantovani et al. 2015).

A purposeful use of black locust in reclamation requires significantly less plant protection products compared to other plants (Böhm et al. 2011). Black locust can thus complement native species in fulfilling a number of ecological functions (Kowarik 2011; Kowarik et al. 2013), even in a specific (extreme) urban environment (Kowarik 2005), where cultivation of many regionally indigenous tree species can be problematic. Prudent use of black locust (or directing its natural spread) in places far from valuable communities, facilitates the desired greening of some habitats, even promoting biodiversity. An example is the spontaneously grown stands of black locust and birch in an industrial area near the former Tempelhof Airport in Berlin, which is a valuable and protected example of urban and industrial nature now (Kowarik, Langer 2005), although black locust had a lower amount of native as well as non-native plant species in the undergrowth (Trentanovi et al. 2013).

Black locust is an important honey tree that contributes significantly to the production and export of high-quality honey in some countries (Keresztesi 1977; Farkas, Zajácz 2007; Samsonova et al. 1974) and is also used in medicine. The value of honey produced in black locust stands can reach up to half the value of wood production in the given conditions (Keresztesi 1977). Specifically, it can be up to 400 kg of honey per year from 1 ha of black locust stands (Vítková et al. 2017). Medicines with blossom extracts and fresh bark are indicated for headaches, gastrorrhagia (gastric wall bleeding) and gastritis. In folk medicine, black locust blossoms are used for treatment of high pressure, for soothing cough and treatment of gout (Bartha et al. 2008).

In the Czech Republic, a common forestry use of black locust for its considerable ecological risks is not anticipated yet, but there are situations where this species could be found useful, be it energy plantations, lignicultures, reclamations or urban greenery. Black locust can also be grown in stands surrounded by cultivated agricultural land that does not allow its spontaneous spread.

The advantages of black locust in terms of its possible use in Central Europe can be summarized as follows: fast growth and ability to resist forest weeds, ability to bind air nitrogen, high wood density and its good usability for fibre/timber processing, resistance to diseases and pests, ability to grow in poor habitats, resistance to air pollution, drought and high temperatures, photophily and high rate of pure photosynthesis, fast leaf growth, relatively good crown canopy permeability for light, ability to adapt foliage to light intensity, very plastic root system usually consisting of skeletal roots penetrating deeper and dense networks of fine roots at the soil surface, blossoming from a young age (important for beekeeping), frequent and abundant seed years, easy processability of seed material, good seed emergence rate and easy storage of seed, rapid seed germination, high genetic variability and ease of *in vitro* cultivation (Rédei et al. 2011).

6.8 Control and elimination of black locust

Prevention

In many economically attractive introduced species, it is their biological properties (undemanding cultivation, fast growth, good production and reproduction abilities, resistance etc.) that can, under certain circumstances, turn them into invasive species (Dodet, Collet 2012). Black locust has many useful properties, but is non-native in Europe and exhibits invasive behaviour in many habitats, which may endanger valuable communities (Vilà et al. 2009; Sitzia et al. 2016a). Problems with persistent invasive species may then outweigh their benefits for which they were cultivated.

Prevention is the most effective aspect of protecting the environment against (not only) black locust invasiveness (Leung et al. 2002). There is ample experience with black locust, so it is possible to apply a differentiated approach with respect to a specific environment (Sádlo et al. 2017). In the Czech Republic, the most vulnerable habitats to black locust are mainly relict pine forests, dwarf oak forests and xerothermic herb communities (Vítková 2014). Any use of black locust should be excluded in the vicinity or close proximity of such habitats.

Biological methods

Where black locust is already in contact with habitats already affected by its invasive spread, or needs to be replaced for other reasons and prevented from regeneration, measures must be taken to eradicate it. There are several methods and procedures for the eradication of black locust, but no method proved successful on a one-shot basis. The sites have to be inspected repeatedly and spontaneous regeneration of black locust regularly eliminated. In principle, these processes include mechanical, chemical and combined methods (Sabo 2000), or, possibly, physical and biological methods as well (Vítková 2011).

In non-forest habitats, sheep and especially goats can be recommended as a means of long-term follow-up after the intervention as they readily consume black locust root suckers. It is a biological method. Simple felling or cutting must be avoided, as it is a counterproductive measure that, in turn, encourages the formation of root suckers, especially if appropriate aftercare is not ensured (Silva et al. 2014). Nor can the pulling of young trees be recommended, as it is usually not possible to pull the whole root system and the root segments that remain in the ground will immediately begin to send out suckers. Permanent elimination of the suckers purely by mechanical means after felling the black locust on a larger area is practically unaccomplishable. Even after many years of efforts to mechanically eliminate the young stems, black locust is able to shoot out of the stumps in one season and its root suckers are able to expand in the vicinity of the parent stump (Trylč 2007; Böcker, Dirk 2008).

