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Review

Invasive Characteristics of *Robinia pseudoacacia* and Its Impacts on Species Diversity

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Abstract: *Robinia pseudoacacia* is native to North America and has been introduced into many other countries in Europe, South and South East Asia, South America, Africa, and Oceania. The species has been planted intensively in a large area of these countries because of its ornamental and economic values. However, *R. pseudoacacia* often infests unintended places, including protected areas, and causes significant ecological impacts. The species is now listed as one of the harmful invasive plant species. The characteristics of its life-history, such as the high growth and reproduction rate and adaptive ability to various environmental conditions, may contribute to the invasiveness of the species. The defense ability against natural enemies such as pathogenic fungi and herbivores and its allelopathic potential against the competitive plant species may also contribute to its invasiveness. The *R. pseudoacacia* infestation alters the ecological functions of the plant community, including the soil microbe community, and reduces the abundance and diversity of the native plant species, including vertebrates and invertebrates in the introduced ranges. *R. pseudoacacia* is a shade intolerant and early successional tree species and is replaced by larger and more shade tolerant tree species in the native ranges, while plant succession seems not to occur always in the introduced ranges across the different ages of *R. pseudoacacia* stands. Several other review articles have summarized the afforestation, utilization, biology, and management of the species, but this is the first review focusing on the invasive mechanism of *R. pseudoacacia* and its impacts on species diversity.

Keywords: adaptation; allelopathy; growth potential; microbe; natural enemy; reproduction; plasticity; succession; symbiosis

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1. Introduction

Robinia pseudoacacia L., belonging to the family of Fabaceae, is a hardwood deciduous tree species and reaches 10–30 m in height and 0.6–1.3 m in diameter. The bark is greyish-brown to dark brawn, forming longitudinal groves with age. The leaves are alternate and composed, and each leaf is 10–30 cm long and contains 3–25 leaflets (odd pinnate). The leaflets are ovate, 2–5 cm long, and 1.5–2.5 cm wide with the entire margin. The species bears racemes that are 10–20 cm long. The corollas are white to cream and up to 2 cm long. Each flower contains 10 stamens and a pistil. The fruit is a typical leguminous pod, dark brown, 5–12 cm long, and 1–1.5 cm wide and contains 2–15 seeds. The typical life span of the species is 60–100 years [1–4] (Figure 1).

R. pseudoacacia is native to eastern USA and has already spread across the USA and south Canada due to its extensive planting for silvicultural and horticultural operations [5–7]. The species was introduced into Europe in the early 17th century as a horticultural plant and became a popular ornamental tree soon after the introduction [7,8]. *R. pseudoacacia* was also introduced into many countries in South America, South and South East Asia, Africa, and Oceania for its ornamental and economic values [5,6,9–11].

R. pseudoacacia has been encouraged to grow as a forestry tree for producing rot- and water-resistant timber, nectar for honey, and leaf forage for livestock [12,13]. The mechanical

property of the wood is moderate to high, and the wood has been used for, e.g., furniture, boats, wine barrels, mine timbers, railway sleepers, vineyards poles, fence posts, roof shingles, and firewood [2,4,14,15]. *R. pseudoacacia* is also planted as shade and nurse trees and for erosion control, soil reclamation, and reforestation of disturbed lands. It is also planted as an ornamental tree, such as in landscape gardens, parks, and tree-lined streets [3,11,16,17].



Figure 1. *Robinia pseudoacacia*. Leaves and infestation.

The extensive planting of *R. pseudoacacia* increased its population. *R. pseudoacacia* stands were reported to be in 42 countries alone in Europe, covering with pure and mixed forests, e.g., over 460,000 ha in Hungary, 300,000 ha in Poland, 250,000 ha in Romania, 230,000 ha in Italy, and 200,000 ha in France [3,11,18]. *R. pseudoacacia* occupied approximately 24%, 6%, and 5% of the forested area in Hungary, Romania, and Slovenia, respectively [11,18–21]. *R. pseudoacacia* also occupied a large area in, e.g., China, Korea, Japan, South Africa, and Australia [1,4,6,10].

The infestation of *R. pseudoacacia* into unintended places had not been documented for a long time after the introduction. The escape of the species was recorded in 1824 in Brandenburg, Germany, in 1830 in Slovakia, and in 1850 in Austria [11]. The increasing trend of *R. pseudoacacia* infestation has been recorded since the middle of the 20th century [22]. It was also documented that populations of spontaneous origin were counted in 615 locations in Czech Republic, although the plantations of *R. pseudoacacia* were established only in 36 locations in the country [23].

The high ability of *R. pseudoacacia* to spread into unintended places and protected areas makes it an invasive species [24–28]. The species also causes significant adverse effects on the biodiversity in the introduced ranges [29–34]. *R. pseudoacacia* has been classified as highly invasive and listed as an invasive woody plant species [5,6,35] and in the IUCN Red List of Threatened Species [36]. *R. pseudoacacia* is being controlled for nature conservation [3,11].

Several review articles for *R. pseudoacacia* describing its afforestation, utilization, biology, and management are available [1,2,4,11,17,18,20]. The information on the invasive characteristics of *R. pseudoacacia* has been accumulated over three decades. However, there has been no review article focusing on the invasive characteristics of *R. pseudoacacia* and its impacts on species diversity. This review provides an overview of the invasive characteristics and the impacts of *R. pseudoacacia* on the species diversity in the introduced ranges. The literature has been searched using a combination of the predominant online search engines: Scopus, ScienceDirect, and Google Scholar, and all possible combinations of *R. pseudoacacia* with the following words: invasion, adaptation, botany, habitat, plasticity, reproduction, succession, impact, natural enemy, allelopathy, allelochemical, and secondary metabolite.

2. Invasive Characteristics of *Robinia pseudoacacia*

2.1. Growth

R. pseudoacacia is a fast-growing medium-size tree species. The first true leaf appears within a week after germination, and the seedlings grow to 8–10 cm in height in two months [37]. The juvenile plants on the riverbank were recorded to become 140 cm from 8 cm in height in one year [38]. The growth rate of the *R. pseudoacacia* is 50 cm per year under sunny conditions, faster than 79 other broadleaf tree species [38]. The annual growth rate of 5-year-old *R. pseudoacacia* is recorded to be 30–80 cm in plantations [39]. Compared to other tree species of the same age, *R. pseudoacacia* grows faster and taller and reaches reproductive maturity earlier [40,41]. The total biomass of 4-, 17-, and 38-year-old *R. pseudoacacia* stands in fertile mesic sites was 33, 174 and 339 ton per ha, respectively, whereas the biomass of the manure mixed *Quercus ilex* forest was 198 ton per ha [8].

The rate of photosynthesis was estimated to be 21–26 μmol par leaf m^2 s^1 [38,42], higher than 30 other broadleaf tree species, such as *Populus maximowiczii* and *Betula ermanii* [38]. *R. pseudoacacia* increases the synthesis of ribulose-1,5-bisphosphate carboxylase oxygenase (RuBisCo), which is a key enzyme for photosynthesis, under sunny conditions and allocates much more nitrogen to the leaves [42]. The high leaf nitrogen concentration leads to an increase in the photosynthetic capacity [43]. On the other hand, the leaves under shade conditions increase the chlorophyll contents, which maximizes the light capture ability for photosynthesis [44].

R. pseudoacacia shows a circadian rhythm for leaflet movement in the day–night cycle; open in the daytime and closed at nighttime [45,46]. The species also has the ability to reorient its leaflets to prevent photoinhibition by the excess solar radiation and high temperature [47–49]. The leaflet movement is known to be caused through the turgor changes induced by the K^+ flux into the cells of the pulvini at the base of the petioles of the leaflets [45,46].

As a leguminous species, *R. pseudoacacia* lives associated with rhizobium species, such as *Rhizobium*, *Sinorhizobium*, and *Mesorhizobium*, and the main symbiotic rhizobia are *Mesorhizobium* species [50,51]. Although the symbiotic *Mesorhizobium* species of *R. pseudoacacia* showed taxonomic diversity in the populations of North America (native range), Germany, Poland, Japan and China, these rhizobia shared very similar sequences of *nodA*, *nodC*, and *nifH* genes, and these genes play a critical role in symbiosis [50–53]. This observation suggests that the symbiotic rhizobia of *R. pseudoacacia* may have evolved under strong host plant constraints. The symbiotic nitrogen fixation was reported to be 23 kg to 300 kg per ha per year [54–56]. The symbiosis with rhizobia may contribute to the growth of *R. pseudoacacia* under nitrogen-limited soil conditions and to an increase in photosynthesis [43,57]. In addition, *R. pseudoacacia* may influence the evolution of symbiotic rhizobium population due to the strong host constraints, such as *nodA*, *nodC*, and *nifH* genes [50,51].

When *R. pseudoacacia* seedlings were grown together with a native plant species, such as *Quercus robur* or *Carpinus betulus*, in the same pots, *R. pseudoacacia* allocated more nutrients to its roots and enhanced the root growth, resulting in the occupation of most of the rooting capacity in the pots and in the absorption of most of the nutrients and water. Consequently, these native species suffer nutrient deficiency and growth suppression [58]. Therefore, the competitive ability of *R. pseudoacacia* may be high against native plant species through the enhancement of the root growth.

These observations suggest that *R. pseudoacacia* grows very fast, which may be supported by the effective nitrogen allocation and nitrogen supply by symbiosis, effective photosynthesis through the synthesis of RuBisCo and chlorophyll, and the leaflet movement to avoid photoinhibition. Its roots also grow fast and contribute to absorption of nutrients and water.

2.2. Reproduction

R. pseudoacacia reproduces both sexually and asexually [2]. The flowering occurs from the late spring to early summer in its native ranges. Although the flower contains

both stamens and a pistil, the stigma of the pistil is receptive to pollen before the anthers of the stamens release pollen, and a hairy collar just below the stigma prevents self-fertilization. Therefore, the species is considered to be cross-fertilized [59–62]. Insects such as hymenopteran species mainly contribute to the pollination [59,61]. *R. pseudoacacia* produces seeds from the age of 5–6 years old, and good seed production occurs every one to two years. *R. pseudoacacia* produces 6–12 kg of seeds per plant per year [60] and 120–150 kg of seeds per year per ha in a good crop year [18] (Figure 2).



Figure 2. *Robinia pseudoacacia*. Bearing pods.

The seeds are primarily dispersed around the mother plants by gravity and wind [2,63]. Some of the seeds are carried for long distances by birds and mammals, water streams including flooding water, rolling on the snow surface by wind, and attachments to motor vehicles along roads [63–66]. The seeds show dormancy. A seed coat impermeable to water and oxygen is thought to be one of the reasons for the dormancy [67,68]. Some of the seeds persist in a dormant state in the soil for 10–40 years with viability, resulting in the accumulation of long-lived seed banks [18,39,69,70].

The germination rate of the seeds is low, ranging from 3.5–22% under natural conditions [2,71]. The germination rate was significantly increased with mechanical, chemical, thermal (heat or cold shock), burning, and plasma treatments to the impermeable seed coats [63,67,68,72]. The infestation of *R. pseudoacacia* was often observed in disturbed areas after fire [73,74]. The fire may enhance the germination of the species. In addition, the germination rate of the seeds obtained from the European populations of *R. pseudoacacia* was significantly higher than that from the American populations (native range) [75]. The higher germination rate in the introduced ranges may contribute to the invasion success of the species.

