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Robinia pseudoacacia Invasions and Control in North America and Europe

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Introduction

As open spaces become increasingly scarce due to population growth and development, concern about maintaining and restoring natural communities is of greater priority. A worldwide problem affecting the success of habitat conservation is the invasion of alien species. An invasive alien species was defined by the Invasive Species Specialist Group, part of the International Union for the Conservation of Nature (2000) as "an alien species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity." According to Davis (2000) "Species invasions are one of the main ecological consequences of global changes in climate and land use."

Due primarily to man's land use practices involving the distribution and planting of non-native species, *Robinia pseudoacacia* L. (black locust) is recognized as a global invader. One of the reasons for this is that *R. pseudoacacia* has most of the characteristics associated with "weediness." Weedy species have the ability to colonize successfully over a wide range of environmental conditions as well as produce a large quantity of seeds that are dispersed prolifically (Bazzaz 1986). *R. pseudoacacia* possesses these weedy characteristics and is, therefore, a problematic plant in woodlands in many countries.

Life History

R. pseudoacacia is a deciduous tree that belongs to the Fabaceae (legume) family and the Caesalpinioideae subfamily (Smith 1977). Mature trees reach heights of 12.2 to 30.5 m and diameters of .3 to .9 m (Converse 1984). Typically, *R. pseudoacacia* has a fibrous root system but it is capable of developing a taproot (Hanover, 1990). *R. pseudoacacia* flowers are pollinated by insects, especially bees. Four to 8 seeds per pod mature by early fall. The best seed crops occur when trees are between 15 and 40 years old, but seeding may occur on trees as young as 6 years old. *R. pseudoacacia* typically produces abundant amounts of wind-carried seeds but a very thick seed coat lowers successful germination (Converse 1984). Despite this, *R. pseudoacacia*'s ability to reproduce vegetatively, particularly through root suckering and stump sprouting, has enabled it to expand its distribution rapidly (Wisconsin DNR 1999).

R. pseudoacacia is well adapted for growth in a wide variety of soils and environmental conditions. Due to its nitrogen fixing ability, *R. pseudoacacia* is capable of colonizing very low nutrient substrates where few other tree species could thrive. Duke (1983) reports that it can tolerate mean annual precipitation of 61-191 cm and mean annual temperature of 7.6-20.3 degrees Celsius. Optimum conditions include sandy/loamy, well-drained, aerated soils in humid climates and open, sunny locations (Wisconsin DNR 1999, Keller 2000). *R. pseudoacacia* is highly shade-intolerant (Keller 2000) and is susceptible to severe insect damage (Wisconsin DNR 1999) These two characteristics limit its dominance within its native range and may therefore be worth exploring for control methods. *R. pseudoacacia* invasion needs to be controlled because it has the ability to vary its growth patterns, thrive in many regions, and grow at very aggressive rates.

Geography and Impacted Systems

R. pseudoacacia is native to forest edges and slopes in the Southern Appalachian and Ozark mountains of the United States (Wisconsin DNR 1999). In 1601, it was the first forest species introduced to Europe from the United States (Geyer and Bresnan 1992). It was initially brought to Europe by the gardeners of France's King Louis XIII and planted for ornamental purposes (Keller 2000). Since then, it has been planted to reclaim disturbed sites and cultivated for agricultural and commercial uses in North America, Europe, Asia, Australia, South America, and Africa (Keresztes, 1988), and is now reported as invasive across much of its global range. This paper will focus on *R. pseudoacacia* in North America and Europe.

The reasons that *R. pseudoacacia* has been planted globally are numerous and varied. It is useful for soil erosion control, durable wood that also has high fuel value, forage for livestock, an excellent nectar source (Keresztes 1980), edible seeds, reforestation, crop nurse species (Dzwonko and Loster 1996, Torbert et al. 1995), and reclamation of mining lands (Zeleznik and Skousen 1996). Hyun (1956) recommended reforesting northern sections of Korea with *R. pseudoacacia*. Lowe (1979) wrote that *R. pseudoacacia* was "highly recommended" for rehabilitation and screening purposes in Southern Ontario. As of 1984, there were over 1 million hectares of *R. pseudoacacia* plantations, making it the second, behind *Eucalyptus* spp., most planted broad-leaved species worldwide in terms of area (Boring and Swank 1984).