Physical methods include burning of black locust stands, which, however, is not feasible in our conditions. Moreover, burning supports generative and vegetative propagation of black locust.

Mechanical methods

Thin trees (up to 5 cm in diameter) are felled approximately 10 to 15 cm above the ground and the stumps are subsequently split (Trylč 2007). "Plastic-bag" method can be used for individual adult trees. At the turn of spring and summer, the trees are felled on a tall tree stump (1 m), whose upper half is wrapped in a dark strong plastic bag. Suckers on the stump, enclosed in the dark bag, gradually wither from heat during the summer days, exhausting the root system. Surviving suckers under the wrapping usually do not manage to mature in the autumn and freeze during the winter (Veverková 2009). Both of these procedures are laborious and applicable only locally.

Of the mechanical procedures, only felling on high stumps and ring girdling are more widely applied. In the first case, the tree is felled to a tall tree stump (approx. 1 m), which then begins to shoot abundantly. The suckers are then eliminated during the subsequent tending. The formation of stump suckers limits the occurrence of root suckers (apical dominance theory) around the parent tree (Sterrett, Chappell 1967).

Ring girdling is an effective method of eliminating older trees in lower-density stands (Böcker, Dirk 2008). It consists in the mechanical interrupting of the bark and phloem by a saw or axe around the trunk at a height of about 1 m. The ring must be deep enough to penetrate to the heartwood and its width should be roughly the size of the palm. At first, a short "bridge" is left in the range of about 10% of the perimeter of the tree where the bark and cambium are preserved. The roots still try to supply the crown with priority, thereby reducing the formation of root suckers. The crown, however does not provide adequate nutrition to the roots, which significantly weakens the tree and gradually depletes it. The bridge is interrupted in the following year and any callus tissue is removed. Winter (February) proved to be the most effective in terms of limiting the formation of root suckers, both for the first (incomplete) girdling and subsequent removal of the bridge (Böcker, Dirk 2007). Ring girdled trees often do not die after the intervention, or they are able to form suckers despite weakening. As a rule, it is necessary to remove the suckers or repeat the girdling (Silva et al. 2014). A special type of ring girdling is the so-called spiralling, where a spiral is cut into the log by a chainsaw, at least once completely encircling the stem. However, the efficiency of this method is usually lower (Böcker, Dirk 2007; Veverková 2009). Ring girdling is a simple, ecological and undemanding method. However, it is laborious and time-consuming, moreover, the drying of the crowns leads to gradual fall of branches, so it is more suitable for protected or poorly accessible areas with minimal attendance.

Chemical methods

In our conditions, usually glyphosate or triclopyr herbicides are mainly used to eliminate suckers up to a height of approximately 1.5 m or in dense groups of young black locust trees in the subsequent tending after mechanical or combined intervention (Sabo 2000). For application, high pressure systems can be used to produce a sufficiently fine aerosol so as to affect as much leaf area as possible (Heim et al. 2017). The application of the herbicides must be as purposeful and targeted as possible not to affect non-target species, which is often technically difficult to carry out.

Combined methods

In practice, mechanical and chemical methods of black locust eradication are usually used in combination. There are numerous variants and modifications, the methodology is not uniform and often depends on the personal experience to deal with the issue (Vítková 2011).

When converting mature black locust stands in Prague forests, felling is followed by immediate application of a systemic glyphosate herbicide on the stump cutting area. Felling is carried out in September to October. In June of the following year, a leaf herbicide is applied to any suckers or seedlings. Low stumps felling is more favourable for subsequent applying the herbicide to a fresh cutting surface, to shorten the path to the roots. High-stump felling together with the application of the herbicide to the cutting surface is not very effective because the herbicide does not get to the roots sufficiently through the high stump. This will only reduce the formation of less problematic stump (stem) suckers, not root suckers (Trylč 2007).

In Hungary, a method based on the injection of a glyphosate-based systemic herbicide into 4 to 7 cm deep holes with a diameter of about 8 mm, drilled at a distance of about 10 cm into standing trees, is also used. Optimally, the injection is performed in the second half of August and September, when the herbicide is transported to the roots and causes the tree to die together with the roots. When the intervention is performed in spring and summer, the herbicide is transported with the sap up into the crown, which reduces the effectiveness of the measure (Šefferová, Stanová et al. 2008). Application of the herbicide to the cutting surfaces also supports the efficiency of the ring girdling method (Pergl et al. 2016).

Another method consists in cutting notches with an axe or a machete or sawing with a subsequent application of herbicide (Veverková 2009). This procedure can be accelerated by a so-called hypo-axe, which applies the active substance to each wound by means of a piston mechanism, or by means of an application kit (e.g. EZ-Ject herbicide system) firing special herbicide-containing cartridges into the stem (Vitelli, Madigan 2011).