R. pseudoacacia spreads asexually through the ramets from adventitious buds at the base of the main trunks and at horizontal roots [76,77]. Formation of the ramets is associated with regeneration and propagation. The sprouting of the ramets occurs when *R. pseudoacacia* is damaged by, e.g., cutting, disease, and fire [77]. *R. pseudoacacia* forests are able to regenerate through ramet sprouting within a few years after clear-cutting [21,76,77].

The horizontal roots of *R. pseudoacacia* were recorded to grow 1.6 m per year and to reach 61 m [78]. The propagation potential of *R. pseudoacacia* from root suckers (ramets from the horizontal roots) is very high. The mother plants support the growth of these root suckers for a few years through the nutrient supply [76,77]. One plant produces up to 45 suckers, and these suckers make the clone stands (genets) [18]. The density of the root suckers was up to 50,000 clonal plants per ha [21], and one genet covered the area of several hundred square meters [78,79]. The boundaries between the genets in the local population were relatively distinct, suggesting that the spatial exclusion of root suckers from neighboring genets may occur [76]. The exclusion may contribute to the avoidance of the intraspecific competition.

These observations suggest that *R. pseudoacacia* easily escapes to unintended places through the vigorous extension of horizontal roots and root suckers. Seed dispersal is also an important strategy for reaching new habitats. Once established, *R. pseudoacacia* is able to maintain its stand for a long time and increases the area through the sprouting of ramets from the base of the main trunk and horizontal roots.

2.3. Adaptivity

R. pseudoacacia grows well in the native ranges in places characterized by a humid and moderate climate where the annual precipitation ranges from 1020 mm to 1830 mm, mean temperature ranges from −4 °C to 7 °C in winter and from 18 °C to 27 °C in summer, and mean annual snowfall ranges from 50 mm to 1520 mm [39]. *R. pseudoacacia* grows in quite different climatic conditions in its introduced ranges from its native ranges. The species is abundant in temperate and subtropical regions in Europe, South and South East Asia, South America, Africa, and Oceania and in the tropical regions of higher altitudes and cooler places. *R. pseudoacacia* is distributed in Central Europe, where the annual precipitation ranges from 480 mm to 800 mm and mean annual temperature ranges from 6 °C to 11 °C [11]. The species tolerates temperatures from −12 °C to 40 °C [6]. *R. pseudoacacia* was recorded in colder (−8 °C) and hotter (38 °C) climate regions in New Mexico, USA, and in the dry habitats in Israel and Cyprus [4,59]. *R. pseudoacacia* also is distributed where the climate varies from semi-arid temperate with hot summers in north-west Australia to temperate and cool regions along the coast in south-eastern Australia and from an annual precipitation of 1000 mm to 2000 mm in southeastern Australia to 250 mm in the inland and northern Australia [4].

R. pseudoacacia grows best in moist, rich, loamy soils and soil of limestone origin. However, the species can grow on a variety of soil types: pH values between 3.2 and 8.2, nutrient-rich to nutrient-poor soil, moist to dry soils, sandy soil, medium to highly base saturated soils, but it avoids wet or compacted soils because of a requirement for aerated soil [6,38,80]. The species grows occasionally as a shrub in rocky places in the southern foothills of the Alps. The plant shape is distinct from the plant grown in other places [2].

R. pseudoacacia also lives together with arbuscular mycorrhizal fungi (AMF). AMF are widespread symbiotic soil microorganisms of the phylum Glomeromycota [81]. AMF symbiosis causes the morphological alteration of *R. pseudoacacia* roots, such as root length, average root diameter, root volume, and root tensile strength, as well as the enhancement of its drought and oxidative stress tolerance [82,83]. The symbiosis may increase the adaptive ability of *R. pseudoacacia* against some environmental stress conditions.

Global warming is considered to cause a significant threat to the biodiversity in the world [84–88]. The global warming trend may contribute to the expansion of *R. pseudoacacia* infestation northward in the Northern hemisphere, southward in the Southern hemisphere, and to the higher altitude because one of the limiting factors of the species distribution is temperature [89,90]. The species could possibly infest these areas in the near future and may cause serious threats to the biodiversity. However, increasing temperature may also affect the south and north distribution of *R. pseudoacacia* for the Northern and Southern hemispheres, respectively [91,92].

These observations suggest that the adaptative ability of *R. pseudoacacia* to various climate and soil conditions is high. The symbiosis with AMF increases its drought and oxidative stress tolerance, and contribute to the enhancement of its adaptivity to the adverse conditions.

2.4. Natural Enemy

Herbivorous mammals, such as *Odocoileus virginianus* (white-tailed deer) and *Cervus canadensis* (elk) browse young *R. pseudoacacia* plants in Appalachia (native range) with reports of 70–90% of the plant damage [39,93]. *Oryctolagus cuniculus* (European rabbit) and *Lepus europaeus* (European hare) feed on the bark of young trees, and *Cervus elaphus* (red deer)

and *Capreolus capreolus* (roe deer) eat the young shoots, leaves, and buds [18,20,94]. Therefore, several herbivorous mammals may disturb the growth of young *R. pseudoacacia* plants.

More than 75 insect species including 14 monophagous species were identified in the native ranges as the natural enemies of *R. pseudoacacia* [95–98]. The most serious pest of *R. pseudoacacia* is the locust borer *Megacyllene robiniae*. The insect is monophagous, and sympatric with *R. pseudoacacia*. Its larvae make feeding tunnels throughout the wood of *R. pseudoacacia*, resulting in the tree losing its vigor. The tunnels also serve as entry points for the pathogenic fungus *Phellinus rimosus*, which causes extensive wood decay and root rot [28]. A locust leaf-miner *Odontota dorsalis* is present throughout the year in the native ranges. The insect causes heavy defoliation to *R. pseudoacacia* trees, and the trees are killed when the rainfall is low [6,95]. The larvae of two moth species, a leaf mining moth *Phyllonorycter robiniella* and a locust digitate leaf miner *Parectopa robiniella*, feed on the leaves of *R. pseudoacacia* and other *Robinia* species [6,95]. A gall midge *Obolodiplosis robiniae* induces leaf-margin gall on *R. pseudoacacia* leaves and causes defoliation. *Obolodiplosis robiniae* is spreading in the introduced ranges from Europe to East Asia [2,99], and *Phyllonorycter robiniella* and *Parectopa robiniella* are increasing their population in central and eastern Europe [2].

Although *R. pseudoacacia* is classified as a species that produces strong and rot-resistant timber [1,14,15,18,77], many fungal species have been found on the wood and leaves of *R. pseudoacacia* in the native and introduced ranges. Pathogen fungus genera, such as *Aglaospora*, *Phomopsis*, *Fusarium*, *Polyporus*, *Perenniporia*, *Ganoderma*, and *Laetiporus* cause, e.g., mildew, leaf-spot diseases, necrosis, stem canker, and white, brown, and red rots [2,100,101]. Phytoplasmas, which are intracellular parasites of plant phloem tissue, cause witches' broom and dieback symptoms on *R. pseudoacacia* [102].

R. pseudoacacia contains a toxic substance, robinin (chemical class, toxalbumin), in leaves, bark, and seeds. The robinin inhibits protein synthesis, leading to cell death [103–105]. The toxic property of *R. pseudoacacia* was reported to cause critical emesis and extensive tissue necrosis in human bodies [106,107]. The toxicity of *R. pseudoacacia* was also reported in livestock, causing symptoms of transient hyperammonemia and encephalopathy and the reduction of protein digestibility [108,109] (Figure 3). However, it has not been reported if the toxic substance protects *R. pseudoacacia* from herbivorous mammals and insects under natural conditions.

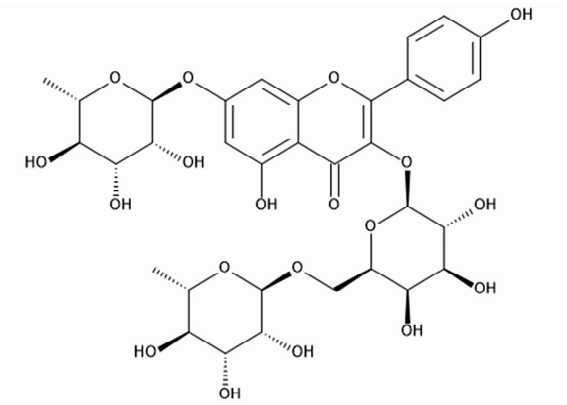


Figure 3. Toxic substance of *R. pseudoacacia*, robinin.

These observations suggest that *R. pseudoacacia* has many natural enemies, such as herbivorous insects and mammals and pathogenic fungi in the native and introduced ranges. However, the impact of natural enemies on the population and regeneration of *R. pseudoacacia* is not clear because the species populations are still increasing in the native and introduced ranges. Therefore, *R. pseudoacacia* may have the ability to prevent the attacks from natural enemies.

2.5. Allelopathy

Allelopathy is the chemical interaction between donor plants and neighboring receiver plant species through certain plant secondary substances (allelochemicals). Allelochemicals are released from the donor plants to the neighboring environments and suppress germination and growth and establishment of these neighboring plants, resulting in the enhancement of the competitive ability of the donor plant species against neighboring plant species [110–113]. Allelopathy was reported to be involved in the invasive characteristic of several other invasive plant species [114–118].

Aqueous extracts of *R. pseudoacacia* leaves and bark suppressed the germination and growth of four crop species: *Triticum aestivum*, *Hordeum vulgare*, *Lens culinaris*, and *Brassica rapa*, under laboratory and greenhouse conditions [119]. Aqueous extracts of *R. pseudoacacia* leaves and roots also inhibited the germination of three tree species: *Thuja orientalis*, *Hibiscus syriacus*, and *Alnus firma.* The root extracts suppressed the germination of *Thuja orientali* and *Hibiscus syriacus* more than the leaf extracts, whereas the leaf extracts suppressed the germination of *Alnus firma* more than the root extracts. A growth inhibitory substance, gentisic acid, was more abundant in the leaf extracts, and vanillic acid and syringic acid were more abundant in the root extracts [120]. Aqueous extracts of *R. pseudoacacia* leaves suppressed the growth of two weed species: *Echinochloa crus-galli* and *Phleum pretense.* When the *Echinochloa crus-galli* was grown in the soil containing the leaves of *R. pseudoacacia*, the growth of *Echinochloa crus-galli* was significantly suppressed. Three growth inhibitory substances, robinetin, myricetin, and quercetin, were isolated from the leaves [121] (Figure 4).