In order to gain a broader view of the distribution, growth habits, and current management of *R. pseudoacacia*, I sent a survey to Long-Term Ecological Research (LTER) sites in the United States and internationally (ILTER). These sites form a network that facilitates research across a wide range of ecosystems and temporal scales. Some of the survey responses are included in this paper to enhance information available from the literature.

Aggressiveness

An important factor leading to the heavy cultivation of *R. pseudoacacia* has been its aggressive nature. The aggressive growth pattern of *R. pseudoacacia* is a result of its high photosynthesis rate, fast seed germination, fast seedling growth (Hanover 1990), and extensive root system (Wisconsin DNR 1999). High photosynthetic rates, up to 30 μmol CO_2 m^{-2} s^{-1} in nursery grown seedlings (Mebrahtu 1992), provide the necessary sugars for growth. For the first 10 years, growth in height of the seedlings per year averages 0.46 to 1.22 meters or more, depending on site quality (Converse 1984). *R. pseudoacacia* is therefore able to out-compete other pioneer species for light and, once a dense stand develops, many understory plants are stunted or die from the heavy shade.

Scientists at some LTER/ILTER sites have detailed high densities of *R. pseudoacacia*. For example, J. Chytil (personal communication) reports that there are an average of 1-20 stems/ha and a maximum of about 400 stems/ha on the Palava Biosphere Reserve, Czech Republic. At Cedar Creek Natural History Area (CCNHA) in Minnesota, a restored oak savanna and woodland research site, stem densities range between 10 to 1000 per hectare. “We have many locations the black locust have either taken over completely or have a small colony started” (D. Kruger, personal communication). In Southern Switzerland and Northern Italy, *R. pseudoacacia* has replaced entire valleys of chestnut (*Castanea sativa*) and many more areas in that region are still being invaded (P.Cherubini, personal communication).

Effects on Reclaimed and Restored Systems

R. pseudoacacia has an important history of reclaiming mine sites. In the 1920s, studies on revegetating mine sites with trees began and successful plantings occurred during the 1940s. *R. pseudoacacia* was the most extensively studied and the most successful species (Zeleznik and Skousen 1996). Its ability to grow under extreme conditions proved useful for colonizing bare soil. For example, on urban wastelands in Berlin, it grows on rubble and gravel and supports colonization of shade-tolerant and nutrient demanding species (Hintikka 1987).

Despite these positive qualities, *R. pseudoacacia* can cause problems in planted situations like reclamation sites and “it has also become a pest in natural systems outside of native range” (Williams 1997). Torbert et al. (1995) report that, when planted as a nurse tree, it can physically damage the leaders and bark of nearby seedlings with its thorny branches. Such physical damages, as well as increasing shade and nutrient levels above normal and out-competing native vegetation, are concerns for many systems, including woodlands, forests, savannas, and grasslands.

R. pseudoacacia, because of its pioneering abilities, invades disturbed systems, such as restorations, and inhibits the growth of native species. It thereby hinders return of the system to the desired state. At the restored savanna LTER site, CCNHA, invasive *R. pseudoacacia* is disrupting the capabilities for experimentation (Krueger, personal communication). Experimental plots are being overtaken by *R. pseudoacacia* and the native vegetation is reducing in abundance.

Effects on Remnant Forests

The composition of forests in Europe can be heavily impacted by a canopy of *R. pseudoacacia*. Kowarik (1990) reports that, although *R. pseudoacacia* forests in Berlin often have a high diversity of understory plants, few shade-tolerant species actually move into dominant positions. Similarly, in Poland, Pacyniak (1981) found no examples of forests succeeding from being dominated by *R. pseudoacacia* to dominance by native tree species. In its native range of the southeastern United States, *R. pseudoacacia* dominance is short-lived due to attack by *Megacyllene robiniae* (locust stem-borer). *R. pseudoacacia* is then replaced by more shade-tolerant species so that, in very old stands, its density is quite low (Boring and Swank 1984). However, *R. pseudoacacia* dominated woodlands outside of the southeastern United States are only slowly colonized by native tree species and woodland plants (Dzwonko and Loster 1997). The invasion and dominance of *R. pseudoacacia* outside of its native range can result in a loss of native biodiversity and, therefore, degradation of restored and natural areas.