Conclusion

Black locust is a woody plant with remarkable, but also rather embarrassing properties. Even in our conditions it shows considerable economic potential. Its wood has unique properties (especially durability and calorific value). If grown in a suitable habitat, black locust has considerable production capacity. It also provides significant non-timber production (bee forage). It can also grow in extreme locations, therefore can be used, for example, in reclamations or in urban environments. In some areas (e.g. south Moravia), black locust stands have already integrated into landscape and may, under certain circumstances, contribute to increasing its diversity, biological and aesthetic value (groves, black locust stands in the fields etc.).

On the other hand, black locust is characterized by a high invasive potential and its eradication is very difficult, expensive and arduous. It shows an ability to influence the soil environment, particularly through eutrophication. Its purposeful cultivation or management of existing stands must therefore take into account these undesirable ecological characteristics. Preserving the existing stands, or even the establishment of new ones, should only be considered at sites where further invasion is excluded.

In our conditions, black locust, as a non-native tree, is completely excluded from purposeful cultivation and distribution in protected areas. In these areas, it is desirable to gradually replace black locust with native species. In the proximity of protected areas and other valuable habitats and communities that could be endangered by black locust, it is certainly appropriate to take into account the precautionary principles rather than think of potential economic effects.

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Summary

Black locust (*Robinia pseudoacacia* L.) is a medium-sized tree with height of up to ca 35 m and diameter of up to ca 75 cm, depending on region, climatic and site conditions. Black locust is the most widespread non-native tree species in Europe as well as in the Czech Republic (Fig. 6.1a, b). There were probably more pathways through which the species got to Europe from its native area in North America. In the Czech Republic, the area of black locust stands covers 14,000 ha. Across the European countries, black locust stands or plantations are very common especially in Hungary (465,000 ha). Black locust is a fast-growing, pioneer, light demanding species. The height growth is very rapid in the initial years, being followed by a decrease in the growth rate relatively early.

Black locust regenerates by seeds and through resprouting, e.g. by root suckers or stem sprouts. Black locust is invasive tree which is able to rapidly expand to its surroundings, especially through roots suckers. For generative reproduction,

it prefers disturbed sites to avoid weed competition (burnt places after forest fires, sites with damaged or removed surface humus), because the seedlings demand a high amount of light. Native thermophilous grasslands, dwarfed thermophilous pine and oak forests are the most vulnerable biotopes prone to black locust invasion. The detrimental effects of black locust on some plant communities rest dominantly in eutrophication and acidification of invaded habitats and induction of specific microclimatic conditions. The role of allelopathy is probably less significant than assumed in the past. On the other hand, there are many positive attributes of black locust, as for example: rapid growth rate, biomass production, high quality and durability of wood, ability to fix atmospheric nitrogen, resistance to drought stress, high temperatures and air pollution as well as honey-production. Production plantations (lignicultures) with short rotation, energy plantations or urban greenery mean suitable ways of the purposeful cultivation.

Black locust represents a deciduous species with ring-porous structure of wood, with typical greenish heartwood and with noticeably narrow sapwood (Fig. 6.2). Compared to our native commercial timbers, it has different appearance and properties to a great extent. It is very hard, heavy and strong timber, with high durability and resistance to fungi and pests (Tab. 6.1, 6.2). These characteristics predetermine it for production of posts, columns, sleepers or pins. It can be also used to manufacture furniture, including the production of veneers, and parquets.

Black locust is an introduced tree species that provides one of the most valuable wood in the Czech Republic. It meets the requirements of aesthetic appearance, but above all shows high hardness and strength characteristics. Its durability in exterior is similar to tropical woods, but it is available at much lower price. In terms of wood utilization, it is possible to regard it as a substitute of oak, the kind of substitute that exceeds this native species in many ways. Leaving aside legislative obstacles, curvature of the trunk, spiral grain or other defects of the trunk shape are the main limitation for the wider utilization of black locust wood in the wood processing industry.

In the Czech Republic, black locust is not included in the conventional forestry schemes because of environmental hazards related to its invasiveness. However, in some European countries, e.g. Hungary and Romania, black locust represents an integral and important part of forestry, especially the short rotation stands are widely used.

Nevertheless, there are situations in which strict control or eradication of black locust is of crucial importance. Various methods are described in this chapter. Incomplete girdling as one of mechanical measures is recommendable for older trees. Spraying with herbicides is applicable in dense resprouting thickets or large populations in areas dominated by black locust with low nature-conservation requirements. Felling the black locust trees followed by immediate application of herbicide on the cutting surface of stumps is a convenient measure when rapid eradication of black locust is required.

The stumps should be as short (and their cutting surface as close to the ground) as possible.

Available information and experience indicate that black locust could play a beneficial role even in the Czech Republic if we minimize the environmental hazards, which is mainly connected with the effort to reduce the invasive potential.