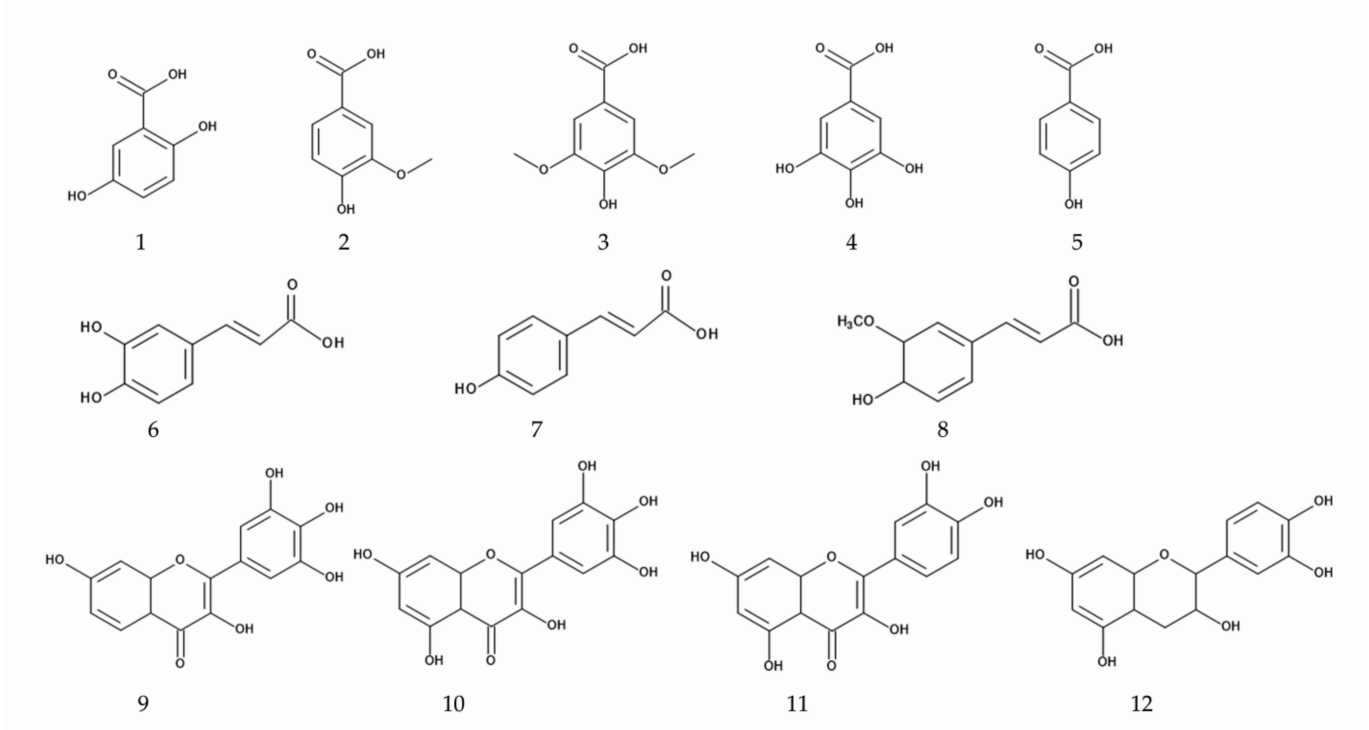


Figure 4. Allelochemicals of *R. pseudoacacia.* 1: gentisic acid, 2: vanillic acid, 3: syringic acid, 4: gallic acid, 5: hydroxybenzoic acid, 6: caffeic acid, 7: coumaric acid, 8: ferulic acid, 9: robinetin, 10: myricetin, 11: quercetin, 12: catechin.

Allelochemicals are synthesized and stored in certain plant tissues and released into the neighboring environment through, e.g., root exudation, decomposition of plant residues in the rhizosphere soil, and volatilization from plant parts [110–113]. Therefore, these observations described above suggest that *R. pseudoacacia* may contain certain allelochemicals in the leaves, roots, and bark, and gentisic acid, vanillic acid, syringic acid, robinetin,

myricetin, and quercetin may work as allelochemicals of *R. pseudoacacia* [119–121]. In addition, several other compounds, such as caffeic acid, coumaric acid, ferulic acid, gallic acid, hydroxybenzoic acid, and catechin were identified in leaves, flowers, seeds, and bark of *R. pseudoacacia* [122,123] (Figure 4). These compounds were known to act as allelochemicals [112,124–127] and possess growth and germination inhibitory activity and anti-microbe activity [112,128–132]. Some of these compounds were involved in the invasive characteristics of other invasive plant species, such as *Tithonia diversifolia* and *Pueraria montana* [133,134]. However, it is not clear how much of these allelochemicals is released into the neighboring environment of *R. pseudoacacia*. It is also not clear how much these allelochemicals contribute to the invasiveness of *R. pseudoacacia.*

3. Impacts of *Robinia pseudoacacia* on Species Diversity

3.1. Effects on Microbial Community

As a nitrogen fixing leguminous species, *R. pseudoacacia* adds 23–300 kg nitrogen per ha per year to the ecosystem [54–56]. Such an amount of nitrogen input may affect the species productivity and composition in the local plant community [135,136]. The input of nitrogen to the ecosystem depends primally on the litterfall. The green and senescent leaves of *R. pseudoacacia* contained higher amounts of nitrogen compared to the leaves of the native plant species, such as *Pinus pinea*, *Pinus rigida*, *Pinus nigra*, *Quercus ilicifolia*, and *Quercus ilex* [136–138]. The nitrification rate of *R. pseudoacacia* litter was reported to be no higher than that of the litter of the native tree species, *Fraxinus angustifolia* and *Ulmus minor* under laboratory conditions [139]. However, under field conditions, the litter nitrification rate of *R. pseudoacacia* was much higher than that of the mixed forests of native plant species, *Pinus rigida*, *Quercus ilicifolia*, and *Quercus prinoides*, and the available nitrogen concentration in the forest soil under *R. pseudoacacia* was also much higher than that under the mixed forests of the native species [136]. It was also reported that *R. pseudoacacia* creates nitrogen-rich soil ecosystems [54,138,140–142]. In addition, *R. pseudoacacia* significantly increased the proportion of the large size of soil aggregates and decreased the small size of soil aggregates, resulting in increasing soil stability [143].

Nitrogen availability strongly affects the ectomycorrhizal (ECM) fungal community in the soil and affects the ECM fungal colonization of the host plant species. The ECM fungal colonization improves the nutrient and water uptake and increases the pathogen tolerance of the host plant species [144–146]. *R. pseudoacacia* alters the ECM fungal species and abundance in its rhizosphere soil due to the increasing concentration of soil nitrogen [147,148]. The altered ECM fungal populations colonize well with *R. pseudoacacia*, and increase the ability for nutrient and water uptake and pathogen tolerance in *R. pseudoacacia*, but the altered ECM fungal populations do not colonize well with the native plant species *Pinus thunbergii*, resulting in the reduction of nutrient and water uptake and pathogen tolerance. Consequently, *R. pseudoacacia* can use nutrients and water with priority, and the competitive native plants lose their vigor and pathogen tolerance [147,148].

R. pseudoacacia also alters the community of the arbuscular mycorrhizal fungi (AMF) in the infested soil due to the increasing concentration of soil nitrogen [82,86,149,150]. AMF colonization also increases the nutrient and water uptake and stress tolerance of the host plants [151,152]. The altered AMF community provides better conditions for *R. pseudoacacia* but not for the native plant species [82,149,150]. In addition, the diversity of the functional groups of the soil microbial community was significantly affected by the infestation of *R. pseudoacacia* [153].

Some other invasive plant species, such as *Mimosa pigra*, *Imperata cylindrica*, *Chromolaena odorata*, *Ageratum conyzoides*, and *Fallopia japonica*, also alter the soil microbial communities including AMF and rhizobium communities through releasing certain compounds from their roots into the rhizosphere soil, resulting in the suppression of the muralism of the nighening competitive plant species. These established soil microbial communities also affect the carbon and nitrogen availability and the decomposition rate of organic matter in the rhizosphere soil [154–159].

These observations suggest that *R. pseudoacacia* alters ECM fungus, AMF, and other microbial communities in the rhizosphere soil. These altered microbe communities increase the nutrient and water uptake and pathogen and stress tolerance of *R. pseudoacacia* but not for the competitive plant species. The alterations of microbial species composition in its rhizosphere soil may contribute to the invasiveness of *R. pseudoacacia.*

3.2. Effects on Understory Plant Community

The infestation of *R. pseudoacacia* into the forests in the introduced ranges results in the replacement of the canopy species from the native plant species to *R. pseudoacacia* and the alteration of the canopy structures. *Robina pseudoacacia* creates lower canopy closure forests compared with the native floodplain forests (dominated by *Salicion albae* and *Fraxino-Quercion roboris*), oak forests (dominated by *Quercus cerris*, *Quercus robur*, or *Quercus petraea)*, and mixed oak–hornbeam forests (dominated by *Quercus* spp. and *Carpinion betuli*) [160,161]. The canopy structures affect the microclimate conditions in the forests. The light irradiance and temperature of *R. pseudoacacia* forests were higher, and the humidity of *R. pseudoacacia* forests was lower than these native forests, although these forests belong to the same region with the same climate condition [160–162]. *R. pseudoacacia* also creates soil conditions with higher C/N ratio and higher phosphate concentration compared with the soil conditions under the native plant forests [163].

These microclimate and soil conditions created by *R. pseudoacacia* probably affect the community of the understory plant species. In fact, the understory plant community was very different between the *R. pseudoacacia* forests and the native plant forests in terms of biomass and biodiversity [164–170]. The understory plant community in the native forests consists of oligothrophic and acidophilus species. However, the understory plant community in *R. pseudoacacia* forests consists of heliophilous, nutrient demanding, and/or un-forest species, such as *Galium aparine*, *Urtica dioica*, *Anisantha sterilis*, *Glechoma hederacea*, and *Chelidonium majus*. Alien plant species, such as *Erigeron annuus*, *Solidago gigantea*, and *Symphyotrichum novi-belgii*, were also often observed in *R. pseudoacacia* forests [160–162,171]. The different understory plant community makes different litter composition on the forest floor. The different understory plant community, including different litter composition, is responsible for the replacement of the invertebrate species, such as nematodes, arthropods, and mollusks, and vertebrate species, such as birds and mammals [161,172–174]. *R. pseudoacacia* also affects the richness and abundance of the epiphytic lichen species in the forests [175].

Although Siztia et al. [176] did not find significant differences in the richness and diversity of the understory plant species in the *R. pseudoacacia* and native plant forests in the European Mediterranean Mountains, many other researchers have recorded the significant differences in the richness and diversity of the understory plant species between the *R. pseudoacacia* and native plant forests, as described. Therefore, *R. pseudoacacia* infestation probably affects the abundance and biodiversity of the understory plant community and the biodiversity of the residential vertebrates and invertebrates.

3.3. Effects on Plant Succession

R. pseudoacacia is an early successional and shade-intolerant tree species. The species spreads quickly and colonizes a broad range of habitats, such as grasslands, floodplains, tree plantations, disturbed lands, and open sites within deciduous forests. *R. pseudoacacia* makes up the majority of its stands during the early stages of plant succession [2,4,11]. In native ranges, after 15–30 years, *R. pseudoacacia* tends to be replaced by larger and more shade-tolerant tree species such as *Liriodendron tulipifera* and *Quercus* spp. [8,54,177].

However, the successional gradient of *R. pseudoacacia*-dominated forests is not always observed in the introduced ranges. Plant succession seems not to occur across the different ages of *R. pseudoacacia* stands [166,178–180]. As described above, the heliophilous, nutrient-demanding, and un-forest species dominate in the *R. pseudoacacia* forests, while most of the oligothrophic and acidophilus species disappear from the forests [160–162,171].