Changes in vegetation resulting from *R. pseudoacacia* invasion are not the only components of the ecosystem affected. The carbon:nitrogen ratio of leaf litter from *R. pseudoacacia* was found to be lower than leaf litter from hardwoods (Cotrufo 1977), as would be expected due to *R. pseudoacacia*'s nitrogen fixing ability. Haines (personal communication) reports that in studies on *R. pseudoacacia* stands in its native range, stream waters draining out of the watershed had 10 to 100 times the nitrogen concentration of water draining out of a nearby watershed of mixed hardwoods. Although the increased soil nitrogen levels provided by *R. pseudoacacia* may be beneficial for the colonization of species that are unable to fix nitrogen themselves, *R. pseudoacacia*'s own high growth rate, and therefore high nutrient uptake rate, may negate such benefits.

Management Techniques

Because of the negative impacts that *R. pseudoacacia* can exert on reclaimed, restored, and natural woodland systems, learning to manage it has become an important task. Luken (1997) explains that the traditional methods of managing plant communities with well established alien invasive species are those methods typically employed in weed science. These include chemical, physical and biological control of the problem species. Although management for *R. pseudoacacia* is occurring throughout much of the world, no widely accepted technique has been found yet. Many desirable plants are killed by both mechanical and chemical controls even when the goal is to remove only a few weeds (DeLoach 1997).

Mechanical Techniques

Mechanical control is often very labor intensive and costly. Even so, the Wisconsin Department of Natural Resources (DNR) (1999) uses several mechanical methods, which, with limited success, are employed to control or eradicate *R. pseudoacacia*. Although extreme, on disturbed lands, the most effective option to rid the site of *R. pseudoacacia* may be to bulldoze the surface. Unfortunately, removing all vegetation will likely result in high rates of soil erosion (DeLoach 1997). Burning is often a viable option for managing invasive species over a large area. In prairie systems, annual haying may be able to control the spread of first year seedlings since their root systems are not very developed yet. However, if reproductively mature trees are also present, mowing of small seedlings can promote seed germination (Heim 2000), probably by scarifying the thick seed coats of previously dropped seeds. Roots that remain after top removal by mechanical methods often result in suckers and sprouts with increased vigor (Converse 1984). Girdling, which involves cutting the inner bark, or phloem, but leaving the sapwood, or xylem, is a common method for killing trees, as is cutting near the tree base (Solecki 1997). Neither of these well-known methods are recommended for *R. pseudoacacia* though, since killing the main stem is often followed by the formation of suckers from the tree base.

Combination Mechanical/Chemical Techniques

Due to the unsuccessfulness of mechanical methods alone, a common method of *R. pseudoacacia* control involves both mechanical and chemical treatment. First, cutting or girdling a tree and then, applying herbicide on the stump appears to be a viable option. This method, when completed carefully, is feasible for use in high quality restored or natural systems since it is selective to the target tree. Directions from the Roundup (glyphosate) manufacturer suggest that stumps should be treated with a 50-100% concentration but, according to Heim (2000), a 20% concentration is sufficient. Heim (2000) states that "the best success with herbicides has resulted from basal bark application of herbicides to live standing trees…when trees are small and thin-barked." For this, he recommends using a 2% solution of Remedy (a formulation of triclopyr) in diesel fuel. Heim (2000) discourages use of picloram (Tordon RTU) for stump treatments since robust spouting occurs afterwards. Additionally, he states that picloram is both highly mobile and persistent in the soil, so it should not be used on sandy soils. Another herbicide, triclopyr is manufactured for dilution with diesel fuel or mineral oil. Although mineral oil is more costly, it is likely to be less toxic to non-target organisms (Wisconsin DNR 1999).

Chemical Techniques

Controlling *R. pseudoacacia* with chemical techniques alone is a common practice, probably because it can be less labor intensive than a combination of mechanical and chemical methods. When *R. pseudoacacia* has an extensive root system over a broad area, widespread chemical application may be most feasible. Glyphosate, triclopyr diluted with water, or fisamine ammonium can be utilized as foliar sprays late in the growing season. Foliar sprays work best on thick patches under five feet high or small isolated plants since every branch and stem needs to be treated. This technique is not recommended for high quality natural areas. Glyphosate in particular should not be sprayed on such sites since it is a nonselective herbicide (Wisconsin DNR 1999).

Non-target species can be harmed by herbicide treatment to neighboring plants. For example, triclopyr, which is sometimes used for controlling *R. pseudoacacia*, releases volatile organic compounds in the immediate vicinity of application. Runoff from triclopyr can also harm non-target species. Therefore, it should not be used if rain is forecasted within the next one to four days (Heim 2000). In addition to harming non-target organisms, inefficient spraying can damage water quality. Furthermore, chemical treatment is often too expensive for areas with low economic return (DeLoach 1997).