R. pseudoacacia may affect the natural successional process by decreasing the regeneration density of native tree species and by altering the species composition of understory plant species [166,178–180]. These observations suggest that *R. pseudoacacia* can maintain its dominance in the forests for a longer time in the introduced ranges than the native ranges.

4. Conclusions

R. pseudoacacia has been introduced into many continents for its ornamental and economic values. However, the high ability of *R. pseudoacacia* to spread into unintended places, including protected areas, makes it an invasive species [2–4,6,7,35,36]. *R. pseudoacacia* grows very fast through rhizobium nitrogen fixation, effective nitrogen allocation, high photosynthesis ability through the effective synthesis of RuBisCo and chlorophyll, and leaflet movement to avoid photoinhibition [42,44,47–49]. *R. pseudoacacia* produces abundant seeds from the age of 5–6 years old [18,60]. The species also propagates and reproduces through the ramets from adventitious buds at the base of the main trunks and at horizontal roots [76,77]. *R. pseudoacacia* forests were regenerated within a few years after clear-cutting through the ramet sprouting [21,76,77]. The horizontal roots grow up to 61 m, and the ramet sprouting often occurs from the horizontal roots [21,78]. *R. pseudoacacia* has a strong adaptive ability to the various environmental conditions, such as temperature, precipitation, and soil type [4,6,39,80]. These characteristics of its life history may contribute to the invasiveness of the species.

R. pseudoacacia has many natural enemies, such as herbivorous insects and mammals and pathogenic fungi in the native and introduced ranges [2,39,95,96,99,100]. However, the impact of natural enemies on the population of *R. pseudoacacia* is not clear because the species populations are still increasing in the native and introduced ranges. The species may have the ability to prevent pathogen infection and herbivore attacks. *R. pseudoacacia* contains the toxic substance robinin, which causes extensive tissue necrosis, hyperammonemia, and encephalopathy in animals [106,107]. *R. pseudoacacia* also possesses allelochemicals [120,121], which enhance the competitive ability of *R. pseudoacacia* against the neighboring plant species due to the suppression of germination, growth, and/or establishment of these neighboring plant species. The defense ability against natural enemies and the allelochemicals of *R. pseudoacacia* against competitive plant species may also contribute to the invasiveness of the species.

R. pseudoacacia was reported to significantly change species diversity and abundance in the native plant community. *R. pseudoacacia* alters the symbiotic soil microbe community, including ectomycorrhizal fungi and arbuscular mycorrhizal fungi, to a species favorable community from a native plant favorable community [147–150]. The infestation of *R. pseudoacacia* into the native plant forests causes the alteration of the canopy structures and soil nutrient conditions of the forests [160–163]. The created canopy structures affect the microclimate conditions, such as higher irradiation and temperature and lower humidity. These microclimate and soil conditions affect the community of the understory plant species. The understory plant community in the native forests consists of oligothrophic and acidophilus species, while the undergrowth plant community in *R. pseudoacacia* forests consists of heliophilous, nutrient-demanding, un-forest and/or alien plant species [162–170]. These understory plant communities and forest structures are also responsible for the replacement of the invertebrate and vertebrate species in the forests [161,162,172–174] (Figure 5).

R. pseudoacacia is a shade-intolerant and early successional tree species and forms its dominant stands quickly. The species' dominant stands tend to be replaced by larger and more shade-tolerant tree species after 15–30 years in the native ranges [8,54,177]. However, *R. pseudoacacia* may affect the natural successional process by decreasing the regeneration density of native tree species and altering the species composition of the understory plant species in the introduced ranges. Plant succession seems not to occur always across the different ages of *R. pseudoacacia* stands [166,178–180].

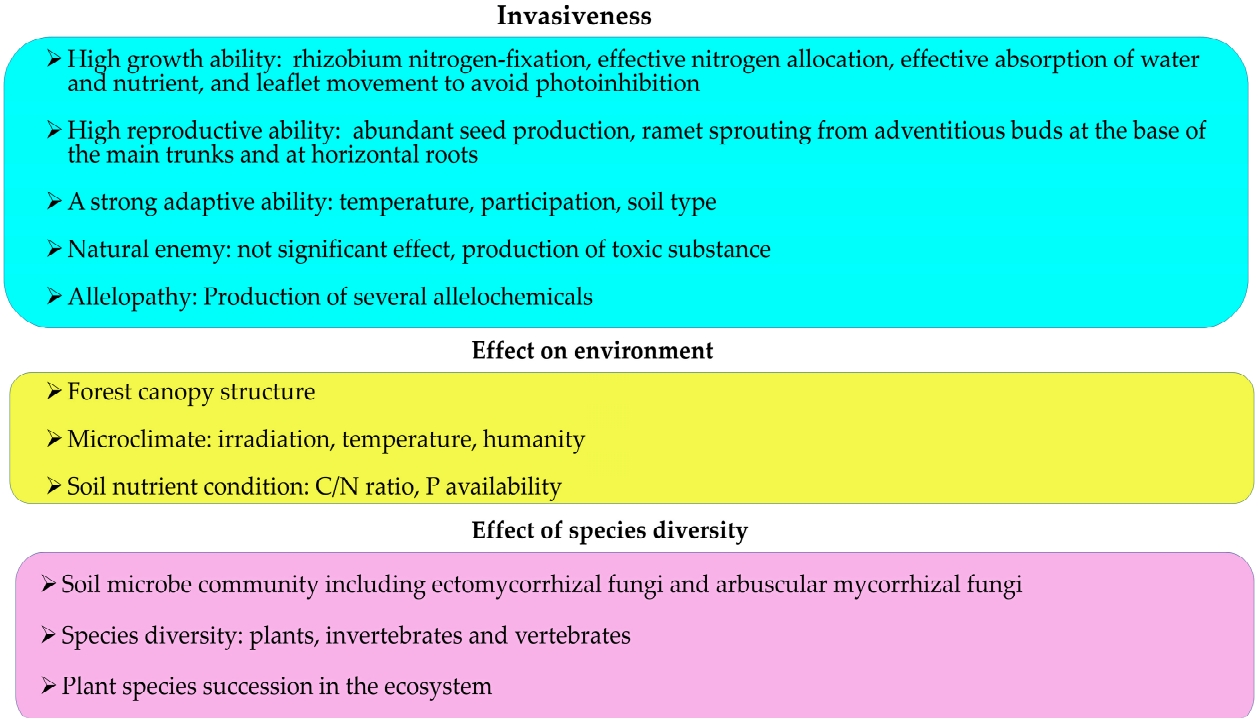


Figure 5. Invasive characteristics and impacts of *Robinia pseudoacacia*.

The management of *R. pseudoacacia* is difficult due to its fast growth ability and clonal reproduction by ramets from its lateral roots and the base of the main trunks [21,76,77]. Several review articles have summarized the management of the species [4,18,181,182]. The species is mainly controlled chemically and mechanically. However, effective long-term control techniques for *R. pseudoacacia* infestation have not yet been suggested. Further investigations into biological and ecological aspects are still required to understand the species of *R. pseudoacacia* in more detail and to develop management options. Due to its invasive behavior in unintended places and protected areas, the species needs to be controlled. If left unmanaged, *R. pseudoacacia* would continue to spread and cause significant problems in the species abundance and diversity in the introduced ranges. The global warming trend may also contribute to the expansion of the *R. pseudoacacia* infestation.

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References

1. Kanwar, K.; Bhardwaj, A.; Deepika, R.; Sharma, D.R. *Robinia pseudoacacia* Linn. *Tree For. Sci. Biotechnol.* **2007**, *1*, 74–80.
2. Cierjacks, A.; Kowarik, I.; Joshi, J.; Hempel, S.; Ristow, M.; von der Lippe, M.; Weber, E. Biological flora of the British Isles: *Robinia pseudoacacia*. *J. Ecol.* **2013**, *101*, 1623–1640. [CrossRef]
3. Sitzia, T.; Cierjacks, A.; de Rigo, D.; Caudullo, G. Robinia pseudoacacia in Europe: Distribution, habitat, usage and threats. In *European Atlas of Forest Tree Species*; San-Miguel-Ayanz, J., de Rigo, D., Caudullo, G., Houston Durrant, T., Mauri, A., Eds.; Publications Office of the European Union: Luxembourg, 2016; pp. 166–167.
4. Martin, G.D. Addressing geographical bias: A review of *Robinia pseudoacacia* (black locust) in the Southern hemisphere. *S. Afr. J. Bot.* **2019**, *125*, 481–492. [CrossRef]
5. Global Invasive Species Database, Species Profile: *Robinia pseudoacacia*. Available online: https://www.iucngisd.org/gisd/species.php?sc=572 (accessed on 12 November 2024).
6. Invasive Species Compendium, *Robinia pseudoacacia*. Available online: https://doi.org/10.1079/cabicompendium.47698 (accessed on 12 November 2024).

7. Greene, W. Black Locust: The Tree on Which the US Was Built. Available online: https://barkhouse.com/2020/11/04/black-locust-the-tree-on-which-the-us-was-built/ (accessed on 12 November 2024).
8. Boring, L.R.; Swank, W.T. The role of black locust (*Robinia pseudoacacia*) in forest succession. *J. Ecol.* **1984**, *72*, 749–766. [CrossRef]
9. Papanastasis, V.P.; Platis, P.D.; Dini-Papanastasi, O. Effects of age and frequency of cutting on productivity of Mediterranean deciduous fodder tree and shrub plantations. *For. Ecol. Manag.* **1998**, *110*, 283–292. [CrossRef]
10. Li, G.; Xu, G.; Guo, K.; Du, S. Mapping the global potential geographical distribution of black locust (*Robinia pseudoacacia* L.) using herbarium data and a maximum entropy model. *Forests* **2014**, *5*, 2773–2792. [CrossRef]
11. Vítková, M.; Müllerová, J.; Sádlo, J.; Pergl, J.; Pyšek, P. Black locust (*Robinia pseudoacacia*) beloved and despised: A story of an invasive tree in Central Europe. *For. Ecol. Manag.* **2017**, *384*, 287–302. [CrossRef]
12. Dalby, R. A honey of a tree: Black locust. *Am. Bee J.* **2004**, *144*, 382–384.
13. Burner, D.M.; Pote, D.H.; Ares, A. Foliar and shoot allometry of pollarded black locust, *Robinia pseudoacacia* L. *Agrofor. Syst.* **2006**, *68*, 37–42. [CrossRef]
14. Pollet, C.; Verheyen, C.; Hebert, J.; Jourez, B. Physical and mechanical properties of black locust (*Robinia pseudoacacia*) wood grown in Belgium. *Can. J. For. Res.* **2012**, *42*, 831–840. [CrossRef]
15. Bijak, S.; Lachowicz, H. Impact of tree age and size on selected properties of black locust (*Robinia pseudoacacia* L.) wood. *Forests* **2021**, *12*, 634. [CrossRef]
16. Farkas, Á.; Zajácz, E. Nectar production for the Hungarian honey industry. *Eur. J. Plant Sci. Biotechnol.* **2007**, *1*, 125–151.
17. Ciuvăt, A.L.; Abrudan, I.V.; Ciuvăt, C.G.; Marcu, C.; Lorent, A.; Dincăa, L.; Szilard, B. Black locust (*Robinia pseudoacacia* L.) in Romanian Forestry. *Diversity* **2022**, *14*, 780. [CrossRef]
18. Nicolescu, V.N.; Rédei, K.; Mason, W.L.; Vor, T.; Pöetzelsberger, E.; Bastien, J.C.; Brus, R.; Benčať, T.; Đodan, M.; Cvjetkovic, B.; et al. Ecology, growth and management of black locust (*Robinia pseudoacacia* L.), a non-native species integrated into European forests. *J. For. Res.* **2020**, *31*, 1081–1101. [CrossRef]
19. Zelnik, I. The presence of invasive alien plant species in different habitats: Case study from Slovenia. *Acta Biol. Slovenica* **2012**, *55*, 25–38. [CrossRef]
20. Redei, K.; Keseru, Z.; Csiha, I.; Raso, J.; Honfy, V. Plantation silviculture of black locust (*Robinia pseudoacacia* L.) cultivars in Hungary—A review. *South-East Eur. For.* **2017**, *2*, 151–156. [CrossRef]
21. Nicolescu, V.N.; Buzatu-Goanta, C.; Bartlett, D.; Lacob, N. Regeneration and early tending of black locust (*Robinia pseudoacacia* L.) stands in the North-West of Romania. *South-East Eur. For.* **2019**, *10*, 97–105. [CrossRef]
22. Berg, C.; Drescher, A.; Wagner, V.; Essl, F. Temporal trends in the invasions of Austrian woodlands by alien trees. *Preslia* **2016**, *88*, 185–200.
23. Křivánek, M.; Pyšek, P.; Jarošík, V. Planting history and propagule pressure as predictors of invasion by woody species in a temperate region. *Conserv. Biol.* **2006**, *20*, 1487–1498. [CrossRef]
24. Arianoutsou, M.; Bazos, I.; Delipetrou, P.; Kokkoris, Y. The alien flora of Greece: Taxonomy, life traits and habitat preferences. *Biol. Invasions* **2010**, *12*, 3525–3549. [CrossRef]
25. DAISIE—Inventory of Alien Invasive Species in Europe. Available online: https://www.gbif.org/species/159514375 (accessed on 12 November 2024).
26. Pyšek, P.; Chytrý, M.; Pergl, J.; Sadlo, J.; Wild, J. Plant invasions in the Czech Republic: Current state, introduction dynamics, invasive species and invaded habitats. *Preslia* **2012**, *84*, 575–629.
27. Richardson, D.M.; Rejmánek, M. Trees and shrubs as invasive alien species—A global review. *Divers. Distrib.* **2011**, *17*, 788–809. [CrossRef]
28. Sheppard, A.W.; Shaw, R.H.; Sforza, R. Top 20 environmental weeds for classical biological control in Europe: A review of opportunities, regulations and other barriers to adoption. *Weed Res.* **2006**, *46*, 93–117. [CrossRef]
29. Andreu, J.; Vilă, M.; Hulme, P.E. An assessment of stakeholder perceptions and management of noxious alien plants in Spain. *Environ. Manag.* **2009**, *43*, 1244–1255. [CrossRef]
30. Celesti-Grapow, L.; Alessandrini, A.; Arrigoni, P.V.; Assini, S.; Banfi, E.; Barni, E.; Bovio, M.; Brundu, G.; Cagiotti, M.R.; Camarda, I.; et al. Non-native flora of Italy: Species distribution and threats. *Plant Biosys.* **2010**, *144*, 12–28. [CrossRef]
31. Kowarik, I.; Rabitsch, W. *Biologische Invasionen. Neophyten und Neozoen in Mitteleuropa*, 2nd ed.; Ulmer Eugen Verlag: Stuttgart, Germany, 2010; pp. 1–492.
32. Liu, J.; Chen, H.; Kowarik, I.; Zhang, Y.; Wang, R. Plant invasions in China: An emerging hot topic in invasion science. *NeoBiota* **2012**, *15*, 27–51.
33. Xu, H.G.; Qiang, S.; Genovesi, P.; Ding, H.; Wu, J.; Meng, L. An inventory of invasive alien species in China. *NeoBiota* **2012**, *15*, 1–26. [CrossRef]
34. Kurokochi, H.; Toyama, K. Invasive tree species *Robinia pseudoacacia*: A potential biomass resource in Nagano prefecture, Japan. *Small-Scale For.* **2015**, *14*, 205–215. [CrossRef]
35. EPPO Global Database: *Robinia pseudoacacia*. Available online: https://gd.eppo.int/taxon/ROBPS (accessed on 12 November 2024).
36. The IUCN Red List of Threatened Species: *Robinia pseudoacacia*. Available online: https://www.iucnredlist.org/species/19891648/20138922 (accessed on 12 November 2024).
37. Fire Effects Information System. USDA Forest Service. *Robinia pseudoacacia*. Available online: https://www.fs.usda.gov/database/feis/plants/tree/robpse/all.html (accessed on 12 November 2024).

38. Sakio, H. Why did the black locust expand broadly at the river basin in Japan? *J. Jpn. Soc. Reveget. Technol.* **2015**, *40*, 465–471. [CrossRef]
39. Huntley, J.C. Robinia pseudacacia L. Black locust. In *Silvics of North America*; Hardwoods, Agriculture Handbook 654; Burns, R.M., Honkala, B.H., Eds.; US Department of Agriculture: Washington, DC, USA, 1990; Volume 2, pp. 755–761.
40. Vítková, M.; Kolbek, J. Vegetation classification and synecology of *Bohemian Robinia pseudacacia* stands in a Central European context. *Phytocoenologia* **2010**, *40*, 205–241. [CrossRef]
41. Castro-Díez, P.; Valle, G.; González-Muñoz, N.; Alonso, Á. Can the life-history strategy explain the success of the exotic trees *Ailanthus altissima* and *Robinia pseudoacacia* in Iberian floodplain forests? *PLoS ONE* **2014**, *9*, e100254. [CrossRef] [PubMed]
42. Choi, D.; Jang, W.; Toda, H.; Yoshikawa, M. Differences in characteristics of photosynthesis and nitrogen utilization in leaves of the black locust (*Robinia pseudoacacia* L.) according to leaf position. *Forests* **2021**, *12*, 348. [CrossRef]
43. Makino, A. Rubisco and nitrogen relationships in rice: Leaf photosynthesis and plant growth. *Soil Sci. Plant Nut.* **2003**, *49*, 319–327. [CrossRef]
44. Xu, F.; Guo, W.H.; Wang, R.Q.; Xu, W.H.; Du, N.; Wang, Y.F. Leaf movement and photosynthetic plasticity of black locust (*Robinia pseudoacacia*) alleviate stress under different light and water conditions. *Acta Physiol. Plant.* **2009**, *31*, 553–563. [CrossRef]
45. Moysset, L.; Solé-Sugrañes, L.; Simon, E. Changes in morphometry and elemental composition of *Robinia pseudoacacia* pulvinar motor cells during leaflet movements. *J. Exp. Bot.* **1991**, *42*, 1315–1323. [CrossRef]
46. Gómez, L.A.; Simón, E. Circadian rhythm of *Robinia pseudoacacia* leaflet movements: Role of calcium and phytochrome. *Photochem. Photobiol.* **1995**, *61*, 210–215. [CrossRef]
47. Zhang, S.R.; Ma, K.P.; Chen, L.Z. Photosynthetic gas exchange and leaflet movement of *Robinia psedoacacia* in relation to changing light environments. *Acta Bot. Sin.* **2002**, *44*, 858–863.
48. Liu, C.C.; Welham, C.V.J.; Zhang, X.Q.; Wang, R. Leaflet movement of *Robinia pseudoacacia* in response to a changing light environment. *J. Integr. Plant Biol.* **2007**, *49*, 419–424. [CrossRef]
49. Arena, C.; Vitale, L.; De Santo, A.V. Paraheliotropism in *Robinia pseudoacacia* L.: An efficient strategy to optimise photosynthetic performance under natural environmental conditions. *Plant Biol.* **2008**, *10*, 194–201. [CrossRef]
50. Wei, G.; Chen, W.; Zhu, W.; Chen, C.; Young, J.P.; Bontemps, C. Invasive *Robinia pseudoacacia* in China is nodulated by *Mesorhizobium* and *Sinorhizobium* species that share similar nodulation genes with nativ American symbionts. *FEMS Microbiol. Ecol.* **2009**, *68*, 320–328. [CrossRef]
51. Mathesius, U. Are legumes different? Origins and consequences of evolving nitrogen fixing symbioses. *J. Plant Physiol.* **2022**, *276*, 153765. [CrossRef] [PubMed]
52. Mierzwa, B.; Wdowiak-Wróbel, S.; Malek, W. *Robinia pseudoacacia* in Poland and Japan is nodulated by *Mesorhizobium amorphae* strains. *Antonie Leeuwenhoek* **2010**, *97*, 351–361. [CrossRef] [PubMed]
53. Tsyganova, A.V.; Brewin, N.J.; Tsyganov, V.E. Structure and development of the legume-rhizobial symbiotic interface in infection threads. *Cells* **2021**, *10*, 1050. [CrossRef] [PubMed]
54. Boring, L.R.; Swank, W.T. Symbiotic nitrogen fixation in regenerating black locust (*Robinia pseudoacacia* L.) stands. *For. Sci.* **1984**, *30*, 528–537.
55. Danso, S.K.A.; Zapata, F.; Awonaike, K.O. Measurement of biological N_2-fixation in field-grown *Robinia pseudoacacia* L. *Soil Biol. Biochem.* **1995**, *27*, 415–419. [CrossRef]
56. Noh, N.J.; Son, Y.; Koo, J.W.; Seo, K.W.; Kim, R.H.; Lee, Y.Y.; Yoo, K.S. Comparison of nitrogen fixation for north- and south-facing *Robinia pseudoacacia* stands in Central Korea. *J. Plant Biol.* **2010**, *53*, 61–69. [CrossRef]
57. Mylona, P.; Pawlowski, K.; Bisseling, T. Symbiotic nitrogen fixation. *Plant Cell* **1995**, *7*, 869–885. [CrossRef]
58. Kawaletz, H.; Mölder, I.; Annighöfer, P.; Terwei, A.; Zerbe, S.; Ammer, C. Back to the roots: How do seedlings of native tree species react to the competition by exotic species? *Ann. For. Sci.* **2014**, *71*, 337–347. [CrossRef]
59. Converse, C.K. Element Stewardship Abstract: *Robinia pseudoacacia*-Black Locust. The Nature Conservancy. 1984. Available online: https://www.invasive.org/weedcd/pdfs/tncweeds/robipse.pdf (accessed on 12 November 2024).
60. Schütt, P. Robinien. Bäume Nordamerikas. Von Alligator-Wacholder bis Zucker-Ahorn. In *Alle Charakteristischen Arten im Porträt*; Roloff, H., Weisgerber, H., Lang, U., Stimm, B., Eds.; Wiley-VCH Verlag: Weinheim, Germany, 2010; pp. 215–236.
61. Surles, S.E.; Hamrick, J.L.; Bongarten, B.C. Mating systems in open-pollinated families of black locust (*Robinia pseudoacacia*). *Silvae Genet* **1990**, *39*, 35–40.
62. Susko, D.J. Effect of ovule position on patterns of seed maturation and abortion in *Robinia pseudoacacia* (Fabaceae). *Can. J. Bot.* **2006**, *84*, 1259–1265. [CrossRef]
63. Morimoto, J.; Kominami, R.; Koike, T. Distribution and characteristics of the soil seed bank of the black locust (*Robinia pseudoacacia*) in a headwater basin in northern Japan. *Lands. Ecol. Eng.* **2010**, *6*, 193–199. [CrossRef]
64. Gilman, E.F.; Watson, D.G. *Robinia pseudoacacia, Back Locust. Fact Sheet ST-570*; Institute of Food and Agricultural Sciences, University of Florida: Gainesville, FL, USA, 1994; pp. 1–4.
65. Von der Lippe, M.; Kowarik, I. Do cities export biodiversity? Traffic as dispersal vector across urban-rural gradients. *Divers. Distrib.* **2008**, *14*, 8–25. [CrossRef]
66. Säumel, I.; Kowarik, I. Propagule morphology and river characteristics shape secondary water dispersal in tree species. *Plant Ecol.* **2013**, *214*, 1257–1272. [CrossRef]