Preventative Management Techniques

Hobbs and Humphries (1995) assert that management strategies must be approached at multiple levels, in particular, with regard to the invader, the characteristics of the system that has been invaded, and the human influences that affect both. The invasion of a species begins with its transportation into a new area (Wade 1997). Reichard (1997) suggests limiting propagule sources by planting only native species for landscaping near natural or restored areas, restricting vehicle access to those areas, and frequent cleaning of service vehicles and footwear. Roads, hiking trails, and riparian corridors are common places for alien species to initially establish, so managers should monitor such areas carefully (Reichard 1997). As described earlier, in many areas, *R. pseudoacacia* has already progressed to invasive status.

Future Directions

Aside from taking precautions against new invaders, removal experiments are needed for established invaders. According to McCarthy (1997), useful data collection may take a minimum of three to five years. Optimally, this research should be performed across the range of habitats and site qualities in which the invasive species is found (McCarthy 1997).

Another possible research direction explores the third technique employed in weed science, biological control. *Megacyllene robinae* is a major insect pest of *R. pseudoacacia* that often transmits the fungus *Phillinus rimosus* (syn. *Fomes rimosus*), causing rimosus root rot. Adult *M. robinae* feed on the pollen of *Solidago* spp. (goldenrod) and then lay their eggs in the bark of *R. pseudoacacia*. In the spring, larvae bore into the tree's wood, which results in a weakened tree more susceptible to wind breakage and possible fungal rot (Hoffard 1992). *M. robinae* has a wide distribution because it was inadvertently transported along with *R. pseudoacacia*. Research into augmenting current *M. robinae* populations, possibly by capturing neighboring populations and releasing them into regions invaded by *R. pseudoacacia* or by encouraging success of local populations by enhancing habitat with an increased abundance of *Solidago* spp., may be worthwhile. J. Haarstad, CCNHA naturalist, (personal communication) doubts the practicality of biological control with *M. robinae*, at least in Minnesota, but he has noticed another insect pest, the leafhopper *Thelia bimaculata*, which causes more damage to *R. pseudoacacia*. Research into these pests seems merited but the disadvantage of trying to control *R. pseudoacacia* biologically is that it is likely damage ornamental, agricultural, commercial, and reclamation plantings as well.

Future Assessment

Due to the continued sale and use of *R. pseudoacacia*, preventing further invasion will be difficult. Is it possible for us to continue propagating this species worldwide without it becoming more of a nuisance? Obviously, we should at least advocate that introducing *R. pseudoacacia* should be taken under careful consideration.

The World Seed Program has recently begun to facilitate reforestation by small-scale farmers worldwide. Farmers need to send an environmental description of their area and how they intend to use the trees, and, in return the World Seed Program sends them free seeds and technical information. One of 13 species they are distributing worldwide is *R. pseudoacacia* (Ruiz 1998). The World Seed Program may be doing a service to the small-scale farmers who will experience economic gains from planting *R. pseudoacacia*, but native species in reforested regions may not fare as well.

As mentioned earlier, chemical treatment is the most successful method for killing invasive *R. pseudoacacia* trees. Startlingly, research is being carried out to develop herbicide tolerant transgenic *R. pseudoacacia* (Arrillaga and Zaragoza 1999). If transgenic strains are used in plantations or for reclamation purposes, and they are able to disperse without human intervention, it is possible that chemical means may be ineffective on some individuals.

Effective management techniques will become more crucial as the abundance of invasive *R. pseudoacacia* increases. Its tolerance of low fertility sites, high genetic variability, and resistance to drought stress, air pollutants, temperature extremes, and most fungal decay (Hanover 1990) may be predictors of its prevalence in the future. *R. pseudoacacia* has also been shown to exhibit increased growth under elevated CO_2 (Olesniewicz and Thomas 1999). Possible implications of this study could be that, as atmospheric CO_2 concentrations continue to rise, *R. pseudoacacia* invasion could become more serious, particularly in areas without appropriate mycorrhizae such as newly reclaimed and restored sites.

In closing, as our environment changes due to processes like international trade, technological advances, global warming, and land use, invasive species such as *R. pseudoacacia* are likely to become more prevalent. *R. pseudoacacia* is an unusual case of an alien invasive species because, while it has become a problem in many nations, it is also an important resource in those same countries. Perhaps the first major step to controlling the worldwide invasion of *R. pseudoacacia* is to decide which is more important, the benefits it provides, or the problems it creates.

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