67. Roman, A.M.; Truta, A.M.; Viman, O.; Morar, I.M.; Spalevic, V.; Dan, C.; Sestras, R.E.; Holonec, L.; Sestras, A.F. Seed germination and seedling growth of *Robinia pseudoacacia* depending on the origin of different geographic provenances. *Diversity* **2022**, *14*, 34. [CrossRef]
68. Šerá, B.; Jirešová, J.; Scholtz, V.; Julák, J.; Khun, J. Non-thermal plasma treatment improves properties of dormant seeds of black locust (*Robinia pseudoacacia* L.). *Forests* **2023**, *14*, 471. [CrossRef]
69. Toole, F.H. Final results of the duvel buried seed experiment. *J. Agric. Res.* **1946**, *72*, 201–210.
70. Masaka, K.; Yamada, K.; Koyama, Y.; Sato, H.; Kon, H.; Torita, H. Changes in size of soil seed bank in *Robinia pseudoacacia* L. (Leguminosae), an exotic tall tree species in Japan: Impacts of stand growth and apicultural utilization. *For. Ecol. Manag.* **2010**, *260*, 780–786. [CrossRef]
71. Singh, D.P.; Hooda, M.S.; Bonner, F.T. An evaluation of scarification methods for seeds of two leguminous trees. *New For.* **1991**, *5*, 139–145. [CrossRef]
72. Masaka, K.; Yamada, K. Variation in germination character of *Robinia pseudoacacia* L. (Leguminosae) seeds at individual tree level. *J. For. Res.* **2009**, *14*, 167–177. [CrossRef]
73. Anderson, R.C.; Brown, L.E. Stability and instability in plant communities following fire. *Am. J. Bot.* **1986**, *73*, 364–368. [CrossRef]
74. Waldron, J.D.; Lafon, C.W.; Coulson, R.N.; Cairns, D.M.; Tchakerian, M.D.; Birt, A.; Klepzig, K.D. Simulating the impacts of southern pine beetle and fire on the dynamics of xerophytic pine landscapes in the southern Appalachians. *Appl. Veg. Sci.* **2007**, *10*, 53–64. [CrossRef]
75. Bouteiller, X.P.; Moret, F.; Ségura, R.; Klisz, M.; Martinik, A.; Monty, A.; Pino, J.; van Loo, M.; Wojda, T.; Porté, A.J.; et al. The seeds of invasion: Enhanced germination in invasive European populations of black locust (*Robinia pseudoacacia* L.) compared to native American populations. *Plant Biol.* **2021**, *23*, 1006–1017. [CrossRef] [PubMed]
76. Jung, S.C.; Matsushita, N.; Wu, B.Y.; Kondo, N.; Shiraishi, A.; Hogetsu, T. Reproduction of a *Robinia pseudoacacia* population in a coastal *Pinus thunbergii* windbreak along the Kujukurihama Coast, Japan. *J. For. Res.* **2009**, *14*, 101–110. [CrossRef]
77. Kurokochi, H.; Toyama, K.; Hogetsu, T. Regeneration of *Robinia pseudoacacia* riparian forests after clear-cutting along the Chikumagawa River in Japan. *Plant Ecol.* **2010**, *210*, 31–41. [CrossRef]
78. Gyokusen, K.; Ma, Y.; Yahata, H. Spatial distribution and morphological features of root sprouts in false acacia (*Robinia pseudoacacia* L.) growing under a coastal black pine forest. *Bull. Kyushu Univ. For.* **1991**, *64*, 13–28.
79. Krízsik, V.; Körmöczi, L. Spatial spreading of *Robinia pseudoacacia* and *Populus alba* clones in sandy habitats. *Tiscia* **2000**, *32*, 3–8.
80. Vítková, M.; Tonika, J.; Müllerová, J. Black locust—Successful invader of a wide range of soil conditions. *Sci. Total Environ.* **2015**, *505*, 315–328. [CrossRef]
81. Yang, Y.; Song, Y.; Scheller, H.V.; Ghosh, A.; Ban, Y.; Chen, H.; Tang, M. Community structure of arbuscular mycorrhizal fungi associated with *Robinia pseudoacacia* in uncontaminated and heavy metal contaminated soils. *Soil Biol. Biochem.* **2015**, *86*, 146–158. [CrossRef]
82. Zhang, H.; Liu, Z.; Chen, H.; Tang, M. Symbiosis of arbuscular mycorrhizal fungi and *Robinia pseudoacacia* L. Improves root tensile strength and soil aggregate stability. *PLoS ONE* **2016**, *11*, e0153378. [CrossRef]
83. He, F.; Sheng, M.; Tang, M. Effects of *Rhizophagus irregularis* on photosynthesis and antioxidative enzymatic system in *Robinia pseudoacacia* L. under drought stress. *Front. Plant Sci.* **2017**, *8*, 183. [CrossRef] [PubMed]
84. Walther, G.R.; Roques, A.; Hulme, P.E.; Sykes, M.T.; Pyšek, P.; Kühn, I.; Zobel, M.; Bacher, S.; Botta-Dukát, Z.; Bugmann, H.; et al. Alien species in a warmer world: Risks and opportunities. *Trends Ecol. Evol.* **2009**, *24*, 686–693. [CrossRef] [PubMed]
85. Mainka, S.A.; Howard, G.W. Climate change and invasive species: Double jeopardy. *Integr. Zool.* **2010**, *5*, 102–111. [CrossRef] [PubMed]
86. Verlinden, M.; Nijs, I. Alien plant species favoured over congeneric natives under experimental climate warming in temperate Belgian climate. *Biol. Invasions* **2010**, *12*, 2777–2787. [CrossRef]
87. Di Febbraro, M.; Bosso, L.; Fasola, M.; Santicchia, F.; Aloise, G.; Lioy, S.; Tricarico, E.; Ruggieri, L.; Bovero, S.; Mori, E.; et al. Different facets of the same niche: Integrating citizen science and scientific survey data to predict biological invasion risk under multiple global change drivers. *Glob. Chang. Biol.* **2023**, *29*, 5509–5523. [CrossRef]
88. Morente-López, J.; Arjona, Y.; Salas-Pascual, M.; Reyes-Betancort, J.A.; del Arco-Aguilar, M.J.; Emerson, B.C.; García-Gallo, A.; Jay-García, L.S.; Naranjo-Cigala, A.; Patiño, J. Biogeographic origins and drivers of alien plant invasions in the Canary Islands. *J. Biogeogr.* **2023**, *50*, 576–590. [CrossRef]
89. Kleinbauer, I.; Dullinger, S.; Peterseil, J.; Essl, F. Climate change might drive the invasive tree *Robinia pseudacacia* into nature reserves and endangered habitats. *Biol. Conser.* **2010**, *143*, 382–390. [CrossRef]
90. Nadal-Sala, D.; Hartig, F.; Gracia, C.A.; Sabaté, S. Global warming likely to enhance black locust (*Robinia pseudoacacia* L.) growth in a Mediterranean riparian forest. *For. Ecol. Manag.* **2019**, *449*, 117448. [CrossRef]
91. Yan, X.Y.; Zhang, Z.D.; Huang, M.B.; Zhao, X.F.; Yang, F.; Wu, X.F. The impact of climate change on growth and drought-induced mortality risk of *Robinia pseudoacacia* plantations along a precipitation gradient on the Chinese Loess Plateau. *Agric. For. Meteorol.* **2022**, *325*, 109160. [CrossRef]
92. Zhao, S.; Wang, H.; Liu, Y. Impact of climate change on distribution of suitable niches for black locust (*Robinia pseudoacacia* L.) plantation in China. *Forests* **2024**, *15*, 1616. [CrossRef]
93. Brinks, J.S.; Lhotka, J.M.; Barton, C.D.; Warner, R.C.; Agouridis, C.T. Effects of fertilization and irrigation on American sycamore and black locust planted on a reclaimed surface mine in Appalachia. *For. Ecol. Manag.* **2011**, *261*, 640–648. [CrossRef]

94. Claessens, H.; Alderweireld, M.; Thibaut, A. Potentialities of black locust in Wallonia. *For. Wall* **2006**, *84*, 30–39.
95. Hargrove, W.W. An annotated species list of insect herbivores commonly associated with black locust, *Robinia pseudoacacia*, in the southern Appalachians. *Entomol. News* **1986**, *97*, 36–40.
96. Navia, D.; Ochoa, R.; Welbourn, C.; Ferragut, F. Adventive eriophyoidmites: A global review of their impact, pathways, prevention and challenges. *Exp. Appl. Acarol.* **2010**, *51*, 225–255. [CrossRef]
97. Kennedy, C.E.J.; Southwood, T.R.E. The number of species of insects associated with British trees: A re-analysis. *J. Anim. Ecol.* **1984**, *1*, 455–478. [CrossRef]
98. Verma, T.D.; Ajay, S.; Anil, S. Insect pests of *Robinia pseudoacacia* and *Paulownia tomentosa* in Solan District of Himachal Pradesh. *Ind. For.* **2005**, *131*, 1235–1237.
99. Uechi, N.; Yukawa, J.; Usuba, S. Recent distributional records of an alien gall midge, *Obolodiplosis robiniae* (Diptera: Cecidomyiidae) in Japan, and a brief description of its pupal morphology. *Kyushu Plant Prot. Res.* **2005**, *51*, 89–93. [CrossRef]
100. Farr, D.F.; Bills, G.F.; Chamuris, G.P.; Rossman, A.Y. *Fungi on Plants and Plant Products in the United States*; APS Press: St. Paul, MN, USA, 1995; pp. 1–252.
101. Bosso, L.; Lacatena, F.; Varlese, R.; Nocerino, S.; Cristinzio, G.; Russo, D. Plant pathogens but not antagonists change in soil fungal communities across a land abandonment gradient in a Mediterranean landscape. *Acta Oecol.* **2017**, *78*, 1–6. [CrossRef]
102. Chapman, G.B.; Buerkle, E.J.; Barrows, E.M.; Davis, R.E.; Dally, E.L. A light and transmission electron microscope study of a black locust tree, *Robinia pseudoacacia* (Fabaceae), affected by witches'-broom, and classification of the associated phytoplasma. *J. Phytopathol.* **2001**, *149*, 589–597. [CrossRef]
103. Tian, F.; Chang, C.J.; Grutzner, J.B.; Nichols, D.E.; McLaughlin, J.L. Robinlin: A novel bioactive homo-monoterpene from *Robinia pseudoacacia* L. (Fabaceae). *Bioorg. Med. Chem. Lett.* **2001**, *11*, 2603–2606. [CrossRef]
104. Oakes, J.A.; Wang, R.Y. Toxalbumins. In *Critical Care Toxicology*; Brent, J., Burkhart, K., Dargan, P., Hatten, B., Megarbane, B., Palmer, R., Eds.; Springer: Cham, Switzerland, 2016; pp. 1–11.
105. Burner, D.M.; Carrier, D.J.; Belesky, D.P.; Pote, D.H.; Ares, A.; Clausen, E.C. Yield components and nutritive value of *Robinia pseudoacacia* and *Albizia julibrissin* in Arkansas, USA. *Agrofor. Syst.* **2008**, *72*, 51–62. [CrossRef]
106. Hui, A.; Marraffa, J.M.; Stork, C.M. A rare ingestion of the black locust tree. *J. Toxicol. Clin. Toxicol.* **2004**, *42*, 93–95. [CrossRef] [PubMed]
107. Browne, D.T.; Aguilo-Seara, G.; de Franzo, A., Jr. The black locust tree: Toxalbumin-induced tissue necrosis of the upper extremity. *Cureus* **2020**, *12*, e11758. [CrossRef] [PubMed]
108. Kumar, R. Anti-nutritional factors, the potential risks of toxicity andmethods to alleviate them. Legume trees and other fodder trees as protein source for livestock. *FAO Anim. Prod. Health Pap.* **1992**, *102*, 145–160.
109. Vanschandevijl, K.; van Loon, G.; Lefère, L.; Deprez, P. Black locust (*Robinia pseudoacacia*) intoxication as a suspected cause of transient hyperammonaemia and enteral encephalopathy in a pony. *Equine Vet. Edu.* **2010**, *22*, 336–339. [CrossRef]
110. Kato-Noguchi, H. Defensive molecules momilactones A and B: Function, biosynthesis, induction and occurrence. *Toxins* **2023**, *15*, 241. [CrossRef]
111. Kato-Noguchi, H. Bioactive compounds involved in the formation of the sparse understory vegetation in pine forests. *Curr. Org. Chem.* **2021**, *25*, 1731–1738. [CrossRef]
112. Rice, E.L. *Allelopathy*, 2nd ed.; Academic Press: Orlando, FL, USA, 1984; pp. 1–422.
113. Bais, H.P.; Weir, T.L.; Perry, L.G.; Gilroy, S.; Vivanco, J.M. The role of root exudates in rhizosphere interactions with plants and other organisms. *Annu. Rev. Plant Biol.* **2006**, *57*, 233–266. [CrossRef]
114. Callaway, R.M.; Ridenour, W.M. Novel weapons: Invasive success and the evolution of increased competitive ability. *Front. Ecol. Environ.* **2004**, *2*, 419–426. [CrossRef]
115. Cappuccino, N.; Arnason, J.T. Novel chemistry of invasive exotic plants. *Biol. Lett.* **2006**, *2*, 189–193. [CrossRef]
116. Chengxu, W.; Mingxing, Z.; Xuhui, C.; Bo, Q. Review on allelopathy of exotic invasive plants. *Procedia Eng.* **2011**, *18*, 240–246. [CrossRef]
117. Kato-Noguchi, H.; Kurniadie, D. The invasive mechanisms of the noxious alien plant species *Bidens pilosa*. *Plants* **2024**, *13*, 356. [CrossRef] [PubMed]
118. Kato-Noguchi, H.; Kurniadie, D. Allelopathy and allelochemicals of *Leucaena leucocephala* as an invasive plant species. *Plants* **2022**, *11*, 1672. [CrossRef] [PubMed]
119. Khanduri, V.P.; Bali, R.S.; Rawat, P.; Rawat, M. Allelopathic effect of *Robinia pseudoacacia* on germination and growth of some important food crops of the Garhwal Himalayas. *J. Pharm. Phytochem.* **2019**, *8*, 206–210.
120. Lee, C.; Park, J.Y.; Kim, J.H.; Park, Y.G. Allopathic effect of black locust (*Robinia pseudoacacia* L.) and analysis for its allelochemicals. *Korea For. Energy Res. Soc.* **2003**, *22*, 11–19.
121. Nasir, H.; Iqbal, Z.; Hiradate, S.; Fujii, Y. Allelopathic potential of *Robinia pseudo-acacia* L. *J. Chem. Ecol.* **2005**, *31*, 2179–2192. [CrossRef] [PubMed]
122. Tyśkiewicz, K.; Konkol, M.; Kowalski, R.; Rój, E.; Warmiński, K.; Krzyżaniak, M.; ukasz Gil, Ł.; Stolarski, M.J. Characterization of bioactive compounds in the biomass of black locust, poplar and willow. *Trees* **2019**, *33*, 1235–1263. [CrossRef]
123. Uzelac, M.; Sladonja, B.; Šola, I.; Dudaš, S.; Bilić, J.; Famuyide, I.M.; McGaw, L.J.; Eloff, J.N.; Mikulic-Petkovsek, M.; Poljuha, D. Invasive alien species as a potential source of phytopharmaceuticals: Phenolic composition and antimicrobial and cytotoxic activity of *Robinia pseudoacacia* L. leaf and flower extracts. *Plants* **2023**, *12*, 2715. [CrossRef]

124. Dalton, B.R. The occurrence and behavior of plant phenolic acids in soil environments and their potential involvement in allelochemical interference interactions: Methodological limitations in establishing conclusive proof of allelopathy. In *Principals and Practices in Plant Ecology: Allelochemical Interactions*; Inderjit, D.K.M.M., Foy, C.L., Eds.; CRC Press: Boca Raton, FL, USA, 1999; pp. 57–74.
125. Kato-Noguchi, H. Involvement of allelopathy in the invasive potential of *Tithonia diversifolia*. *Plants* **2020**, *9*, 766. [CrossRef]
126. Kato-Noguchi, H.; Kurniadie, D. Allelopathy of *Lantana camara* as an invasive plant. *Plants* **2021**, *10*, 1028. [CrossRef]
127. Einhellig, F.A. Mode of action of allelochemical action of phenolic compounds. In *Chemistry and Mode of Action of Allelochemicals*; Macías, F.A., Galindo, J.C.G., Molino, J.M.G., Cutler, H.G., Eds.; CRC Press: Boca Raton, FL, USA; London, UK; New York, NY, USA; Washington, DC, USA, 2004; pp. 217–238.
128. Fernández-Aparicio, M.; Masi, M.; Cimmino, A.; Vilariño, S.; Evidente, A. Allelopathic effect of quercetin, a flavonoid from *Fagopyrum esculentum* roots in the radicle growth of *Phelipanche ramosa*: Quercetin natural and semisynthetic analogues were used for a structure-activity relationship investigation. *Plants* **2021**, *10*, 543. [CrossRef]
129. Li, Z.H.; Wang, Q.; Ruan, X.; Pan, C.D.; Jiang, D.A. Phenolics and plant allelopathy. *Molecules* **2010**, *15*, 8933–8952. [CrossRef] [PubMed]
130. Weston, L.A.; Mathesius, U. Flavonoids: Their structure, biosynthesis and role in the rhizosphere, including allelopathy. *J. Chem. Ecol.* **2013**, *39*, 283–297. [CrossRef] [PubMed]
131. Treutter, D. Significance of flavonoids in plant resistance: A review. *Environ. Chem. Lett.* **2006**, *4*, 147. [CrossRef]
132. Mierziak, J.; Kostyn, K.; Kulma, A. Flavonoids as important molecules of plant interactions with the environment. *Molecules* **2014**, *19*, 16240–16265. [CrossRef] [PubMed]
133. Kato-Noguchi, H. The impact and invasive mechanisms of *Pueraria montana* var. *lobata*, one of the world's worst alien species. *Plants* **2023**, *12*, 3066. [CrossRef] [PubMed]
134. Kato-Noguchi, H. Isolation and identification of allelochemicals and their activities and functions. *J. Pestic. Sci.* **2024**, *49*, 1–14. [CrossRef]
135. Evans, R.D.; Rimer, R.; Sperry, L.; Belnap, J. Exotic plant invasion alters nitrogen dynamics in an arid grassland. *Ecol. Appl.* **2001**, *11*, 1301–1310. [CrossRef]
136. Rice, S.K.; Westerman, B.; Federici, Y. Impacts of the exotic, nitrogen-fixing black locust (*Robinia pseudoacacia*) on nitrogen-cycling in a pine-oak ecosystem. *Plant Ecol.* **2004**, *174*, 97–107. [CrossRef]
137. De Marco, A.; Arena, C.; Giordano, M.; De Santo, A.V. Impact of the invasive tree black locust on soil properties of Mediterranean stone pine-holm oak forests. *Plant Soil* **2013**, *372*, 473–486. [CrossRef]
138. De Marco, A.; Esposito, F.; Berg, B.; Zarrelli, A.; De Santo, A.V. Litter inhibitory effects on soil microbial biomass, activity, and catabolic diversity in two paired stands of *Robinia pseudoacacia* L. and *Pinus nigra* Arn. *Forests* **2018**, *9*, 766. [CrossRef]
139. Castro-Díez, P.; Fierro-Brunnenmeister, N.; González-Muñoz, N.; Gallardo, A. Effects of exotic and native tree leaf litter on soil properties of two contrasting sites in the Iberian Peninsula. *Plant Soil* **2012**, *350*, 179–191. [CrossRef]
140. Akamatsu, F.; Ide, K.; Shimano, K.; Toda, H. Nitrogen stocks in a riparian area invaded by N-fixing black locust (*Robinia pseudoacacia* L.). *Landsc. Ecol. Eng.* **2011**, *7*, 109–115. [CrossRef]
141. Medina-Villar, S.; Castro-Diez, P.; Alonso, A.; Parker, I.M.; Pérez-Corona, E. Do the invasive trees, *Ailanthus altissima* and *Robinia pseudoacacia*, alter litterfall dynamics and soil properties of riparian ecosystems in Central Spain? *Plant Soil* **2015**, *396*, 311–324. [CrossRef]
142. Poblador, S.; Lupon, A.; Martí, E.; Sabater, F.; Sabaté, S.; Bernal, S. The influence of the invasive alien nitrogen-fixing *Robinia pseudoacacia* L. on soil nitrogen availability in a mixed Mediterranean riparian forest. *Eur. J. For. Res.* **2019**, *138*, 1083–1093. [CrossRef]
143. Wang, X.; Zhong, Z.; Li, W.; Liu, W.; Zhang, X.; Wu, S.; Ren, Z.; Wu, Q.; Shen, Z.; Ren, C.; et al. Effects of *Robinia pseudoacacia* afforestation on aggregate size distribution and organic C dynamics in the central Loess Plateau of China: A chronosequence approach. *J. Environ. Manag.* **2020**, *268*, 110558. [CrossRef]
144. Smith, S.E.; Read, D.J. *Mycorrhizal Symbiosis*, 2nd ed.; Academic Press: New York, NY, USA, 1997; pp. 1–605.
145. Duchesne, L.C.; Ellis, B.E.; Paterson, R.L. Disease suppression by the ectomycorrhizal fungus *Paxillus involutus*: Contribution of oxalic acid. *Can. J. Bot.* **1989**, *67*, 2726–2730. [CrossRef]
146. Avis, P.G.; McLaughlin, D.J.; Dentinger, B.C.; Reich, P.B. Long-term increase in nitrogen supply alters above- and below-ground ectomycorrhizal communities and increases the dominance of *Russula* spp. in a temperate oak savanna. *New Phytol.* **2003**, *160*, 239–253. [CrossRef]
147. Taniguchi, T.; Kanzaki, N.; Tamai, S.; Yamanaka, N.; Futai, K. Does ectomycorrhizal fungal community structure vary along a Japanese black pine (*Pinus thunbergii*) to black locust (*Robinia pseudoacacia*) gradient? *New Phytol.* **2007**, *173*, 322–334. [CrossRef]
148. Taniguchi, T.; Kataoka, R.; Tamai, S.; Yamanaka, N.; Futai, K. Distribution of ectomycorrhizal and pathogenic fungi in soil along a vegetational change from Japanese black pine (*Pinus thunbergii*) to black locust (*Robinia pseudoacacia*). *Mycorrhiza* **2009**, *19*, 231–238. [CrossRef]
149. Yang, Y.; Tang, M.; Sulpice, R.; Chen, H.; Tian, S.; Ban, Y. Arbuscular mycorrhizal fungi alter fractal dimension characteristics of *Robinia pseudoacacia* L. seedlings through regulating plant growth, leaf water status, photosynthesis, and nutrient concentration under drought stress. *J. Plant Grow. Regul.* **2014**, *33*, 612–625. [CrossRef]

150. Sheng, M.; Chen, X.; Zhang, X.; Hamel, C.; Cui, X.; Chen, J.; Chen, H.; Tang, M. Changes in arbuscular mycorrhizal fungal attributes along a chronosequence of black locust (*Robinia pseudoacacia*) plantations can be attributed to the plantation-induced variation in soil properties. *Sci. Total Environ.* **2017**, *599*, 273–283. [CrossRef] [PubMed]
151. Diagne, N.; Ngom, M.; Djighaly, P.I.; Fall, D.; Hocher, V.; Svistoonoff, S. Roles of arbuscular mycorrhizal fungi on plant growth and performance: Importance in biotic and abiotic stress regulation. *Diversity* **2020**, *12*, 370. [CrossRef]
152. Tang, H.; Hassan, M.U.; Feng, L.; Nawaz, M.; Shah, A.N.; Qari, S.H.; Liu, Y.; Miao, J. The critical role of arbuscular mycorrhizal fungi to improve drought tolerance and nitrogen use efficiency in crops. *Front. Plant Sci.* **2022**, *13*, 919166. [CrossRef] [PubMed]
153. Xu, M.; Gao, D.; Fu, S.; Lu, X.; Wu, S.; Han, X.; Yanga, G.; Feng, Y. Long-term effects of vegetation and soil on the microbial communities following afforestation of farmland with *Robinia pseudoacacia* plantations. *Geoderma* **2020**, *367*, 114263. [CrossRef]
154. Kato-Noguchi, H. Allelopathy of knotweeds as invasive plants. *Plants* **2022**, *11*, 3. [CrossRef]
155. Kato-Noguchi, H. Allelopathy and allelochemicals of *Imperata cylindrica* as an invasive plant species. *Plants* **2022**, *11*, 2551. [CrossRef]
156. Kato-Noguchi, H.; Kato, M. Allelopathy and allelochemicals of *Solidago canadensis* L. and *S. altissima* L. for their naturalization. *Plants* **2022**, *11*, 3235. [CrossRef]
157. Kato-Noguchi, H.; Kato, M. Evolution of the secondary metabolites in invasive plant species *Chromolaena odorata* for the defense and allelopathic functions. *Plants* **2023**, *12*, 521. [CrossRef]
158. Kato-Noguchi, H. Invasive mechanisms of one of the world's worst alien plant species *Mimosa pigra* and its management. *Plants* **2023**, *12*, 1960. [CrossRef]
159. Kato-Noguchi, H.; Kato, M. Defense molecules of the invasive plant species *Ageratum conyzoides*. *Molecules* **2024**, *29*, 4673. [CrossRef]
160. Slabejová, D.; Bacigál, T.; Hegedüšová, K.; Májeková, J.; Medvecká, J.; Mikulová, K.; Šibíková, M.; Škodová, I.; Zaliberová, M.; Jarolímek, I. Comparison of the understory vegetation of native forests and adjacent *Robinia pseudoacacia* plantations in the Carpathian-Pannonian region. *For. Ecol. Manag.* **2019**, *439*, 28–40. [CrossRef]
161. Slabejová, D.; Čejka, T.; Hegedüšová, K.; Májeková, J.; Medvecká, J.; Mikulová, K.; Šibíková, M.; Škodová, I.; Šustek, Z.; Jarolímek, I. Comparison of alien *Robinia pseudoacacia* stands with native forest stands across different taxonomic groups. *For. Ecol. Manag.* **2023**, *548*, 121413. [CrossRef]
162. Kastler, B.; Samimi, C. The Impact of *Robinia pseudoacacia* on Ground Vegetation and Plant Nutrient Matter in Donau-Auen National Park. In Proceedings of the 5th Symposium for Research in Protected Areas, Mittersill, Austria, 10–12 June 2013; pp. 345–352.
163. Sitzia, T.; Campagnaro, T.; Kotze, D.J.; Nardi, S.; Ertani, A. The invasion of abandoned fields by major alien tree filters understory plant traits in novel forest ecosystems. *Sci. Rep.* **2018**, *8*, 8410. [CrossRef] [PubMed]
164. Dzwonko, Z.; Loster, S. Effects of dominant trees and anthropogenic disturbances on species richness and floristic composition of secondary communities in southern Poland. *J. Appl. Ecol.* **1997**, *34*, 861–870. [CrossRef]
165. Rahmonov, O. The chemical composition of plant litter of black locust (*Robinia pseudoacacia* L.) and its ecological role in sandy ecosystems. *Acta Ecol. Sin.* **2009**, *29*, 237–243. [CrossRef]
166. Benesperi, R.; Giuliani, C.; Zanetti, S.; Gennai, M.; Lippi, M.M.; Guidi, T.; Nascimbene, J.; Foggi, B. Forest plant diversity is threatened by *Robinia pseudoacacia* (black-locust) invasion. *Biodivers. Conserv.* **2012**, *21*, 3555–3568. [CrossRef]
167. Trentanovi, G.; Von der Lippe, M.; Sitzia, T.; Ziechmann, U.; Kowarik, I.; Cierjacks, A.; Pyšek, P. Biotic homogenization at the community scale: Disentangling the roles of urbanization and plant invasion. *Divers. Distrib.* **2013**, *19*, 738–748. [CrossRef]
168. Gentili, R.; Ferrè, C.; Cardarelli, E.; Montagnani, C.; Bogliani, G.; Citterio, S.; Comolli, R. Comparing negative impacts of *Prunus serotina*, *Quercus rubra* and *Robinia pseudoacacia* on native forest ecosystems. *Forests* **2019**, *10*, 842. [CrossRef]
169. Guo, Q.; Wen, Z.; Zheng, C.; Li, W.; Fan, Y.; Zhu, D. Effects of *Robinia pseudoacacia* on the undergrowth of herbaceous plants and soil properties in the Loess Plateau of China. *J. Plant Ecol.* **2021**, *14*, 896–910. [CrossRef]
170. Dyderski, M.K.; Jagodziński, A.M. Impacts of invasive trees on alpha and beta diversity of temperate forest understories. *Biol. Invasions* **2021**, *23*, 235–252. [CrossRef]
171. Montecchiari, S.; Tesei, G.; Allegrezza, M. Effects of *Robinia pseudoacacia* coverage on diversity and environmental conditions of central-northern Italian *Quercus pubescens* sub-mediterranean forests (habitat code 91AA*): A threshold assessment. *Ann. Bot.* **2020**, *10*, 33–54.
172. Lazzaro, L.; Mazza, G.; d'Errico, G.; Fabiani, A.; Giuliani, C.; Inghilesi, A.F.; Lagomarsino, A.; Landi, S.; Lastrucci, L.; Pastorelli, R.; et al. How ecosystems change following invasion by *Robinia pseudoacacia*: Insights from soil chemical properties and soil microbial, nematode, microarthropod and plant communities. *Sci. Total Environ.* **2018**, *622*, 1509–1518. [CrossRef] [PubMed]
173. Laiolo, P.; Caprio, E.; Rolando, A. Effects of logging and non-native tree proliferation on the birds overwintering in the upland forests of north-western Italy. *For. Ecol. Manag.* **2003**, *179*, 441–454. [CrossRef]
174. Hanzelka, J.; Reif, J. Responses to the black locust (*Robinia pseudoacacia*) invasion differ between habitat specialists and generalists in central European forest birds. *J. Ornithol.* **2015**, *156*, 1015–1024. [CrossRef]
175. Nascimbene, J.; Nimis, P.L.; Benesperi, R. Mature non-native black-locust (*Robinia pseudoacacia* L.) forest does not regain the lichen diversity of the natural forest. *Sci. Total Environ.* **2012**, *421–422*, 197–202. [CrossRef]

176. Sitzia, T.; Campagnaro, T.; Dainese, M.; Cierjacks, A. Plant species diversity in alien black locust stands: A paired comparison with native stands across a north-Mediterranean range expansion. *For. Ecol. Manag.* **2012**, *285*, 85–91. [CrossRef]
177. Shure, D.J.; Phillips, D.L.; Bostick, P.E. Gap size and succession in cutover southern Appalachian forests: An 18 year study of vegetation dynamics. *Plant Ecol.* **2006**, *185*, 299–318. [CrossRef]
178. Terwei, A.; Zerbe, S.; Mölder, I.; Annighöfer, P.; Kawaletz, H.; Ammer, C. Response of floodplain understory species to environmental gradients and tree invasion: A functional trait perspective. *Biol. Invasions* **2016**, *18*, 2951–2973. [CrossRef]
179. Goto, S.; Shimano, K. Riparian forest invasion by *Robinia pseudoacacia* and its effects of riverside vegetation. *Veg. Sci.* **2008**, *35*, 49–65.
180. Dyderski, M.K.; Jagodziński, A.M. Impact of invasive tree species on natural regeneration species composition, diversity, and density. *Forests* **2020**, *11*, 456. [CrossRef]
181. Sádlo, J.; Vítková, M.; Pergl, J.; Pyšek, P. Towards site-specific management of invasive alien trees based on the assessment of their impacts: The case of *Robinia pseudoacacia*. *NeoBiota* **2017**, *35*, 1–34. [CrossRef]
182. Vítková, M.; Sádlo, J.; Roleček, J.; Petřík, P.; Sitzia, T.; Müllerová, J.; Pyšek, P. *Robinia pseudoacacia*-dominated vegetation types of Southern Europe: Species composition, history, distribution and management. *Sci. Total Environ.* **2020**, *707*, 134857. [CrossRef] [PubMed]

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